POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2023 ✦ Volume 26 ✦ Issue 2 ✦ 23–46

DOI: 10.33223/epj/163355

Vahe Davtyan[1], Silva Khachikyan[2], Yulia Valeeva[3]

An assessment of the sustainability and security of energy systems: an analysis of the energy trilemma index on the example of Russia, Kazakhstan and Armenia

Abstract: Ensuring access to sustainable, affordable and clean energy sources is a top priority of the global energy agenda. It is reflected in the seventh goal of the UN Sustainable Development Agenda with the three dimensions of economic growth, social inclusion and environmental protection. The seventh goal is aimed at providing the sustainable development of energy systems whilst taking into account these dimensions. To assess the development trends of national energy systems within the framework of the global energy agenda, certain methods of quantitative measurement have acquired particular relevance. Approaches to assessing energy security mainly depend on the interpretation of the "energy security" concept. The main methods for the integrated assessment of the energy security of states are generally compiled by international organizations. An important indicator for the measurement of the sustainable development of energy systems is the Energy Tri-

✉ Corresponding Author: Vahe Davtyan; e-mail: vahe.davtian@gmail.com

[1] Russian-Armenian (Slavonic) University, Yerevan, Armenia; ORCID iD: 0000-0002-0848-3436; e-mail: vahe.davtian@gmail.com

[2] Russian-Armenian (Slavonic) University, Yerevan, Armenia; ORCID iD: 0000-0003-3604-1392; e-mail: khachikyans@gmail.com

[3] Kazan State Power Engineering University, Kazan, Russia; ORCID iD: 0000-0002-1356-0360; e-mail: valis2000@mail.ru

lemma Index, built within the framework of the "energy trilemma" concept. It allows quantifying the ability of states to ensure energy security, energy equity and environmental sustainability, taking into account the national context.

Special attention is paid to the analysis of the energy systems of Russia, Kazakhstan and Armenia through the Energy Trilemma Index 2022. The studied countries actively participate in the integration processes in the Eurasian and post-Soviet space. Thus, the analysis of the Energy Trilemma Index 2022 allows us to become acquainted with the main trends of the energy sector development in the Eurasian space, exploring the conjuncture of energy markets and their main challenges. The study of the energy systems of Russia, Kazakhstan and Armenia through the energy trilemma index enables the identification the methodological significance of the index for assessing the sustainable development of national energy systems. The practical relevance of the index in the formation of the state energy policy for the sustainable development of the energy systems has also been emphasized.

Keywords: energy trilemma index, energy security, energy equity, environmental sustainability

Introduction

Any national energy system has a complex structure, including economic, (geo)political, social, environmental and security aspects. The development of energy policies in different economies depends on their specific circumstances with different geographies, socio-economic systems, and natural resources (Khan et al. 2021). This complicates the process of assessing the degree of stability and security of national energy systems. International organizations and scientific communities have developed various methodologies, indicators and indices to assess various aspects of the sustainability and security of energy systems. Of particular scientific value are those methods of studying the world energy industry which comprehensively consider the industry in all its complexity and include several evaluation parameters. Complex indicators are more widely used to assess the state of energy security, determine its dynamics and conduct cross-country comparisons (Kononov 2018).

Methods for assessing the state of energy security largely depend on the interpretation and content of the "energy security" concept. D. Yergin notes that the traditional concept of energy security, which arose during the 1973 crisis, needs to be expanded to include the protection of the entire energy supply chain and infrastructure. At the same time, he highlights some principles of energy security that countries must reckon with to ensure energy security: the diversification of supplies, sustainability, recognition of the reality of integration, the importance of information to support well-functioning markets. The new concept of energy security should include two critical aspects: recognition of the globalization of the energy security system and recognition of the fact that the entire energy supply chain needs to be protected (Yergin 2006). Since 2015, with the introduction of the UN Sustainable Development Agenda, the "energy security" concept has been enriched with new approaches. Thus, modern methods

for assessing energy security are mainly based on the principle of ensuring socio-economic and environmental development.

1. Literature review

The main methodological approaches to the assessment of energy security and energy sustainability are discussed by Cherp and Jewell (2014), Sovakool and Mukherjee (2011), Koyama and Kutani (2012) and Kuntjoro et al. (2021). Zakharov (2017) writes about the importance of the Energy Trilemma for identifying threats and challenges to global energy security, noting that this concept boils down to "finding a balance between the desire for energy security, the availability of energy supply and environmental sustainability" (Zakharov 2017). The evaluation of the Energy Trilemma Index reliability is discussed by Šprajc et al. (2019). Mastepanov and Chigarev (2020) discuss the importance of the energy trilemma index for assessing the sustainability of national energy policies and developing safe, equitable, affordable and environmentally sustainable energy (Mastepanov and Chigarev 2020). Kang (2022) analyses the relationship between the energy trilemma and economic growth, noting that the dimensions of the energy trilemma are all closely related to economic activities, and vice versa (Kang 2022). The implications for understanding the impact of the energy trilemma on sustainable economic development and geopolitics are given by Shirazi et al. (2023). The authors note that energy, particularly energy security, is interconnected with geopolitical tensions, as illustrated by the two Gulf Wars and the current Ukrainian war.

The issues of applying the energy trilemma index in the context of risks and threats to global development in the context of COVID-19 are analyzed in the article by Medzhidova and Grigoryev (2020). The authors note a decrease in all indicators of the index dimension associated with the disruption of a stable energy supply, the paralysis of transport communications and a decrease in energy consumption in the world. The responses to Russia's war in Ukraine with regard to energy policyin terms of challenges of energy trilemma are discussed by Kuzemko et al. (2022). They emphasize that the conflict has led to a refocus in policy circles on geopolitical energy security and has made it harder to set a balance in energy policy goals.

2. Materials and methods

An integrated approach was used in the research which includes the analysis of scientific and regulatory literature and the study of international practice with regard to ensuring energy security. The work uses analytical, statistical methods and methods of comparative typological

research. Due to the interdisciplinary nature of the study, the authors use the SWOT analysis tool to identify various aspects and problems of the functioning of the energy systems of Russia, Kazakhstan and Armenia in the context of the Energy Trilemma Index.

An adopted approach to assessing energy security is a "four A" framework, including assessing the availability, accessibility, affordability and acceptability of energy resources. In 2007, the Asia -Pacific Energy Research Center (APERC) used this framework to assess energy security in Asian countries (Cherp and Jewell 2014). Meanwhile, some researchers offer an updated version of the "four A" scheme. It is formulated as "4 A + 1 S", where "S" means sustainability, meaning that the energy source used must be able to be used continuously in the long term (Kuntjoro et al. 2021).

Any comprehensive indicator for assessing the level of energy security needs goal setting with regard to the research tool, theoretical foundations, the choice of constituent components, indicators and sub-indices, their grouping, methods for determining their quantitative significance and summarizing the results. The complexity of the index depends on the number and complexity of the indicators and sub-indices used to measure the level of energy security. Sovacool and Mukherjee (2011) propose considering the following five dimensions that include energy security: affordability, technology development and efficiency, environmental and social sustainability, regulation and governance. They include 320 simple indicators and 52 complex indicators that can be used to analyze, measure, track and compare national energy security indicators (Sovacool and Mukherjee 2011). However, the more indicators an index uses, the more difficult it is to collect reliable data, summarize results, and make comparisons.

Thus, scientific communities use different approaches with regard to assessing energy security. In international practice, complex tools and indices for assessing energy security are more widely used, which makes it possible to take into account various aspects of state energy and economic policy and the impact of global trends on the functioning of national energy systems.

The International Energy Agency (IEA) has developed a methodology for assessing the security of energy supply by individual energy carriers – the Model of Short-Term Energy Security (MOSES). Based on quantitative indicators, MOSES groups countries with a similar mix of energy system risks and vulnerabilities. The security of the supply of seven primary energy sources (crude oil, natural gas, coal, bioenergy and waste, hydropower, geothermal energy and nuclear energy) and two groups of secondary fuels (petroleum products and biofuels) is analyzed (Grigoriev and Mejidova 2020). MOSES examines the external and internal factors that affect the safe operation of each energy carrier in terms of assessing the risk exposure and sustainability of energy systems. In order to analyze these aspects of energy security, MOSES uses thirty-five indicators to assess risks and levels of resilience for each energy source of national energy systems. For example, indicators of dependence on net imports (risk), political stability of suppliers (risk), entry points (resilience) and diversity of suppliers (resilience) are used to assess the impact of external factors on the reliability of the crude oil supply. At the same time, to analyze the influence of internal factors, indicators of the share of offshore production (risk), volatility of domestic production (risk) and the average level of storage (stability) are used.

The quantitative values of the indicators are combined in two stages. In the first stage, the degree of riskiness (low, moderate, high) of external and internal risks and the sustainability of energy

sources are determined. In the second stage, a generalized description and assessment of the degree of provision of the country with a certain source of energy is given. The countries are divided into five groups from A (highest level) to E (lowest level), which makes it possible to cluster countries with the same energy security risks. This can become the basis for studying the characteristics of the energy policy of individual countries in order to reduce a certain type of energy risk and thus, to revise the national energy policy. MOSES does not imply a comprehensive assessment of energy security and the determination of the overall impact of various energy resources on it. This is an effective tool for short-term planning and risk management in the field of energy security.

The ASEAN and East Asia Economic Research Institute (ERIA) used the principle of risk management to improve the energy security situation to develop the Energy Security Index (ESI) (Koyama and Kutani 2012). ESI quantifies the status of each factor underlying the overall energy security: developing domestic resources, acquiring foreign resources, securing a reliable domestic supply chain, managing demand, preparedness for supply disruptions, and environmental sustainability. Transport risk management is not assessed due to the difficulty of quantifying large differences in the means of transporting energy resources. Each component of the ESI has indicators that can be determined separately by implementing the corresponding formulas. The definition of ESI enables tracking of the dynamics of indicators for individual countries and regions in the longer term. However, like the previous assessment tool, ESI does not provide an overall assessment of the state's energy security.

In the United States, a different approach is used to quantify the energy security by using the US Energy Security Risk Index developed by the Global Energy Institute (GEI). The US Energy Security Risk Index combines four sub-indices (geopolitical, economic, reliability, and environmental) with nine categories and thirty-seven indicators (US Energy... 2020). Since 2012, the GEI has developed the International Energy Security Risk Index to analyze energy security risks globally and compare US energy security risks with twenty-four other major energy consumer countries (International energy... 2020). The International Energy Security Risk Index uses twenty-nine indicators to assess levels of risk in eight broad categories: global fuels, fuel imports, energy costs, price and market volatility, energy intensity, electricity sector, transport sector, environment. Some indicators used in the index are not directly measured. A feature of the International Energy Security Risk Index is the consideration of political and civil freedoms in the countries under study by assessing the reserves or the production of oil, natural gas and coal in each country according to the corresponding Freedom house weighting. It is assumed that civil and political freedoms indirectly affect the political stability and reliability of the country as an energy supplier and trading partner.

The starting point for tracking energy risk dynamics was the 1980 OECD value set to 1000. Thus, the energy security risks are measured in two ways: in absolute terms and relative to the baseline average of OECD countries. Each indicator of the International Energy Security Risk Index has its own weight in the overall risk assessment. Certain indicators are combined to get an overall index for each country. Energy security indicators can also be compared separately. The lower the overall index score, the lower the energy security risks. In 2018, the US has the best energy security risk score ever compared to the other twenty-four countries with a risk score

of 727, while the average OECD risk score is 884. Compared to 1980, the overall index is down 67.9 %. The Security Risk Index has a limited geographic coverage so far and allows the determination of energy security risks only for large energy consuming countries.

The advantages and disadvantages of each studied indicator are presented in Table 1.

Table 1. The advantages and disadvantages of the studied indexes (developed by the authors)

Tabela 1. Zalety i wady badanych wskaźników (opracowanie autorów)

Index name	Benefits (+)	Flaws (–)
Model of short-term energy security (MOSES)	An assessment of energy security, taking into account external and internal risks for each type of energy carrier enables signaling the level of risk for each energy sector and track the impact of a particular policy on energy security over time. Clustering of countries with similar risks can be useful for studying the specifics of the energy policy of individual countries and facilitating dialogue between politicians. It is an effective risk management tool in the energy sector.	The tool is focused on the short-term, physical provision of meeting the needs for individual energy resources. It doesn't address environmental, economic, institutional and other aspects of energy security. MOSES is not designed as a comprehensive energy security assessment tool and does not summarize indicators.
Energy Security Index (ESI)	ESI allows you to analyze changes in energy security in the long term and make historical comparisons. A feature of the index is the measurement of the dependence of national energy systems on the Middle East in terms of the acquisition of oil and gas, which makes it possible to determine the level of diversification of import sources.	It does not address the impact of the availability of energy sources and institutional aspects on energy security. Transport risk management is considered as a measure of energy security, but there is no corresponding index for it. The ESI makes it possible to quantify each factor underlying energy security without a generalized assessment of the overall level of energy security.
International Energy Security Risk Index	The index comprehensively assesses energy security and can be used to analyze the dynamics of energy security in the long term. The dynamics for each index metric and for the overall score can be traced historically for each country. A feature of the index is the weighting of the energy reserves of each country by its corresponding weighting of Freedom House, assuming that the more democratic the political regime in a country, the more politically stable and reliable a trading partner is the studied country.	In terms of assessing the impact of institutional factors on energy security, the index considers only political and civil freedoms (according to the Freedom House) without taking into account the impact of the efficiency of the government, macroeconomic factors and other factors on energy security. The index has limited geographic coverage and is designed to compare US energy security risks with other major energy consuming countries.

The studied indexes for assessing energy security partially examine certain aspects of the sustainable and safe development of energy systems. Among them, only the International Energy Security Risk Index combines all metrics into an overall risk score, making it easier to compare countries for energy policy making. In addition, the limited geographic coverage of the indexes makes it difficult to understand trends in the global energy system.

The Energy Trilemma Index, developed by the World Energy Council (WEC) in partnership with the consulting company "Oliver Wyman Group", is another comprehensive index for assessing the level of sustainability and security of energy systems worldwide.

3. The Energy Trilemma Index

The Energy Trilemma Index evaluates and ranks countries by their ability to provide sustainable energy systems. The methodology of the Energy Trilemma Index for assessing energy systems aligns with the three pillars of the UN Sustainable Development Agenda: economic efficiency, social equity and environmental sustainability. These three pillars of the Sustainable Development Agenda laid down the foundation for the concept of the "trilemma", which shows the interconnectedness and interdependence of these three dimensions. The term "trilemma" has been used to create the World Energy Trilemma Index, which quantifies the provision of safe, fair, affordable and environmentally sustainable energy. The three main dimensions of the index are energy security, energy equity and environmental sustainability (Fig. 1).

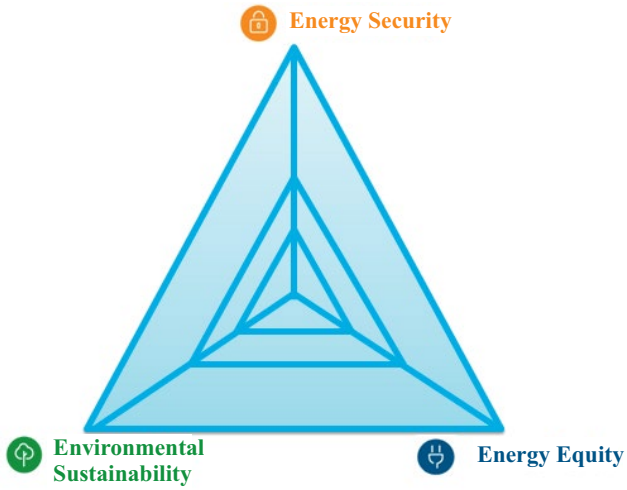

Fig. 1. Main parameters of the Energy Trilemma Index

Rys. 1. Główne parametry Energy Trilemma Index

The first dimension of the index, energy security, shows the reliability of the energy infrastructure through the diversification and decarbonization of the energy system, as well as the ability of energy suppliers to meet the current and future energy demand. The second dimension is energy equity (accessibility and affordability), which evaluates a country's ability to provide

access to reliable and affordable energy to the population against the backdrop of socio-economic development. This component includes basic access to high quality domestic and commercial electricity, clean fuels and cooking technologies, and the availability of electricity, gas and fuels. The third dimension of the energy trilemma is environmental sustainability, which refers to the greening of energy systems based on the principle of reducing and preventing environmental damage, air pollution, the effects of environmental degradation and climate change.

Increasing environmental sustainability shows an energy transition to the low-carbon or carbon-free energy sources and, in particular, renewable energy sources (RES). Renewable energy allows energy-importing states to significantly reduce their dependence on external supplies, thereby strengthening their energy security (Simonova and Zakharov 2016).

In addition to the above three dimensions, the index also takes into account the fourth dimension – the national context – which includes the main macroeconomic, geographical, political and institutional features of the studied countries, allowing them to implement their energy policy. The structure of the Energy Trilemma Index is presented in Table 2.

Table 2. Energy Trilemma Index 2021 structure and weighting of the indicators

Tabela 2. Struktura Energy Trilemma Index 2021 i wagi wskaźników

Energy Security – 30%	A1. Security of supply and demand – 12%	A1a. Diversity of primary energy supply – 6%	Energy Equity – 30%	B1. Energy access – 12%	B1a. Access to electricity – 6%
		A1b. Import independence – 6%			B1b. Access to clean cooking – 6%
	A2. Resilience of enerrgy systems – 18%	A2a.Diversity of electricity generation – 6%		B2. Quality energy access – 6%	B2a. Access to «modern» energy – 6%
		A2b. Energy storage – 6%		B3. Energy affordability – 12%	B3a. Electricity prices – 3%
					B3b. Gasoline and diesel prices – 3%
		A2c. System stability and recovery capacity – 6%			B3c. Natural gas prices – 3%
					B3d. Affordability of electricity for residents – 3%
Environmental Sustainability – 30%	C1. Resource productivity – 10%	C1a. Final energy intensity – 5%	Country Context – 10%	D1. Macroeconomic environment – 2%	D1a. Macroeconomic stability – 2%
		C1b. Efficiency of power generation and T&D – 5%		D2. Governance – 4%	D2a.Effectiveness of government – 1%
	C2. Decarbonisation – 10%	C2a. Low carbon electricity generation – 5%			D2b. Political stability – 1%
					D2c. Rule of law – 1%
		C2b. Trend of GHG emissions from energy – 5%			D2d. Regulatory quality – 1%
	C3. Emissions and pollution – 10%	C3a. CO_2 intensity – 2%		D3. Stability for investment and innovation – 4%	D3a. Foreign direct investment net inflows – 1%
					D3b. Ease of doing business – 1%
		C3b. CO_2 per capita – 2%			D3c. Perception of corruption – 0.5%
		C3c. CH4 emissions from energy per ktoe – 1%			D3d. Efficiency of legal framework in challenging regulation – 0.5%
					D3e. Intellectual property protection – 0.5%
		C3d. $PM_{2.5}$ mean annual exposure – 5%			D3f. Innovation capacity – 0.5%

Each dimension of the index is evaluated in the ranges A, B, C and D. The first letter stands for energy security, the second letter for energy equity, and the third letter for environmental sustainability. The first three letters make up 90% of the total score, with the remaining 10% is formed by an additional fourth dimension. Thus, the Energy Trilemma Index has four letters, each ranging from A (best) to D (worst). The main measurements of the index have their own summary indicators, each of which has its share in the overall assessment (World Energy Trilemma Index 2022 Report 2022).

In the 2022 report, the necessity of further reimagination of the Trilemma methodology to reflect all the processes in the energy transition is emphasized. To gain a more holistic view with regard to energy systems, some new metrics, such as water/energy nexus, energy storage, regional integration, humanizing energy and fuel poverty, will be taken into account in future Trilemma iterations.

4. Sustainable development of energy systems according to the Energy Trilemma Index

The Energy Trilemma Index tracks and quantifies 133 countries, but only 127 countries are included in 2022. Some countries were not included in the list due to political instability and a lack of data. The number of places in the ranking is ninety-one due to the same number of points being scored by some countries. Changes in the method of calculating the index performed in 2021 made it impossible to make comparisons with index ratings for previous periods. However, it is possible to trace the dynamics of changes in the main parameters of the index. The Energy Trilemma Index in 2022 is highly impacted by the converging Russian-Ukrainian crisis which led to energy shocks, the disruption of energy supplies and the formation of new regional blocs of energy supply. However, the global energy crisis is not only due the ongoing war in Europe but also a consequence of the COVID-19 pandemic which has undermined the global economy, exposing the social vulnerability of the global community and heightening concerns about energy availability.

The trilemma top ten for 2022 are OECD member countries. In particular, the leading positions in the index are occupied by European countries due to the implementation of effective long-term energy policy and the proper diversification of energy systems. The top three included Sweden (84.3 points), Switzerland (83.4), Denmark (83.3) and Finland (82.7).

The top three countries in terms of Energy Security are Canada (82.3), the United States (78.5) and Finland (82.7). Canada and the United States have resource-rich and self-sufficient economies. Generally, all the top performers in energy security benefit from the diversification of their energy systems and economies. Finland pays great attention to reducing the share of hydrocarbon energy and increasing the share of solar and wind energy in order to diversify the

energy mix. Even though Finland imports about 70% of its gas from Russia, it doesn't affect the energy security scores of the country as gas has a low share in the energy mix of Finland. Against the backdrop of the Ukrainian crisis, most European countries are facing an energy security crisis. European countries reconsider their energy policies in order to decrease their dependance on Russian energy supplies and to change the future energy mix by implementing strategies like REPowerEU. EU membership serves as an important catalyst for improving energy systems and liberalizing energy markets.

The top performers in terms of energy equity are Luxembourg (77.9), Qatar (68), Kuwait (67.6), UAE (70.5) and Oman (65), due to their high GDP, successful integration and low energy prices owing to the provision of subsidies and the presence of significant reserves of easily extractable hydrocarbon resources, especially the Middle Eastern countries. At the same time, many Gulf countries are performing economic reforms to diversify the energy market. Luxembourg particularly benefits from its central location in Europe allowing it to be connected to its neighboring energy networks. Given the lowest energy taxes and the highest GDP per capita in Europe, Luxembourg has become a country for energy tourism in Europe.

The leaders in environmental sustainability in 2022 are Sweden (84.3), Switzerland (83.4) and Norway (81). The top ten for environmental sustainability has traditionally been dominated by European countries due to high levels of renewable energy production and energy system efficiency.

Mention should be made of the assessment of the energy sustainability of Eurasian countries by using the Energy Trilemma Index. For this, it is appropriate to consider the energy systems of Russia, Kazakhstan and Armenia, which are actively involved in the integration processes in the Eurasian space. Key indicators of the energy trilemma index for Russia, Kazakhstan and Armenia are presented in Table 3.

Table 3. Key Indicators of the Energy Trilemma Index for Russia, Kazakhstan and Armenia in 2022

Tabela 3. Kluczowe wskaźniki Energy Trilemma Index dla Rosji, Kazachstanu i Armenii w 2022 roku

Index rank	Country	Balance grade	Trilemma score	Energy security rank	Energy security score	Energy equity rank	Energy equity score	Environmental sustainability rank	Environmental sustainability score
29	Russia	ABCc	69.6	16	69.9	40	81.4	64	63.9
40	Kazakhstan	BBDc	67.3	33	62.7	36	86.3	85	58.2
53	Armenia	DCBc	62.2	77	48.1	52	72.7	49	70.1

5. The analysis of national energy systems by the Energy Trilemma Index

Russia: Russia has the highest score on the energy trilemma among the three countries with an overall ABCc score of 69.6 and is ranked 29th in the world. However, there are a number of factors that make it difficult for Russia to reach a certain level of sustainable energy including the presence of large hydrocarbon reserves, the lack of distributed generation, significant depreciation of power plants, and the lack of incentives to reduce GHG emissions in a difficult economic situation and the presence of country specifics in relation to ensuring energy security (Loktionov 2018).

Russia's energy security is traditionally at level A with a score of 69.9 points in 2022, which allows it to enter the top twenty in this indicator. Russia is an energy-sufficient country, being one of the main producers and exporters of all types of carbon energy sources as well as being one of the world leaders in nuclear energy and hydropower. It continues to diversify the national energy system, exports of energy products, markets and transport routes.

The Russian-Ukrainian crisis has significantly affected Russian exports of fossil fuels. While the future of the Nord Stream 2 gas pipeline was uncertain after Russia recognized the independence of the DPR and LPR; furthermore, an explosion was detected in the Nord Stream pipelines in 2022. Following the developments of the war in Ukraine, the EU unveiled the "REPowerEU" plan, which aims to make Europe independent of the Russian gas well before 2030 by diversifying gas supplies, increasing LNG imports and pipelines from non-Russian suppliers, and increasing biomethane and renewable, hydrogen energy production and imports and a fast reduction in the use of fossil fuels in homes, buildings, industry and the energy system through the improvement of energy efficiency and the increased availability of renewable energy sources (REPowerEU: affordable, secure... 2022). It can be assumed that such structural changes in the global energy sector will affect the energy security of both Russia and European countries.

In addition to Nord Stream pipelines, Russia is also implementing other gas export pipeline projects: Power of Siberia (from Yakutia to Primorsky Krai, China and Asia-Pacific countries), Turkish Stream (from Anapa to Turkey via the Black Sea), Balkan Stream (from Turkey to Southeast Europe), Blue Stream (from Russia to Turkey) and others. In fact, the current geopolitical processes will only temporarily affect the export of Russian gas against the background of the growing energy crisis in the world. The concentration of Russian gas pipelines in the territory of Turkey and plans for Ankara to play the role of strategic transit corridor and a continental hub will possibly allow Russia to retain its positioning in some European energy markets (Secrieru et al. 2021).

Russia is one of the world leaders in the development of nuclear energy with thirty-seven operating reactors with a total capacity of 27,727 MW. The portfolio of foreign orders of the Russian state corporation, Rosatom, includes 35 NPP units at various stages of implementation, including the construction of the Belarusian NPP, the Akkuyu NPP in Turkey, the Kudankulam

NPP in India, the Paks-2 NPP in Hungary, the Rooppur NPP in Bangladesh, the Khudapu and Tianwan NPPs in China, and the El-Dabaa NPP in Egypt. The current positions of Rosatom in the global nuclear technology market can become decisive for promoting multilateral cooperation in nuclear energy through the development of nuclear energy in the Eurasian space and in the world, including the construction and operation of nuclear power plants, cooperation in the field of transportation, processing and the disposal of spent nuclear fuel and radioactive waste. Russia continues to develop nuclear technology as a low-carbon and reliable source of energy generation. In today's geo-economic realities, Rosatom is faced with the task of firmly gaining a foothold in the market for technologies and equipment for the nuclear fuel cycle, including the development of advanced nuclear technologies and fourth-generation reactors.

Russia has a score of 81.4 with a B level in energy equity. In terms of access to energy resources, Russia is implementing the federal program "Guaranteed Supply of Affordable Electricity" for the period up to 2024. The program includes measures to develop the power generation system and the power grid complex. The implementation of the program will ensure the growth of electricity consumption in centralized energy systems, reduce the unused excess installed capacity of power plants and ensure the commissioning of generating capacities in the amount of 4,000 MW (On topical issues... 2020).

In the "Energy Strategy of Russia for the period up to 2035", one of the tasks of Russia in the development of international relations in the field of energy is to spend participation in international efforts to ensure the sustainable development of world energy, according to the seventh goal of the UN Sustainable Development Agenda – ensuring universal access to affordable, reliable, sustainable and modern energy sources for all (Energy strategy of... 2020). In 2021, the State Duma adopted amendments to the law "On Gas Supply in the Russian Federation", including a newly adopted socially oriented free gasification program. According to the program, gas will be supplied to the population without attracting funds from citizens (The law on free...).

In terms of environmental sustainability, Russia has a C level with a score of 63.9. It is worth noting that Russia accepted the Paris Agreement in December 2015 and committed itself to reducing greenhouse gas emissions by 25% compared to 1990 levels. In accordance with this, the state regulation of GHG emissions and other anthropogenic impacts of the fuel and energy complex on the climate is performed taking into account the international obligations of the Russian Federation. In 2021, Russia adopted the "Strategy for the socio-economic development of the Russian Federation with low greenhouse gas emissions until 2050" (Strategy for the socio-economic... 2021). Planned actions under this strategy include next-generation smart heat, power and gas grids, energy storage, demand response, e-mobility, energy waste reduction, energy efficiency and smart metering. Energy efficient and environmental projects, according to the strategy, should reduce the carbon intensity of Russia's GDP by 8–10% by 2030 and by 40–50% by 2050 (World Energy Trilemma Index 2021 Report 2021).

In 2021, Russia adopted its green taxonomy, which creates a regulatory framework for sustainable (green) development in the Russian Federation. Renewable energy sources, low-carbon and hydrogen fuel, hydropower and nuclear power are recognized as environmentally sustainable types of economic activity in the energy sector of the Russian Federation (Taxonomy of

green projects... 2021). In this regard, it should be noted that Russian NPPs prevent 210 million tons of emissions per year, so the increase in nuclear capacity is another measure to manage the climate agenda (Rosatom designed...).

The presented table shows that the main negative factor affecting the development of the industry is the weak technological development in the field of renewable energy (Table 4). Long payback periods and high initial costs repel investors. Other factors follow from this factor: the weak development of renewable energy sources, the high cost of production based on renewable energy sources, the dependence on foreign equipment, the lack of necessary investments, price

Table 4. SWOT – analysis of the energy industry in Russia (developed by the authors)

Tabela 4. SWOT – analiza energetyki w Rosji (opracowanie autorów)

Strengths	Weaknesses
✦ implementation of modern information technology solutions; ✦ introduction of new generating capacities; ✦ modernization and reconstruction of generating equipment; ✦ sale of capacity under capacity supply agreements (CDA); ✦ establishment of indicators of limiting values of renewable energy facilities, target indicators of commissioning volumes and the degree of localization by years; ✦ setting of a price limit for electricity produced by RES; ✦ determination of a procedure for long-term tariff regulation and the rules for their functioning; ✦ provision of subsidies from the federal budget for the connection of generating facilities operating on the basis of RES.	✦ high depreciation of fixed assets of enterprises; ✦ lack of technologies and production of modern equipment; ✦ lack of generating capacities and poor development of power grids; ✦ reduction in the volume of investments and inefficient management of them; ✦ weak development of renewable energy sources; ✦ losses in electrical networks; ✦ high cost of electricity generation based on renewable energy sources; ✦ dependence on foreign equipment; ✦ use of services of foreign companies; ✦ regulatory barriers to the development of the electricity market; ✦ heterogeneity of the territorial structure; ✦ difficult geopolitical situation.
Capabilities	**Threats**
✦ construction of new capacities; ✦ ensuring the technological independence of the industry; ✦ improvement of the legal framework; ✦ reducing taxes on electricity and restructuring the use of excess heat; ✦ transition to environmentally friendly and resource-saving energy; ✦ formation of new energy sources, methods of transportation and storage; ✦ growth of the industry efficiency due to the implementation of large-scale investment projects; ✦ strengthening research in the field of energy and climate; ✦ availability of natural and climatic resources; ✦ reducing the burden on the environment.	✦ introduction of new sanctions affecting the industry; ✦ lack of necessary investment; ✦ increase in prices for used fuel and transportation; ✦ non-fulfillment of obligations for the supply of power; ✦ downtime and breakdown of generating equipment; ✦ changes in taxation, currency regulation, customs control and duties; ✦ reduction of electricity consumption; ✦ dependence on climatic conditions; ✦ natural disasters and man-made accidents.

increases, etc. The power industry market is undergoing significant changes and transformations that are associated with the introduction of innovative solutions. Companies need to rethink how they use innovation to capture market opportunities and change their overall growth strategy. The introduction of innovations was aimed at selective R&D related to energy generation and current operations, but in modern conditions, the view on them is changing and innovations are becoming the main components of the market entry strategy.

One of the main priorities of the energy policy of Russia is the formation of common markets for electricity, natural gas, oil and petroleum products from 2025 in the Eurasian Economic Union (EAEU), ensuring the free movement of goods, services, technologies and investments in the energy sector of the member states (Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia) and increases in the availability and affordability of energy resources.

Kazakhstan: In the Energy Trilemma Index 2022, Kazakhstan's balance sheet score is BBDc (67.3) and the country ranks 40th in the world. The country has a level B (62.7) in terms of energy security and there is a negative trend in this dimension compared to 2021. The Kazakh economy is highly dependent on global trends in the world energy market, which have a significant impact on the performance of the fuel and energy complex of the country. Kazakhstan is a net exporter of primary energy resources (mainly oil), so the Kazakh economy's heavy dependence on energy means that global trends such as declining commodity prices will continue to have a huge impact on the situation in Kazakhstan, affecting performance of the fuel and energy complex. The country has diversified export markets and reduced dependence on any particular export route. At the same time, due to the COVID-19 pandemic, the net exports of primary energy resources from Kazakhstan decreased sharply in 2020–2021 (National Energy Report 2021).

According to the forecast for the electric power industry development of Kazakhstan until 2035, abnormal rates of electricity consumption have brought Kazakhstan closer to an energy deficit, which was not expected until 2025 (World Energy Issues Monitor 2022). In this regard, it is planned to increase generation volumes by diversifying the energy system by increasing renewable energy sources, gas and hydroelectric power plants.

In 2022, the Ministry of Energy of the Republic of Kazakhstan presented its vision of the Energy Balance, within the framework of which, modeling of the development of the energy complex was performed. To meet the demand for electricity by 2035, it will be necessary to ensure the considerable introduction of new generating capacities, especially low-carbon generation sources and renewable energy sources. To cover the needs of the economy and the population by 2035, it will be necessary to commission 17.5 GW of new generation. The composition of new energy capacities includes more than 2 GW of nuclear generation (On the energy balance of Kazakhstan until 2035). Negotiations regarding the location of a nuclear power plant are already underway in Kazakhstan, which is in line with the requirements of the "green agenda". Moreover, Kazakhstan is the world leader in the production of the main type of nuclear fuel (uranium) and plans to maintain its position in the world uranium market.

In the Republic of Kazakhstan, energy security is under fairly strict state management and regulation by various state bodies. At the same time, operating and investment decisions are made

by legal entities (although many of them are state-owned), and the bodies of the Government of the Republic of Kazakhstan, for the most part, exercise the supervision and strategic management of the fuel and energy complex (Table 5).

Table 5. SWOT analysis of the current state of the energy industry in Kazakhstan (developed by the authors)

Tabela 5. Analiza SWOT aktualnego stanu energetyki w Kazachstanie (opracowanie autorów)

Strengths	Weak sides
✦ political stability of the country; ✦ investment attractiveness of the country; ✦ diversity and abundance of mineral resources; ✦ strong state control in the energy sector; ✦ "multi-vector" approach in the energy development strategy, incl. diversification of export routes; ✦ creation of the National Fund to manage the country's oil wealth.	✦ insufficient level of economic diversification; ✦ dependence on external factors, primarily on oil prices; ✦ high share of imports of services; ✦ high costs for the transportation of energy resources; ✦ high level of depreciation of fixed assets; ✦ lack of highly qualified personnel.
Capabilities	**Threats**
✦ stable access to the markets of the WTO countries and the EAEU; ✦ implementation of smaller-scale exploration and production projects; ✦ modernization of the oil refining industry; ✦ transit potential of the country; ✦ use of natural gas in the transportation sector; ✦ development of a large petrochemical industry based on gas; ✦ alternative use of coal as a fuel (coal chemistry); ✦ development of all stages of the nuclear industry in Kazakhstan.	✦ reduced demand for traditional energy sources by developed countries; ✦ high level of presence of foreign capital in the fuel and energy complex; ✦ volatility of world prices for energy resources; ✦ reduction of oil production at fields that are in the last stage of development; ✦ a threat to transit supplies of energy resources through individual states; ✦ insufficiently developed regulatory framework with the EAEU countries; ✦ restructuring of the Kazakh energy system.

In Table 5, the presented SWOT analysis allows us to draw several conclusions. Given the strategic importance of energy to the economy of Kazakhstan in general, it is no wonder that the energy sector is significantly influenced by the state. Despite the growth in the basic production of hydrocarbons, a sufficient influx of investments and the implementation of various projects which lead to the improvement in multiple indicators, the industry is experiencing systemic issues associated with higher costs for the transportation of energy resources and a considerably high level of depreciation of fixed assets. The state administration is aimed at a "multi-vector" approach in the energy strategy. However, legislative documents with the EAEU countries are not sufficiently developed. Despite the identified weaknesses and threats in the energy sector of the country, Kazakhstan's fuel and energy complex has a great potential for the use of natural gas in the transport sector, the development of a large gas-based petrochemical industry, the alternative use of coal as a fuel (coal chemistry) and the development of the nuclear energy.

Kazakhstan has maintained a stable level of energy equity rated B (86.3 points). The country's economy and domestic needs for electricity are fully provided. In accordance with the General Gasification Scheme of the Republic of Kazakhstan for 2015–2030, the government economically determines sound strategic directions to ensure a reliable gas supply to the country. As of January 1, 2021, the level of gasification of the Kazakhstan's population reached 53.07%, and 9.8 million people had access to natural gas. Thus, access to clean fuels and cooking technologies in the country is not yet fully secured.

In terms of environmental sustainability, Kazakhstan ranks low with a score of 58.2 and a D level, despite its efforts to control emissions. In the Development Strategy of Kazakhstan until 2050, it is planned to generate up to 50% of all consumed energy from renewable energy sources by 2050, not including large hydropower. In accordance with the UN Framework Convention on Climate Change, Kazakhstan aims to reduce GHG emissions by 15% by 2030 compared to 1990 levels. In addition, in December 2020, President Tokayev promised that the country would achieve net carbon neutrality by 2060. Obviously, such a transition requires profound policy reforms and the implementation of new sources of energy beyond fossil fuels. An institutional framework is being prepared for the transition to green development. In particular, on July 1, 2021, Kazakhstan adopted a new environmental code, which is an important step forward in reducing and mitigating the impact of hydrocarbon energy on the environment.

The creation of common markets for electricity, natural gas, oil and oil products in the EAEU will allow Kazakhstan to diversify the routes of export and transportation of energy resources and open up new opportunities for business entities to trade electricity among themselves within the framework of the concluded agreements.

Armenia: According to the results of the 2021 Energy Trilemma Index, Armenia ranks 53rd in the world with a score of 62.2 and a DCBc balance sheet score. In terms of energy security, Armenia ranks 77th with a score of 48.1 points, in terms of energy equity, it is 52nd with a score of 72.7 points, and in terms of environmental sustainability, it is 49th with a score of 70.1 points.

The level of energy security in Armenia in 2022 is the lowest it has been in the last two decades, which is due to many factors. Armenia is dependent on imports due to the lack of domestic fossil fuel resources. The forty-four-day war in Karabakh in the fall of 2020 negatively affected the state of the country's energy system, which used to import electricity from Nagorno-Karabakh (about 4% of total electricity generation) (Trilemma WEC. Country profile 2022).

In January 2021, the Armenian government approved the Strategic Energy Development Program until 2040 and the timetable for its implementation. Among the main directions of the strategy are the development and maximum use of the potential of renewable energy sources, increasing energy efficiency, extending the life cycle of the Armenian NPP until 2026, implementing the program for the construction of the North-South electricity transit corridor, improving regional energy integration and liberalizing the Armenian energy market (Energy Strategic... 2021).

Due to the expiration of the operating life of the second unit of the Armenian NPP, the construction of a new power unit is of paramount importance to meet the growing demand for

electricity. The lack of own hydrocarbon reserves, the dependence on supplied energy resources, the blockade of railway and pipeline communications, the limited opportunities for exporting electricity and the geopolitical tensions in the region dictate the need to raise funds for the construction of a new nuclear power unit, which can bring Armenia to a new level of energy independence (Davtyan 2018). However, the development of the construction of a new power unit has been delayed due to the need for significant investment funds for its implementation. The Armenian NPP also plays an important role in environmental sustainability by reducing CO_2 emissions. According to the World Nuclear Association (WNA), 51.52 metric tons of CO_2 emissions were prevented during the entire period of operation of the Armenian NPP (World Nuclear Power Performance Report 2021).

It should be noted that since February 2022, the average electricity tariff for 1 kWh has increased by 4.7 Armenian drams. This is due to the shutdown of the fifth power unit of the Hrazdan TPP due to the lack of profitability for the owner of the facility, Gazprom-Armenia CJSC, as well as due to the repayment of the Russian interstate loan attracted for modernization work at the Armenian NPP. The increase in the electricity tariff has affected the dimension of energy equity which has declined in comparison with 2021 level.

By the end of 2021, a new power unit of the Yerevan Thermal Power Plant with a capacity of 254 MW was put into operation. It should be noted that the energy barter between Armenia and Iran is carried out by the fifth power unit of the Hrazdan TPP and the Yerevan TPP on the principle of exchanging electricity for gas. The creation of a legal framework for electricity trade will allow expanding supplies to Iran and Georgia, as well as to the EAEU market. Electricity exports to Georgia and Iran are expected to increase due to the construction of a North-South electricity transit corridor. The new transmission line from Iran to Armenia as part of the North-South Electric Corridor program was planned to be put into operation in 2021. However, due to a number of economic and geopolitical factors, the completion date of the project has been postponed to 2023–2024. Diversification of the energy system will have a positive impact on the aspect of energy security.

Armenia's ongoing electricity market liberalization program aims to create a competitive environment and stimulate exports. The regulatory framework is already in place and the process of market liberalization will begin in 2022. Traders will work on the market, and electricity prices will be determined by supply and demand, which will allow the establishment of competitive conditions and a socially oriented tariff policy (Markarov and Davtyan 2021). However, the liberalization of the electricity market may lead to an increase in imports and a reduction in exports of electricity, which is contrary to the long-term energy interests of Armenia.

Armenia is building a long-term policy of decarbonization of the energy sector in accordance with the principles of the Paris Agreement and in accordance with its energy potential and market characteristics. The source of GHG emissions in Armenia is mainly the energy sector. If the set goals are achieved by 2030, harmful emissions will be reduced by 40% compared to 1990 (Trilemma WEC. Country profile 2022).

Armenia has a significant potential for "green" economy development, especially in energy conservation (including housing), renewable energy, agriculture (organic farming), mining and

manufacturing (environmental technology adoption), and potentially in tourism (ecotourism, agrotourism) (Table 6). With regard to this, some strategies, programs and plans are developed. Changes in the legislation are aimed at harmonization with EU legislation and some important regulations have already been adopted or will be adopted in the near future. The system of both public administration and auxiliary institutions is well developed. There is potential in the regulatory framework to introduce integrated permitting (including technology-based and best available technology requirements) and to increase the use of market-economy-based instruments, especially air and water pollution or import/production charges. The Report on Incentive Opportunities and Ways "green" economy in the countries of the Eastern Partnership 47 environmentally harmful products. High potential can be found in changing consumption patterns in both the public sector (green purchasing) and in households. In the long term, some change in household consumption patterns can be achieved through advocacy. Priorities presented by the national authorities and other stakeholders (common to all) are as follows: increasing the share of industry in GDP (up to 30% as planned by the Ministry of Economy), which could be an opportunity for the introduction of advanced technologies; promoting exports (mainly agricultural products); energy security (through increased energy efficiency); balanced regional development (reduction of regional inequalities); waste management (infrastructure development); water resources management (infrastructure development).

By 2035, Armenia intends to provide about half of its domestic electricity needs from renewable energy sources. The government sets a goal to increase the share of solar energy production by 2030 and bring its share to 15% of the total. To this end, it is planned to build solar power plants with a capacity of about 1,000 MW, which will positively affect the energy sector in terms of its diversification and environmental sustainability. It can be assumed that the indicator of environmental sustainability of the Energy Trilemma Index will continue to demonstrate positive dynamics in the case of the progressive implementation of the decarbonization program for the energy sector.

Conclusion

The Energy Trilemma Index is a comprehensive tool used to quantify the sustainability of the global energy system. The index allows an objective assessment of global, regional and national trends in the development of the energy sector. Assessing the energy sustainability of the energy systems of Russia, Kazakhstan and Armenia using the Energy Trilemma Index makes it possible to determine the practical value of the index for comparative studies of national energy systems. The index assessment of countries has taken into account the complex state of energy systems, government policy, legal framework, the state of generating capacities, the availability of energy resources, the diversification and greening of energy industries, and socio-economic and political factors.

Table 6. Brief SWOT analysis of the Armenian economy (developed by the authors)

Tabela 6. Krótka analiza SWOT gospodarki Armenii (opracowanie autorów)

Strengths	Weak sides
✦ energy sector with low carbon emissions (nuclear, hydro, gas); ✦ high share of vehicles running on gas fuel (30%); ✦ well-developed strategies and legislation in the energy and economic sectors; ✦ promising environmentally innovative entrepreneurship (innovative company , technology parks, innovation centers, business incubators); ✦ organic food certification system in place; ✦ active and well-structured chamber of commerce and industry; ✦ well-developed and active entities of civil society with environmental orientation ✦ well-developed mechanisms under UNFCCC (national communications, CDM projects).	External factors: ✦ high dependency on imported energy resources; ✦ high dependence on foreign investors. ✦ Internal factors: ✦ some of the environmental legislation is outdated (a legacy from the Soviet period); ✦ small forest patches (8–11% of the total area of the country); ✦ poor waste management (lack of reuse, unsafe landfills); ✦ deficient supply of drinking water and wastewater treatment, especially in rural areas; ✦ underestimation of the importance of air quality management (despite the poor air quality in cities); ✦ reduced public transport; ✦ limited knowledge of English in public administration and to some extent in research institutions.
Capabilities	**Threats**
External factors: ✦ Attracting FDI. Internal factors: ✦ Implementation of existing strategies and policies in the real economic and energy sectors; ✦ adoption and implementation of a new National Environmental Policy; ✦ use of the national potential in hydropower with full respect for environmental constraints (30% of national electricity consumption can be covered by 2025); ✦ industrial development in line with green economy issues; ✦ adoption and implementation of a new environmental code, harmonized with EU legislation, with a focus on green economy (integrated permits, best available technologies, product standards, eco-labels), Further development of activities “bottom-up” by the public sector (product certification, CSR implementation, eco-innovations); ✦ establishment of free economic zones focused on the “green” economy; ✦ advancement of organic agriculture and the food industry (including certification); ✦ optimization of economic instruments of environmental policy.	External factors: ✦ economic vulnerability; ✦ vulnerability to climate change and natural disasters; ✦ decreased interest from foreign investors. Internal factors: ✦ unsatisfactory implementation of strategies; ✦ lack of internal funding for the implementation of development plans.

Russia, Kazakhstan and Armenia have formed their energy policies in accordance with the seventh goal of the UN Sustainable Development Agenda, by implementing projects for ensuring access to affordable, reliable, sustainable and modern energy sources. According to the

Energy Trilemma Index 2022, Russia, Kazakhstan and Armenia have overall scores of ABCc (69.6), BBDc (67.3) and DCBc (62.2), respectively.

In terms of energy security, Russia and Kazakhstan are energy-sufficient countries with A and B ratings for this dimension of the Energy Trilemma Index. However, new challenges in the global energy market and structural geopolitical changes dictate the need to revise energy policy in order to strengthen energy security. Meanwhile, the consequences of the forty-four-day war in Karabakh, the difficult geopolitical situation around Armenia and the unstable domestic political situation create significant problems for the country's energy security. In the context of energy equity, all three countries fully provide access to electricity for domestic consumption. Armenia lags behind Russia and Kazakhstan in terms of energy affordability with C grade in this dimension. All three states have acceded to the Paris Agreement and are forming state strategies for the development of the energy sector with the intention to develop renewable and nuclear energy, taking into account the global climate agenda. Kazakhstan has a low score (D) in the dimension of environmental sustainability due to the significant share of hydrocarbon energy in the energy system of the republic. It should be noted that the overall scores of the Energy Trilemma Index of all the countries studied were affected by low scores (C) for the fourth component – the national context – which includes an assessment of macroeconomic stability, governance and stability for investment and innovation in Russia, Kazakhstan and Armenia.

It should be noted that the integration of the energy markets of Russia, Kazakhstan and Armenia will increase the volume of mutually beneficial electricity trade between the EAEU countries. In general, the common markets for electricity, natural gas, oil and oil products of the EAEU will help to stabilize energy prices and improve the energy security of all member states. Energy integration will make it possible to export surplus electricity to third countries as well as to satisfy their own needs. It is obvious that the Russian-Ukrainian war and the confrontation between the West and Russia will significantly affect the main trends in the development of world energy. This will also have an impact on the formation of a common energy market in the EAEU.

In general, the Energy Trilemma Index is of scientific and practical importance for the formation of the state strategy for the development of energy systems. It can be useful for studying the characteristics of the energy systems and energy policies of individual countries and identifying their main problems in the field of energy security. In the context of integration processes, the Energy Trilemma Index can facilitate a dialogue between politicians to assess the potential of energy integration.

Acknowledgements. The work was supported by the Science Committee of Republic of Armenia in the frames of the research project № 21T-2H107.

References

Cherp, A. and Jewell, J. 2014. The concept of energy security: beyond the four "A". *Energy Policy* 75, pp. 415–421, DOI: 10.1016/j.enpol.2014.09.005.

Davtyan, V. 2018. Armenian NPP: problems of electricity export. *MATEC Web Conf.* 212, 2018 International Scientific Conference "Investment, Construction, Real Estate: New Technologies and Special-Purpose Development Priorities" (ICRE 2018), pp. 1–7, DOI: 10.1051/matecconf/201821202010.

Energy Strategic Development Program of the Republic of Armenia (until 2040). Decree of the Government of the Republic of Armenia N 48-L dated January 14, 2021. [Online] http://mtad.am/u_files/ file/energy/razmavarutyun-arm.pdf [Accessed: 2022-03-23].

Energy strategy of the Russian Federation until 2035. Decree of the Government of the Russian Federation of June 9, 2020 No. 1523-r.

International energy security risk index: risk assessment in the global energy market. Global Energy Institute. Trading US chamber. 2020.

Jewell, J. 2011. The IEA Model of Short Term Energy Security (MOSES). Primary energy sources and secondary fuels (working paper). Paris: IEA.

Kang, H. 2022. An Analysis of the Relationship between Energy Trilemma and Economic Growth. *Sustainability* 14(7), DOI: 10.3390/su14073863.

Khan et al. 2021 – Khan, I., Hou, F., Irfan, M., Zakari, A. and Le, H.P. 2021. Does energy trilemma a driver of economic growth? The roles of energy use, population growth, and financial development. *Renewable and Sustainable Energy Reviews* 146, DOI: 10.1016/j.rser.2021.111157.

Kononov, Yu.D. 2018. Analytical review of advanced foreign experience of a comprehensive assessment of energy security (*Analiticheskiy obzor peredovogo zarubezhnogo opyta kompleksnoy otsenki energeticheskoy bezopasnosti*). *Energy Policy* 6, pp. 98–107 (*in Russian*).

Koyama, K. and Kutani, I. 2012. Energy Security Index Development Study and Energy Security Assessment for East Asian Countries. *ERIA Research Project Report 2011–2013*. Jakarta: ERIA, pp. 7–47.

Kuntjoro et al. 2021 – Kuntjoro, Y.D., Khotimah, K. and Agustiani, R. 2021. Indonesian Energy Security Concept for Improving the Sustainability of New and Renewable Energy Sources in Indonesia with a Five-fold Helix Model: 4A +1S for National Defense. *IOP conf. Series: Earth and Environmental Sciences* 753, DOI: 10.1088/1755-1315/753/1/012045.

Kuzemko et al. 2022 – Kuzemko, C., Blondeel, M., Dupont, C. and Brisbois, M.C. 2022. Russia's war on Ukraine, European energy policy responses & implications for sustainable transformations. *Energy Research & Social Science* 93, DOI: 10.1016/j.erss.2022.102842.

Loktionov, V.I. 2018. Russia on the Way to Sustainable Energy (*Rossiya na puti k ustoychivoy energetike*). *National Interests: Priorities and Security* 14(4), pp. 725–740, DOI: 10.24891/ni.14.4.725 (*in Russian*).

Markarov, A. and Davtyan, V. 2021. Integration of Armenia into the Common Electricity Market of the EAEU: Risks and Opportunities (*Integratsiya Armenii v Obshchiy rynok elektroenergii YEAES: riski i vozmozhnosti*). *Geoeconomics of Energy* 2(14), pp. 124–138 (*in Russian*).

Mastepanov, A. and Chigarev, B. 2020. Using the energy trilemma index to assess energy security (*Ispol'zovaniye indeksa energeticheskoy trilemmy dlya otsenki energeticheskoy bezopasnosti*). *Energy Policy* 8(150), pp. 66–83, DOI: 10.46920/2409-5516_2020_8150_66 (*in Russian*).

Medzhidova, D. and Grigoryev, L. 2020. Trilemma of global energy. *Russian Journal of Economics* 6(4), pp. 437–462, DOI: 10.32609/j.ruje.6.58683.

National Energy Report 2021. Kazenergo. Nur-Sultan 2021. [Online] https://www.kazenergy.com/upload/document/energy-report/NationalReport21_en.pdf [Accessed: 2022-03-23].

On the energy balance of Kazakhstan until 2035. Ministry of Energy of the Republic of Kazakhstan. [Online] https://www.gov.kz/memleket/entities/energo/press/news/details/345485?lang=ru [Accessed: 2022-03-23].

On topical issues of energy infrastructure development as part of the implementation of the Comprehensive Plan for the Modernization and Expansion of the Main Infrastructure for the Period up to 2024. Decree of the Federation Council of March 25, 2020, № 139-SF. [Online] http://council.gov.ru/activity/documents/115334/ [Accessed: 2022-03-23] (*in Russian*).

REPowerEU: affordable, secure and sustainable energy for Europe. European Commission. [Online] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en#documents [Accessed: 2022-03-23].

Rosatom designed the nuclear power plant in such a way as to exclude the emission of 210 million tons of CO_2 per year. Rosatom. [Online] https://www.rusatom-overseas.com/media/mass-media-about-us/rosatom-s-npp-designed-to-prevent-the-emission-of-210-million-tonnes-of-co2-per-year.html [Accessed: 2022-03-23].

Secrieru et al. 2021 – Secrieru, S., Saari, S. and Bechev, D. 2021. Fire and Ice: The Russian-Turkish partnership. *Chaillot Paper* 168, 21 pp. [Online] https://www.iss.europa.eu/sites/default/files/EUISSFiles/CP_168.pdf [Accessed: 2023-04-03].

Shirazi et al. 2023 – Shirazi, M., Fuinhas, J.A. and Silva, N. 2023. Sustainable economic development and geopolitics: The role of energy trilemma policies. *Sustainable Development*, pp. 1–21, DOI: 10.1002/sd.2523.

Simonova, M.D. and Zakharov, V.E. 2016. Statistical analysis of trends in the development of global renewable energy (*Statisticheskiy analiz tendentsiy razvitiya mirovoy vozobnovlyayemoy energetiki*). *Bulletin of International Relations MGIMO* 3(48), pp. 214–220 (*in Russian*).

Sovacool, B.K. and Mukherjee, I. 2011. Conceptualization and measurement of energy security: a synthesized approach. *Energy* 36, pp. 5343–5355.

Strategy for the socio-economic development of the Russian Federation with a low level of greenhouse gas emissions until 2050. Decree of the Government of the Russian Federation of October 29, 2021 No. 3052-r.

Šprajc et al. 2019 – Šprajc, P., Bjegović, M. and Vasić, B. 2019. Energy security in decision making and governance – Methodological analysis of energy trilemma index. *Renewable and Sustainable Energy Reviews* 114, DOI: 10.1016/j.rser.2019.109341.

Taxonomy of green projects and Russian recommendations on green finance. Decree of the Government of the Russian Federation of September 21, 2021 No. 1587.

The law on free gasification of Russia was adopted. State Duma. [Online] http://duma.gov.ru/news/51648/ [Accessed: 2022-03-23].

Trilemma WEC. Country profile. Armenia. [Online] https://trilemma.worldenergy.org/#!/country-profile?country=Armenia&year=2022 [Accessed: 2022-03-23].

US Energy Security Risk Index: Assessing America's Vulnerability in the Global Energy Market. Global Energy Institute. Trading US chamber. 2020.

World Energy Issues Monitor 2022. WEC. Comments countries. Kazakhstan. March 2022. [Online] https://www.worldenergy.org/assets/downloads/World_Energy_Issues_Monitor_2022_Kazakhstan_commentary.pdf [Accessed: 2022-03-23].

World Energy Trilemma Index 2021 Report. WEC in partnership with Oliver Wyman Group. London. 2021. [Online] https://www.worldenergy.org/assets/downloads/WE_Trilemma_Index_2021.pdf?v=1634811254 [Accessed: 2022-03-23].

World Energy Trilemma Index 2022 report. WEC in partnership with Oliver Wyman Group. London, 2022. [Online] https://www.worldenergy.org/assets/downloads/World_Energy_Trilemma_Index_2022.pdf?v=1669839605 [Accessed: 2022-03-23].

World Nuclear Power Performance Report 2021. COP 26 Edition. BHA. 2021.

Yergin, D. 2006. Ensuring Energy Security. *Foreign Affairs* 85(2), pp. 69–82, DOI: 10.2307/20031912.

Zakharov, A.N. 2017. Global Energy Problem: New Challenges and Threats, Opportunities to Overcome Them (*Global'naya energeticheskaya problema: novyye vyzovy i ugrozy, vozmozhnosti ikh preodoleniya*). *MGIMO Bulletin of International Relations* 1(52), pp. 187–200 (*in Russian*).

Vahe Davtyan, Silva Khachikyan , Yulia Valeeva

Ocena trwałości i bezpieczeństwa systemów energetycznych: analiza wskaźnika trylematu energetycznego na przykładzie Rosji, Kazachstanu i Armenii

Streszczenie

Zapewnienie dostępu do zrównoważonych, przystępnych cenowo i czystych źródeł energii jest jednym z głównych priorytetów globalnej agendy energetycznej. Znajduje to odzwierciedlenie w siódmym celu Agendy Zrównoważonego Rozwoju ONZ z trzema wymiarami wzrostu gospodarczego, włączenia społecznego i ochrony środowiska. Siódmy cel ma na celu zapewnienie zrównoważonego rozwoju systemów energetycznych z uwzględnieniem tych wymiarów. Do oceny tendencji rozwojowych krajowych systemów energetycznych w ramach globalnej agendy energetycznej szczególnego znaczenia nabrały pewne metody pomiaru ilościowego. Podejścia do oceny bezpieczeństwa energetycznego zależą głównie od interpretacji pojęcia „bezpieczeństwo energetyczne". Główne metody zintegrowanej oceny bezpieczeństwa energetycznego państw są na ogół opracowywane przez organizacje międzynarodowe. Ważnym wskaźnikiem pomiaru zrównoważonego rozwoju systemów energetycznych jest Energy Trilemma Index, zbudowany w ramach koncepcji *energy trilemma*. Pozwala na ilościowe określenie zdolności państw do zapewnienia bezpieczeństwa energetycznego, równości energetycznej i zrównoważenia środowiskowego, z uwzględnieniem kontekstu krajowego.

Szczególną uwagę poświęcono analizie systemów energetycznych Rosji, Kazachstanu i Armenii poprzez Energy Trilemma Index 2022. Badane kraje aktywnie uczestniczą w procesach integracyjnych w przestrzeni euroazjatyckiej i poradzieckiej. Tym samym analiza Energy Trilemma Index 2022 pozwala nam zapoznać się z głównymi trendami rozwoju sektora energetycznego w przestrzeni euroazjatyckiej, eksplorując koniunkcję rynków energii i stojące przed nimi główne wyzwania. Badanie systemów energetycznych Rosji, Kazachstanu i Armenii za pomocą wskaźnika trylematu energetycznego umożliwia określenie metodologicznego znaczenia wskaźnika dla oceny zrównoważonego rozwoju krajowych systemów energetycznych. Podkreślono również praktyczne znaczenie wskaźnika w kształtowaniu polityki energetycznej państwa dla zrównoważonego rozwoju systemów energetycznych.

Słowa kluczowe: wskaźnik trylematu energetycznego, bezpieczeństwo energetyczne, równość energetyczna, zrównoważenie środowiskowe