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INNOVATIVE APPROACHES TO SUSTAINABLE DEVELOPMENT: ECOLOGICAL STARTUPS AND GREEN TECHNOLOGIES

ІННОВАЦІЙНІ ПІДХОДИ ДО СТАЛОГО РОЗВИТКУ: ЕКОЛОГІЧНІ СТАРТАПИ ТА ЗЕЛЕНІ ТЕХНОЛОГІЇ

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In the modern world, the issue of sustainable development is becoming increasingly relevant, as it is driven not only by global environmental challenges but also by new economic realities that focus on the transition from a traditional economy to a sustainable one. Such an economy involves resource reuse, waste minimization, and greening of production processes. As a result of the increasing relevance of these needs over the past decade, the development of economic systems today is focused on ecological entrepreneurial initiatives (startups) and the green technologies developed within them. These technologies are capable of ensuring sustainability both for society and for business. Thus, the article aims to study innovative approaches to sustainable development implemented through ecological startups and green technologies. These technologies can reduce carbon emissions, promote renewable energy use, enhance energy efficiency, minimize risks, and adapt economic processes to new climate conditions.

Keywords: renewable energy sources, scaling, social responsibility, biodegradable components and materials, sustainable development.

У сучасному світі питання сталого розвитку стає все більш актуальним, оскільки воно зумовлене не лише глобальними екологічними викликами, а й новими реаліями господарювання, які орієнтуються на перехід від традиційної економіки до сталої. Така економіка потребує повторного використання ресурсів, мінімізації відходів та екологізації. Внаслідок актуалізації цих потреб протягом останнього десятиріччя розвиток економічних систем орієнтований на екологічні підприємницькі ініціативи (стартапи) та зелені технології, розроблені в їх межах (враховуючи що вони здатні забезпечити досягнення сталості як для суспільства, так і для бізнесу). Таким чином, метою статті є дослідження інноваційних підходів до сталого розвитку, які реалізуються через екологічні стартапи та використовувані ними технології, здатні знижувати вуглецеві викиди, забезпечувати використання відновлюваних джерел енергії, підвищувати

енергоефективність, а також мінімізувати ризики та адаптувати економічні процеси до нових кліматичних умов. За результатами дослідження доведено, що екологічні стартапи через застосовувані технології сприяють трансформації економічних моделей, забезпечуючи перехід від лінійної економіки («бери, виробляй, викидай») до циркулярної, яка передбачає мінімізацію відходів та максимальне використання вторинних ресурсів. Ці стартапи також працюють у сфері відновлювальної енергетики, сприяючи зниженню споживання викопного палива. Крім того, зелений бізнес пропонує нові підходи до комерційної діяльності, зокрема моделі «продукт як послуга» та «зелені фінанси». За результатами дослідження доведено, що екологічні стартапи через застосовувані технології сприяють екологічно збалансованому розвитку, внаслідок сприяння зменшенню рівня забруднення, розвитку екологічного транспорту. Крім того, ці стартапи сприяють популяризації екологічно чистих продуктів, біорозкладної упаковки, розумного споживання ресурсів та сталого підходу до ведення бізнесу, формуючи нову культуру споживання. За змістом отриманих результатів зазначимо, що перспективними напрямами подальших досліджень є оцінка ефективності екологічних стартапів, що застосовуються ними у різних галузях економіки, аналіз механізмів їх фінансування та масштабування, а також вивчення впливу зелених технологій на соціально-економічний розвиток і формування політики сталого розвитку.

Ключові слова: відновлювані джерела енергії, масштабування, соціальна відповідальність, біорозкладні компоненти та матеріали, сталий розвиток.

Problem statement. In the modern world, the issue of sustainable development is becoming increasingly relevant, as it is driven not only by global environmental challenges but also by new economic realities that focus on the transition from a traditional economy to a sustainable one. Such an economy involves the reuse of resources, waste minimization, and environmentalization. As a result of the rising demand for these needs over the last decade, the transition to sustainable development has become a primary priority for economic systems, considering the following:

1. Population growth and industrialization drive an increasing demand for natural resources while reserves are limited. It is important to emphasize that the depletion of minerals, the shortage of fresh water, and soil degradation pose threats to both economic stability and food security.

2. The increase in industrial production and consumption leads to significant pollution of air, water, and soil. It is important to emphasize that the consequences of this process result in a deterioration of public health, a decline in biodiversity, and environmental degradation.

3. Global warming is causing more frequent natural disasters, extreme weather events, and changes in the water balance. This negatively impacts agriculture, infrastructure, and the energy sector.

Thus, the development of economic systems today is focused on ecological entrepreneurial initiatives (startups) and green technologies developed within them.

These technologies can reduce carbon emissions, ensure the use of renewable energy sources, improve energy efficiency, minimize risks, and adapt economic processes to new climatic conditions.

Analysis of research and publications. The issues of applying innovative approaches to sustainable development have been explored in the works of scholars such as Dem'ianiuk A. V. [2], Maslihan O., Kushch L., Dudnyk S., and Goblyk-Markovych N. [3]. This research primarily focuses on the general aspects and components of sustainable development, analyzing its economic, social, and environmental dimensions. At the same time, insufficient attention has been given to the research on the role of ecological startups and green technologies as important tools for stimulating and adjusting sustainable development. Innovative eco-startups contribute to solving environmental problems by developing cutting-edge technologies for efficient resource use, reducing pollution, and implementing a circular economy. Thus, further research in sustainable development requires a deeper analysis of the impact of ecological startups and green technologies, as they play a key role in the transformation of economic models and contribute to the transition to environmentally balanced development.

Formulation of the article's objectives. The article aims to study innovative approaches to sustainable development implemented through ecological startups and green technologies.

Presentation of the main research material. Within the framework of the research, the authors highlight that it's the ecological startups and the green technologies they use are modern triggers accelerating the achievement of Ukraine's sustainable development goals or guiding the local transition to an environmentally responsible economy [5].

So, Zaverny A. S. and Chukaieva I. D. [1] note that, categorically, ecological startups should be considered entrepreneurial entities and essentially, as innovative businesses aimed at implementing initiatives to create solutions for addressing environmental problems. Considering the outlined provisions, it should be noted that such businesses focus on the development of technologies for the production of new materials, alternative energy sources, efficient waste recycling methods, and reducing the carbon footprint of production.

The growing importance of such startups in Ukraine is confirmed by the fact that their number has been steadily increasing since 2020 (Table 1). Despite the full-scale invasion by the russian federation, as of 2024, over 100 such startups are successfully operating, actively working on solving environmental issues and expanding the range of available green technologies in Ukraine.

The content of modern practices in the development of domestic environmental startups allows us to state that they play a core role in changing traditional economic models by fostering environmentally balanced development (which is aimed at implementing a range of innovative features that significantly accelerate sustainable development, as is also evident from the data in Figure 1).

This is due to the fact that, in the context of increasing environmental pressure on the surrounding environment, such entities not only offer effective solutions for its reduction but also change the very principles of economic management and production [3–4; 6].

It should be noted that a core feature of the innovativeness of environmental startups is their focus on the development and implementation of green technologies that contribute to solving global environmental problems [4]. These startups are creating innovative solutions to minimize the negative impact of human activity on the environment. In particular, they may develop and improve filters and purification systems to reduce industrial emissions, propose new methods for recycling plastic waste, which lowers pollution levels, or create biodegradable components and materials to replace traditional synthetic counterparts.

Therefore, we agree with Rudych O. O., Herasymenko I. O., and Tkachenko K. V. that such initiatives contribute to the conservation of natural resources, reduction of greenhouse gas emissions, and the implementation of circular economy principles, as outlined in the specifics shown in Figure 2.

With this focus, innovative eco-startups play a key role in shaping a sustainable future, as their technologies reduce harmful environmental impacts and create economically viable, environmentally friendly alternatives to traditional production processes.

It should be noted that in Ukraine, among the examples of environmental startups aimed at solving general environmental problems, the following can be highlighted [4]:

1. "EcoStartup" focuses on creating innovative solutions for the recycling of household waste and reducing environmental pollution. Specifically, this startup has already developed and commercialized over 20 technologies for effective plastic waste recycling and producing new materials used in construction or manufacturing products, including plastic composites for creating environmentally friendly panels, façade materials, and soundproofing boards; paving stones, curbs, and sidewalk tiles made from recycled plastic, which are resistant to wear and weather conditions; thermal insulation blocks combining lightness and energy efficiency; various household items made from compressed plastic waste.

2. "BioGreen," which specializes in bioplastic packaging production, that decomposes in the natural environment. It significantly reduces

Table 1

The dynamics of the increase in the number of environmental startups in the Ukraine economy, 2019–2020

Indicator	The number of entities in the economy of Ukraine at the beginning of the reporting period, units						The rate of change of the indicator, %				
	2019	2020	2021	2022	2023	2024	2020/ 2019	2021/ 2020	2022/ 2021	2023/ 2022	2024/ 2023
Environmental startups, units	50	50	64	73	86	104	100	128	114	118	121

Source: compiled based on EY data [4]

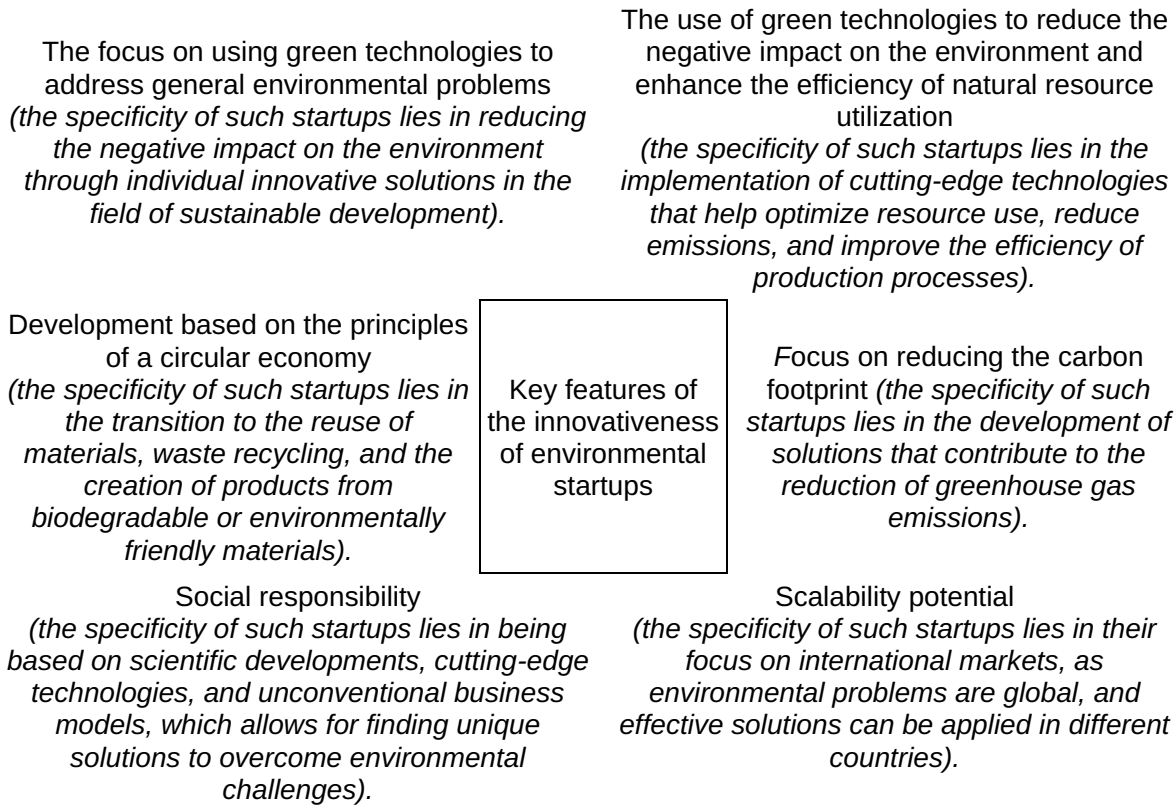

Figure 1. List of core features of the innovativeness of environmental startups

Note

* For example, through the development of renewable energy or the implementation of energy-efficient technologies.

Source: compiled based on [2; 4; 6]

plastic pollution and lowers the environmental impact, as plastic remains one of the largest sources of pollution.

These examples show that currently, startups are actively working on solving environmental problems by creating new, environmentally friendly technologies that help reduce the negative impact on nature.

A core feature of the innovativeness of environmental startups is the use of green technologies aimed at reducing the negative impact on the environment and improving the efficiency of natural resource use, including: renewable energy sources; waste recycling technologies; green transportation; environmentally friendly production methods (Figure 3).

In particular, in Ukraine, among the examples of using environmental technologies to reduce the negative impact on the environment, startups include [4]:

1. "SolarGaps," which develops and manufactures solar blinds that combine the functionality of regular blinds with the ability to collect solar energy. These blinds are equipped with solar panels, allowing them to reduce the energy consumption of buildings and generate electricity used for internal needs or sold to the grid. This technology helps reduce dependence on traditional energy sources and lowers the carbon footprint.

2. "Ecodetergent" specializes in eco-friendly production using biodegradable components that do not pollute water or harm the environment. The technology used to manufacture these products reduces the impact on ecosystems and improves natural resource use.

The startups outlined by us demonstrate that innovative environmental technologies in Ukraine help reduce the environmental burden, increase resource efficiency, and contribute to sustainable development.

Among the features of the innovativeness of environmental startups, an important aspect is the development based on the principles of a circular economy, specifically the focus on green technologies that ensure maximum resource conservation, waste reduction, and

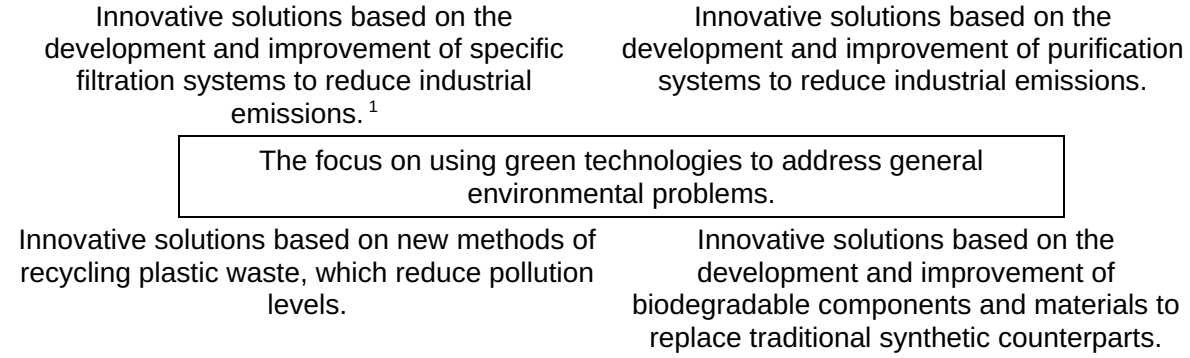

Figure 2. Components of using green technologies to address global environmental problems

Note

1. Filtration based on nanotechnology, filtration using graphene-based materials, biofiltration and bioremediation, filters using activated carbon and adsorbents, filtration systems using plasma technologies.

Source: compiled based on [3-4; 6]

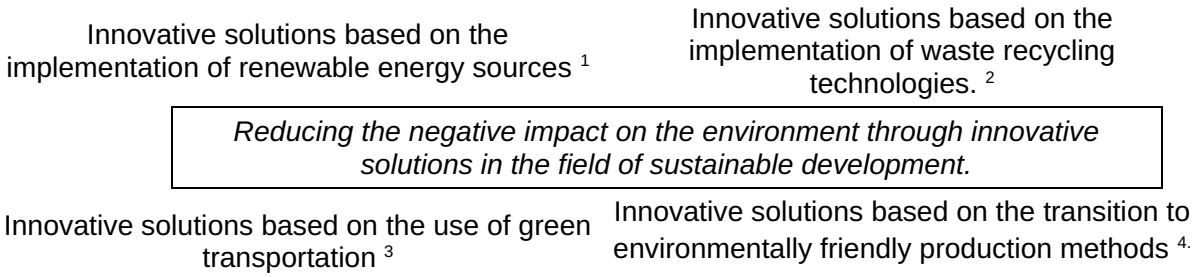

Figure 3. Components of using green technologies to reduce the negative impact on the environment and improve the efficiency of natural resource use

Note

1. Integration of solar panels with building materials, energy from biomass and waste, geothermal energy systems, energy storage technologies, next-generation wind turbines, smart grids, etc.

2. Includes methods and processes aimed at the efficient use of waste as resources for producing new materials, energy, or goods, including plastic waste recycling, energy recovery from waste, electronic waste recycling, composting of organic waste, sorting and purification technologies, etc.

3. Electric vehicles, infrastructure for electric vehicle charging, hybrid vehicles, hydrogen vehicles, biofuel-powered transport, etc.

4. Green materials and technologies, green chemical processes, and the development of electric and hydrogen mobility.

Source: compiled based on [4–6]

material reuse. Among such technologies are mechanical and chemical plastic recycling, organic waste recycling, upcycling, transitioning to biodegradable materials and bioplastics, using bacteria for cleaning water and soil from pollutants, heat recovery technologies, etc. (Figure 4). So, in Ukraine, among the examples of startups that operate based on the principles of a circular economy [4]:

1. "Ukroplast," which focuses on recycling plastic waste to create new products, significantly reducing the need for new plastic materials and minimizing the environmental impact of plastic waste. The project actively implements innovative technologies for plastic recycling and its reuse in various manufacturing processes, such as the production of building materials, furniture, packaging, and more.

2. "Green City," which focuses on creating environmentally friendly materials from secondary resources, including the use of organic waste for producing biodegradable

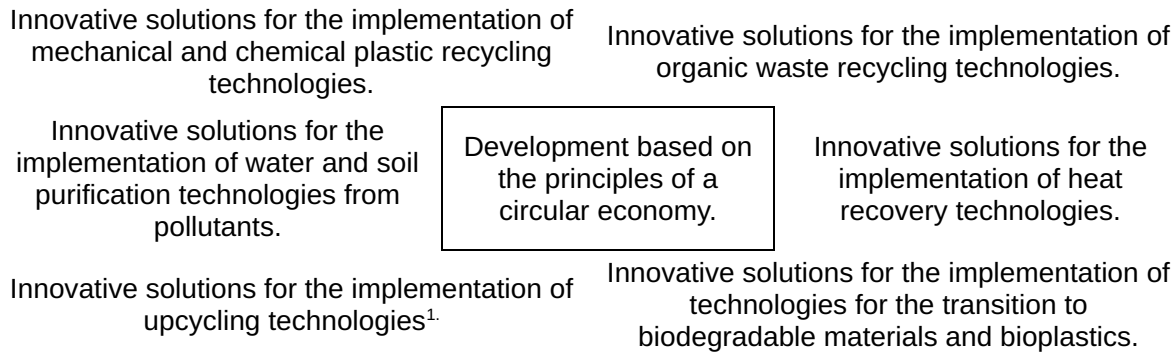

Figure 4. Components of using green technologies for development based on the principles of a circular economy

Note

1. Upcycling involves transforming waste or old materials into new products with higher value or utility.

Source: compiled based on [1–2; 4]

packaging. By utilizing renewable materials and resource reuse technologies, the project reduces the amount of waste sent to landfills and supports the principles of a circular economy.

These startups in Ukraine show that environmental technologies help develop a circular economy, effectively use resources, reduce waste, and minimize environmental impact.

Among the features of innovation in environmental startups with a focus on reducing the carbon footprint is the orientation toward green technologies that reduce the amount of greenhouse gas emissions (primarily CO_2) into the atmosphere (these emissions are the main cause of climate change) [1–2]. First and foremost, these are carbon capture and storage (CCS) technologies, which capture CO_2 produced during the burning of fossil fuels or industrial processes, preventing it from entering the atmosphere. For example, the domestic startup Carbominer is working on Direct Air Capture (DAC) technology, which captures CO_2 directly from the air. The captured CO_2 is then used in greenhouse farming to enhance plant growth, making the process more eco-friendly and reducing the carbon footprint.

In addition, technologies for reducing the carbon footprint include CO_2 emission monitoring and reduction systems, as well as systems aimed at minimizing dependence on fossil fuel energy sources. Notably, in Ukraine, examples of environmental startups focusing on reducing the carbon footprint include [1; 4]:

1. "Ecois.me", which specializes in creating solutions for calculating and reducing the carbon footprint for both companies and individuals. In particular, the startup develops and offers various tools for real-time CO_2 emission monitoring and reduction, allowing businesses and individuals to reduce their environmental impact through analytics and recommendations on optimizing energy consumption, reducing fuel usage, and adopting eco-friendly technologies, among others.

2. "Vega Solar" focuses on implementing solar power stations for small and medium-sized enterprises, helping reduce dependence on fossil fuel sources and, consequently, lowering CO_2 emissions. The use of renewable energy sources, such as solar energy, significantly reduces the carbon footprint of production processes and supports sustainable development at the local level.

These examples show that startups are actively working on reducing greenhouse gas emissions and lowering their carbon footprint, which is a crucial component of the fight against climate change.

One of the key signs of innovation in environmental startups is social responsibility, which focuses on green technologies. These businesses operate in a way that considers the interests of society, protects the environment, and promotes sustainable development. Such technologies include eco-friendly products (e.g., corn starch packaging, eco-friendly cleaning agents, organic textiles); green spaces (creating and maintaining urban parks, eco-roofs, green walls, and landscape projects that improve air quality and biodiversity), and more [5].

In Ukraine, an example of an eco-friendly startup actively demonstrating social responsibility is "Smachno," which specializes

in producing environmentally clean food products, particularly healthy snacks made from local organic ingredients. They prioritize consumer health and support local farmers by using eco-friendly production methods, avoiding chemical additives, and eliminating plastic packaging. This startup actively reduces waste, promotes a healthy lifestyle, contributes to sustainable development, and mitigates negative environmental impacts. Additionally, this group can include startups like "Framiore" and "Anastasia Ivanova," which specialize in eco-friendly clothing using organic materials and sustainable production processes. These companies prioritize environmental responsibility by creating products that minimize ecological impact and promote ethical consumption.

Given the aforementioned points, it's clear that startups of this type can take on social responsibility by focusing on green technologies that improve the quality of life and protect the environment.

Among the characteristics of innovation in ecological startups: are active scaling, focused on the process of rapid and efficient expansion of operations; a focus on reaching a larger market share; gradual increase in production volumes; improving services or growing profitability [1–2]. Among the examples of domestic ecological startups that are successfully scaling [4]:

1. "Bioformat," which specializes in the production of biodegradable packaging for food products. In 2010, this business was focused on small-scale production, but due to high demand and investments in advanced technologies, they were able to scale and expand production.

2. "SolarGiga," which specializes in installing the latest solar panels on residential buildings and businesses. Currently, the startup is rapidly expanding its market presence and reducing the cost of projects for installing electricity generation stations for end consumers.

Proactive scaling of environmental startups enables broader access to green technologies, improving their impact on the economy. This positively impacts the sustainable development of economic entities and reduces environmental footprint.

Conclusions. The research proves that environmental startups and green technologies play a key role in transforming traditional economic models, contributing to the formation of environmentally balanced development. Amid the growing ecological burden on the planet, startups working in the field of green technologies not only offer effective solutions to reduce the negative impact on the environment but also change the very principles of economic management and production. The following conclusions have been made:

1. Environmental startups contribute to the transformation of economic models by promoting the shift from a linear economy model ("take, make, dispose") to a circular one, that focuses on waste minimization and maximizing the use of secondary resources. They operate in the field of renewable energy and contribute to reducing fossil fuel consumption. In addition, green businesses offer new approaches to commercial activities, including models such as "product as a service" (for example, rental instead of ownership) and "green finance" (investments in projects that meet environmental standards).

2. Eco-startups contribute to environmentally balanced development by helping to reduce pollution levels and promote the growth of eco-friendly transportation. Moreover, these startups play a key role in popularizing environmentally clean products, biodegradable packaging, smart resource consumption, and sustainable business practices, thus shaping a new culture of consumption.

Based on the obtained results, it can be noted that promising areas for further research include the assessment of the effectiveness of environmental startups in various sectors of the economy, the analysis of their financing and scaling mechanisms, as well as studying the impact of green technologies on socio-economic development and the formation of sustainable development policies.

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