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Economic and environmental dimensions of energy production with the use of renewable technologies

Abstract: Accelerating the transition of the energy sector to ecologically clean energetics using renewable energy technologies will ensure the security of the energy sector of the European Union based on highly energy-efficient and cost-effective technologies for generating heat and electricity. The aim of the study is to assess the economic and ecological aspects of the implementation of renewable energy technologies in Ukraine based on the analysis of trends in the transformation of both the global and the European energy sector. The approach proposed in this article makes it possible to reasonably determine the prospects for the use of environmentally safe energy-saving technologies using renewable energy sources. The analysis of the economic and environmental aspects of energy production based on renewable energy technologies, the condition of development and

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directions of transformation of the European energy sector is illustrated on the basis of a comprehensive assessment of the efficiency of the use of energy- and resource-saving, environmentally safe and cost-effective innovative technologies of non-traditional and renewable energy sources. This is achieved through the use of a comprehensive generalized dimensionless criterion of energy-ecological-economic efficiency of innovative technologies with the aim of increasing the level of energy-economic efficiency and environmental safety of the energy sector. According to this approach, it is determined that the effective integration of a certain energy- and resource-saving, environmentally safe and economically efficient innovative technology using renewable sources in Ukraine is possible.

Keywords: renewable energy sources, energy security, energy sector, economic and environment aspects

Introduction

The energy sector of the economics, which is usually characterized by slow rates of change, is currently undergoing a very dynamic transformation, both in Europe and in Ukraine. The widespread introduction of renewable energy sources in the energy sector and related modern technologies has become an important solution for stopping climate change, reducing energy poverty, and achieving energy security (Zamasz et al. 2021). At least 80% of the world's population lives in countries that are net importers of fossil fuels (IRENA 2022a). However, each country has a certain potential for the use of renewable energy sources to increase energy security and independence.

According to global forecasts, the transition to energetics based on the use of technologies with renewable energy sources is the way to limit global warming to 1.5°C by 2050. Renewable energy technologies have recently come to dominate the global energy market for new power generation capacity, as they have become the cheapest sources of electricity in many markets.

A perspective trajectory for the decarbonization of the energy sector has testified an increase in the level of generating capacity of 260 GW based on renewable energy sources in 2020, which is more than four times the capacity added from other sources (IRENA 2022a). Europe, the USA and China accounted for the largest share of newly installed capacities based on renewable energy sources.

The expansion of energy capacities using renewable energy sources witnessed the growth of renewable energy capacities in 2021 by 6% and amounted to almost 295 GW (IRENA 2022b). An analysis by the International Renewable Energy Agency IRENA (IRENA 2022b) shows that more than 90% of the solutions that will shape a successful outcome in 2050 will include renewable energy sources through direct supply, electrification, energy efficiency, green hydrogen and bioenergy combined with technologies for the catching and storage of carbon. By 2050, electricity will be the main source of energy, with its share increasing from 21% of the total final energy consumption in 2018 to over 50% in 2050. This increase will be largely due to the use of electricity from renewable sources instead of fossil fuels in the end use (Komorowska et al. 2022).

According to estimated forecasts, the growth of installed capacities based on renewable energy sources is expected to be more than 8% in 2022, reaching a value of 320 GW. It is expected that this trend will also be observed in 2023. The military actions on the territory of Ukraine have exacerbated the situation in the energy sector, as a result of which, it is necessary to change the approach to the regulation of the rapid increase in energy prices, the reduction of the dependence of the energy markets of countries on a single energy supplier and the development of a number of measures for a broad transition to environmentally friendly energy technologies.

The introduction of renewable energy sources will have a significant potential to ensure the reduction in the cost of generated electrical and thermal energy and to get rid of the dependence on fossil fuels, which is relevant in the short and long term. The increase in the cost of traditional energy carriers (natural gas, oil, and coal) ensures the improvement of the competitiveness of renewable energy technologies (Fig. 1). According to the data of the International Energy Agency (IEA) (International Energy Agency 2022b), in 2022–2023, a global increase in the implementation of technologies based on renewable energy and an increase in the demand for biofuels is predicted. The global energy crisis will accelerate the transition of the global energy sector to environmentally clean energetics, and the use of renewable energy technologies will play a key role in this transition. Large-scale implementation of a number of renewable energy technologies will allow a reduction in the dependence of the energy sector of the European Union.

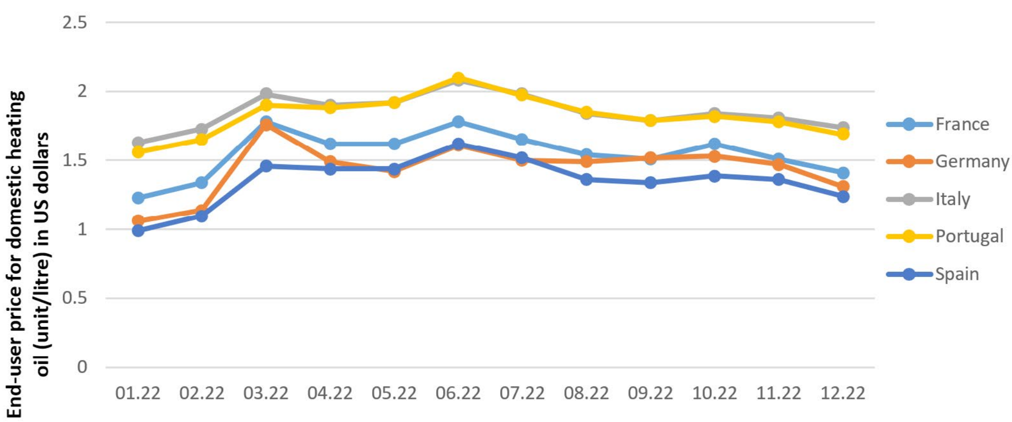

Fig. 1. End-user price for domestic heating oil (unit/liter) in US dollars in Europe in 2022
Source: data obtained by the authors based on results from database of the (International Energy Agency 2022b)

Rys. 1. Cena oleju dla zastosowań domowych/grzewczych dla użytkownika końcowego (jednostka/litr) w dolarach amerykańskich w Europie w 2022 r.

1. Literature review

Innovative solutions change the condition of the energy sector and open up new opportunities. The use of renewable energy sources, including bioenergy and green hydrogen energy (Gołdasz et al. 2022), provides much-needed solutions in transportation, construction and industry. The study by Ostapenko et al. (2020) examines the prospects of applying innovative resource-saving technologies in the concepts of green logistics and sustainable development. The assessment of the prospects for the application of innovative resource-saving technologies in Ukraine was performed taking into account the main goals of sustainable development, trends in the development of sustainable energy and the fuel and energy complex of Ukraine in the direction of European integration, thus ensuring the reduction of greenhouse gas emissions and increasing the use of non-traditional and renewable energy sources. The study shows the application of the principles and tasks of the concept of green logistics in order to increase the level of the energy-economic efficiency of the energy sector of Ukraine with the use of energy- and resource-saving, environmentally safe and cost-effective innovative technologies. Idzikowski and Cierlicki (2021) show that the level of use of renewable energy and biofuels indicates the need to increase the share of the use of non-traditional and renewable energy sources in the fuel and energy complex and energy. In the literature, there is also research on energy storage in mining as this is an opportunity for energy transformation in some countries, for example Poland (Kulpa et al. 2021; Dyczko et al. 2021). Changing this country's energy economy towards a greener alternative is an important issue (Kulpa et al. 2022) as using fossil fuels negatively affects the environment (Stecuła and Tutak 2018). Another important activity for Poland is using photovoltaics on a broader scale (Olczak et al. 2022).

Ostapenko et al. (2022) analyzed the possibilities of using geoinformation systems to assess the potential of renewable energy sources in Ukraine. The possibility of using software products of the International Renewable Energy Agency IRENA, namely Global Atlas, was analyzed. Global Atlas has been identified as providing GIS-based spatial analysis using the IRENA method for large-scale programs and applications, which provides an analysis of key parameters (resource quality, distance to transmission networks, population density, terrain and security), which makes it possible to determine suitable territories for the development of renewable energy sources and give an approximate estimate of the technical potential. The application of geoinformation systems of Ukrainian web resources for assessing the potential of renewable energy sources in Ukraine is analyzed. The possibilities of the modern information web resource "UA MAP", which contains information about renewable energy and energy efficiency in Ukraine, are illustrated. The study shows the principles of using huge data sets formed on the basis of analyzed global and regional GIS systems, which are proposed to be used as a basis for research in the fields of unconventional and renewable energy in Ukraine. The analyzed software products make it possible to evaluate the effectiveness of the integration of individual technologies for the use of renewable energy sources in the energy sector of Ukraine. An alternative approach to the above-mentioned strategy includes methods based on ERA5 or the MERRA database (European Centre for Medium-Range Weather Forecasts (ECMWF) 2019; Staffell and Pfenninger 2016).

The aim of this study is to evaluate the economic and environmental aspects of the implementation of renewable energy technologies in Ukraine based on the analysis of trends in the transformation of the global and European energy sector. The approach proposed in this article makes it possible to reasonably determine the prospects for the use of environmentally safe energy-saving technologies using renewable energy sources in Ukraine.

In the conditions of the energy crisis in Ukraine, the issue of finding highly energy-efficient and cost-effective technologies for generating heat and electricity using available traditional, renewable and non-traditional energy sources in Ukraine is becoming urgent.

2. Research methods

The study of renewable energy sources is based on the resource "Tracking SDG7", which uses the databases of the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), the World Bank, the United Nations Statistics Division (UNSD) and others ("Tracking SDG7", "Rise", "Esmap"). Statistics from the resources of Eurostat and the World Bank ("Eurostat", "Data Bank. World Bank") were also used.

The study (Tagliapietra et al. 2019) assessed the trends of reforming the energy sector of the world, the European Union and Ukraine for the perspective of 2050 using renewable energy sources and the concept of sustainable development. In addition, the advantages of using renewable energy sources are defined and the prospects for using innovative technologies based on renewable energy sources in the concept of sustainable development are assessed. A number of energy, economic and ecological efficiency criteria for innovative technologies for the use of renewable energy sources were analyzed, which was conducted with the aim of a comprehensive assessment of the efficiency of energy- and resource-saving environmentally friendly and economically efficient innovative technologies in the field of sustainable development. This approach made it possible to reasonably determine the prospects for the use of such technologies for the use of renewable energy sources in the context of sustainable development, which will contribute to increasing energy efficiency and the level of environmental safety of the energy complex of Ukraine. It is the application of sustainable energy methods and the concept of sustainable development that will allow increasing the levels of energy efficiency and environmental safety of the energy sector of Ukraine based on technologies for the use of renewable energy sources (Tagliapietra et al. 2019).

Studies of the environmental efficiency of the use of various types of fuel for the generation of thermal and electrical energy are performed on the basis of methodological and statistical data of the European Environment Agency (EEA) (European Environment Agency 2022). Economic efficiency in the local and regional dimension (Sołtysik et al. 2022) as well as the experience of neighboring countries are also of great importance (Kulpa et al. 2022).

3. Results and discussion

To estimate the amount of greenhouse gas emissions, data from the IEA database (IEA 2022a) was used; this contains a comparable amount of data on greenhouse gas emissions for more than 190 countries and regions of the world. Emissions data are based on the 2022 IEA Global Energy Balances and the 2006 IPCC Guidelines for Greenhouse Gas Inventories.

Figure 2 presents an estimate of the specific amount of greenhouse gas emissions (CO_2) based on the use of results from the "IEA (2022), GHG Emissions from Energy" database (IEA 2022a), which contains a comparable amount of data on greenhouse gas emissions for more than 190 countries and regions of the world. Emissions data are based on the 2022 IEA Global Energy Balances and the 2006 IPCC Guidelines for Greenhouse Gas Inventories and Greenhouse Gas Emission Intensity Levels for World, Europe, North America, and Economic Cooperation Organization countries and Development (OECD) and non-OECD countries (non-OECD). Specific levels of the intensity of greenhouse gas emissions in Figure 2 are presented for various sectors of the economy. As can be seen from Figure 2, significant specific levels of the intensity of CO_2 emissions are provided by the transport and energy sectors, in particular, due to the generation of electric and thermal energy. It should be noted that the electric power sector of the EU provides lower values of the specific intensity levels of greenhouse gas emissions compared to global and regional levels (Fig. 2).

Figure 3 presents the volume of CO_2 emissions for the period 2019–2021 as a result of energy generation for the whole world, for countries that are members of the Organization for Economic Cooperation and Development (OECD) and for countries that are not members of this organization (non-OECD). As can be seen from Figure 3, there is a tendency to decrease CO_2 emissions in the energy sector for the world as a whole as well as for the countries that are part of the Organization for Economic Cooperation and Development, which indicates the use of political and economic levers of influence for the widespread implementation of energy-saving measures, increasing the efficiency of the use of energy resources, popularizing the generation of electricity from renewable sources and ensuring the optimal and safe use of infrastructures and electricity markets.

Table 1 presents the amount of investments in energy technologies in Europe for the period 2017–2021. The data was obtained by the authors based on the results from the "IEA (2022), GHG Emissions from Energy" database (IEA 2022a).

According to the EEA, the EU electricity sector is expected to make a significant contribution to mitigating the effects of climate change in 2030 and ensure that the EU achieves net climate neutrality by 2050 in line with projected scenarios. Therefore, the intensity of greenhouse gas emissions in this sector should decrease in the coming decade.

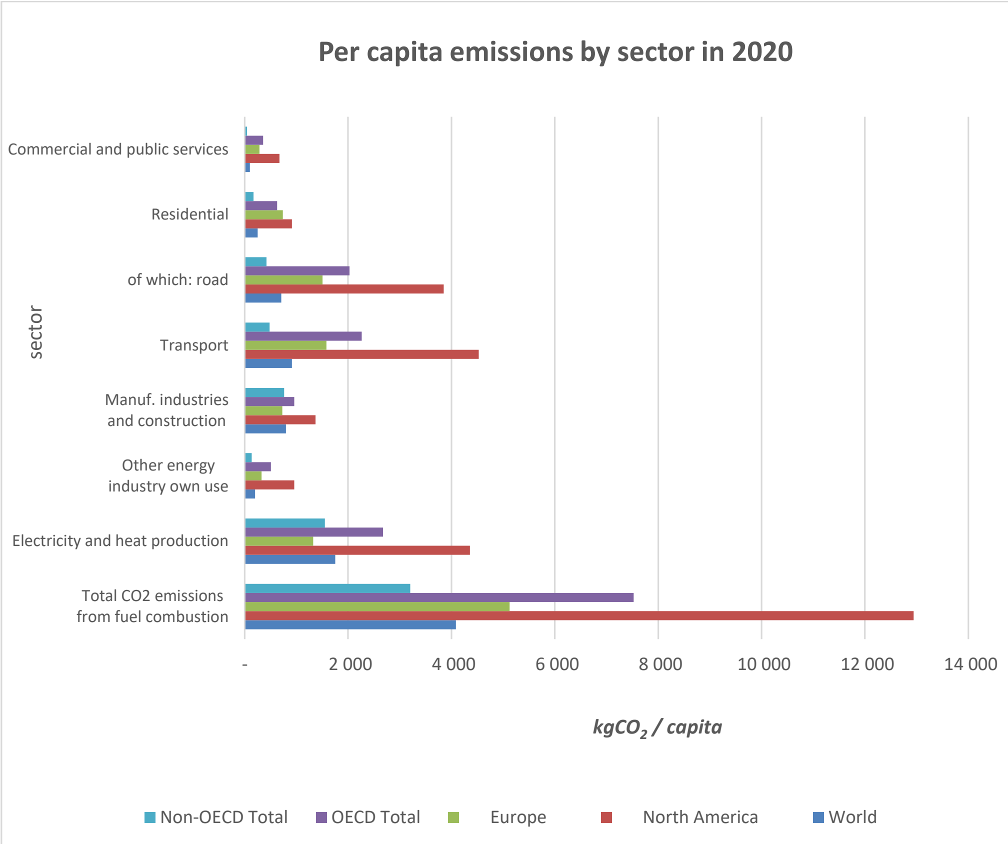

Fig. 2. Specific levels of the intensity of CO_2 emissions
Source: data obtained by the authors based on results from the "IEA (2022), GHG Emissions from Energy" database (IEA 2022a)

Rys. 2. Sektorowe poziomy intensywności emisji CO_2

Until 2010, the increase in the efficiency of converting fossil fuels into electrical energy ensured a decrease in carbon intensity, which was facilitated by the need to comply with the emission limit values established in accordance with legislation such as the "Directive on large combustion plants 2001/80/EC" (EC 2021).

Since 2010, the decrease has occurred almost exclusively due to the transition from the use of fossil fuels to renewable energy sources in electricity production, with an increase in the price of quotas under the EU Emissions Trading Scheme; this has been especially true since 2019 (European Union 2018; U.S. Environmental Protection Agency 2022).

In order to reduce net greenhouse gas emissions in the EU by 55% by 2030 (compared to 1990), and to achieve carbon neutrality by 2050, electricity generation in the EU must decarbonize as quickly as possible.

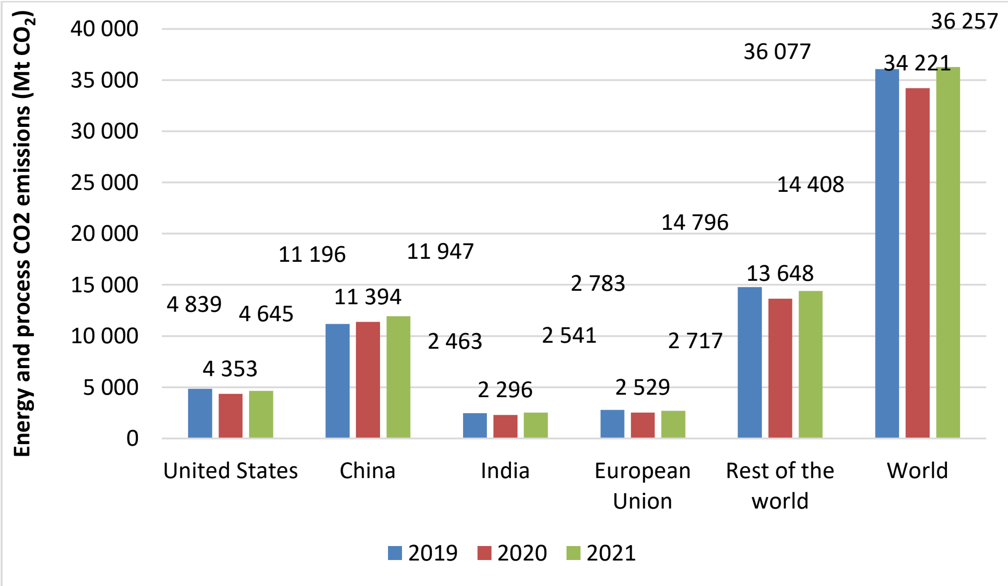

Fig. 3. Volumes of CO_2 emissions for the period 2019–2021 due to energy generation
Source: data obtained by the authors based on results from the "IEA (2022), GHG Emissions from Energy" database (IEA 2022a)

Rys. 3. Wielkość emisji CO_2 w latach 2019–2021 z tytułu wytwarzania energii

Today's geopolitical context calls for faster decarbonization to replace gas and coal in electricity, heating and industry. This would significantly reduce the cost of electricity and increase energy security (Koval et al. 2021, 2022).

To achieve these objectives, there is a necessity for additional political steps and measures for energy saving, a significant increase in the efficiency of the use of energy resources, the activation of electricity generation from renewable sources and the provision of optimized and safe use of infrastructures and electricity markets in the European Union.

It should be noted that the intensity of greenhouse-gas emissions in the case of electricity production differs significantly in each state of the European Union.

In 2021, Estonia, Poland, Cyprus and Greece had the highest carbon intensity of electricity production in the EU, which was the result of the extensive use of solid fossil fuels and the presence of a relatively small number of renewable energy sources and a limited number of nuclear power plants or their absence in national energy structures.

The intensity of greenhouse-gas emissions in the case of electricity production was the lowest in Sweden, France and Luxembourg due to the high share of low-carbon sources of electricity (nuclear and renewable energy). The same structure of electricity sources will be characteristic of Ukraine in the foreseeable future.

Table 1. Volumes of investments in energy technologies in Europe for the period 2017–2021

Tabela 1. Wielkość inwestycji w technologie energetyczne w Europie w latach 2017–2021

Europe	2017	2018	2019	2020	2021
Total (billion $2019)	319	311	313	290	345
Supply (by type)	215	208	212	179	223
Fossil fuels (fuel supply & power)	84	85	90	60	74
Renewables	77	67	63	55	80
Electricity networks	48	49	48	51	56
Other supply	6	7	11	12	12
End-use	104	103	101	111	122
Energy efficiency	95	93	91	101	115
Renewables and other end-use	10	10	10	9	8
Fuels	77	76	79	51	65
Fossil fuels	72	71	74	47	59
Oil	42	44	43	28	30
Gas	29	26	29	18	29
Coal	1	1	2	1	1
Low-carbon fuels	5	5	5	5	6
Power	138	132	133	128	158
Generation	89	82	84	76	101
Coal	5	6	7	7	6
Gas and oil	7	8	10	7	9
Nuclear	5	6	10	11	11
Renewables	72	62	57	51	75
Battery Storage	1	1	1	1	1
Electricity networks	48	49	48	51	56
Memo: Oil & natural gas upstream	47	45	47	31	34

Source: Data obtained by the authors based on results from the "IEA (2022), GHG Emissions from Energy" database (IEA 2022a).

Our research used literary, methodological and statistical data of the European Environment Agency (EEA) (EEA 2022), studies of environmental-efficiency indicators were performed using the specialized program EPA Simplified GHG Emissions Calculator (SGEC), which is the property of the US Environmental Protection Agency (EPA) in the US Government (U.S. Environmental Protection Agency 2022).

Statistical data with indicators of the ecological efficiency of burning fuels for the energy sector of the industry were analyzed and the burning and processing of fuel for the purpose of generating thermal and electrical energy was foreseen. A detailed description of the methods by which the data used in this study was obtained is presented in the documentation of the European

Integrated Pollution Control and Prevention Bureau (EIPPCB) and the US Environmental Protection Agency Emission Calculation Methodology.

In this study, a number of indicators of the amount of harmful emissions that occur when different types of fuels are burned to generate thermal and electrical energy in various types of installations have been evaluated, namely: NOx – the indicator of NOx emissions per unit of energy produced [g/GJ]; CO – the indicator of CO emissions per unit of produced energy [g/GJ]; NMVOC – the indicator of emissions of non-methane volatile organic compounds (NMVOC) per unit of produced energy [g/GJ]; SOx – the indicator of SOx emissions per unit of produced energy [g/GJ]; TSP – the indicator of the total concentration of suspended particles (TSP) per unit of produced energy [g/GJ]; PM10 – the indicator of the content of finely dispersed particles (PM10 with a diameter of less than 10 microns) per unit of produced energy [g/GJ].

An analysis was made of the amount of harmful emissions in the case of burning the following types of traditional fuel and alternative fuel from renewable sources for the generation of thermal and electrical energy: hard coal (coking coal, other bituminous coal, sub-bituminous coal, coke, manufactured ‘patent’ fuel), brown coal (lignite, oil shale, manufactured ‘patent’ fuel, peat), gaseous fuels (natural gas, natural gas liquids, liquefied petroleum gas, refinery gas, gas works gas, coke oven gas, blast furnace gas), heavy diesel fuel (residual fuel oil, refinery feedstock, petroleum coke, Orimulsion, bitumen) and biomass (wood, charcoal, vegetable (agricultural) waste). The results of studies of the amount of emissions in the case of burning different types of fuels are shown in Figure 4.

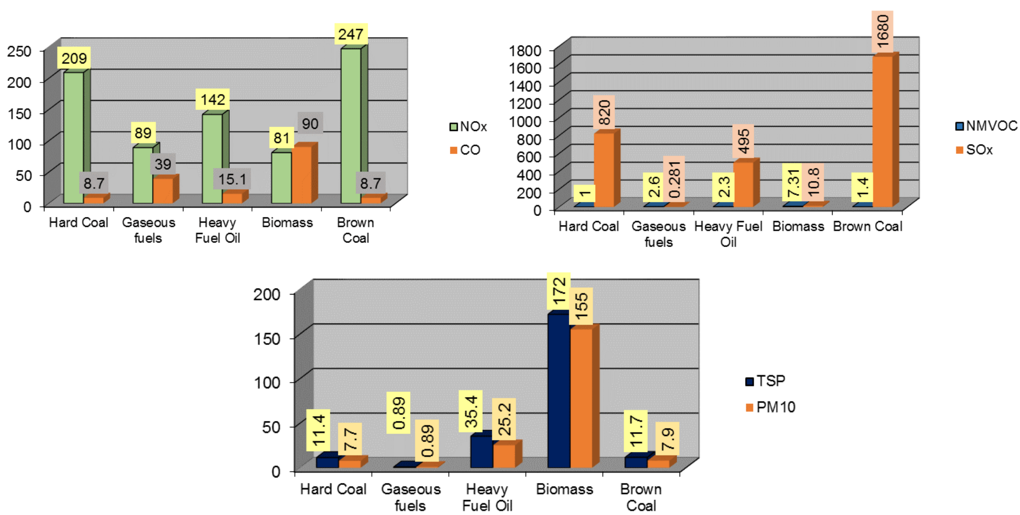

Fig. 4. The values of the emission indicator per unit of energy produced in the case of burning different types of fuel [g/GJ]

Rys. 4. Wartości wskaźnika emisji na jednostkę wyprodukowanej energii przy spalaniu różnych paliw [g/GJ]

An analysis of the amount of harmful emissions was performed in the case of using different technologies for burning different types of fuel to generate thermal and electrical energy, this specifically applies to: energy generation in hard coal-burning boilers; energy generation in boilers burning gaseous fuels; energy generation in boilers burning wood and its waste; energy generation in engines burning gaseous fuels.

The results of studies on the amount of emissions in the case of using different technologies for burning different types of fuel for generating thermal and electrical energy are presented in Figure 5.

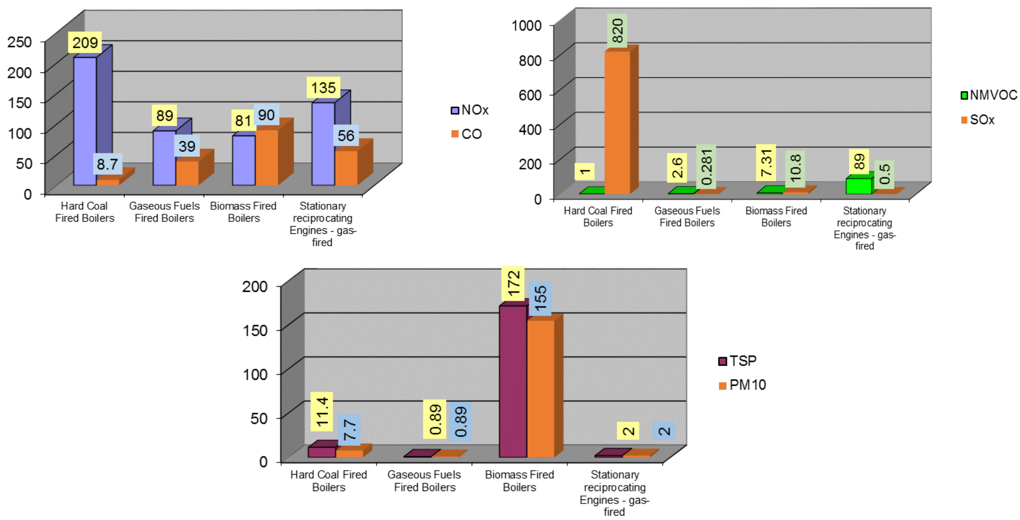

Fig. 5. The values of the emission indicator per unit of produced energy in the case of using different technologies for burning different types of fuel for the generation of thermal and electrical energy [g/GJ]

Rys. 5. Wartości wskaźnika emisji na jednostkę wyprodukowanej energii w przypadku stosowania różnych technologii spalania różnych paliw do produkcji energii cieplnej i elektrycznej [g/GJ]

According to the research results presented in Figures 4 and 5, it is possible to draw a conclusion about the significant environmental advantages of using gaseous fuel (for example, biogas produced from renewable energy sources and generator gas) for generating thermal and electrical energy. The direct burning of biomass in boilers as a renewable energy source has a significant negative impact on the environment and requires appropriate flue gas cleaning technologies.

In the study by Ostapenko et al. (2020), it was proposed to carry out a comprehensive assessment of the effectiveness of the application of energy- and resource-saving, environmentally safe and cost-effective innovative technologies in the contexts of green logistics and sustainable development according to a comprehensive generalized dimensionless criterion of the energy-ecological-economic efficiency of innovative technologies:

$$K_{INN}{}^{compl.} = \beta \cdot K_{RES} + \Delta E + \Delta EC + K_{REC} \qquad (1)$$

where:

- β – is the share of the replacement of traditional technology with an innovative alternative,
- K_{RES} – a dimensionless criterion of the efficiency of the corresponding energy- and resource-saving innovative technology, which is used to determine energy- and re-source-saving modes of operation,
- ΔE – relative economic efficiency of innovative technology, which is used to economically determine justified modes of operation,
- ΔEC – the relative environmental efficiency of innovative technology, which makes it possible to develop environmentally safe modes of operation of innovative technology,
- K_{REC} – a dimensionless criterion of the relative efficiency of recycling (and/or waste utilization) of innovative technology, which is used to determine the possibilities of recycling or waste utilization of innovative technology.

Figure 6 presents the area of effectiveness of the application of energy- and resource-saving, environmentally safe and economically efficient innovative technology of using the heat of rene-

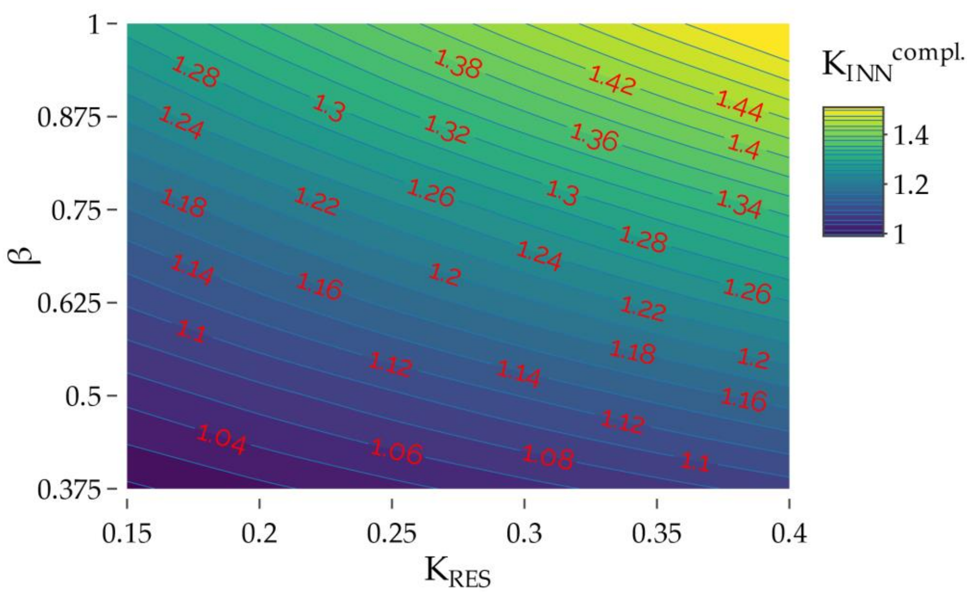

Fig. 6. Assessment of the effectiveness of the application of energy- and resource-saving, environmentally safe and economically efficient innovative technology of using the heat of renewable energy sources

Rys. 6. Ocena skuteczności zastosowania energooszczędnej i zasobooszczędnej, bezpiecznej dla środowiska i efektywnej ekonomicznie innowacyjnej technologii wykorzystania ciepła z odnawialnych źródeł energii wable energy sources in Ukraine based on cogeneration heat-pump technology using the heat of surface water, which is determined according to the comprehensive generalized dimensionless criterion of the energy-ecological-economic efficiency of innovative technologies from the formula (1).

Figure 6 illustrates the implementation of a comprehensive assessment of the effectiveness of the application of energy- and resource-saving, environmentally safe and cost-effective innovative technologies based on non-traditional and renewable energy sources using a comprehensive generalized dimensionless criterion of energy-ecological and economic efficiency of innovative technologies. This approach makes it possible to provide a well-founded determination of the prospects for the application of energy- and resource-saving, environmentally safe and cost-effective innovative technologies based on non-traditional and renewable energy sources in order to increase the level of energy-economic efficiency and the environmental safety and energy independence of the energy sector of Ukraine.

Conclusions

This study has evaluated the economic and environmental aspects of energy production based on renewable energy technologies in Ukraine. It was determined that in the conditions of the energy crisis in Ukraine, the issue of finding highly energy-efficient and cost-effective technologies for generating heat and electricity using existing traditional, renewable and non-traditional energy sources in Ukraine is becoming urgent. The article has assessed the condition of development and directions of transformation of the global and European energy sector. The influence of the global energy crisis on the acceleration of the transition of the global and European energy sector to environmentally friendly energy has been assessed; it was stated that the key role in this transition would be played by the use of renewable energy technologies. It was determined that the large-scale implementation of a number of renewable energy technologies would allow a reduction in the dependence of the energy sector of the European Union on a single supplier of carbon resources. It is well-founded that in the conditions of the energy crisis in Ukraine, the issue of finding highly energy-efficient and cost-effective technologies for generating heat and electricity using existing traditional, renewable and non-traditional energy sources in Ukraine is becoming urgent.

The prospects for the development of renewable energy technologies and the economic and ecological consequences of their implementation in Ukraine were assessed. The study has evaluated the economic and ecological aspects of the implementation of renewable energy technologies in Ukraine based on the analysis of trends in the transformation of the global and European energy sector. The approach proposed in the article makes it possible to reasonably determine the prospects for the use of environmentally safe energy-saving technologies using renewable energy sources in Ukraine. The study illustrates the implementation of a comprehensive assessment of the effectiveness of the application of energy- and resource-saving, ecologically safe and cost-effective innovative technologies based on non-traditional and renewable energy sources with the use of a complex generalized dimensionless criterion of the energy-ecological and economic efficiency of innovative technologies. This approach makes it possible to provide a well-founded determination of the prospects for the application of energy- and resource-saving, environmentally safe and cost-effective innovative technologies based on non-traditional and renewable energy sources in order to increase the level of energy-economic efficiency and the environmental safety and energy independence of the energy sector of Ukraine.

According to this approach, it is determined that the effective integration of a certain energy- and resource-saving, environmentally safe and economically efficient innovative technology using renewable sources in Ukraine is possible if the following conditions are met for the generalized indicator: $K_{INN}^{compl.} > 0$ and $K_{RES} > 0$ and $\Delta E > 0$ and $\Delta EC > 0$ and $K_{REC} > 0$. The effectiveness of the application of the evaluated technology for the generation of thermal and electrical energy using renewable energy sources in Ukraine is $K_{INN}^{compl.} = 1{,}0...1{,}54$; which confirms that this technology ensures the fulfillment of the necessary conditions for energy- and resource saving, environmental safety and economic efficiency indicators. The greater the value of the dimensionless efficiency indicator, the more energy-efficient, environmentally safe, economically efficient and competitive the innovative renewable-source technology offered in Ukraine will be.

List of designations and abbreviations

β	–	the share of replacement of traditional technology with an innovative alter native
ΔE	–	relative economic efficiency of innovative technology
ΔEC	–	the relative environmental efficiency of innovative technology
CO	–	the indicator of CO emissions per unit of produced energy [g/GJ]
$K_{INN}^{compl.}$	–	complex generalized dimensionless criterion of the energy-ecological-eco nomic efficiency of innovative technologies
K_{REC}	–	a dimensionless criterion of the relative efficiency of recycling (and/or wa ste utilization) of innovative technology
K_{RES}	–	a dimensionless criterion of the efficiency of the corresponding energy- and resource-saving innovative technology
NMVOC	–	the indicator of emissions of non-methane volatile organic compounds (NMVOC) per unit of produced energy [g/GJ]
NOx	–	the indicator of NOx emissions per unit of energy produced [g/GJ]
PM10	–	the indicator of the content of finely dispersed particles (PM10 with a dia meter of less than 10 microns) per unit of produced energy [g/GJ]

SOx	–	the indicator of SOx emissions per unit of produced energy [g/GJ]
TSP	–	the indicator of the total concentration of suspended particles (TSP) per unit of produced energy [g/GJ]

ECMWF	–	European Centre for Medium-Range Weather Forecasts
EEA	–	European Environment Agency
EIPPCB	–	European Integrated Pollution Control and Prevention Bureau
EPA	–	US Environmental Protection Agency
EU	–	European Union
GIS	–	Geoinformation System
GHG	–	Greenhouse Gas
IEA	–	International Energy Agency
IPCC	–	Intergovernmental Panel on Climate Change
IRENA	–	International Renewable Energy Agency
OECD	–	Organization for Economic Cooperation and Development
NMVOC	–	Non-Methane Volatile Organic Compounds
SGEC	–	Simplified GHG Emissions Calculator
TSP	–	Total Concentration of Suspended Particles
UNSD	–	United Nations Statistics Division

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Wymiar ekonomiczny i środowiskowy produkcji energii przy zastosowaniu odnawialnych technologii

Streszczenie

Przyspieszenie przejścia sektora energetycznego do ekologicznie czystej energetyki za pomocą technologii energii odnawialnej zapewni bezpieczeństwo sektora energetycznego Unii Europejskiej w oparciu o wysoce energooszczędne i opłacalne technologie generowania ciepła i energii elektrycznej. Celem badania jest ocena ekonomicznych i ekologicznych aspektów wdrażania technologii energii odnawialnej na Ukrainie na podstawie analizy trendów w transformacji zarówno globalnego, jak i europejskiego sektora energetycznego. Podejście zaproponowane w tym artykule umożliwia rozsądne określenie perspektyw stosowania bezpiecznych technologii oszczędzania energii dla środowiska z wykorzystaniem odnawialnych źródeł energii. Analiza ekonomicznych i środowiskowych aspektów produkcji energii w oparciu o technologie energii odnawialnej, warunek rozwoju i kierunki transformacji europejskiego sektora energetycznego są zilustrowane na podstawie kompleksowej oceny wydajności wykorzystania energii i zasobów. Osiąga się to poprzez zastosowanie kompleksowego uogólnionego bezwymiarowego kryterium wydajności energetyczno-ekonomicznej innowacyjnych technologii w celu zwiększenia poziomu wydajności energetyczno-ekonomicznej i bezpieczeństwa środowiska sektora energetycznego. Zgodnie z tym podejściem ustalono, że możliwa jest skuteczna integracja pewnej ilości energii i zasobów, bezpiecznych dla środowiska i ekonomicznie wydajnych technologii z wykorzystaniem źródeł odnawialnych na Ukrainie.

Słowa kluczowe: odnawialne źródła energii, bezpieczeństwo energetyczne, sektor energetyczny, aspekty ekonomiczne i środowiskowe