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# CIRCULAR ECONOMY BUSINESS MODELS IMPLEMENTATION IN THE GREEN ENERGY DEVELOPMENT IN UKRAINE

# ВПРОВАДЖЕННЯ БІЗНЕС-МОДЕЛЕЙ ЦИРКУЛЯРНОЇ ЕКОНОМІКИ У РОЗВИТОК ЗЕЛЕНОЇ ЕНЕРГЕТИКИ В УКРАЇНІ

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Is devoted to exploring the possibilities of adopting circular business models within Ukraine's green energy sector. This approach is intended to enhance resource efficiency, decrease waste, lessen environmental effects, and contribute to economic recovery following the war. The following business models of the circular economy were considered: closed-loop model, product-as-a-service model, product life cycle extension model, sharing model, and resource recycling and reuse model. A SWOT analysis was carried out to identify the strengths, weaknesses, opportunities and threats associated with the implementation of circular models in the country's renewable energy sector. The results of the study show that effective adaptation of circular economy models in the green energy sector in Ukraine requires comprehensive support from the state, attraction of international investments, and development of new mechanisms to stimulate environmental responsibility in the business environment. The proposed strategies and measures can ensure Ukraine's sustainable development and facilitate its integration into the international renewable energy market with high environmental standards.

**Keywords:** circular economy, green energy, renewable energy sources, business models, Ukraine, sustainable development, recycling, energy strategy.

Статтю присвячено дослідженню потенціалу впровадження циркулярних бізнес-моделей у секторі зеленої енергетики України як стратегії підвищення ефективності використання ресурсів, мінімізації відходів, зменшення впливу на навколишнє середовище та післявоєнного економічного відновлення. Розглядалися такі бізнес-моделі циркулярної економіки: модель замкнутого циклу, модель продукту як послуги, модель продовження життєвого циклу продукту, модель спільного використання, модель переробки та повторного використання ресурсів. Було проведено SWOT-аналіз, щоб визначити сильні та слабкі сторони, можливості та загрози, пов'язані з впровадженням циркулярних моделей у секторі відновлюваної енергетики країни. До основних сильних сторін можна віднести можливість зменшення залежності від імпортних ресурсів і підвищення економічної ефективності за рахунок повторного використання та переробки компонентів енергетичного обладнання. Водночас в Україні наразі відсутня необхідна інфраструктура для переробки та повторного випуску компонентів, низький рівень екологічної свідомості населення та бізнесу. Серед можливостей розвитку – перспективи міжнародної фінансової підтримки та створення законодавчої бази, яка стимулюватиме перехід до циркулярної економіки. Впровадження нових технологій і розвиток місцевого ринку зелених послуг

може сприяти підвищенню доступності зеленої енергії для бізнесу та населення. При цьому до основних загроз можна віднести високу вартість впровадження циркулярних бізнес-моделей і непередбачуваність регуляторних змін, що ускладнює довгострокове планування. Результати дослідження показують, що ефективна адаптація моделей циркулярної економіки в секторі зеленої енергетики в Україні потребує всебічної підтримки з боку держави, залучення міжнародних інвестицій та розробки нових механізмів стимулювання екологічної відповідальності в бізнес-середовищі. Запропоновані стратегії та заходи можуть забезпечити сталий розвиток України та сприяти її інтеграції в міжнародний ринок відновлюваної енергетики з високими екологічними стандартами.

**Ключові слова:** циркулярна економіка, зелена енергетика, відновлювані джерела енергії, бізнес-моделі, Україна, сталий розвиток, переробка, енергетична стратегія.

**Problem formulation.** Modern economic and environmental challenges require an innovative approach to the development of industries related to the use of natural resources and energy. Ukraine, with its considerable potential in green energy, is now facing the need to introduce new models that would not only promote energy independence but also integrate the principles of sustainable development. The circular economy, a concept that maximizes the reuse of resources and minimizes waste, is an important tool in achieving these goals.

Circular business models can significantly change the way production and consumption processes are organized, creating closed cycles of material and energy use. They are aimed at creating added value while reducing dependence on traditional resources and reducing the negative impact on the environment. For Ukraine, which is currently actively implementing energy transition strategies, the integration of circular economy principles into green energy is an important step towards achieving national sustainable development goals and fulfilling international climate commitments, as well as a potential solution to the problems associated with the destruction of energy infrastructure due to missile attacks.

**The purpose of the article** is to study the potential for implementing circular business models in the green energy sector of Ukraine as a strategy for increasing resource efficiency, minimizing waste, reducing environmental impact, and post-war economic recovery. This article explores the prospects for implementing circular economy business models in the green energy sector of Ukraine, analyzes international experience, and assesses the possibilities of adapting these approaches in national conditions.

The following research methods are used in this article:

1. Analysis of literature and regulatory documents. The study begins with a review of scientific papers and official reports covering the circular economy and green energy. Ukrainian and international documents regulating the implementation of environmental standards in the energy sector, as well as the policies of the EU and other leading countries in this area are analyzed.

2. A comparison of circular economy business models that have been successfully implemented in different countries is conducted to identify their key features and potential adaptation for Ukraine. This allows us to identify the most effective strategies that promote the development of green energy using circular approaches.

3. SWOT analysis. The study uses a SWOT analysis to assess the strengths, weaknesses, opportunities, and threats associated with the implementation of circular business models in the green energy sector in Ukraine. This helps to identify what factors can contribute to the successful implementation of the models and what risks may arise on the way to sustainable development.

4. Case-study analysis. Specific cases of implementing circular business models in green energy in different countries that can be an example for Ukraine are considered. This approach allows us to explore the practical aspects of project implementation, identify best practices and potential barriers.

These methods allow for a comprehensive assessment of the opportunities and challenges of implementing circular economy business models in the green energy sector in Ukraine, contributing to the formation of sound conclusions and recommendations.

**Literature review.** The energy sector is an important aspect of the transition of Ukrainian enterprises to the circular economy.

The circular economy (CE) and green energy are the main focus of current research and policy initiatives aimed at achieving sustainable development. These concepts contribute to the efficient use of resources, waste reduction, and mitigation of negative environmental impact.

Research and reports confirm that integrating circular economy principles into the energy sector can help countries reduce their dependence on fossil fuels, cut greenhouse gas emissions, and create closed loops of materials and energy use.

Most researchers emphasize that the circular economy involves optimizing all processes based on the reuse of materials and recycling (Geissdoerfer et al., 2017). These principles are particularly relevant in the green energy sector, where there is already a significant amount of waste, for example, from solar panels and lithium-ion batteries. Studies show that the introduction of circular business models can reduce costs and increase economic benefits from green energy (Stahel, 2016).

Research papers highlight practices for extending the life cycle of energy products, including repairs, modernization, and renovation (Kalmykova et al., 2018). This is particularly important for solar and wind power plants, where continuous component renewal contributes to longer service life and reduces the need for new materials.

Research indicates that technological innovations, such as automated waste processing or the development of biodegradable materials, can significantly increase the efficiency of CE in green energy (Lieder & Rashid, 2016). These innovations not only promote reuse, but also reduce pollution and $CO_2$ emissions.

The EU is a leader in the implementation of the circular economy and green energy. In 2020, the New Circular Economy Action Plan was adopted, which defines the circular economy as a central element of the European Green Deal (European Commission, 2020). The document emphasizes the need to recycle materials, extend the life of products, and optimize energy resources to achieve carbon neutrality by 2050.

Reports by the International Renewable Energy Agency (IRENA) examine the potential of the circular economy to reduce the negative environmental impact of energy projects. The 2021 report “Renewable Energy and the Circular Economy” (IRENA, 2021) provides recommendations for waste recycling and reuse of renewable energy components, including solar panels and batteries.

In the United States, the federal government stimulates the development of green energy by funding innovations that support the transition to a circular economy. The Inflation Reduction Act of 2022 allocates significant funds to support renewable energy, including research and implementation of circular technologies in the energy sector (US Congress, 2022).

Let's look at the Ukrainian documentary base on green energy policy:

1. Energy Strategy of Ukraine until 2035. The Ukrainian strategy declares a commitment to sustainable development and an increase in the share of renewable energy sources. The document envisages optimization of resource use and gradual transition to renewable energy, but lacks specific mechanisms to support the circular economy (Cabinet of Ministers of Ukraine, 2017).

2. National Economic Strategy for the period up to 2030. The strategy supports the greening of the economy and the reduction of the carbon footprint. It includes CE concepts, such as waste reduction and resource efficiency, but does not yet contain detailed solutions for green energy (Cabinet of Ministers of Ukraine, 2021).

3. Ukrainian environmental laws and regulations. Legislative acts such as the Law on Waste offer regulation in the field of waste management, which can form the basis for the development of a circular economy in green energy. However, the regulations need to be supplemented to take into account the specifics of renewable energy in more detail (Verkhovna Rada of Ukraine, 1998).

An analysis of scientific papers and official documents shows that internationally, the circular economy is actively supported by government policies and regulations, especially in the EU. The EU and other developed countries are investing in technologies that promote the circular use of materials and create incentives for businesses that implement circular economy in the energy sector. In Ukraine, although the development of renewable energy is actively supported, the concept of the circular economy has not yet received adequate attention at the state level, and requires improvement of the regulatory framework and development of state incentives for business.

**The main research material.** The main business models of the circular economy aim to move from the traditional linear production model to a system where resources are maximized, recycled or returned to the cycle with minimized waste.

Table 1 shows the key business models of the circular economy and their possible application in the field of green energy.

The described business models of the circular economy provide Ukraine with an opportunity to significantly reduce the environmental burden,

Table 1

**Key business models of the circular economy and their possible application in the green energy sector**

| Circular economy business models | Description | Possible application in the green energy sector |
|---|---|---|
| Closed Loop | Maximizes the return of products and materials to the production cycle. | Recycling components of solar panels and wind turbines, utilizing agricultural waste for bioenergy. |
| Product-as-a-Service | Products are offered for rent or as a service, allowing firms to retain control over the product's life cycle. | Leasing solar panels and wind turbines, providing batteries as a service. |
| Recycling and Upcycling | Focuses on maximizing material use through recycling or improvement. | Recycling lithium-ion batteries, utilizing ash from biomass combustion as fertilizer. |
| Product Life Extension | Aims to extend the life cycle through repair and modernization. | Regular maintenance of renewable energy systems, battery modernization. |
| Resource Sharing | Involves sharing resources among multiple users or companies. | Shared ownership of solar or wind farms, micro-grid networks for local energy sharing. |

*Note: based on literature review (Kalmykova, Y., Sadagopan, M., & Rosado, L., 2018; Lieder, M., & Rashid, A., 2016)*

increase resource efficiency, and facilitate the transition to sustainable development in the energy sector.

According to the report “Ukraine's Transition to Renewable Energy by 2050,” Ukraine plans to switch to 91% renewable energy sources by 2050. In particular, the goal is to achieve the use of 25% of “green” energy in total energy consumption by 2035 (Dyachuk, Chepelev, Podolets, Tripolska, Ogarenko, Aliyeva, 2017).

According to the Eurostat statistical service (Eurostat, 2023), Ukraine is capable of generating up to 74% of its energy from renewable sources.

Figure 1 shows the distribution of renewable energy sources by efficiency for Ukraine.

The development of renewable energy is one of the priorities of Ukraine's state policy in order to become an equal subject of the EU's climate-neutral European Green Deal policy (European Council Council of the European Union, 2020). As a result of the feed-in tariff introduced by the state, solar and wind energy generation in Ukraine has been growing in recent years. From 2018 to 2022, the total capacity of solar panels increased more than 5 times, and as of the beginning of 2022, it amounts to 1205 MW (about 45 thousand units). It is worth noting that the leaders in the use of solar energy are Kyiv, Kyiv, Dnipro, and Ternopil regions.

In Ukraine, before wind power became widespread, there were 34 wind farms with a total installed capacity of 1,672.9 MW. Each of these plants had an average capacity of 3.5 MW. In terms of total installed capacity, wind power was second only to solar power (Ukrainian Wind Energy Association, 2023).

The project “Green Energy: Action Plan for 2023” (AW-Therm, 2022) envisages a 3-fold increase in the share of green energy in the country's gross energy consumption – from 9% in 2020 to 27% in 2030, in particular in the following sectors

– electricity – increasing the share of renewable energy from 14% to 25%;

– heating and cooling – increasing the share of green energy from 9% to 35%;

– transportation – increase the share of energy from renewable sources from 3% to 14%.

Table 2 shows the results of incentives and use of energy produced from renewable sources in Ukraine in 2018–2022 by key areas of application.

A significant portion of the country's renewable energy facilities are located in the southern and southeastern regions of Ukraine, where active hostilities have been taking place since

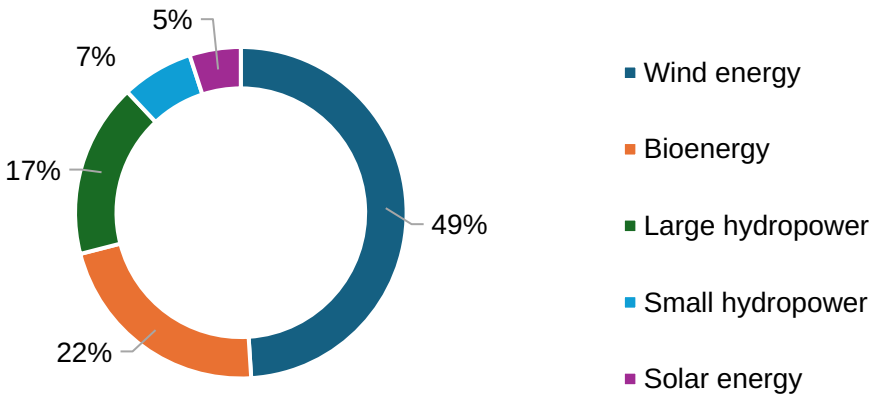


**Figure 1. Distribution of renewable energy sources according to efficiency for Ukraine according to Eurostat**

*Note: based on Eurostat data (Eurostat, 2023)*

Table 2

**Results of stimulating and using energy produced from renewable sources in Ukraine in 2018–2022**

| Scope of application | Years | | | | |
|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2021 | 2022 |
| Heating and cooling systems | 6,20% | 7,56% | 8% | 9,03% | 9,28% |
| Electric power industry | 7,91% | 8,64% | 8,9% | 10,89% | 13,92% |
| Transportation sector | 2,10% | 2,44% | 2,2% | 3,07% | 2,47% |
| Total share of renewable energy sources | 5,85% | 6,67% | 7% | 8,08% | 9,19% |

*Source: State Agency on Energy Efficiency and Energy Saving of Ukraine, 2023*

February 2022. According to experts, as of August 2022, 30-40% of renewable power plants in these regions were damaged or destroyed.

According to the Ukrainian Wind Energy Association (Ukrainian Wind Energy Association, 2023), more than 3/4 of wind power capacities have been shut down since February 2022, and 5 wind turbines in Kherson region have been destroyed.

Nevertheless, Ukrainian companies continue to develop ambitious high-tech renewable energy projects. Sirocco Energy has developed an innovative linear wind turbine that can be installed on rooftops and has a high capacity of up to 30 kW (Sirocco Energy Official Website, 2024).

As for the development of solar energy, KNESS PV is the only and largest automated production of solar panels in Ukraine (Official website of KNESS PV, 2024).

Here is a comparison of circular economy business models in the green energy sector, as well as various approaches that have been successfully implemented in different countries. Below is an overview of such models and their key features with an analysis of potential adaptation for Ukraine.

The European Union, in particular Germany is successfully implementing a model of recycling components for green energy. Thanks to EU support, special recycling technologies for solar panels and lithium-ion batteries have been developed that include the return of important materials such as silicon, silver, and lithium back into the production cycle. This reduces dependence on imported materials and minimizes waste (Vazquez, D., Valverde, J., & Pastor, M., 2022).

Ukraine should consider developing local green energy component recycling facilities. This will not only minimize dependence on imports, but also create new jobs and reduce waste from renewable energy sources.

The Netherlands is actively developing a business model in which energy equipment (solar panels, batteries) is offered for rent as a service rather than sold. Customers pay for energy consumption, while manufacturers retain

ownership of the equipment. This allows them to control the product life cycle, ensure its timely maintenance and replacement, which reduces waste.

This model has great potential for implementation in Ukraine, where many consumers find it difficult to make one-time large investments in renewable energy sources. Offering solar panels and batteries for rent can stimulate the spread of green energy among small businesses and households, reducing the burden on consumers' budgets.

Japan has successfully implemented programs to extend the life cycle of energy equipment. Maintenance, modernization, and repair reduce the need to manufacture new components. Japanese companies are also actively implementing a system of “reuse” – in particular, for batteries from electric vehicles, which after a certain service life are used to store energy at solar stations.

In Ukraine, it may be useful to incentivize companies that provide maintenance and modernization services for existing green energy installations. This will extend the service life of the equipment, reduce costs, and reduce waste. Such a model is promising for regions where renewable installations are already in operation but require regular maintenance and improvement.

In China, the model of sharing energy resources is popular, in particular through the creation of local mini-grids (micro- or nano-grids). These local networks allow several users to share energy from common installations, such as solar or wind farms, which reduces the cost of equipment and infrastructure.

This model can be applied in small communities or remote regions of Ukraine where building large energy grids is impractical. Sharing solar panels or wind turbines between several households or businesses can significantly reduce costs and ensure the availability of green energy in isolated communities.

Sweden is successfully implementing a circular waste management model where waste from green energy production, including biomass, is recycled to produce additional energy or materials. In addition, the country implements strict requirements for the recycling of electronic components such as batteries, which helps reduce waste and conserve resources.

Ukraine should implement more efficient waste management systems in the green energy sector. For example, biomass and waste from the agricultural sector can be used to produce bioenergy, reducing the need for fossil fuels. Developing national standards for the disposal of waste from energy equipment will also help to conserve resources and maintain environmental standards.

A comparison of these business models shows that successful circular economy practices in the green energy sector focus on maximizing resource utilization, reusing components, efficient waste management, and creating sharing models. In Ukraine, these approaches can be adapted to meet the available resources and needs of the local market:

– Investing in component recycling: creating an infrastructure for battery and solar panel recycling will help reduce waste and provide resources for new projects.

– Developing a rental model and green energy services: Companies can offer equipment rental services, which will increase the availability of renewable energy for small businesses and households.

– Support for sharing models and microgrids: local communities can use shared energy installations, reducing the need for large investments in energy infrastructure.

The successful adaptation of these business models can strengthen Ukraine's energy independence, reduce environmental impact, and increase the cost-effectiveness of green energy, which is an important step in the transition to sustainable development.

Based on the analyzed data, it is reasonable to conduct a SWOT analysis for the implementation of circular business models in the green energy sector of Ukraine.

The strengths include:

– Reducing dependence on imported resources: Circular business models allow for the recycling and reuse of components (solar panels, batteries), which reduces dependence on imported materials and technologies.

– Improving resource efficiency: Circular models maximize the use of materials and equipment, which reduces costs and minimizes waste in green energy production.

Opportunities for economic growth: The circular economy creates new markets for the recycling, maintenance, and renewal of energy equipment, which contributes to job creation and stimulates the development of small and medium-sized businesses.

– Positive image of Ukraine at the international level: The introduction of circular business models and a focus on the green economy could improve Ukraine's image as

an environmentally responsible country, which would make it more attractive to foreign investors.

Among the weaknesses are the following:

– Insufficient infrastructure for recycling: Ukraine lacks modern facilities for recycling green energy components such as batteries, solar panels, and e-waste.

– Low public awareness and support: Circular business models require a high level of environmental awareness among citizens and businesses, which is still relatively low in Ukraine.

– Lack of qualified personnel: The implementation of circular business models in the green energy sector requires specialists with new skills, in particular in recycling, product design, and product life cycle management.

– Limited funding: The small amount of investment in the circular economy and the lack of special funds make it difficult to introduce new models in green energy on a large scale.

– A large number of destroyed infrastructure facilities as a result of missile attacks. For example, more than 3/4 of wind power capacities have been shut down since February 2022.

Opportunities include:

– Developing the legal framework: The adoption of new environmental standards, laws on waste recycling and support for renewable energy creates favorable conditions for the implementation of circular models in the green energy sector.

– Access to international financial assistance and grants: Ukraine can attract funding from the EU, the World Bank, and other international organizations that actively support circular economy projects and environmental initiatives.

– Technological innovation and digitalization: New technologies allow for more efficient tracking and control of the product life cycle, including the use of blockchain, the Internet of Things (IoT), and artificial intelligence, which can significantly increase the efficiency of circular models.

– Growing demand for green energy: Increasing demand for renewable energy in Ukraine and globally creates opportunities for implementing models that allow for more efficient use of resources and reduce waste.

The main threats are:

– High initial investment: Implementation of circular business models requires significant investments in new equipment and infrastructure, which can be difficult to implement in times of economic instability.

– Competition with traditional energy companies: Renewable energy and circular models may face competition from traditional energy companies that currently dominate the market.

– Unpredictable regulatory changes: The lack of stability and predictability in Ukrainian legislation may negatively affect the investment climate and the development of the green economy.

– Economic and social barriers: Distrust of new models on the part of business and society, as well as limited investment opportunities, may slow down the transition to a circular economy.

– Possible missile attacks and destruction of energy infrastructure. Due to active hostilities on the territory of Ukraine, infrastructure facilities are potential targets for the enemy.

Table 3 summarizes the SWOT analysis for the implementation of circular business models in the green energy sector of Ukraine.

The SWOT analysis shows that the implementation of circular business models in Ukraine's green energy sector has significant potential, but requires strategic support at the national level, investment in new infrastructure, and raising public awareness. Successful adaptation depends on the development of the legal framework, access to international financing, and support for innovative technologies. Addressing these challenges can provide Ukraine with a competitive advantage in the green energy market and contribute to the country's sustainable development.

**Conclusion.** The introduction of circular economy business models in the green energy sector of Ukraine opens up significant prospects for the country's sustainable development, helps reduce dependence on traditional resources, and ensures effective waste management. The analysis of the main business models showed that each of them can strengthen Ukraine's energy independence and increase the resilience of the economy through a closed resource cycle, extending the life cycle of products, using renewable energy, and recycling.

In particular, the closed-loop model, which involves the recycling and reuse of energy system components, can significantly reduce the environmental burden. The Product as a Service model allows businesses to maintain control over the life cycle of their products and ensure their proper disposal or reuse. Sharing resources and developing microgrid creates an opportunity for local supply of renewable energy to consumers, which increases energy stability

Table 3

**SWOT analysis for the implementation of circular business modelsin the green energy sector of Ukraine**

| Strengths | Weaknesses |
|---|---|
| – Reducing dependence on imported resources<br>– Improving resource efficiency<br>– Opportunities for economic growth<br>– Positive image of Ukraine at the international level | – Insufficient infrastructure for recycling<br>– Low public awareness and support<br>– Lack of qualified personnel<br>– Limited funding<br>– A large number of destroyed infrastructure facilities |
| **Opportunities** | **Threats** |
| – Developing the legal framework<br>– Access to international financial assistance and grants<br>– Technological innovation and digitalization<br>– Growing demand for green energy | – High initial investment:<br>– Competition with traditional energy companies<br>– Unpredictable regulatory changes<br>– Economic and social barriers<br>– Possible missile attacks and destruction of energy infrastructure |

*Note: developed by the author*

and affordability for communities, as well as the prospect for post-war economic recovery.

When analyzing potential opportunities and challenges for Ukraine, it is important to note the need to improve the regulatory framework, stimulate investment, and raise awareness of the benefits of the circular economy among businesses and society. The experience of international practices shows that the adaptation of circular approaches to the green energy sector can contribute to the achievement of environmental goals and at the same time have a positive impact on economic performance, which is extremely important in the context of the transition to a low-carbon economy.

Thus, the introduction of circular business models in the green energy sector is a strategically important step for Ukraine, which requires cross-sectoral cooperation, government support, and innovative approaches to achieve maximum efficiency and sustainable development at the national level.

Opportunities for further research on the implementation of circular business models in the green energy sector of Ukraine are quite broad and may include several key areas:

1. Sectoral research. Conducting an in-depth study of circular models in specific green energy sectors, such as solar, wind, and bioenergy. This may include studying best practices, technical innovations and economic benefits of implementing circular business models in each sector.

2. Technological innovations. Research on new technologies that can facilitate the implementation of circular models, such as methods of recycling, recovery and reuse of energy equipment, as well as the impact of digitalization (IoT, artificial intelligence) on process optimization.

3. Economic analysis. Development and testing of financial models that can be used to assess the economic feasibility of investments in circular business models, including financing and risk management options.

5. Social aspects. Studying social aspects, in particular, the level of public awareness and attitudes towards circular business models and green technologies, as well as the impact of educational programs on changing environmental habits.

These areas can contribute to a deeper understanding and implementation of circular business models in Ukraine's green energy sector, which in turn will contribute to the country's sustainable development and increase its competitiveness in the international market.

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