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Energy Resilience as a Challenge for the European Union in Times of Energy Crisis[1]

Abstract: Energy resilience is an important paradigm in energy security research, as it allows for the analysis of many aspects of the functioning of the energy system. The main aim of the article is to analyse the process of strengthening the EU's energy resilience during the energy crisis following the outbreak of Russia's war in Ukraine. The questions posed in the research include: what types of risks the EU is exposed to in the energy sector, whether and to what extent the EU is strengthening its energy resilience, what are the dimensions of this resilience, was the EU prepared for the energy crisis, what is the current level of the EU's energy resilience. Various methods were used in the research: critical qualitative analysis of documents and reports as well as scientific literature, process tracing analysis of EU energy policy, analysis of statistical data on energy. The research puts forward the thesis that the EU insufficiently identified the most important risks to energy resilience by 2022 and only began to intensively strengthen it after Russia's military invasion of Ukraine. However, the level of this resilience is still not satisfactory, as indicated by the criteria used in the research.

Key words: energy resilience, European Union, energy security, the energy crisis

1. Introduction

The energy resilience of the European Union (EU) is an essential element in ensuring a stable and sustainable energy supply. In the face of growing geopolitical, economic and technological challenges, the EU faces numerous threats and risks.

The main objective of the presented research is to analyse the development of the EU's energy resilience in the period 2019–2024, as one of the most important elements of the functioning of the economy and society in the Union, guaranteeing security and stability, especially during the energy crisis in Europe. The research aims to clarify what energy resilience is, its dimensions and indicators, and the extent to which the EU is developing its energy resilience. The research puts forward the thesis that the EU has insufficiently identified the most important risks and threats to its energy resilience by 2022 and only after the outbreak of Russia's war in Ukraine and the start of the energy crisis began to systematically strengthen it. Still, the level of this resistance in some dimensions is not satisfactory. The added value of the research is an attempt to demonstrate that it is the category of energy resilience, not energy security, that is a more adequate and accurate approach to the analysis of the stability and reliability of the energy system in emergency and crisis situations. The article aims to fill the

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gap visible in research, as few publications have been published on the EU’s energy resilience. In addition, the article provides a review of the literature related to energy resilience research.

2. Energy resilience versus energy security

The use of the energy resilience category in social science allows to analyse many aspects of the functioning of the energy system in the long term, especially in turbulent times. For this reason, it is more useful than the energy security category. Energy security is treated as a certain specific state in which parameters such as accessibility of energy resources, reliability, affordability, and diversity of resources are analysed (Misiągiewicz, 2022, pp. 120–122), while energy resilience is defined as a process in which specific stages can be distinguished (e.g., breakdowns, recovery from a crisis), and attention is focused not only on ensuring energy supplies, but also on a possible response to threats (endurance and recovery), adaptation to change, and recovery from disruptions” (Joshi, Gokhale-Welch 2022, p. 5). Energy resilience is therefore defined as the ability of an energy system to adapt and survive crises and disruptions, such as hostilities, natural disasters, cyber-attacks, or market changes.

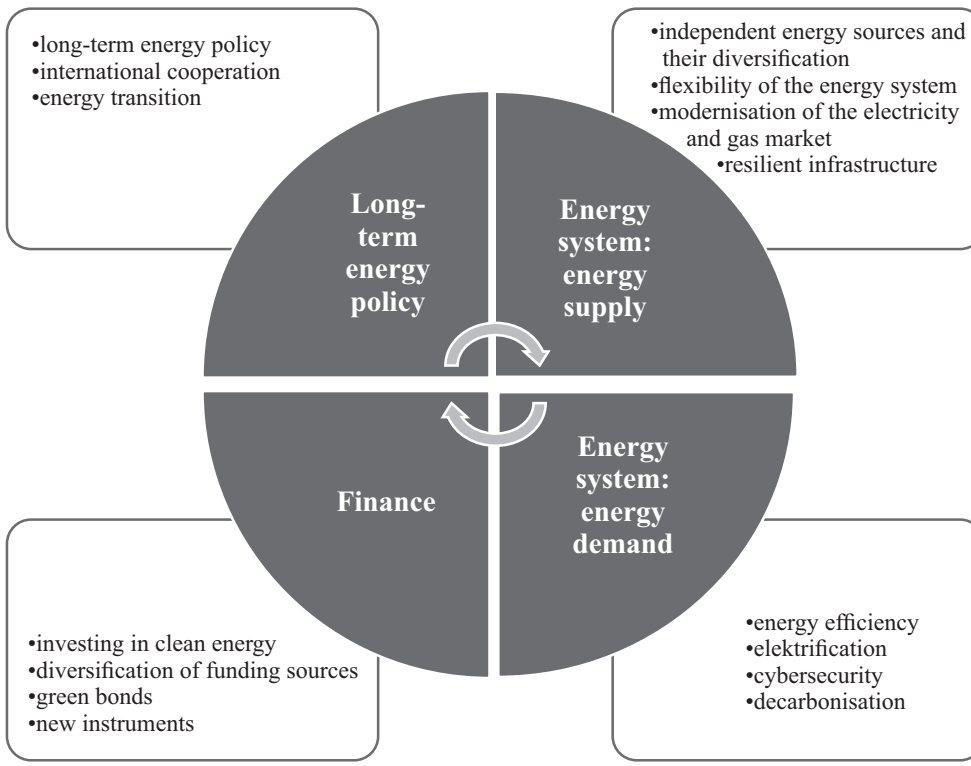
To date, several approaches have been developed in defining and measuring energy resilience. According to Gatto and Drago (2020, p. 2), energy resilience is a multifaceted concept and should be defined as “the ability of an energy system to retain, react, overcome and overpass perturbations caused by a shock in economic, social, environmental and institutional terms, coming from the learning capacity to adapt to change.” Energy resilience is assumed to be based on three elements: renewable energy, energy access, and energy efficiency. The approach of Aldieri et al. (2021, p. 2) pays more attention to external risks such as dependence on raw material supply and adaptability. Energy resilience can be closely related to energy vulnerability defined as the degree to which a country is prone to adverse energy-related shocks, such as supply disruptions and price volatility, highlighting weaknesses that may increase the likelihood and severity of negative impacts (Guarascio, Reljic, Zezza 2025, p. 4). In this approach, it is assumed that the main dimensions of energy resilience are: energy availability (security of supply, dependency and diversification), energy affordability (price stability, access and equity), technological efficiency (innovation and investment), energy intensity (energy use) and environmental sustainability (climate change).

Energy resilience is determined by political, economic, technological and environmental factors. The use of energy resilience categories in research allows for a more in-depth and multidimensional analysis of the stability and balance of the Union’s energy security and the possibilities of managing risks and minimising the effects of disturbances. Russia’s military invasion of Ukraine shows that it is energy resilience, not just energy security, that guarantees the functioning of the economy and society in the EU in a situation of serious threats and conflicts.

Previous research shows that the most important components of energy resilience are: long-term energy policy, energy transition, international cooperation, energy independence and diversification of energy sources, energy efficiency, cybersecurity, infra-

structure resilience, modernization of the energy market, innovation and new technologies, electrification of many sectors, decarbonization, etc. (Jasiunas, Lund, Mikkola, 2021, p. 2).

Figure 1. Aspects of energy resilience



Source: Own compilation based on: World Economic Forum (2021) and R. Knight, A. Hutchinson, A. Horigoshi, S. Custer (2023).

3. Threats and risks to the EU’s energy resilience

The most important threats and risks to the EU’s energy resilience relate primarily to the lack of security of energy supplies, a high level of dependence on imports of energy resources, an unstable geopolitical situation, terrorist threats and cyberattacks, insufficiently developed network infrastructure, and extreme weather events.

1. Geopolitical risks, such as political and military conflicts, have a significant impact on the EU’s energy resilience, as they not only pose a direct physical threat to energy systems, but also have an impact on international energy markets, i.e. they destabilise or disrupt energy supply chains, increase the risk of a sharp increase in energy prices as a result of increased demand, cause panic on the markets and increase competition, etc. After the outbreak of Russia’s war in Ukraine and the increase in demand for energy resources, markets reacted with a sharp increase in gas prices. In August 2022, its price

increased from 20 euros/MWh to over 200 euros/MWh (Dzierżanowski, Nowak, 2023, p. 2).

2. High level of dependence on imports of energy resources – this is one of the most important risks to the EU’s energy resilience, as the EU has been systematically dependent on supplies of this type of raw materials for many years, especially from politically unstable regions. The lack of insufficient use of its own energy sources has forced the EU to import natural gas, oil and coal, mainly from Russia. In 2019, energy resources accounted for 62% of Russia’s total imports to the EU. In the EU’s energy imports, Russian gas, oil, hard coal and lignite accounted for 40%, 28%, 46% and 20%, respectively (European Commission, 2024). Following the outbreak of Russia’s war in Ukraine in 2022, the EU has taken steps to diversify energy sources and reduce this dependency, but the results have not been satisfactory.
3. Terrorist and cyber threats – energy systems are particularly vulnerable to this type of attack because they belong to critical infrastructure. In 2023, more than 200 major cyberattacks were recorded in the EU, of which more than 100 targeted the energy sector (ENISA, 2024). The most commonly used attack methods are ransomware (ransomware extortion), phishing (data theft) and advanced persistent threat. In 2023, cybercriminals used ransomware to infiltrate 22 European energy companies. The country that conducts and sponsors hostile cyber operations against the European energy sector is Russia and some Asian countries. In 2023, 61% of all registered cyberattacks worldwide originated from Russia, many of which targeted European critical infrastructure (Eurelectric, 2025).
4. Extreme weather events and climate change will increase and cause serious threats to the EU’s energy systems. More intense and frequent heat waves cause changes in the structure of energy supply and demand, often in opposite directions. The countries most vulnerable to climate change in the EU are: Spain, Italy and Greece, which have recorded tens of thousands of deaths and huge economic losses caused by climate events over the past decades (Euronews, 2025).

Table 1

Types of risks and threats to the EU’s energy resilience

Threats	Description	Statistics on the EU’s energy resilience in the period 2019–2024
Dependence on natural gas imports	High dependence on external natural gas suppliers	Gas imports from Russia fell from 40% in 2019 to 3% in 2023 and 18% in 2024.
Dependence on coal imports	Coal imports from external sources	Coal imports from Russia have been reduced from 45% in 2019 to 1% in 2024.
Increase in energy prices	Soaring prices of energy commodities on global markets	Gas prices in 2024 were 30% higher than the average, but in 2022 there was a tenfold jump in gas prices
Geopolitical threats	International conflicts affecting the stability of energy supply	The outbreak of Russia’s war in Ukraine has interrupted the supply chains of the EU’s energy resources
Cyber threats	Increase in cyberattacks on energy systems	The number of attacks on energy systems in the EU has increased to 200 in 2023.

Source: Own compilation based on data from: Eurelectric (2023) and European Commission (European Commission, 2024).

4. Is the EU developing its energy resilience, and if so, to what extent?

In order to assess the level of energy resilience of the EU to geopolitical, technological and climate risks and threats and opportunities for its development, several criteria should be taken into account. These are: the character of the EU’s energy policy, the model of the EU energy system, and the sources of financing energy policy. The analysis of data on these three criteria and the use of selected measurement indicators will allow to determine the level of energy resilience of the EU during the energy crisis in Europe in the period 2019–2024.

4.1. A long-term energy policy as a cornerstone of the EU’s energy resilience

In order to increase energy resilience, it is necessary to conduct a long-term, predictable energy policy that accurately identifies risks and threats and is able to anticipate them or mitigate their negative effects. The EU initiated the EU’s energy and climate policy two decades ago, with the current goal of creating a climate-neutral economy by 2050. Although competences in the field of energy policy are shared between the EU and the Member States, the Union is taking many initiatives to develop it and increase the energy resilience of the Union as a whole. So far, further climate and energy packages and programs setting new energy and climate goals have been adopted and implemented. Although the energy policy models of the Member States are diverse, they all are striving to achieve the EU’s energy transition goals, albeit at different paces.

The beginnings of the EU’s energy policy date back to the 1990s, when the framework for cooperation in the energy transition process was established. In 2015, the EU adopted a strategy on building an Energy Union, in which it defined five priorities for energy policy, including: ensuring energy security through diversification of energy sources, solidarity and cooperation between EU countries; ensuring the functioning of an integrated internal energy market and the free flow of energy; improving energy efficiency, reducing dependence on energy imports and reducing emissions; decarbonisation of the economy; development of research and innovation of clean technologies. Currently, the most important strategy is the European Green Deal, which sets out the framework objectives of the EU’s energy policy, including an ambitious priority to achieve climate neutrality by 2050, as well as the “Fit for 55” package of directives and regulations, which sets 2030 targets consistent with climate policy, including: reducing greenhouse gas emissions by 2030, by 55% compared to 1990; increasing the share of energy from renewable sources in energy consumed in the EU to 42.5% (and even 45%); improving energy efficiency by 11.7% by 2030 (European Commission, 2023).

From the beginning, the EU has focused primarily on developing sustainable energy and ensuring energy supplies, while maintaining the competitiveness of the economy. Achieving such ambitious goals and increasing energy resilience is extremely difficult due to geopolitical conditions and differences between Member States in terms of national energy policies, especially the high level of dependence on energy imports. As recently as 2021, the EU’s dependence on energy supplies was very high,

especially in the field of gas, coal and oil, which is due to the high energy intensity of the economy. The EU imported 40% of its gas consumption (155 billion m^3) from Russia, with Central and Eastern European countries being the most dependent, e.g. Russia provided 95% of Hungary’s gas, 80% of Austria’s gas and 65% of Germany’s gas (Eurostat, 2024). Russia also had a 45% share in EU coal imports and a 25% share in oil imports. After Russia’s military invasion of Ukraine and the imposition of restrictions on imports of Russian raw materials, these shares decreased in 2024: gas to 18%, oil to 2%, coal to 1% (Eurostat 2024, p. 2). At the same time, the EU has increased its purchases of natural gas and LPG from Norway (34% of imported gas) and the US (18% of imported gas), Azerbaijan, the United Kingdom and North Africa, which also does not guarantee the EU’s energy security, as the recent decisions of the US president show that US foreign policy can be unpredictable. The dependence rate on EU energy imports is still 58%, which means that more than half of the EU’s energy demand is met by imports (Eurostat, 2025). Therefore, the EU, due to the high level of dependence on gas and oil imports, still does not have long-term security of energy supplies..

In response to the energy crisis caused by Russia’s war in Ukraine, the European Commission has launched the REPowerEU initiative, which aims to ensure energy security and accelerate the energy transition by diversifying energy sources, improving energy efficiency and developing energy storage technologies, hydrogen technologies and electromobility (European Commission, 2022). Already in the first year of the implementation of this initiative, excessive increases in gas prices in the EU were reduced, electricity demand was reduced by 5% and gas demand by 15%, the amount of gas stored was increased to 95%, platforms for the joint purchase of gas (e.g. the AggregateEU), LNG and hydrogen mechanism were created, the diversification of energy sources was accelerated, investments in infrastructure were increased (European Commission, 2024). In addition, efforts have been launched to develop hydrogen energy, and a European Industrial Alliance has been established to build small modular nuclear reactors by 2030 (European Commission 2024).

As a result, REPower EU has contributed to stabilising the market for energy resources, especially gas, guaranteeing its supply and reducing its prices, accelerating the transition to renewable energy, strengthening cooperation between countries and initiating projects for new energy technologies. Therefore, it can be concluded that the energy crisis in 2022 not only did not stop the EU’s energy transition process, but on the contrary, accelerated its pace, primarily in terms of increasing the share of energy from renewable sources and improving energy efficiency. The high level of dependence on energy imports, high electricity prices, and insufficient development of energy networks remain a problem.

The energy crisis in 2022 has shown that the risks and threats arising from geopolitical changes have not been sufficiently identified in the EU’s energy policy. Dependence on imports of energy resources, especially on one unstable supplier (Russia), was a serious mistake not only for the Member States, but also for the EU as a whole. The problem of dependence on imports of energy resources has not been solved, because the EU still imports a significant part of these raw materials from other countries that do not guarantee stability and reliability of supply.

4.2. Energy system stability and reliability as part of the EU’s energy resilience

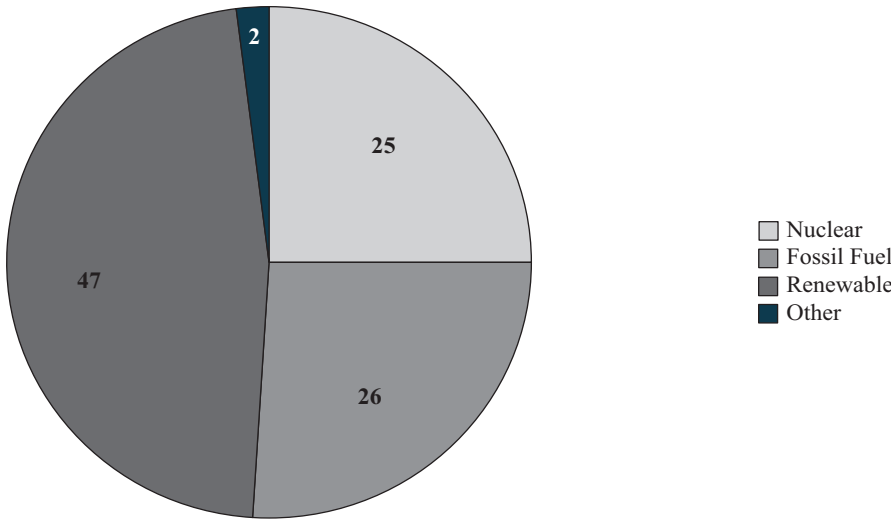
4.2.1. Diversification of energy supplies

One of the most important criteria for assessing the EU’s energy resilience is to determine the level of diversification of supplies of the most important energy resources. The Herfindahl-Hirschman Index (HHI) is used here, which shows the level of concentration (and thus diversification) of energy sources and suppliers of raw materials (Rubio-Varas, Muñoz-Delgado, 2019, p. 1231). The HHI for gas imports to the EU fell from 0.22 in 2019 to 0.18 in 2024, marking a decrease in supply concentration and greater diversification of suppliers. First of all, Russia’s share in EU natural gas imports has decreased from 40% in 2019 to 18% in 2024 (European Commission, 2024). The importance of other suppliers, notably Norway and Algeria (42% and 16% of EU gas imports, respectively), as well as LNG supplies from the US (38% of EU LNG imports) have increased. However, Russian LNG still accounts for 19% of EU LNG imports (European Commission, 2024).

4.2.2. Share of renewable energy sources

An increase in the share of renewable energy contributes to greater energy independence of the EU and at the same time reduces greenhouse gas emissions, which promotes decarbonisation. This is especially true for the production of electricity. According to Eurostat data (2024), the share of RES in electricity production in the EU increased from 34% in 2019 to 47% in 2024. The share of nuclear power was 25%, while fossil fuels fell to a record low of 26% (Ember, 2025).

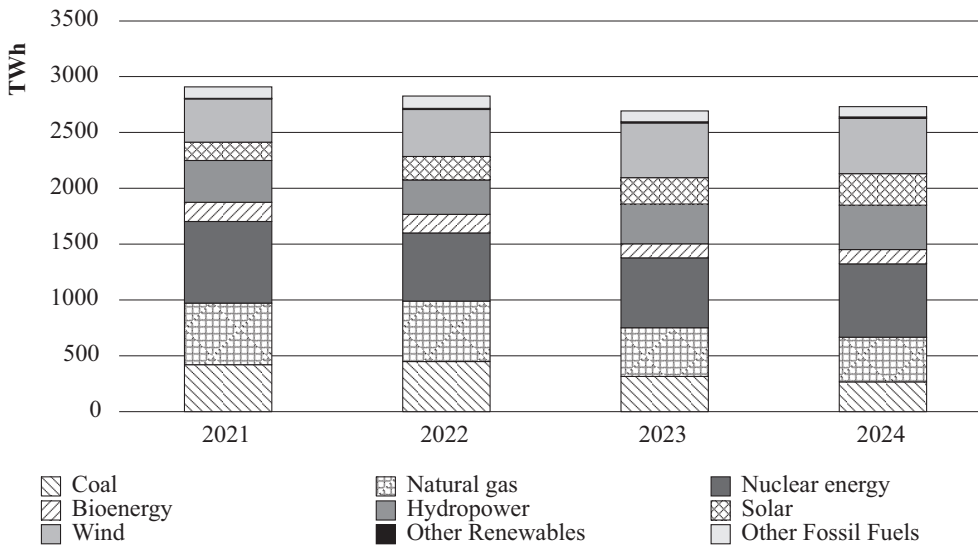
Chart 2. Composition of EU’s electricity generation in 2024 in %



Source: Own study based on data from: EMBER, 2025.

Analysing the data on the volume of electricity production in the EU, it is clear that energy production is generally decreasing due to lower demand (in 2024 2725 TWh) as a result of greater energy efficiency in various sectors. This trend has been observed for a decade. At the same time, the share of clean energy from sources such as solar, wind, hydro, bioenergy has steadily increased to 71%. This is a milestone in the EU’s energy transition. At the same time, fossil fuels fell to its lowest share ever – just a third of total generation. Wind and solar power rose to a record 27% of the EU’s electricity, with wind’s share overtaking gas (EMBER, 2024). An increase in the share of renewables reduces vulnerability to disruptions in the supply of fossil fuels (gas and coal) and thus increases overall energy resilience.

Chart 3. EU annual electricity generation mix in 2021–2024



Source: In-house analysis based on data from EMBER, 2024.

4.2.3. Energy efficiency

Improving energy efficiency aims to reduce energy consumption, leading to lower greenhouse gas emissions and energy costs for households and businesses. The decrease in energy intensity translates into lower sensitivity of economies to fluctuations in commodity prices and better crisis management in the event of energy shortages. Energy efficiency is measured, e.g. by the energy intensity index of the economy (the ratio of primary energy consumption to GDP). According to EEA data (EEA, 2024), energy intensity decreased by an average of 10% in the EU between 2019 and 2024. Member States are now required to further reduce energy consumption by 11.7% by 2030 compared to 2020. By 2030, the total energy consumption in the EU should not exceed 992.5 million Mtoe for primary energy. In 2023, primary energy consumption in the EU reached 1211 Mtoe and was the lowest since 1990 (Eurostat, 2024). The data show that

the EU is steadily reducing its energy intensity and approaching its target, but still needs to take action to increase energy efficiency. The countries where economies are the most energy-intensive are Bulgaria, Slovakia and Poland (Eurostat, 2024).

4.2.4. Security of supply and stability of gas prices

One of the important factors affecting the EU’s energy resilience is the security of gas supplies, which is a key raw material in electricity production, heating, the chemical industry and transport. Russia’s war in Ukraine has caused rapid fluctuations in the European gas market, while with the development of renewable energy sources and the increase in energy efficiency, the demand for gas is also falling. Total gas consumption in the EU decreased from 415 billion m^3 in 2019 to 370 billion m^3 in 2024 (European Commission, 2024). Total gas imports also decreased from 365 billion m^3 in 2019 to 310 billion m^3 in 2024. On the other hand, gas imports from Norway increased to 33% and the importance of LNG, which is imported from the US, Qatar and African countries, increased (IEA, 2024). The increase in the share of LNG in EU imports was a key element in replacing the missing volumes of Russian gas and improving security of supply.

Gas storage also has a major impact on energy resilience, which is why in 2022 the EU obliged member states to store at least 90% of their gas before winter and make it available in solidarity with other countries. Increasing the gas reserve is intended to ensure sufficient supply and protect citizens from high energy prices. The average filling level of gas storage facilities in the EU increased from 80% in 2019 to 95% in 2024 (European Commission, 2024).

Energy price stability is also an important element of energy resilience. After the outbreak of the war in Ukraine, international energy commodity markets reacted sharply with a surge in gas prices, which is key to stabilizing energy supply. Within a few months, gas prices rose from €20/MWh to over €200/MWh, according to the TTF exchange index, but in 2024 prices stabilised at €60–70/MWh (European Commission, 2024). While prices are still higher than before 2019 (by an average of €20–25/MWh), diversification of supplies and improvements in energy efficiency have reduced the negative impact of high gas prices on Member States’ economies.

4.3. Resilience indicators of the EU energy system

Four indicators were used to analyse the level of resilience of the EU energy system in the period 2019–2024 in a more measurable way: the Herfindahl-Hirschman Index (HHI) – used to measure the concentration (and thus diversification) of energy sources and suppliers of raw materials; Shannon-Wiener Index (SWI) – allows you to assess the diversity of the energy mix; Uniform Disruption Index (UDI) – estimating the level of risk of energy supply disruptions; Long-range Supply Index (LRSI) – assesses the stability and reliability of long-term supply, taking into account reserves and available alternative sources. In previous studies of the resilience of energy systems in different countries, these indicators are used to determine the main parameters and assess the

level of resilience to various disturbances (Martišauskas et al., 2022, pp. 3–18). The summary of the four main indicators of the resilience of the EU energy system in the period 2019–2024 is presented below. The presented data are average values for the entire Union.

Table 2

EU energy resilience indicators in the period 2019–2024

Indicators	2019	2024	Trend (↑/↓)	Interpreting the trend
HHI (Natural gas & oil)	0,22	0,18	↓ (decrease in concentration)	Greater diversification of energy supplies.
SWI (EU energy mix)	1,20	1,50	↑ (increase in diversity)	Growing share of RES, decreasing imports from one source of supply.
UDI (0–1; The higher you go, the greater the risk)	0,45	0,35	↓ (Decrease in risk)	Better EU preparedness for disruptions.
LRSI (0–1; The higher, the greater the certainty)	0,60	0,68	↑ (Increase in supply reliability)	Increasing the availability of alternative sources of raw materials.

Source: In-house analysis based on data from European Commission, 2024; IEA, 2023/2024; Eurostat, 2024.

4.4. Sources of financing for the energy sector

Energy resilience is determined not only by political and technological conditions, but also by financial conditions, including public and private investments. Questions about finances primarily concern sectors considered to be the most important for energy resilience: renewable energy sources, expansion of gas and electricity infrastructure, storage, hydrogen projects. The main sources of financing for the energy sector in the EU can be divided into: EU instruments, private sector investment and national budgets. The EU’s financial instruments are primarily the Recovery and Resilience Fund under Next Generation EU, with a budget of EUR 672.5 billion, of which about 40% is allocated to the energy transition, as well as the InvestEU Programme, which offers guarantees for private investment in strategic sectors. In 2023–2024, many renewable energy infrastructure, hydrogen and transmission network projects were financed from this program. Structural and Cohesion Funds also support the modernisation of energy networks, energy efficiency and the development of renewable energy sources.

Private sector investments are most often carried out in the form of consortia and industrial platforms (e.g. H2Global, Clean Hydrogen Alliance), in which private investors (energy companies, investment funds) together with public institutions implement projects related to, for example, green hydrogen, energy storage, offshore wind farms. Green bonds are also issued – mainly by companies and banks to finance sustainable energy projects. According to IEA data, the value of green bond issuance in the energy sector in the EU exceeded EUR 80 billion per year (IEA, 2024). EU member states also have a large share in financing energy resilience, which (e.g. Germany, France) create special support funds and credit lines for the development of low-carbon energy. In Poland and other countries of Central and Eastern Europe, the support from EU funds is of the greatest importance.

Table 3

Sources of financing for EU energy investments

Sources of financing	Selected financial instruments	Financial outlays
EU budget	EU Recovery and Resilience Facility	€723.8 billion (€385.8 billion in loans + €338 billion in grants), 40% of which is for the energy transition.
	InvestEU	€38 billion in guarantees to support energy investments
	ERDF and Cohesion Fund	118 billion Euros for the 2021–2027 programming period
European Investment Bank	Loans and credits	€56 billion in 2018–2022
Private investment	Consortia e.g. H2Global, Clean Hydrogen Alliance	Clean Hydrogen Alliance – €1 billion in EU subsidies + €1 billion in private investment in hydrogen technologies.
	Green bonds	In 2022, corporations increased their green bond issuance to 11% of the total number of corporate bonds. It is about EUR 80 billion per year.
Domestic investments	Special funds and co-financing for EU subsidies	For example, the German government has created a special fund with 100 billion euros for the energy transition In 2023, EU countries invested €100 billion in renewables

Sources: Own elaboration based on data from: IEA, 2024 and European Commission, 2024.

The increase in funding for the EU’s energy transition has contributed significantly to the gradual strengthening of its energy resilience. It is estimated that in the period 2019–2024, the EU has allocated a total of more than EUR 200 billion to projects improving energy security. These funds have made it possible to diversify the energy mix through significant investments in renewable energy sources and independence from gas and oil imports.

5. Conclusions

The analysis shows that the use of the energy resilience category is an accurate and adequate approach to assessing the EU’s energy security, especially in the event of an energy crisis. It allows for the use of a broader perspective, taking into account many aspects of the functioning of the energy system, as well as a process approach, in which attention is focused not only on ensuring energy supply, but also on a possible response to threats and adaptation to changes in the long term. The combination of a qualitative analysis of the EU’s energy policy and its sensitivity to geopolitical, technological and climate risks and threats with the analysis of quantitative indicators allows several conclusions to be drawn.

Firstly, energy policy has become the EU’s strategic policy in the long term, which has a significant impact not only on the European economy, but also on the security of the entire Union. However, despite long-term planning, geopolitical risks and threats were not foreseen, including Russia’s war in Ukraine, which has led to an energy crisis in Europe. Secondly, the resilience of the EU’s energy system is steadily increasing due to the increasing share of renewable energy sources in the energy mix, with a simultaneous

decrease in the share of fossil fuels, as well as the reduction of dependence on Russia through the diversification of energy supplies. There is also a visible improvement in energy efficiency, which results in a relative stabilization or even a decrease in energy demand despite economic growth. Thirdly, not only is there an increase in financial outlays to improve energy resilience, but also an increase in the variety of financial instruments.

The research confirms the thesis that the EU has insufficiently identified geopolitical risks and threats until 2022 and only after the start of Russia’s military aggression in Ukraine did it begin to systematically strengthen its energy resilience. However, the level of this resilience in some dimensions is still unsatisfactory, especially in terms of dependence on gas imports (including LNG), the expansion of transmission networks, and the development of new clean energy technologies. The EU’s energy resilience is exposed to many risks of various natures, but the energy crisis in 2022 shows that geopolitical threats have proven to be the most important, including Russia’s war in Ukraine. The slow-moving energy transition can be the basis for building the EU’s energy resilience, but this requires further efforts and consistent action.

Further research on energy resilience should focus on the development of integrated models and tools to analyse multiple aspects of energy resilience that take into account the complexity of factors (geopolitical, technological, economic).

Bibliography

Aldieri L., Gatto A., Vinci C. (2021), *Evaluation of energy resilience and adaptation policies: An energy efficiency analysis*, “Energy Policy”, 157, pp. 1–3, https://www.sciencedirect.com/science/article/abs/pii/S030142152100375X?via%3Dihub.

Dzierżanowski P., Nowak Z. (2023), *Kryzys energetyczny a ochrona przedsiębiorstw i konsumentów w UE*, „Biuletyn”, nr 69, PISM, pp. 1–2, https://www.pism.pl/publikacje/kryzys-energetyczny-a-ochrona-przedsiebiorstw-i-konsumentow-w-ue.

EMBER (2025), *Solar overtakes coal in EU power sector, as gas declines for the fifth year in a row*, https://ember-energy.org/latest-updates/solar-overtakes-coal-in-eu-power-sector-as-gas-declines-for-the-fifth-year-in-a-row/.

EMBER (2024), *The EU power sector in 2024*, https://ember-energy.org/latest-insights/european-electricity-review-2025/2024-at-a-glance/#solar-reaches-record-highs-while-nuclear-and-hydro.

EMBER (2024), *EU Electricity Trends 2024*, https://ember-energy.org/latest-insights/european-electricity-review-2024/eu-electricity-trends/.

ENISA (2024), *Cyber Europe tests the EU Cyber Preparedness in the Energy Sector*, https://www.enisa.europa.eu/news/cyber-europe-tests-the-eu-cyber-preparedness-in-the-energy-sector.

Eurelectric (2025), *Cybersecurity in the power sector*, https://www.eurelectric.org/in-detail/cybersecurity-in-the-power-sector/.

Eurelectric (2023), *How to strengthen energy resilience in an uncertain world*, https://www.eurelectric.org/in-detail/energy-resilience/.

Euronews (2025), *Three EU countries among worst affected by climate-related extreme weather*, https://www.euronews.com/green/2025/02/13/three-eu-countries-among-worst-affected-by-climate-related-extreme-weather-report-finds.

European Commission (2024), *Factsheet on EU’s response to the high energy prices and security of supply*, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/eu-action-address-energy-crisis_en.

European Commission (2024), *State of the Energy Union Report 2024*, https://energy.ec.europa.eu/publications/state-energy-union-report-2024_en.

European Commission (2024), *EU imports of energy products – latest developments*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_imports_of_energy_products_-_latest_developments.

European Commission (2024), *Quarterly report on European gas markets. Market Observatory for Energy*, DG Energy, vol. 17.

European Commission (2024), *EU gas storages 95% full ahead of 1 November, surpassing the 90% target in the Gas Storage Regulation*, https://energy.ec.europa.eu/news/eu-gas-storages-95-full-ahead-1-november-surpassing-90-target-gas-storage-regulation-2024-10-31_en.

European Commission (2023), *Commission welcomes completion of key ‘Fit for 55’ legislation, putting EU on track to exceed 2030 targets*, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4754.

European Commission (2022), *Communication REPowerEU Plan*, COM(2022) 230 final, Brussels, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52022DC0230.

European Commission (2015), *Energy Union Package, A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy*, Brussels, COM(2015) 80, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0080.

European Energy Agency (2025), *Energy and Environment Report 2024*, https://europeanenergy.com/wp-content/uploads/2025/02/annual-report-2024.pdf.

Eurostat (2025), *Shedding light on energy in Europe*, https://ec.europa.eu/eurostat/web/interactive-publications/energy-2025.

Eurostat (2024), *EU trade with Russia - latest developments 2024* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_trade_with_Russia_-_latest_developments#Latest_developments.

Eurostat (2024), *EU imports of energy products – latest developments*, December 2024, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_imports_of_energy_products_-_latest_developments.

Eurostat (2024), *Energy efficiency statistics*, December 2024, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_efficiency_statistics.

Gatto A., Drago C. (2020), *Measuring and modelling energy resilience*, “Ecological Economics”, 172, https://www.sciencedirect.com/science/article/abs/pii/S0921800919301570.

Guarascio D., Reljic J., Zezza F. (2025), *Energy vulnerability and resilience in the EU: concepts, empirics and policy*, “Journal of Industrial and Business Economics”, February.

IEA (2024), *World Energy Outlook 2024*, https://iea.blob.core.windows.net/assets/140a0470-5b90-4922-a0e9-838b3ac6918c/WorldEnergyOutlook2024.pdf.

IEA (2024), *World Energy Investment 2024*, https://www.iea.org/reports/world-energy-investment-2024.

Jasiunas J., Lund P. D., Mikkola J. (2021), *Energy system resilience – A review*, “Renewable and Sustainable Energy Reviews”, vol. 150, October 2021, 111476.

Joshi P., Gokhale-Welch C. (2022), *Fundamentals of Energy Security and Resilience*, NREL, November, https://www.nrel.gov/docs/fy23osti/84499.pdf.

Knight R., Hutchinson A., Horigoshi A., Custer S. (2023), *Illuminating Energy Security: Assessing Risks and Resilience in Europe & Eurasia*, AIDATA, Policy Brief, June, https://www.aiddata.org/publications/illuminating-energy-security-assessing-risks-and-resilience-in-europe-and-eurasia.

Martišauskas L., Augutis J., Krikštolaitis R., Urbonas R., Šarūnienė I., Kopustinskas V. (2022), *A Framework to Assess the Resilience of Energy Systems Based on Quantitative Indicators*, “Energies”, 15(11), https://www.mdpi.com/1996-1073/15/11/4040.

Misiągiewicz J. (2022), *Energy security as an area of international security*, „Stosunki Międzynarodowe – International Relations”, vol. 58.

Rubio-Varas M., Muñoz-Delgado B. (2019), *The Energy Mix Concentration Index (EMCI): Methodological considerations for implementation*, MethodsX, vol. 6, pp. 1228–1237.

World Economic Forum (2021), Fostering Effective Energy Transition, https://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2021.pdf.

Odporność energetyczna jako wyzwanie dla Unii Europejskiej w czasach kryzysu energetycznego

Streszczenie

Odporność energetyczna jest ważnym paradygmatem w badaniach nad bezpieczeństwem energetycznym, ponieważ pozwala na analizę wielu aspektów funkcjonowania systemu energetycznego. Głównym celem artykułu jest analiza procesu wzmacniania odporności energetycznej UE w czasie kryzysu energetycznego po wybuchu wojny Rosji w Ukrainie. Pytania stawiane w badaniach to: na jakiego rodzaju ryzyka narażona jest UE w sektorze energetycznym, czy i w jakim stopniu UE wzmacnia swoją odporność energetyczną, jakie są wymiary tej odporności, czy UE była przygotowana na kryzys energetyczny, jaki jest obecny poziom odporności energetycznej UE. W badaniach wykorzystano różne metody: krytyczną analizę jakościową dokumentów i raportów oraz literatury naukowej, analizę *process tracing* polityki energetycznej UE, analizę danych statystycznych dotyczących energii. W badaniu postawiono tezę, że UE w niewystarczającym stopniu zidentyfikowała najważniejsze zagrożenia dla odporności energetycznej do 2022 r. i zaczęła ją intensywnie wzmacniać dopiero po inwazji militarnej Rosji w Ukrainie. Jednak poziom tej odporności wciąż nie jest zadowalający, co pokazują wskaźniki zastosowane do jej pomiaru.

Słowa kluczowe: odporność energetyczna, Unia Europejska, bezpieczeństwo energetyczne, kryzys energetyczny

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