ECONOMIES' HORIZONS
Економічні горизонти

DOI: doi.org/10.31499/2616-5236
Homepage: http://eh.udpu.edu.ua

ISSN 2522-9273 (print)
2616-5236 (online)

UDC: 620.9+608

JEL Classification Q40, Q42, Q43

DOI: 10.31499/2616-5236.2(31).2025.327441

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«NET-ZERO» ECONOMY AND THE RENEWABLE ENERGY MARKET THROUGH THE PRISM OF CARBON NEUTRALITY

«ЧИСТА НУЛЬОВА» ЕКОНОМІКА ТА РИНОК ВІДНОВЛЮВАЛЬНОЇ ЕНЕРГІЇ КРІЗЬ ПРИЗМУ ВУГЛЕЦЕВОЇ НЕЙТРАЛЬНОСТІ

Анотація: *Вуглецева і кліматична нейтральність на порядку денному в більшості країн світу. Мета статті полягає у тому, щоб запропонувати авторське бачення концепції розвитку вуглецево-нейтральної економіки на шляху становлення в Україні «чистої нульової» економіки. У статті обґрунтовано особливості запровадження вуглецевої і кліматичної нейтральності, розвитку «чистої нульової» економіки. Представлено соціально-економічні й екологічні ефекти і втрати від функціонування відновлювальних джерел енергії. Напрацьовано заходи та інструменти підтримки розвитку вуглецево-нейтральної економіки України.*

Abstract: *Carbon and climate neutrality are on the agenda in most countries of the world. Ukraine is no exception. The development of a «net-zero» economy in innovation leader-countries is characterized by zero carbon emissions, the use of «green» technologies, and institutional encouragement of economic agents for their widespread implementation.*

The purpose of the article is to offer the author's vision of the concept of developing a carbon-neutral economy on the path to establishing a «net-zero» economy in Ukraine, to identify support tools to encourage economic agents to «adhere» to environmental friendliness, carbon, and climate neutrality in business, and to present the socio-economic and environmental effects and losses from the operation of renewable energy sources.

To achieve the purpose, methods of analysis and synthesis, grouping, comparison, graphical and tabular methods were used, which allowed for a comprehensive study of existing scientific developments on the issues of carbon and climate neutrality of economies, to solve the tasks set for scientists, and to outline the prospects for future research in terms of the formation of a «net-zero» economy in Ukraine.

The article substantiates the features of the implementation of carbon and climate neutrality and the development of a «net-zero» economy. The socio-economic and environmental effects and losses from the operation of renewable energy sources are presented. A comparative analysis of total electricity production and electricity production by different types of energy sources in Ukraine in 2015–2023 is conducted. The possibilities of establishing a «net-zero» are considered.

The practical value of the study lies in the author's suggestions provided, in particular: it makes sense to create hydrogen hubs across Ukraine in the post-war period and include large industrial facilities that are motivated to invest in renewable energy sources in them; a central place in sustainable urban development should be given to the decarbonization of housing, which has socio-economic benefits, makes energy affordable, creates jobs that require skills with new technologies, and improves the level of well-being of citizens in general; the post-war reconstruction of the Ukrainian economy should be implemented through the introduction of breakthrough innovations and the transition to the VI technological level in all industries.

Keywords: *carbon neutrality, climate neutrality, renewable energy sources, sustainable development goals, net-zero economy, environmental friendliness, «green» technologies, energy transition*

Ключові слова: *вуглецева нейтральність, кліматична нейтральність, джерела відновлювальної енергії, цілі сталого розвитку, «чиста нульова» економіка, екологічність, «зелені» технології, енергетичний перехід*

Statement of the problem. The aspiration of world leaders for zero emissions and carbon neutrality is reflected in such climate agreements as the Paris Agreement and the Kyoto Protocol. In an effort to ensure Ukraine's national interests in sustainable economic development and civil society in order to increase the standard and quality of life of Ukrainians, in 2019 the President of Ukraine signed a Decree on the Sustainable Development Goals of Ukraine for the period until 2023 [1] and specified the features of their adaptation to the development of the national economy in the National Report «Sustainable Development Goals: Ukraine» [2]. However, due to the military operations taking place on the territory of Ukraine, a significant part of the energy infrastructure has been damaged, either partially or completely destroyed. In particular, this applies to the renewable energy sector, which is currently only in its infancy in Ukraine. Ukraine's wind and solar power plants have suffered enormous losses during the three years of war.

But despite the destruction, both

the government and strategic partners consider Ukraine's post-war recovery only in terms of «green» recovery, taking into account the Sustainable Development Goals (SDG) espoused by post-industrial countries of the world. Doing business should become environmentally friendly, transport should be characterized by reduced carbon dioxide emissions, electricity consumption should be «smart» and economical, the process of building residential facilities should be inherently low-carbon, and new buildings should be zero-energy; for urban infrastructure, the priority should be given to universal «green» solutions. Obtaining biofuels as a result of waste processing and separate garbage collection would reduce the number of landfills around cities of regional significance, improve soil quality, and reduce the potential for pollution of surrounding water bodies and air pollution around landfills. «Cities can reach or approach zero net carbon, but this requires a systemic transformation» [3, p. 377] in the direction of their carbon neutrality and the creation of a single ecosystem of cities and towns.

Analysis of recent research and publications. Foreign researchers N. Stern [4], G. Chen, M. Lim, W. Yeo, M.-L. Tseng [5], R. Jiang, B. Liu [6], S. Yang, D. Yang, W. Shi, Ch. Deng, Ch. Chen, S. Feng [7], K. Seto, G. Churkina, A. Hsu, M. Keller, P. Newman, B. Qin, A. Ramaswami [3], etc. have studied the formation of a carbon-neutral economy, and have investigated the level of influence of technological innovations and open trade on achieving carbon neutrality. Scientists have proven that «the structure and organization of government are of great importance on the path to zero carbon emissions» [4, p. 6], and «with the acceleration of urbanization and industrialization, carbon neutrality and peaking of carbon dioxide emissions have become common sustainable development goals worldwide» [7, p. 81725]. In order to effectively mitigate the effects of greenhouse gases and emission stages, the researchers «recommend considering the life cycle and strategies such as bio-based materials, optimized transportation, and electric vehicles» [5, pp. 1–2].

Foreign experts A. Kachi, Z. Modajk, and K. Warnecke presented a research paper on climate neutrality, in which they indicated how to distinguish climate leadership from greenwashing [8]. We consider the Report on modeling possible scenarios for the development of Ukraine as a result of the introduction of new technologies, such as hydrogen, carbon capture and storage; increasing the level of electrification of transport; improving waste management practices and water use [9], prepared by Ukrainian experts O. Dyachuk, N. Kushko, I. Onopchuk, R. Podoletsky, M. Chepelev, and S. Shmarin, to be valuable.

The monograph «Problems and Prospects of the Transition to a Carbon-Neutral Economy», edited by Yu. Matveeva and I. Vakulenko [10] are devoted to the study of issues of environmentally oriented competitive development of energy industry enterprises and the development of an innovation management mechanism at energy industry enterprises based on the implementation of renewable energy technologies.

Scientists D. Vasylkivskyi and V. Sysyuk studied existing instruments for improving the energy efficiency of the economies of European countries. Among them, they analyzed Directive 2012/27/EU on energy efficiency, the European Green Deal, the 2030 Energy Efficiency Targets, the Horizon Europe Program, the Clean Energy for All Europeans Package, the Modernization Fund and Economic Instruments, Regulation 2021/241 EU on recovery and resilience, Regulation (EU) No. 2017/1369 on energy labelling, and Directive 2018/844/EU on the energy performance of buildings [11, p. 4].

A team of Ukrainian researchers, I. Vakulenko, Yu. Matveeva, Yu. Opanasyuk, K. Taranyuk, and A. Rosokhata presented their own scientific vision of a roadmap for the transition to a carbon-free economy based on the transfer of energy innovations [12]. Ukrainian professors O. Borysiak, V. Brych, P. Popovych, V. Semanyuk, and U. Tkach also studied financial and economic instruments for the development of transport infrastructure for a carbon-neutral economy [13].

At one time, we also investigated the issue of developing high-quality management of «green» businesses in the «blue» economy [14] and studied the energy efficiency of renewable energy sources (RES) through the prism of tools for ensuring environmental safety and innovation and investment activity [15].

At the same time, a significant number of pressing issues to be resolved, namely the concept of developing a carbon-neutral economy on the way to a «net-zero» economy require additional study. In particular, there is no clear understanding of the differences between a carbon-neutral economy and a «net-zero» economy and determining the actual state of affairs in terms of the volume of polluted wastewater discharges into water bodies in Ukraine and the volume of electricity production by various types of energy sources in Ukraine for 2015–2023.

Setting the task. The purpose of the article is to offer the author's vision of the concept of developing a carbon-neutral economy on the path to a «net-zero» economy. Among the activities: to identify the strengths and weaknesses of the application of RES; to present a comparative analysis of the volume of emissions of pollutants into the atmosphere by stationary emission sources in Ukraine for 2015–2023, the volume of discharges of polluted wastewater into water bodies in Ukraine, and the volume of electricity production by various types of energy sources in Ukraine for 2015–2023.

Methods. To achieve the goal of scientific research, a solid and reliable database is taken as a basis. A significant role belongs to theoretical and research developments presented in scientific publications of rated and cited journals indexed in the Scopus database, which is distinguished by the high quality of scientific articles and openness. This provides the work with relevant materials that cover a wide range of scientific works on climate and carbon neutrality, containing substantiated hypotheses regarding the formation and development of RES to achieve SDG.

The data sources for the scientific article are the reporting materials Future possibilities. Index

2024, which includes information by country on the formation of a «net-zero» economy, the basics of environmental friendliness, and energy produced from renewable sources. Open data from the website of the State Statistics Service of Ukraine was used, which allows for a qualitative comparative analysis by year in Ukraine of electricity production by different types of energy sources in the country for 2015–2023 and to identify factors for the rapid achievement of SDG. The presented materials «Support to the government of Ukraine on updating its nationally determined contribution» provide an idea of the actual state of affairs in the transition to a sustainable low-carbon and climate-resilient economy with a significant reduction in greenhouse gas emissions in accordance with the goals of the Paris Agreement, allowing for targeted and methodically substantiated research.

The scientific work used various methods, including: graphical – to present the volumes of emissions of pollutants into the atmosphere by stationary emission sources in Ukraine for 2015–2023 and the share of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies in the total volume of discharges in Ukraine for 2015–2023; tabular method – to analyze the socio-economic and environmental effects and losses from the operation of RES; comparison method – to present the characteristic features of the development of a carbon-neutral and «net-zero» economy.

Presentation of the main research material. «Climate change threatens human survival by causing heat waves, droughts, floods, storms, loss of polar ice, ocean acidification, and rising sea levels. These impacts are damaging food supplies and habitats and are contributing to chronic diseases» [5, p. 1]. The need to develop a carbon-neutral economy and support alternative energy sources is becoming evident. According to experts, the economic benefits expected from the establishment and development of the so-called «net-zero» economy by 2030 will amount to $2.3 trillion. The leading country in the development of this economy is Denmark [16, p. 8].

The top five countries also include Sweden, Finland, Singapore, and Norway [16, p. 19]. The main features inherent in their economies are adherence to long-term commitments to a «net-zero» economy, carbon neutrality, leadership in implementing quality climate policies [16, p. 10], and consistency between companies and governments of their strategies to harmonize economic growth and environmental sustainability [16, p. 11].

Becoming a climate- and carbon-neutral country is possible only if there are zero carbon emissions, the development of «green» technologies, and institutional encouragement of economic agents for their widespread implementation. This can be achieved by becoming an innovator of «clean» economic development, investing in «green» development of a closed-loop economy, advocating «smart» consumption, and economical high-tech production. In the process of «building a carbon-neutral economy, a number of countries face great risks and uncertainties related to climate change,

and the urgency of action needed to combat climate change» [4, p. 2].

«Carbon neutrality is an important step in partially stimulating systemic changes in supply chains, as it takes into account complex interdependencies and different sources of emissions… a net-zero economy is a more reliable and scalable solution to complex supply chain sustainability challenges» [5, p. 11]. The development of a «net-zero» economy directly depends on the emergence of breakthrough innovations in technological solutions for waste management, «investment models and markets for new energy sources, battery technologies, electric vehicles, energy-efficient buildings, and hydrogen fuel cells» [16, p. 30]. In practice, it is important to focus on «increasing environmental sustainability and efficiency of the supply chain through innovation and integration of technologies» [5, p. 14]. The interpretation of the basic categories used by the energy sector in Ukraine is presented in Table 1.

Table 1 – Interpretation of basic categories used by the energy sector in Ukraine

Category	Interpretation in accordance with the methodology presented by the relevant ministries of Ukraine
1	2
Electrical energy	Energy produced at power plants and is a commodity intended for purchase and sale.
Alternative energy sources (AES)	RES, which include solar, wind, geothermal, hydrothermal, aerothermal, wave and tidal energy, hydropower, biomass energy, gas from organic waste, gas from sewage treatment plants, biogases, and secondary energy resources, which include blast furnace and coke oven gases, methane gas from coal field degassing, and conversion of waste energy potential of technological processes.
Energy produced from renewable sources	Energy produced from non-fossil renewable sources, which include wind, solar, aerothermal, geothermal, hydrothermal, wave and tidal energy, hydropower, biomass energy, organic waste gas, sewage treatment plant gas and biogas.
Polluted water without treatment	Return (waste) waters that are discharged into natural water bodies without treatment and whose quality does not meet the established maximum permissible discharges.
Insufficiently purified water	Return (waste) waters that are discharged into natural water bodies after treatment facilities and whose quality does not meet the established maximum permissible discharges.
Emissions	The entry of pollutants or mixtures of such substances into the atmospheric air.
Pollutant	A substance of chemical or biological origin that is present in or enters the atmospheric air and can directly or indirectly have a negative impact on human health and the state of the natural environment.
«Greenhouse gases»	Means those gaseous components of the atmosphere, both natural and anthropogenic in origin, that absorb and re-emit infrared radiation (p. 5 of Art. 1 of the UNFCCC).
«Adverse effects of climate change»	Means changes in the physical environment or biota caused by climate change that cause significant adverse effects on the composition, resilience or productivity of natural and managed ecosystems or on the functioning of socio-economic systems, human health and well-being (Art. 1, p. 1, of the UNFCCC).

*Source: compiled based on sources [17]**

**Goal 7. Affordable and clean energy. 2.2. Concepts: Electric energy, Alternative energy sources; Goal 6. Clean water and adequate sanitation. 2.2 Concepts: Untreated water pollution, insufficiently treated water; Goal 11. Sustainable development of cities and communities. 2.2 Concepts: Atmospheric air, Emissions, Pollutant, Stationary source of emissions; Goal 13. Mitigation of climate change. 2.2 Concepts: «Adverse effects of climate change», «Greenhouse gases».*

From Fig. 1 it becomes obvious that there is a negative trend in 2022–2023 in terms of electricity production in Ukraine. The reason for this, first of all, is the destruction, as a result of shelling, of power grids and energy

system facilities of Ukraine. In 2023, total production decreased by 50.8 billion kWh compared to 2021. In fact, this is 1.5 times. Ukraine had the best indicator of electricity generation in 2018.

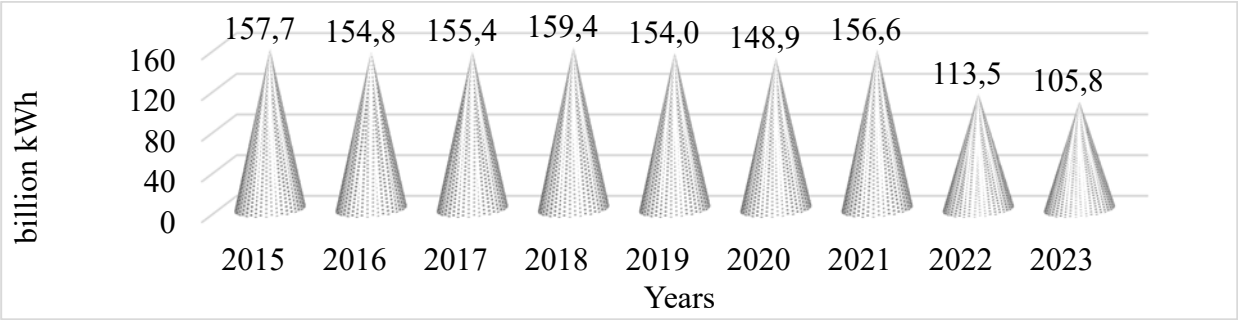

Figure 1 – Total electricity production in Ukraine in 2015–2023

*Source: compiled based on sources [17]**

**Goal 7. Affordable and clean energy. 7.1.1. Electricity generation, billion kWh.*

The data in Fig. 2 demonstrate electricity production by different types of energy sources in Ukraine for the period 2015–2023, namely: AES, nuclear power plants, hydroelectric power plants, pumped storage power plants, thermal power plants, combined heat and power plants, and blocks. In 2023, Ukraine failed to restore the volume of electricity production from AES to the pre-war level of 2021. Thus, in 2023 it is 2.1 billion kWh less than in 2021, but 0.9 billion kWh more than in 2022.

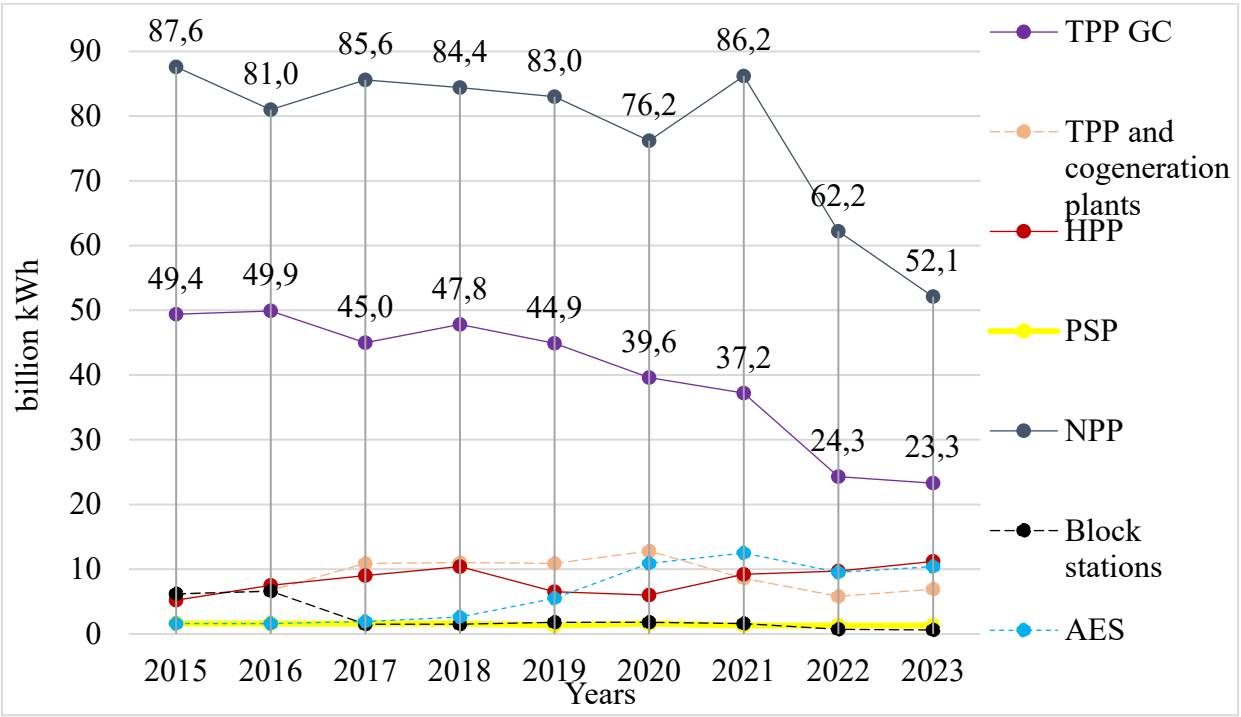

Figure 2. Electricity production by different types of energy sources in Ukraine for 2015–2023

*Source: compiled based on sources [17]**

**Goal 7. Affordable and clean energy. 7.1.1. Electricity generation, billion kWh.*

Nuclear power plants generated 1.65 times less electricity in 2023 than in 2021 and 1.19 times less than in 2022. Over the past 3 years, there has been a systematic decrease in electricity production at unit plants,

which in 2023 amounted to only 0.6 billion kWh, while in 2015 it amounted to 6.2 billion kWh (Fig. 2).

A negative trend is observed from 2018 to 2023. and in the volumes of electricity generation of TPPs of GC. During this period, TPPs of GC reduced their volumes by 24.5 billion kWh. The indicator for the last three years remained unchanged for PSPs (1.6 billion kWh). CHPs and cogeneration plants failed to reach pre-war volumes. Thus, in 2023 it amounted to 6.9 billion kWh, which is 1.7 billion kWh less than in 2021 (8.6 billion kWh). A positive trend is observed in the operation of HPPs. In 2023, electricity production amounted to 11.2 billion kWh, which is 1.21 times more than in pre-war 2021 (Fig. 2).

Ukraine's desire to comply with SDG requires reducing the volume of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies. Analysis of statistical data in Fig. 3 and Fig. 4 demonstrates the fact that in general, Ukraine has seen a decrease in the volume of discharges of polluted wastewater into water bodies in Ukraine for 2017–2023.

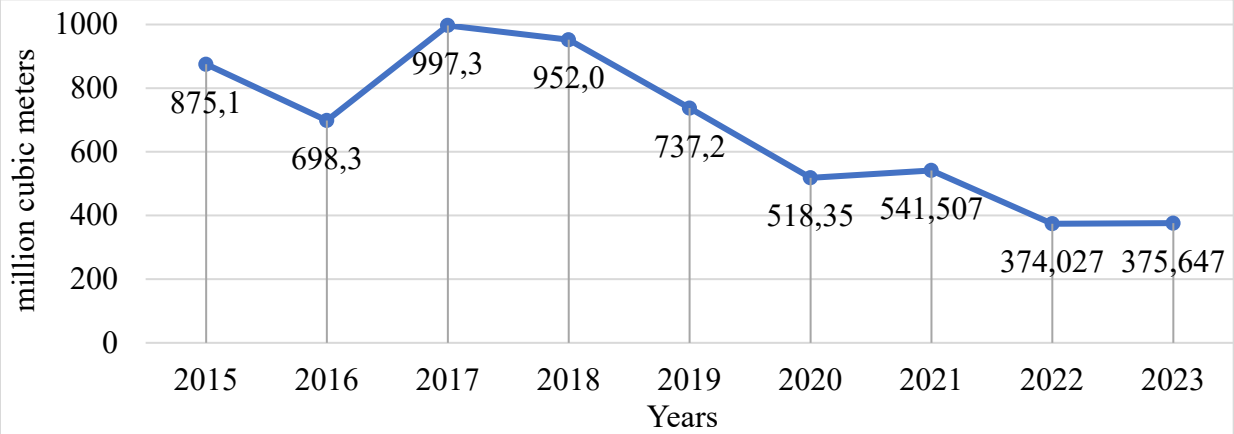

Figure 3. Volumes of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies in Ukraine for 2015–2023

*Source: compiled based on sources [17]**

**Goal 6. Clean water and adequate sanitation. 6.3.1. Volumes of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies, million m^3; 6.3.2. Share of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies in the total volume of discharges, %.*

The smallest discharges of polluted wastewater into water bodies in the total volume of discharges in Ukraine were in 2020 (10.05%) and 2023 (11.74%) (Fig. 4). The largest volumes of polluted wastewater discharges into water bodies in Ukraine were in 2017 (997.3 million m^3) and 2018 (952 million m^3).

The goal of a carbon-neutral economy is to reduce environmental pollution, use resources sparingly, consume wisely and work on restoring biodiversity and resource efficiency. An example of a company that has become completely carbon-neutral by 2025 is Google; Microsoft, Amazon, and Apple are all aiming to eliminate their carbon footprint in the next 10 years.

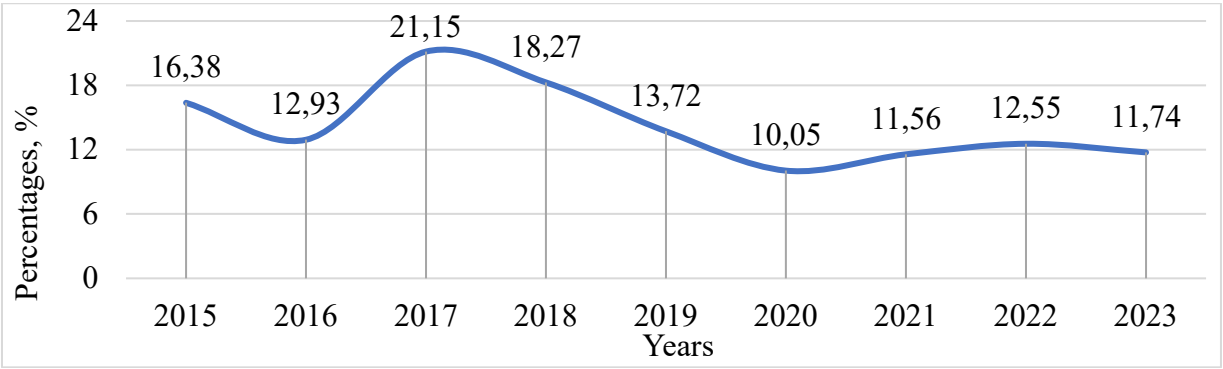

Figure 4. Share of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies in the total volume of discharges in Ukraine for 2015–2023

*Source: compiled based on sources [17]**

**Goal 6. Clean water and adequate sanitation. 6.3.1. Volumes of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies, million m3; 6.3.2. Share of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies in the total volume of discharges, %.*

In an effort to join the ranks of carbon-neutral economic agents, Bolt has presented an ambitious plan to transition to producing electric scooters in its own carbon-free production. An attempt has been made to present the strengths and weaknesses of the use of RES through a matrix analysis in Table 2.

Table 2 – Socio-economic and environmental effects and losses from the operation of RES

Types of RES	***Socio-economic and environmental benefits***	***Weaknesses and losses from renewable energy***
Hydropower	*Generated by using the potential and kinetic energy of water flows. Environmentally friendly energy. Reduces the risk of global warming. Using water-to-air, water-to-water, water-to-electricity heat pumps, you can help dissolve oxygen in water bodies, which will improve the fish stocking process.*	*Depends on natural phenomena.*
Aerothermal energy	*The thermal energy of the air is used to heat houses (provided that radiators and fan coils are used), heat water and cool rooms. Does not pollute the environment. Safe for human health.*	*Different geographical zones have different air temperatures, so not everyone can generate this type of energy.*
Biomass energy	*Energy is produced with little environmental and economic cost. Waste of plant and animal origin, wood, is used to produce electricity, eliminating the environmental risk of waste that emits carbon dioxide during decomposition.*	*Biomass requires sorting before being processed into clean energy.*
Tidal energy	*Electricity is generated by the movement of water during ebb and flow. It's considered the safest of all RES. It does not cause carbon dioxide emissions. It's obtained from natural resources that are not exhausted.*	*Not all countries in the world have access to water bodies and access to seas and oceans, which causes unequal access conditions between countries in terms of the ability to generate this type of energy.*

Continuation of Table 2

Photovoltaic energy of the sun	*Doesn't cause greenhouse gas emissions.*	*The technology is effective only under conditions of high solar radiation.*
Solar thermal energy	*The advantage of water-to-water and water-to-air heat pumps is that they have the ability to operate in cloudy weather, in winter and at night. Allows you to maintain heating of residential premises and heat water.*	*The different climatic zones of the earth allow all countries to have access to the generation of this type of energy.*
Wind energy	*The cheapest renewable energy production. Naturally renewable. Doesn't produce toxic waste.*	*The disadvantage is that the efficiency of air-to-water and air-to-air heat pumps is much lower than those used in solar thermal energy. Production is irregular, as it directly depends on natural phenomena that humans have no control over.*
Geothermal energy	*Natural heat is used, which is located under the surface of the earth and is used to heat residential buildings. Unlimited period of use. Thermal water reserves can be exploited as a geothermal heat extraction system.*	*It isn't cheap to generate.*

Source: based on sources [9; 10] and own observations

Analyzing Table 2, we note that bioenergy facilities operate by generating thermal and electrical energy. Examples of alternative energy products include biomass gas, which is obtained as a result of technological processes in agricultural production, or fuel as a result of processing wood chips, sawdust, pellets, straw, or ponds with algae that condition the air and process organic matter into biogas for heating residential premises. And in general, «discovery, innovation, entrepreneurship, and behavior are the basis of the transition to a net-zero economy, but under the condition of incentives» [4, p. 3] and a transparent and efficient alternative energy market. But it's worth remembering the fact that «environmental damage caused by the blind pursuit of economic growth, or economic decline caused by the blind pursuit of reducing carbon emissions, doesn't contribute to sustainable economic and environmental development» [6, p. 4].

Within the framework of the scientific problem raised in this article, it makes sense to analyze the volume of emissions of pollutants into the atmosphere by stationary emission sources. Fig. 5 presents data on this indicator from 2015 to 2023 as a percentage of the 2015 level. Starting from 2016 to 2022, Ukraine reduced the volume of emissions of pollutants into the atmosphere by stationary sources of emissions, which is a positive signal for partners with the EU. After all, Ukraine demonstrates that it strives to adhere to SDG, which are practiced in their activities by most economic agents in the industrial sector of Europe, the agricultural sector, the transport sector, and the energy sector. The lowest of this indicator is the last two years. So, in 2022 it was 41.6% of the level of 2015 and 42.8% in 2023.

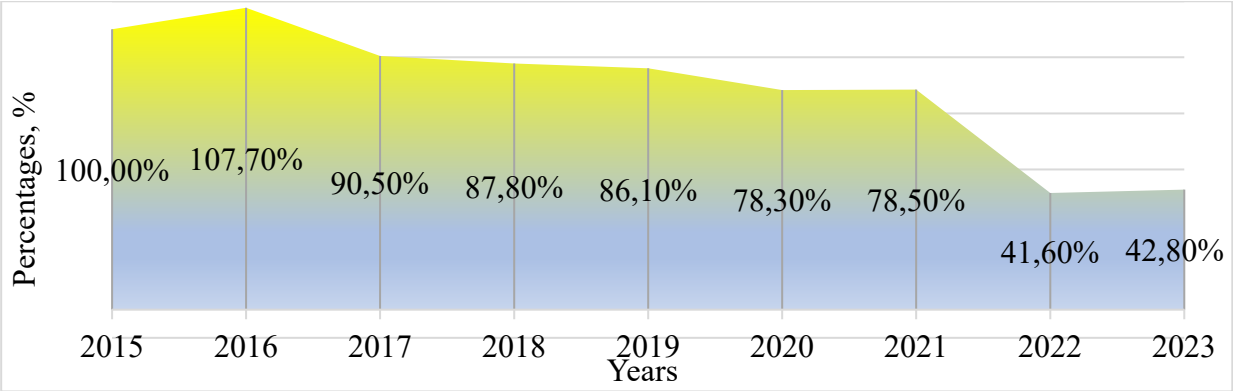

Figure 5. Volume of emissions of pollutants into the atmospheric air by stationary emission sources in Ukraine for 2015–2023, % to the level of 2015

*Source: compiled based on sources [17]**

**Goal 11. Sustainable development of cities and communities. 11.5.1. Volume of emissions of pollutants into the atmosphere by stationary emission sources, % to the level of 2015 kWh.*

The interpretation of the content of a carbon-neutral economy is, so to speak, through the coordinate system of climate and carbon neutrality. Carbon neutrality is understood as the ability of business entities to operate with zero carbon dioxide emissions. This is achieved by balancing carbon emissions with their simultaneous removal from the atmosphere. This means that the company emits as much carbon dioxide as it absorbs, thereby reaching «0». The sectors of the economy that cause the greatest damage to the atmosphere are agriculture, industry, and the transport sector (Fig. 6).

Currently, post-industrial countries of the world are developing tools and ways to reduce carbon emissions into the atmosphere. Among the current solutions proposed by governments of innovatively developed countries and leading institutions such as the World Resources Institute (WRI), the Intergovernmental Panel on Climate Change (IPCC), and the World Business Council for Sustainable Development (WBCSD) is the transition to AES and the production of green energy from their own production and industrial waste (Fig. 6). In addition, innovation of production processes based on the application of high technologies remains necessary. That is, technical and technological improvement in accordance with Industry 5.0 in the industrial sector, mechanical engineering, agriculture, and in the operation of all types of transport, namely sea, air, rail, and road transport, is becoming increasingly relevant.

Decarbonization can be implemented quickly in countries that are innovation leaders, because they have high technologies in their arsenal, they actively use RES and financial resources in sufficient quantities, and the institutional component has «solid» and reliable laws that protect and support the formation and development of a «net-zero» economy. If we are talking about developing countries in which agriculture and heavy industry prevail, then they have a high level of dependence on fossil fuels. In such countries, there is a lack of funding for innovation and support for RES; research and development in the field of high technologies is not supported at the proper level, so as a result there are

problems with rapid decarbonization. Such countries need help from both international partners and the government and local authorities. Industrial enterprises and agriculture of the IV technical and technological level of the structure will not be able to cope on their own.

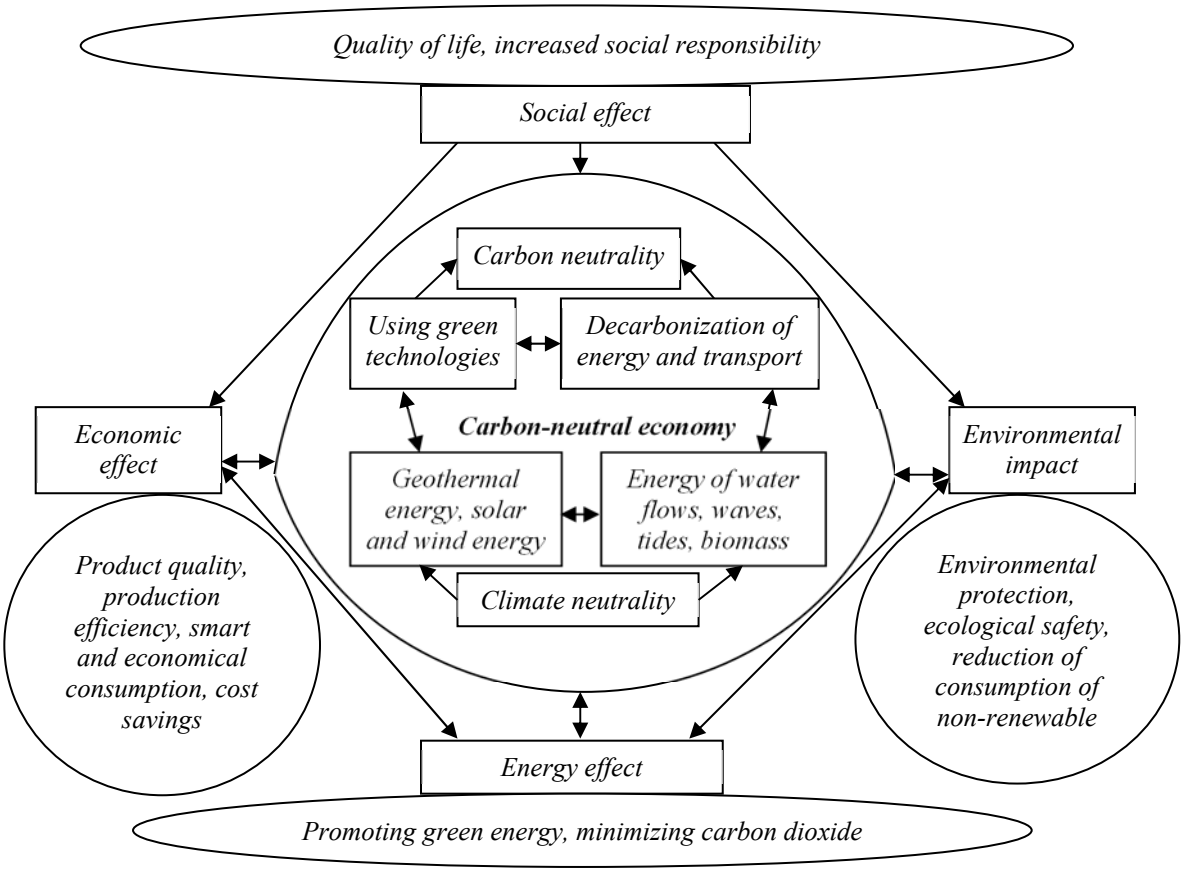

Figure 6. Concept of developing a carbon-neutral economy on the way to a «net-zero» economy

Source: actor's scientific vision

We have presented some measures and tools to support the development of a carbon-neutral economy in Ukraine in Figure 7.

Expanding the list of measures presented in Fig. 7, it is worth noting that the agenda in the post-war period should include the issue of rapidly reducing the volume of solid fuel combustion. The need is caused by the systemic increase in the average temperature on the planet as a result of the release of carbon dioxide as a product of fossil fuel combustion.

When rebuilding residential infrastructure in the post-war period, it is worth pursuing the ambitious goal of building a single ecosystem of cities and towns on the basis of carbon-neutral development. «It's important to note that a city cannot achieve net-zero by focusing only on reducing emissions within its administrative boundaries. Cities must decarbonize key cross-border supply chains and use urban and regional landscapes to absorb carbon from the atmosphere» [3, p. 378]. Improvements in the partial innovation of housing infrastructure should pursue the goal of creating comfortable and environmentally safe living conditions. It's also worth «optimizing the energy supply structure of buildings and increasing the use of clean energy to

reduce CO2 emissions from buildings» [7, p. 81725].

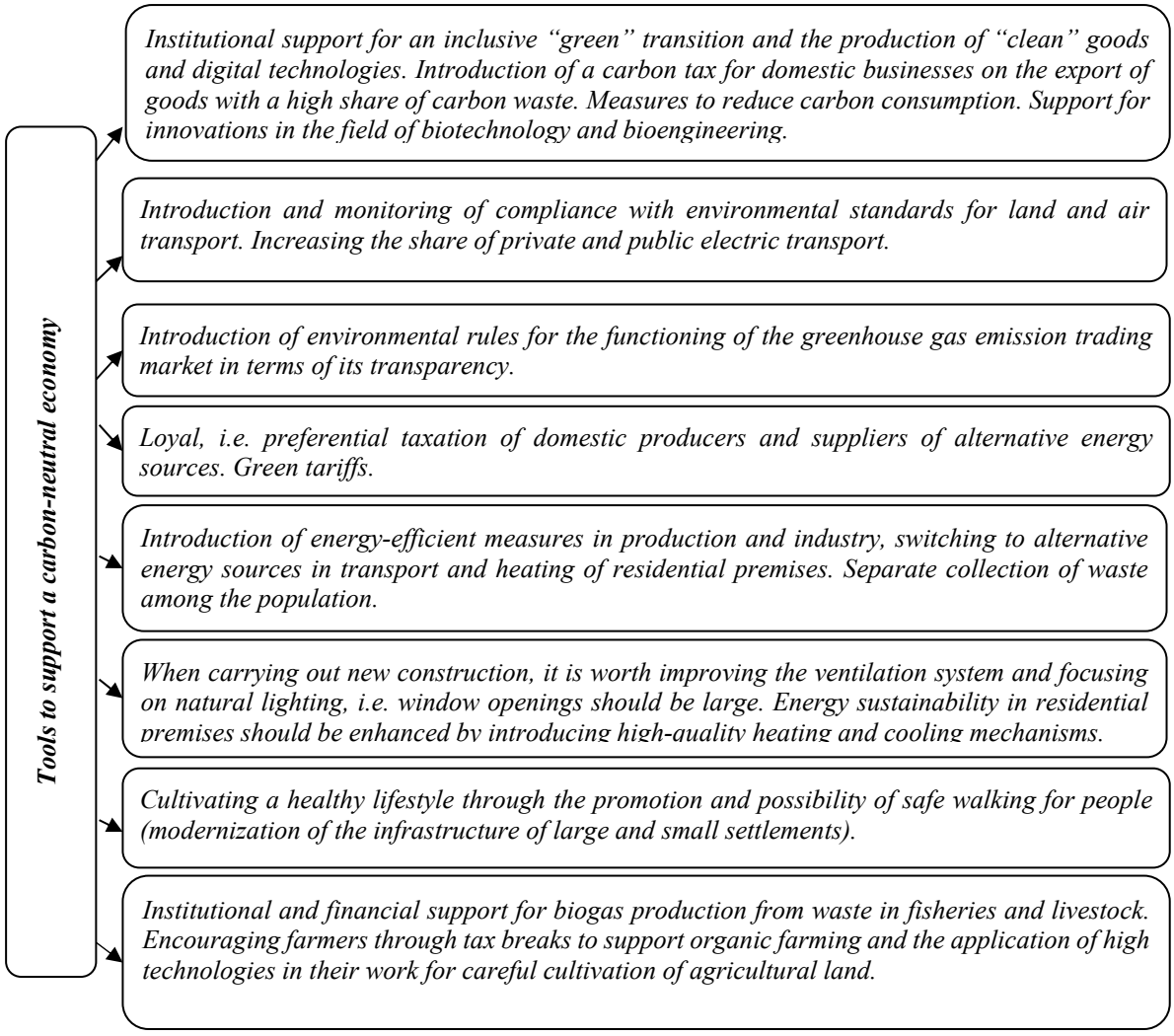

Figure 7. Measures and tools to support the development of a carbon-neutral economy in Ukraine

Source: grouped based on own conclusions and processed material from sources [10; 11; 13; 8; 16, p. 32]

Ukraine can't cope with this on its own, as it needs significant financial investments, innovative ideas, and competent specialists for the implementation of environmental projects. Priority should be given to projects for greening the city, installing treatment plants, and transforming businesses in terms of launching zero-waste production and reuse. «A strategic sequence of mitigation actions is essential for cities to reach net-zero, and this is due to the blocking of carbon emissions and the complex interaction of urban infrastructure and the behavior» [3, p. 378] of individuals and economic agents.

The central place in the sustainable development of cities should be given to the decarbonization of housing, which has socio-economic benefits, makes energy affordable, creates jobs that require skills with new technologies, and improves the level of well-being of citizens in general. By insulating residential buildings, the city realizes its climate neutrality. General cooling of the city can be achieved by installing solar photovoltaic systems on roads, introducing distributed energy

systems into the life processes of the city, and encouraging large businesses to develop wind energy.

Conclusions from the study. In conclusion, it is worth noting that the post-war reconstruction of the Ukrainian economy is possible with the support of breakthrough innovations and the transition to the VI technological level in all sectors of production. The revival economy should be based on the principles of the «green» economy, circular and sharing, depending on the areas of application and implementation. Currently, the Ukrainian government is faced with the urgent issue of developing effective mechanisms and high-quality tools for a «painless» transition of business entities to environmentally friendly business practices and the implementation of climate tasks. Structural restructuring and modernization of post-war recovery should form a climate-neutral national economy; that is, reconstruction should meet the standards of a carbon-neutral economy in terms of generation and consumption.

It's worth updating the issue of establishing hydrogen hubs in Ukraine in the post-war period and including large industrial facilities that are motivated to invest in RES. All united territorial communities of Ukraine should join in building a national eco-network for charging electric vehicles.

In the coordinate system of promising further research is the development of a high-quality mechanism for managing hazardous waste that requires disposal using high-tech capabilities. In addition, most waste contains some types of minerals that were not extracted during primary processing due to outdated technologies. Further scientific research should be conducted in the search for effective tools for working with waste as a primary raw material for the extraction of minerals and the formation of a carbon-neutral economy. Currently, the issue of the partial development by Ukrainian inventors of the latest technologies for processing and utilization of waste and the effective application of completely new methods and approaches in working with them is acute.

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