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## CARBON NEUTRALITY OF UKRAINE AS A DETERMINANT OF GREEN DEVELOPMENT

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The article presents the research results on some aspects of achieving carbon neutrality in Ukraine. Carbon neutrality is a challenge for the whole world. In 2020, the concentration of greenhouse gases in the atmosphere reached a historical maximum. The work aims to study the features of achieving carbon neutrality in Ukraine. The tasks of the work are the analysis of the components of the transition to low-carbon development, analysis of the consumption of fossil fuels, and activities related to the preservation of forests, natural steppe, and meadow ecosystems. Interest in carbon neutrality issues grows yearly, with a particularly in 2021–2022. Most articles on carbon neutrality were published by scientists from China, the USA, Great Britain, Turkey, and Pakistan. They are mainly devoted to carbon dioxide emissions, economic growth, renewable energy, energy consumption, financial development, co-integration, dioxin emissions, etc. Positive trends regarding the achievement of carbon neutrality have been identified: the supply of natural gas, coal, and peat has decreased, while the supply of renewable energy sources has increased; the share of coal and peat decreased by 26.4%, and the percentage of energy produced from renewable sources increased to 6.6%; the use of coal and peat decreased by 8.5%, natural gas by 5%, and biofuels increased by 16%; the share of biofuel use increased to 5.8%. Expenditures for environmental protection increased by 88.5%, for preserving biodiversity and habitat – by 3.6 times, and costs for air protection and climate change problems – by 2.5 times. The share of expenditures on the protection of biodiversity and habitat increased to 3.2%, and costs on atmospheric air protection and climate change problems to 19.3%. Negative trends that restrain the development of a carbon-neutral economy were also revealed: a low share of renewable sources in the structure of supply and use. Thus, the percentage of biofuel in aggregate use remains low – only 5.8% in 2020. The area of forest loss is increasing, and the area of forest regeneration has decreased by 36%. The area of reforestation remained at the same level, but the area of afforestation decreased ten times during 2010–2020. The scientific novelty consists in the development of theoretical foundations for the identification of regularities in the formation of the energy transformation theory, which differs from the existing ones using bibliometric (VOSviewer v. 1.6.13) analysis.

**Keywords:** sustainable development, carbon neutrality, renewable energy, clean fuel, forest restoration, climate change, electricity consumption.

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***Introduction and formulation of the problem***

After adopting the Paris Agreement in 2015, “carbon neutrality” is becoming increasingly important. The Paris Agreement set a goal to “achieve

a balance between anthropogenic emissions from sources and absorption of greenhouse gases in the second half of this century” to “contain the increase in global average temperature and make efforts to

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limit the increase in temperature to 1.5°C". To facilitate this task, some countries have set "carbon neutrality" goals as part of their "long-term strategies to reduce greenhouse gas emissions" [1].

Carbon neutrality is a challenge for the entire world caused by the global climate crisis, alongside the coronavirus pandemic and the Russian invasion of Ukraine. Despite the slowdown of the world economy in 2020 and a selective reduction in greenhouse gas emissions during the pandemic, their concentration in the atmosphere has reached a historical maximum.

Also, according to the latest report of the United Nations World Meteorological Organization, the last eight years have been the warmest on record, facilitated by the ever-increasing concentration of greenhouse gases. Record levels of carbon dioxide, methane, and nitrous oxide (the leading greenhouse gases contributing to global warming) are being observed. Their level is now estimated to be approximately 1.15 °C higher than the pre-industrial level [2].

Thus, studying the theoretical and applied foundations of achieving carbon neutrality in Ukraine is relevant.

#### ***Analysis and research of publications***

Interest in carbon neutrality issues grows yearly, with a particularly sharp jump in 2021-2022. There is a massive amount of research on this issue. Thus, in the Web of Science database, 505 articles and report abstracts were found for the query "carbon neutrality" in the titles of publications.

The works of scientists from many countries are devoted to studying the problems of carbon neutrality; most works are by scientists from China, the USA, Great Britain, Turkey, Pakistan, Australia, Japan, Germany, South Korea, and Finland. Most studies were conducted in ecology, energy, technological sciences, engineering, business economics, public environmental hygiene, meteorology, thermodynamics, urbanism, and agriculture.

The most publications on carbon neutrality are Wang Y., Adebayo T. S., Li X., Li Y., Zhang X. Y., Kirikkaleli D., Liu Y., Umar M., and Zhang Y. Each of them published at least six works regarding carbon neutrality.

In the most cited works of scientists, strategies and countermeasures for achieving carbon neutrality in China are considered [3], local plans of EU cities regarding carbon neutrality are analyzed [4], technologies and prospects for achieving carbon neutrality are investigated [5], export diversification and environmental innovations are studied to achieve

the goals carbon neutrality of economies [6], achieving carbon neutrality in commercial construction [7], use of long-life lithium-CO<sub>2</sub> batteries [8], new energy vehicles [9] and others. Also, the works of scientists are most often devoted to carbon dioxide emissions, economic growth, renewable energy, energy consumption, financial development, co-integration, dioxide emissions, empirical evidence, urbanization, politics, energy efficiency, productivity, models, systems, climate change, etc. [10].

Measures of countries regarding low-carbon development remain unexplored issues. A few works were also found on Ukraine's steps to achieve carbon neutrality.

#### ***Purpose of the article***

The work aims to study the peculiarities of achieving carbon neutrality in Ukraine. The tasks of the work are the analysis of the components of the transition to low-carbon development, analysis of the consumption of fossil fuels, and activities related to the preservation of forests, natural steppe, and meadow ecosystems.

#### ***Presentation of the main material***

In the Web of Science database, articles and report abstracts were found with the query "carbon neutrality" in the titles of the publications. On their basis, publication trends, areas of research, authors of publications by country, and topics of the most cited articles were analyzed. Using the VOSviewer program, research subjects were analyzed by keywords.

Based on statistical information, some aspects of achieving carbon neutrality in Ukraine were analyzed, in particular the volumes of primary energy supply, shares of primary energy supply, volumes of fuel use, areas of regenerative forests, costs for environmental protection and preservation of biodiversity in Ukraine during 2010-2020.

In order to confirm its gradual transition to low-carbon development and achieve the goals of the Paris Agreement, Ukraine signed an appeal to the participants of the climate summit in Glasgow SOR 26, in which it testified its intentions [11]:

- create and update legislation on waste management and reduction of greenhouse gas emissions as soon as possible;
- implement «green» transformation of industry;
- introduce the Ukrainian system of trading quotas for greenhouse gas emissions;
- reduce consumption of fossil fuels;
- create the Ukrainian Climate Fund;
- to reform environmental control;

– increase the area of forests, preserve self-seeded forests, natural steppe and meadow ecosystems;

– stop land degradation from increasing the absorption of greenhouse gases, etc.

To understand the achievement of the set goals, we will consider some aspects of implementing this agreement, particularly fossil fuel consumption and preserving forests, natural steppe, and meadow ecosystems.

Consumption of fossil fuels. According to data from the Ministry of Environmental Protection and Natural Resources of Ukraine [12], 67% of greenhouse gases are caused by energy and the burning of fossil fuels. In 2020, the draft Concept of Ukraine's «green» energy transition by 2050 was presented. The concept envisages the complete replacement of coal generation and the transition of Ukraine's economy, which is based on fossil fuels - coal, oil, and gas, to a climate-neutral economy in

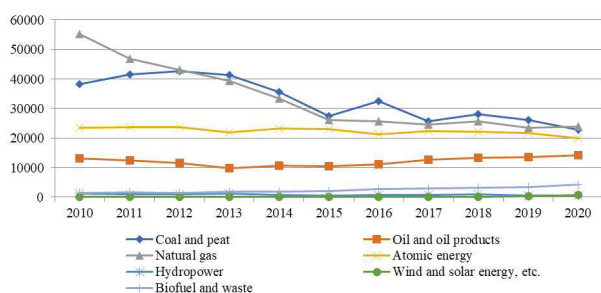


Fig. 1. Supply of primary energy in 2010–2020, thousands of tons per year

Source: formed by the authors based on [12]

the long term.

The supply of primary energy by type of resources is presented in Fig. 1.

As shown in Fig. 1, during 2010–2020, natural gas, coal, and peat supply decreased, and renewable energy sources slightly increased, which are positive trends.

As shown in the Table 1, the positive trends are a decrease in the share of fossil fuels, particularly coal, and peat, from 34.5% to 26.4% and an increase in the share of energy produced from renewable sources from 3.8% to 6.6%. Table 2 shows fuel consumption in 2017–2020.

As shown in the table 2, the use of coal and peat during 2017–2020 decreased by 8.5%, natural gas by 5%, and biofuels increased by 16%, it is a positive trend. The share of biofuel use increased from 4.9% to 5.8% but remains low in aggregate use.

Preservation of forests, steppe, and meadow ecosystems. One of the indicators indicating the effectiveness of forest conservation activities is the increase in the area of regenerated forests compared to their loss and the cost of protection. The area of forest reproduction and the death of forest plantations is presented in Fig. 2.

As can be seen from Fig. 2, the area of the death of forest plantations has a tendency to increase, and the area of reproduction of forests has decreased by 36%, which is a negative trend. Let's consider why this happened (Fig. 3).

As can be seen from Fig. 3, the areas of

Table 1

Share of primary energy supply in 2016–2020, %

Supply of primary energy, %	2016	2017	2018	2019	2020
Coal and peat	34.5	28.8	30.0	29.3	26.4
Oil and oil products	11.9	14.2	14.2	15.1	16.4
Natural gas	27.2	27.5	27.5	26.3	27.5
Atomic energy	22.6	25.1	23.7	24.5	23.1
Energy produced from renewable sources	3.8	4.4	4.6	4.9	6.6

Source: formed by the authors based on [12]

Table 2

Fuel consumption in 2017–2020, thousands of tons

Fuel consumption, thousand tons	2017	2018	2019	2020
Coal and peat, thousand tons	84242	88156	82553	77018
Oil and oil products, thousand tons	4778	9157	9684	9760
Natural gas, thousand tons	31502	31624	27838	29940
Biofuel, thousand tons	6222	6865	7148	7235
Other types of fuel, thousand tons	1180	-	1740	1690
Share of biofuel in total use, %	4.9	5.1	5.5	5.8

Source: formed by the authors based on [12]

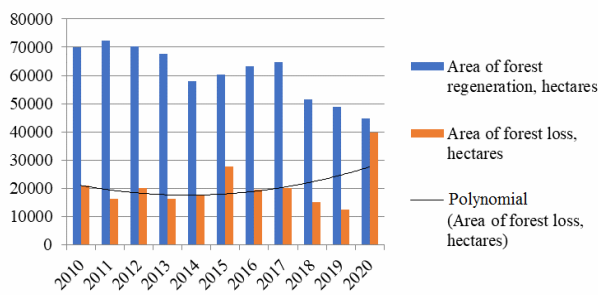


Fig. 2. Areas of regenerated forests and the death of forest plantations in 2010–2020, hectares

Source: formed by the authors based on [12]

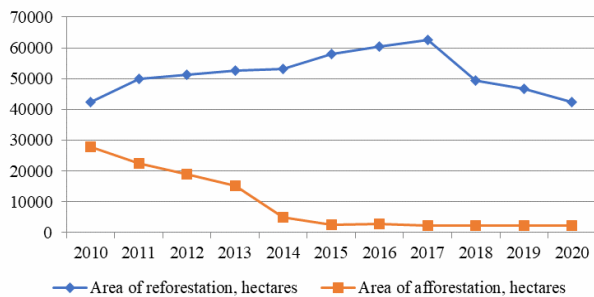


Fig. 3. Areas of reforestation and afforestation in 2010–2020, ha

Source: formed by the authors based on [12]

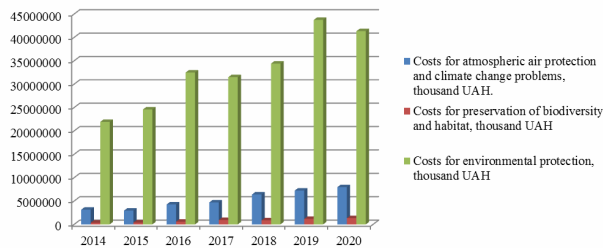


Fig. 4. Expenditures for environmental protection in 2014–2020, UAH thousand

Source: formed by the authors based on [12]

reforestation grew until 2017, and starting from 2018, they began to decrease and almost reached the values of 2010. At the same time, the afforestation area rapidly decreased and decreased by 10 times during 2010–2020.

As can be seen from Fig. 4, overall costs for environmental protection increased by 88.5%. Spending on biodiversity and habitat conservation has also increased by 3.6 times, and spending on air protection and climate change issues by 2.5 times. The share of expenditures on protection of biodiversity and habitat increased from 1.7% to 3.2%, and the share of expenditures on air protection and climate change problems increased from 14.4% to

19.3%. This is a positive trend towards achieving carbon neutrality of Ukraine.

### Conclusions

Carbon neutrality is a challenge for the whole world. In 2020, the concentration of greenhouse gases in the atmosphere reached a historical maximum. Energy and the burning of fossil fuels cause 67% of greenhouse gases. In Ukraine, the concept of the transition of the Ukrainian economy from using fossil fuels to a climate-neutral one has been developed.

According to statistical data, during the years 2010–2020, the supply of natural gas, coal, and peat decreased, and the supply of renewable energy sources increased somewhat. There was a decrease in the share of fossil fuels, particularly coal and peat, from 34.5% to 26.4%, and the share of energy produced from renewable sources increased from 3.8% to 6.6%. During 2017–2020, the use of coal and peat decreased by 8.5%, natural gas by 5%, and biofuels increased by 16%. These are positive trends. The share of biofuel use increased from 4.9% to 5.8% but remains low in aggregate use.

The area of forest loss is increasing, and the area of forest regeneration has decreased by 36%, which is a negative trend. At the same time, reforestation remained at the same level, and the afforestation area decreased ten times during 2010–2020.

Spending on environmental protection increased by 88.5%, biodiversity and habitat preservation increased by 3.6 times, and air protection and climate change problems increased by 2.5 times. The share of spending on biodiversity and habitat protection doubled to 3.2%, and the share on atmospheric air protection and climate change problems increased from 14.4% to 19.3%. It is also a positive trend toward achieving carbon neutrality in Ukraine.

Thus, positive trends contributing to achieving carbon neutrality goals by 2050 and negative trends that inhibit their development have been identified.

The work did not consider other aspects of achieving carbon neutrality, in particular, legislation on waste management and reduction of greenhouse gas emissions; “green” transformation of industry; system of trading quotas for greenhouse gas emissions; creation of the Ukrainian Climate Fund; environmental control; land degradation to increase the absorption of greenhouse gases, etc.

The scientific novelty consists in the development of theoretical foundations for the identification of regularities in the formation of the energy transformation theory, which differs from the existing ones using bibliometric (VOSviewer v. 1.6.13)

analysis, which allowed to describe of the dominant retrospective evolutionary-temporal trends in the development of the energy transformation theory in relation to the concepts sustainable development, green economy and renewable energy.

The article may be helpful to researchers studying the issue of carbon neutrality.

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#### **ВУГЛЕЦЕВИЙ НЕЙТРАЛІТЕТ УКРАЇНИ ЯК ДЕТЕРМІНАНТА ЗЕЛЕНОГО РОЗВИТКУ**

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У роботі наведено результати дослідження окремих аспектів досягнення вуглецевого нейтралітету в Україні. Вуглецевий нейтралітет є викликом для всього світу. У 2020 році концентрація парникових газів в атмосфері досягла історичного максимуму. Робота спрямована на дослідження особливостей досягнення вуглецевого нейтралітету в Україні. Завданнями роботи є аналіз складових переходу до низьковуглецевого розвитку, споживання викопного палива та заходи, пов'язані зі збереженням лісів, природних степових і лучних екосистем. Інтерес до питань вуглецевого нейтралітету зростає щороку, особливо в 2021–2022 рр. Найбільше статей про вуглецевий нейтралітет опублікували вчені з Китаю, США, Великої Британії, Туреччини та Пакистану. В основному їх роботи присвячені викидам вуглекислого газу, економічному зростанню, відновлюваній енергетиці, енергоспоживанню, фінансовому розвитку, коінтеграції, викидам діоксиду тощо. Виявлено позитивні тенденції щодо досягнення вуглецевого нейтралітету: постачання природного газу, вугілля, і торфу зменшилося, а відновлюваних джерел енергії – зросло; частка вугілля та торфу зменшилася на 26,4%, а енергії, виробленої з відновлюваних джерел – зросла до 6,6%; використання вугілля та торфу зменшилось на 8,5%, природного газу – на 5%, біопалива зросло на 16%; а частка використання біопалива зросла до 5,8%. Витрати на охорону навколишнього середовища зросли на 88,5%, на збереження біорізноманіття та середовища існування – у 3,6 рази, а витрати на охорону повітря та проблеми зміни клімату – у 2,5 рази. Частка видатків на охорону біорізноманіття та середовища проживання зросла до 3,2%, а витрат на охорону атмосферного повітря та проблеми зміни клімату – до 19,3%. Виявлено також негативні тенденції, які стримують розвиток вуглецево-нейтральної економіки: низька частка відновлюваних джерел у структурі пропозиції та використання. Таким чином, частка біопалива в сукупному

використанні залишається низькою – лише 5,8% у 2020 році. Площа загибелі лісових насаджень зростає, а площа відтворення лісів зменшилася на 36%; площа лісовідновлення залишилася на тому ж рівні, а площа лісорозведення скоротилася протягом 2010–2020 рр. у 10 разів. Наукова новизна полягає в розробці теоретичних засад для виявлення закономірностей формування теорії перетворення енергії, що відрізняється від існуючих, за допомогою бібліометричного (VOSviewer v. 1.6.13) аналізу.

**Ключові слова:** сталий розвиток, вуглецева нейтральність, відновлювальна енергетика, чисте паливо, відновлення лісів, кліматичні зміни, споживання електроенергії.

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