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Eco-industrial parks as a model of future development in Ukraine

Abstract: The article examines eco-industrial parks (EIPs) as a model for Ukraine's future development, with a focus on the Lviv region. Using a multidisciplinary approach (literature review, EU- and Asia-based case studies, and quantitative/qualitative analysis of economic and environmental indicators), the study finds that EIPs can reduce CO₂ emissions, improve resource efficiency, and support regional diversification. Based on these findings, the paper presents a set of policy recommendations and implementation actions for green reconstruction, alongside the transition to a circular-economy model.

Keywords: eco-industrial parks; industrial symbiosis; circular economy; sustainable development; Ukraine; Lviv region; public policy.

Introduction

The article is devoted to the study of the creation of eco-industrial parks in the western region of Ukraine as a model of future development. The purpose of the scientific research is to develop proposals for the creation of eco-industrial parks in the Lviv region in order to improve the ecological, economic and social unstable situation in the country, to develop recommendations and principles for the selection of industrial enterprises in the territories of industrial parks, taking into account industrial symbiosis, which is

due to the active movement of industrial companies of Ukraine from the war zone to the western region of Ukraine. The research methodology is based on the application of a multidisciplinary approach, which combined a review of existing literature, case studies, and qualitative and quantitative methods of data analysis. The authors analyzed the existing research on eco-industrial parks (EIP), their operational models and their impact on sustainable development. The case studies relate to the analysis of selected eco-industrial parks from the European Union and Asia to understand best practices and the benefits gained from their implementation [1]. Quantitative methods are based on statistical analysis of economic and environmental data related to the efficiency of eco-industrial parks around the world. Qualitative methods include analysis and assessment of feasibility and potential problems of implementing such parks in Ukraine. The authors demonstrate that EIPs are effective in promoting sustainable development by integrating clean production, recycling and resource management. As a result of the conducted research, it was established that eco-industrial parks can significantly reduce CO₂ emissions and increase the efficiency of resource use. In the context of Ukraine, the article proves that Ukraine has significant potential for implementing eco-industrial parks, given its rich natural resources and urgent need for industrial modernization. The authors emphasize that the implementation of EIP in Ukraine can lead to the diversification of the economy, the creation of jobs (especially in the sectors of "green" technologies) and an increase in the competitiveness of exports. The main challenges include the lack of an adequate regulatory and legal framework, the need for significant investment, as well as the need for government and international support. The conclusions draw attention to the fact that eco-industrial parks are a promising model for the future development of Ukraine. The most important steps include creating a regulatory framework, securing investment and facilitating cooperation between the government and international partners. The transition to the EIP model can not only help Ukraine achieve the goals of sustainable development, but also increase its economic competitiveness on the world stage. The implementation of the circular economy system in Ukraine should ensure the following results: optimize business entities, find rational methods of using resources; to ensure a closed cycle of production of products in order to efficiently use available capacities; maintain the pace of economic growth; to develop other sectors of the economy in terms of replenishment of natural reserves, growth of the GDP volume, growth of the labor market.

1. Materials and Methods

The research methodology is based on a comprehensive analysis of scientific sources, including domestic and foreign studies, legislative acts, and standards related to the creation and development of eco-industrial parks both in Ukraine and abroad. The study employed a multidisciplinary approach, combining a literature review, case studies, and both quantitative and qualitative data analysis methods. Existing research on eco-industrial parks (EIPs), their operational models, and their impact on sustainable development were analyzed.

The case studies involved the analysis of selected eco-industrial parks in the European Union and Asia to explore best practices in their operation. Quantitative methods were based on statistical analysis of economic and environmental performance indicators of EIPs worldwide [2]. Qualitative methods focused on assessing the feasibility and identifying key challenges for implementing such parks in Ukraine.

The research found that EIPs are an effective tool for promoting sustainable development, as they integrate environmentally friendly production, recycling, and efficient resource management. It was determined that these parks can significantly reduce CO₂ emissions and improve resource efficiency. In the context of Ukraine, it was highlighted that the country has significant potential for implementing EIPs, given its natural resources and the need for industrial modernization.

2. Review of literary sources

The topic of creation and development of eco-industrial parks remains relevant and significant even in 2023. The topic of creation and development of eco-industrial parks is very relevant in our time, as it is related to the solution of a number of topical problems that concern both ecology and economy. First, the creation of eco-industrial parks will reduce the negative impact of industrial enterprises on the environment. Thanks to the use of environmentally friendly technologies and materials, such parks reduce emissions of harmful substances and water and air pollution. Secondly, eco-industrial parks contribute to the development of a sustainable economy, since enterprises operating in such parks have more opportunities for economic resources and optimization of production. This allows enterprises to reduce production costs and increase competitiveness in the market. Thirdly, the creation of eco-industrial parks is an element of the implementation of the strategy of sustainable development, which ensures the balance between economic development, social needs and environmental protection. Such

parks cannot achieve this balance by promoting job creation and ensuring the balanced development of various sectors of the economy. So, it can be stated that the topic of creation and development of eco-industrial parks is very relevant in modern conditions in terms of a number of important problems that need to be solved to ensure safety. Eco-industrial parks (EIPs) are special industrial zones that combine environmentally sustainable industrial activity with preservation of the natural environment. Their development is aimed at ensuring efficient use of resources, reducing emissions of pollutants and creating favorable conditions for the development of entrepreneurship. Eco-industrial parks are focused on green economy and sustainable production. They combine environmentally friendly technologies with efficient use of resources such as energy, water and raw materials. These parks promote the development of energy-efficient innovations, the use of renewable energy sources, recycling and waste disposal. The issue of eco-industrial parks has been explored in the works of both Ukrainian and international researchers [3-13]. One of the key characteristics of the current situation in Ukraine is the low level of environmental greening in the investment sector at both national and regional levels [14]. The social and environmental impacts of urbanization call for integrated management approaches to urban development and resource metabolism to ensure long-term sustainability and economic growth [15]. Some researchers [16] highlight that management effectiveness is closely tied to investment in innovative and eco-friendly technologies. Meanwhile, other scholars [10] focus on the competitive positioning of enterprises within regional sustainable development frameworks, emphasizing the social, economic, and environmental dimensions of sustainability. Regarding Ukraine's transition from a linear to a circular economy, the circular economy is defined as a closed-loop system centered on recycling and the use of secondary raw materials, minimizing the consumption of primary resources, restoring materials, and maintaining environmental cleanliness [17]. Research on eco-industrial parks is a highly relevant topic among Polish scholars as well. Małgorzata Dąbrowska examines the development of eco-industrial parks and their impact on environmental sustainability and regional economies [18]. Zbigniew Karaczun specializes in environmental policy and sustainable development strategies, particularly in the field of industrial zones and parks [19]. Marek Graczyk studies the environmental efficiency of industrial parks in Poland and their integration with regional environmental strategies [20]. Ewa Chodakowska explores the economic and environmental aspects of eco-industrial parks and their role in the green economy [21]. A review of the literature shows [22,23] that the only way out of the full-scale global environmental crisis is the transition from a linear economy to a circular economy, starting at the micro level. (enterprises, companies, industrial parks) to the macro level

(country, EU and global level). Special attention was paid to the implementation programs of innovative technologies, environmental management tools at each enterprise separately, as well as the development of environmentally oriented investment projects at the regional and state levels [24,25,26,27]: risk management strategies in the process of creating industrial parks in Ukraine are devoted to scientific works [28].

3. Results and discussions

The main principles that are taken into account in eco-industrial parks include: -Environmental sustainability: EIPs set high standards for environmental safety, reducing pollutant emissions and energy efficiency. The strategy of environmental security of Ukraine includes the following main tasks, including: effective use of natural resources; increasing the level of disposal of production and consumption waste; development of a system of effective management of production and consumption waste; creation of a recycling system in industry, in particular the reuse of such waste; stimulating the implementation of the best available innovative technologies; support and regulation of programs at the state level; investment attraction; development of research and cooperation and a number of other tasks [29]. The ultimate goal of green policy, based on the "principle of the three Ps", is a model of society where all resources (minerals, energy, water) will be used so efficiently that the very concept of "waste" will cease to exist. The economy begins to work within the framework of the Zerowaste concept, i.e. "zero waste". In this context, it is eco-industrial parks that are a tool for stimulating environmentally friendly industrial production, attracting investments, increasing employment of the population, equalizing the level of economic development of individual territories, regions and the country as a whole. Great hopes are placed on the functioning of industrial parks in Ukraine, as they are considered the most effective means of economic growth. To improve the efficiency of the functioning of eco-industrial parks in Ukraine, it is necessary to introduce a package of fiscal benefits with parallel amendments to the Tax Code of Ukraine for participants of industrial parks, taking into account that the poorer the territory, the more state aid should be provided to participants of industrial parks [30]. Considering the development of EIP in Ukraine, it is first of all worth focusing attention on the existing industrial parks. It should be noted that in 2019, the EIP implementation program in Ukraine began. As part of the Global Eco-Industrial Parks Program [31], existing industrial parks that showed the highest potential for transition into eco-industrial parks were selected. Parks were selected on the basis of economic, ecological and social indicators of the participating enterprises.

According to the results of the conformity assessment, three parks were chosen for cooperation: "Bilotserkiv Cargo Aviation Complex", or "BVAK" (Bila Tserkva) - received the highest rating and showed the highest potential for transformation into an EIP. "Agromash" (Zaporizhia) and "Patriot" (Sumy) are small industrial parks that have been selected and will receive development assistance [31]. The armed conflict, with the start of hostilities on February 24, 2022, has led to a regressive economic state, with falling production and rising inflation. From April 2022, the Government of Ukraine created the National Council for the Recovery of Ukraine from the Consequences of the War and began planning for the post-conflict development of the country with a focus on economic reconstruction. In this context, the issue of development and implementation of EIP remains a priority. Since April 2022, as part of the National Program for Business Support and Development of EIP, the Ministry of Economy promotes and helps the relocation of EIP and individual enterprises from areas of intense hostilities to safer regions of Western Ukraine. By the method of identification and mapping, with the development of an interactive map of the composition and specialization of enterprises located in the respective territories, the gradual transfer of enterprises and EIP is carried out. This technique makes it possible to maximally develop industrial symbiosis and implement the most convenient placement of transferred enterprises for the development of the Ministry of Economy of Ukraine. One of the goals of our work was to study the stages of creation of industrial parks in the Lviv region for possible further scientific and research cooperation. The strategic development planning of the Lviv region for the period 2021-2027 provides for the development of industrial infrastructure, support for entrepreneurship, the creation of clusters and industrial parks. Thus, there are ten industrial parks in the Lviv region [31], which are at the stage of design, planning, construction and implementation: 1. Lviv Industrial Park "Ryasne-2". 2. Yavorivsky industrial park 3. Kamianka-Buzky industrial park 4. Novorozdilsky industrial park 5. Industrial Park "Sigma Park Yarychiv". 6. Zahid Resurs Industrial Park. 7. Business Prime Industrial Park. 8. Industrial Park "Sparrow Park Lviv". 9. Industrial Park "Mostysky Dry Port". 10. Industrial Park "Eco-smart industrial park "HALIT". We consider that special attention should be focused on the creation of the industrial park "Eco-smart industrial park "HALIT" in the city of Drohobych, Lviv region, included in the register of industrial (industrial) parks in accordance with the Decree of the Cabinet of Ministers of Ukraine dated November 11, 2022. The initiator of the creation of this industrial park is Drohobyt'sk City Council. The developer and managing company of the Eco-smart industrial park "HALIT" is YETI PRO LLC. The management company provides Facility Management and carries out operational management of the industrial park. The eco-industrial park is planned to be located

on a plot of communal property measuring 19 hectares within the industrial zone of the city of Drohobych, Lviv region. The advantage of the location is: the presence of all necessary engineering networks, a railway track and a convenient transport interchange. The construction of the following facilities is planned on the territory of the land plot: two generators with a nominal capacity of 1 MW each, facilities that will provide "smart lighting" of the park territory, monocrystalline solar panels with a nominal capacity of 19,000 kW and heat pumps with a nominal capacity of 5,000 kW. Design and preparatory work is currently underway. The functional purpose of the industrial park "Eco-smart industrial park "HALIT" is: unification of enterprises of light industry, trade, IT technologies, furniture industry, metalworking, mechanical engineering, chemical industry and other industries. Financing will be provided by: the initiator of the creation, the management company, participants of the industrial park and private investors. It is also planned to attract credit funds, grants, business partners and new investments, etc. Table 1 shows strategic directions for managing the most common risks in industrial parks.

Table 1. Risk management strategies in industrial parks

Strategy	Content of the strategy
Risk management in the field of energy supply	Carrying out a thorough analysis of the general energy needs of enterprises, available energy resources and the capabilities of the local network. The design and provision of alternative energy sources, as well as emergency power supply systems, will contribute to reliable and uninterrupted energy supply of the park.
Risk management in the personnel field	Organizing and offering employee incentives such as free transportation, professional development programs, etc.
Risk management in the field of land relations	Developers of industrial parks should carefully assess all risks (legal status of land, social problems, high prices for it, etc.) in the field of land relations before starting construction.
Management of environmental risks	The implementation of a quality strategy and an environmental management system is extremely important (for example, the use of real-time monitoring systems in industrial parks allows timely data collection on production safety and better prevention of threats).

Source: formed on the basis of [32].

Therefore, the industrial development of the infrastructure of the Lviv region is developing and improving. Innovative technologies are being introduced, in accordance with the requirements of environmental protection international standards, and programs are being implemented to attract enterprises for cooperation based on the principles of the closed cycle economy.

The implementation of eco-industrial parks could promote economic diversification, create new jobs (particularly in the "green" technology sectors), and enhance export competitiveness. The main challenges include developing an appropriate regulatory framework, attracting significant investment, and ensuring government and international support.

In our view, eco-industrial parks could become a promising model for Ukraine's future development. Key steps include establishing a legal framework, securing investment, and fostering cooperation between government agencies and international partners. Transitioning to this model will not only help Ukraine achieve its sustainable development goals but also increase its global competitiveness.

Conclusions

Eco-industrial parks (EIPs) are areas with certain infrastructure, designed for industrial enterprises that strive for environmental sustainability and waste reduction. These parks traditionally unite other enterprises specializing in the production of goods and services using environmentally friendly technologies.

EIPs are aimed at reducing the impact of industrial enterprises on the environment by reducing the amount of waste, using alternative energy, energy efficiency and other means. Such parks already have modern infrastructure that allows enterprises to provide the necessary resources, such as energy, water, waste and others, as well as to ensure an appropriate level of safety for employees.

The eco-industrial park is a tool for achieving sustainable industrial development, contributing to the balanced development of the economy and the preservation of natural resources. Therefore, it is the creation of eco-industrial parks and the implementation of eco-industrial development of Ukraine that will help the country move from a linear economy model to a closed-cycle economy model based on environmental protection principles.

Eco-industrial parks offer a promising model for Ukraine's future development. Critical steps include establishing a regulatory framework, securing investment, and fostering collaboration between government and international partners. Transitioning to an EIP model could not only help Ukraine meet its sustainable development goals but also enhance its economic competitiveness on the global stage.

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Parki ekoprzemysłowe jako model przyszłego rozwoju Ukrainy

Synopsis: Artykuł analizuje możliwość wdrożenia parków ekoprzemysłowych (EIP) jako modelu przyszłego rozwoju Ukrainy, ze szczególnym uwzględnieniem obwodu lwowskiego. Zastosowano podejście multidyscyplinarne (przegląd literatury, studia przypadków z UE i Azji oraz analizę ilościową i jakościową wskaźników gospodarczych i środowiskowych), które wskazuje, że EIP mogą ograniczać emisje CO₂, zwiększać efektywność wykorzystania zasobów i wspierać dywersyfikację regionalnej gospodarki. Na tej podstawie przedstawiono zestaw rekomendacji politycznych i działań wdrożeniowych na rzecz zielonej odbudowy oraz przejścia do modelu gospodarki o obiegu zamkniętym.

Słowa kluczowe: parki ekoprzemysłowe; symbioza przemysłowa; gospodarka o obiegu zamkniętym; zrównoważony rozwój; Ukraina; obwód lwowski; polityka publiczna.