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Global trends in the development of a sustainable bioeconomy for rural growth in Ukraine

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Abstract. Growing global environmental problems are forcing humanity to think about transforming the basic principles of doing business, as the traditional economic order leads to an increase in the volume of pollutant and greenhouse gas emissions into the atmosphere, excessive depletion of the main types of fossil fuels, and considerable accumulation of industrial and household waste. In these circumstances, the alternative is to use low-carbon energy sources, which will minimise destructive environmental impacts. Therefore, the purpose of this study was to substantiate the theoretical and

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methodological foundations of bioeconomic activity and practical recommendations for the development of a sustainable bioeconomy in Ukraine. To fulfil this purpose, the study employed general scientific and special methods of theoretical and empirical research, specifically, at the theoretical level, the methods of theoretical generalisation, abstract-logical, hypothetical, historical, methods of ascent from the abstract to the concrete, etc. The empirical level includes comparative, descriptive, SWOT strategic analysis, graphs, and tables. Using the methods outlined in the historical retrospective study, the study monitored the volume of greenhouse gas and pollutant emissions into the atmosphere due to the considerable use of fossil fuels, which provokes an increase in global environmental problems in society. Under these conditions, sustainable economic activity is gaining popularity, allowing for the production of renewable energy from renewable resources, agricultural, forestry and fishery residues, as well as organic industrial and household waste. The study outlined foreign practices and Ukrainian initiatives to promote bioeconomic activity, considering the country's natural resource and intellectual potential, as well as financial national support for the bioindustry. Considering the findings of the study, the strengths and weaknesses of the sustainable bioeconomy were systematised using SWOT analysis, key threats to its formation in Ukraine were foreseen, and constructive opportunities for its development were identified. The practical value of this study lies in the scientific substantiation of proposals for promising strategic guidelines for the development of a sustainable bioeconomy with strengthening its capabilities and finding ways to minimise the destructive impact of key threats

Keywords: greenhouse gas emissions; fossil fuels; organic waste; bioeconomic activity

INTRODUCTION

The economic growth of modern society is associated with the need to rethink the principles of doing business, as the traditional economic order leads to a range of unresolved global environmental problems. Air pollution from exhaust gases from car engines poses a significant risk. According to statistics, 14.7 million tonnes of carbon monoxide are released into the atmosphere from exhaust gases from internal combustion engines (State Statistics Service of Ukraine, 2022). As a result of electricity generation at thermal power plants, millions of tonnes of hydrocarbons, nitrogen oxides, sulphur, phosphorus, iron, molybdenum, and other highly toxic substances are released into the environment. Thermal power plants emit carbon dioxide into the atmosphere, which causes a greenhouse effect and leads to an increase in the average temperature of the lower atmosphere. The accumulation of environmental problems is causing concern in society, forcing scientists to consolidate their efforts to find alternative ways to achieve sustainable development goals.

The issue of bioeconomy development became widespread at the end of the 20th century, due to the need to find effective tools for achieving sustainable goals. Thus, D. D'amato *et al.* (2021) consider the concepts of green economy, circular economy, and bioeconomy, which are popular in discussions of sustainable development at the macro level in politics, research, and business, to be promising ways to overcome global challenges. Each of these is based on renewable bio-diverse and beneficial processes that provide tangible and intangible benefits that meet the economic and social needs of society. N. Szarka *et al.* (2023) proposed a detailed description of the development of a regional bioeconomic strategy, namely effective recommendations for establishing a flexible biodynamic platform that engages stakeholders from politics, science,

industry, and society for a common regional goal. Yu. Maksimiv *et al.* (2021) and T. Shevchenko *et al.* (2022) consider an analogous approach, confirming that in practice, to avoid conflicts of interest, it is worth engaging citizens and stakeholders into the development of bioeconomic strategies, factoring in relevant global sustainable goals.

T. Gorokhova *et al.* (2020) consider the development of the bioeconomy in Ukraine as an element of the state strategy, proposing an algorithm for transforming Ukraine's economic systems into bioeconomic systems. H. Geletukha (2018), V. Yakubiv *et al.* (2020) considered the bioeconomic approach to bioenergy development, arguing that its implementation is possible only if both its founders, the state, and end users of biofuels are interested in the rational use of biomass resources. Therewith, N. Pryshliak *et al.* (2022) argue that the bioenergy potential of the agro-industrial sector of the economy requires research on its integration into the country's energy sector, and therefore the researchers have developed an indicative cluster model for organising the activities of biofuel enterprises and a coordinated development strategy, considering the energy, environmental, and socio-economic parameters of sustainable development of territories. J. Han Yeon and J. Seung-hwan (2023) confirm the fact that the implementation of a sustainable bioeconomy in practical reality requires considerable intellectual investment, proving the constructive impact of research and development, investment in human resources as a key development factor on the efficiency of bio-based businesses. The review of scientific opinions indicates the relevance of research on the bioeconomic aspect of farming in the context of increasing environmental challenges, which led to the investigation of this topic as the subject of this study.

The purpose of this study was to provide a theoretical substantiation for the feasibility of implementing bioeconomic principles of management in the context of accumulated global challenges and to develop practical provisions on the prospects for the development of a sustainable bioeconomy in Ukraine. In the context of this purpose, it is necessary to investigate the prerequisites for promoting economic activity on a sustainable basis; to outline foreign practices and Ukrainian initiatives to promote bioeconomic activity, considering natural resource and intellectual potential, as well as financial national support for the bioindustry; and,

based on the findings of the study, to systematise the strengths and weaknesses of the sustainable bioeconomy, and to foresee key threats and constructive opportunities for development. The hypothesis of the study is that identifying the strengths and weaknesses of the sustainable bioeconomy will make it possible to provide preventive measures to minimise the destructive impact of threats in manifesting constructive opportunities for its development in Ukraine.

MATERIALS AND METHODS

The algorithm of the study is presented in Figure 1.

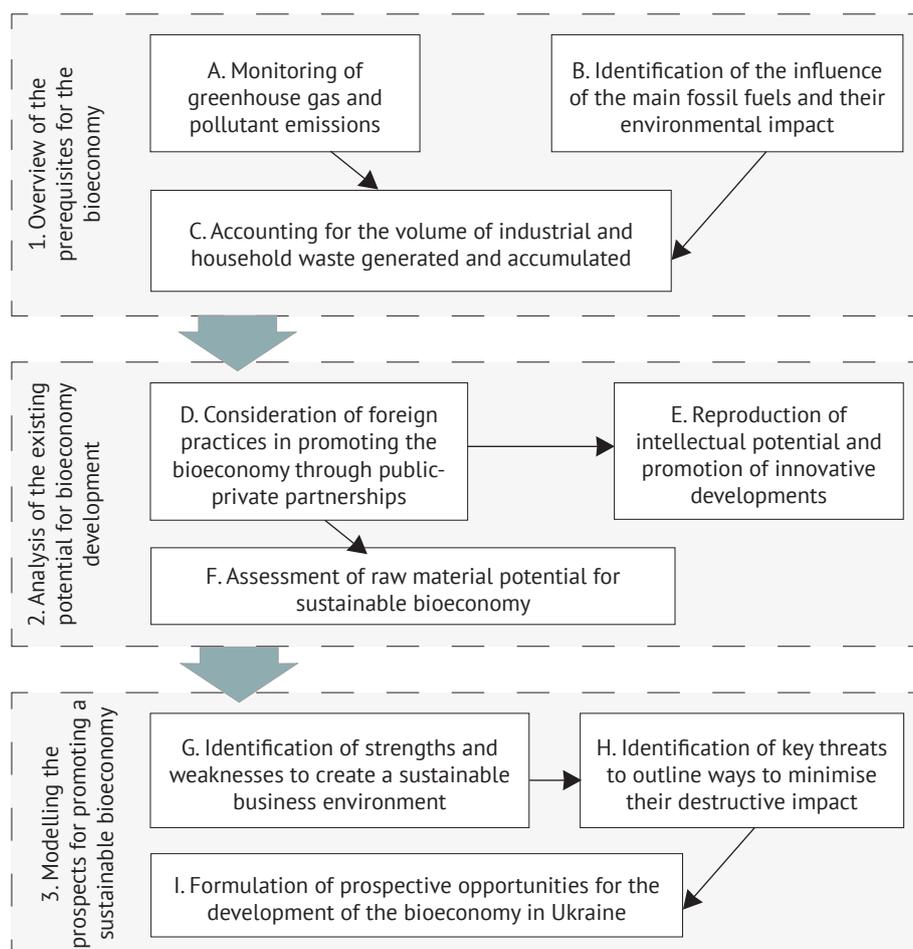


Figure 1. Algorithm for researching trends in the development of a sustainable bioeconomy in Ukraine

Source: compiled by the authors of this study

This study was based on a systematic approach, which enabled a comprehensive consideration of economic processes and phenomena for the development of a sustainable bioeconomy; a dialectical approach covered the investigation of the subject matter with a substantiation for the need to establish the impact of global environmental problems on its development; a synergistic approach involved considering the effective reproduction of natural resource, innovation, and intellectual potentials to enhance the effectiveness of promoting a sustainable bioeconomy in Ukraine, etc. During

the staged study, general scientific and special methods of the theoretical and empirical level were used. At the theoretical level, the methods of theoretical generalisation were used to formulate conclusions on identifying promising opportunities for the development of a sustainable bioeconomy. The abstract-logical method helped to establish the impact of global processes on the state of the environment. The historical method reflected the dynamics of changes in economic phenomena in retrospect. Methods of ascending from the abstract to the concrete made it possible to move from

global problems to their solutions at the local level. The hypothetical method played an important role in outlining the prospects for the development of the bioeconomy in Ukraine. The empirical level included a comparative method to find similarities and differences in the implementation of bioeconomic activities in selected developed countries, drafting graphs and tables to visualise the research material, a descriptive method involved their interpretation, and a strategic SWOT analysis method helped to investigate the current level of bioeconomy development to identify strengths and weaknesses, as well as threats and opportunities for its promotion in Ukraine.

The data visualisation based on the study results was presented with a different spatial and temporal interval depending on the availability of statistical

information in the Global Networks (Our World in DATA, 2022). Some studies were conducted with a time limit of 2020 due to the lack of relevant information for 2021-2023 in official state statistical sources (State Statistics Service of Ukraine, 2022).

RESULTS AND DISCUSSION

The biggest driving force behind global climate change is greenhouse gas emissions, which pollute the air and cause an excessive greenhouse effect on the Earth. On a global scale, their volume in 2022 was 37.15 billion tonnes, compared to 22.75 billion tonnes in 1990. Greenhouse gas emissions from human activities and natural processes increased by 63% in 2022 compared to 1990. Their gradual growth over time is presented in Figure 2.

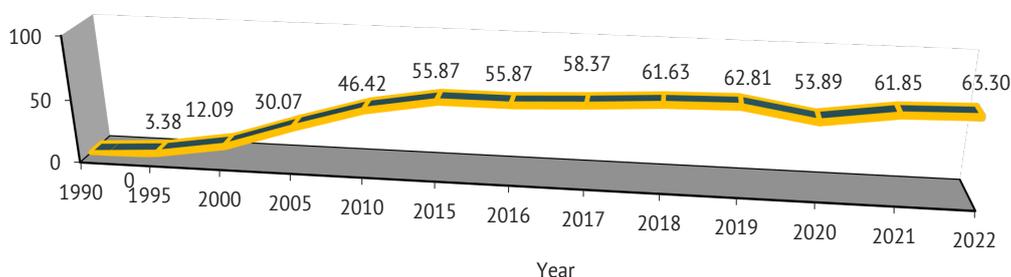


Figure 2. Growth rate of greenhouse gas emissions in the world, %

Source: developed by the authors of this study based on data from Our World in DATA (2022)

China is the world leader in greenhouse gas emissions (30.7%), as it emits almost a third of the total amount of all countries. The top three also include the United States, with a 13.6% share, and India, with a 7.6% share (Fig. 3).

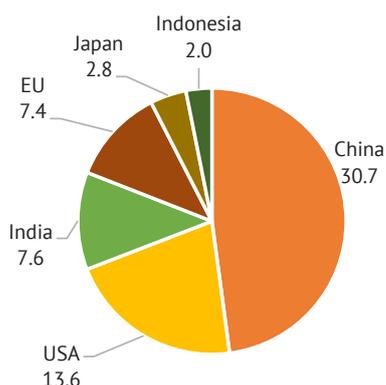


Figure 3. Share of greenhouse gas emissions in the global ratio for 2022, %

Source: developed by the authors of this study based on data from Our World in DATA (2022)

Japan and Indonesia accounted for 2.8% and 2.0%, respectively. In recent years, the EU countries have seen a decrease in greenhouse gas emissions, but their overall percentage is still high at 7.4%. As for Ukraine, the volume of greenhouse gases has decreased threefold

over the past 30 years, but their share in the global ratio is still quite significant – 0.4%. Therewith, according to the Ministry of Economic Development and Trade of Ukraine (2017), the main sources of pollution are concentrated primarily in the energy sector, industrial activities, and agriculture and forestry. Starting from 2021, air emissions are regulated by the Law of Ukraine “On the Principles of Monitoring, Reporting, and Verification of Greenhouse Gas Emissions” (2019), which prescribes registration and subsequent annual monitoring of facilities that emit greenhouse gases to strengthen control over their volumes. At the same time, Ukraine pays a tax for entities that emit more than 500 tonnes of carbon dioxide per year, estimated at UAH 30 per tonne in 2022 compared to UAH 0.41 per tonne in 2018, which indicates a significant increase in the environmental tax.

The global increase in greenhouse gas emissions is primarily caused by the intensive use of fossil fuels. The increase in their production for energy generation occurred during the Industrial Revolution, which was characterised by in-depth research into the composition of oil, coal, and gas, and their introduction into mass production. It is known that until the beginning of the 20th century, a significant part of industrial products was produced on a biological basis using renewable raw materials. In the following decades, chemical technologies and oil field development contributed

to its replacement by products based on petrochemical processing, which led to the development of new industries and provoked an increase in environmental problems. Over the past half century, fossil fuel

consumption has increased approximately eightfold since 1950 and doubled since 1980. Over the past 30 years, there has been an increase in fossil fuel consumption by almost 40% (Fig. 4).

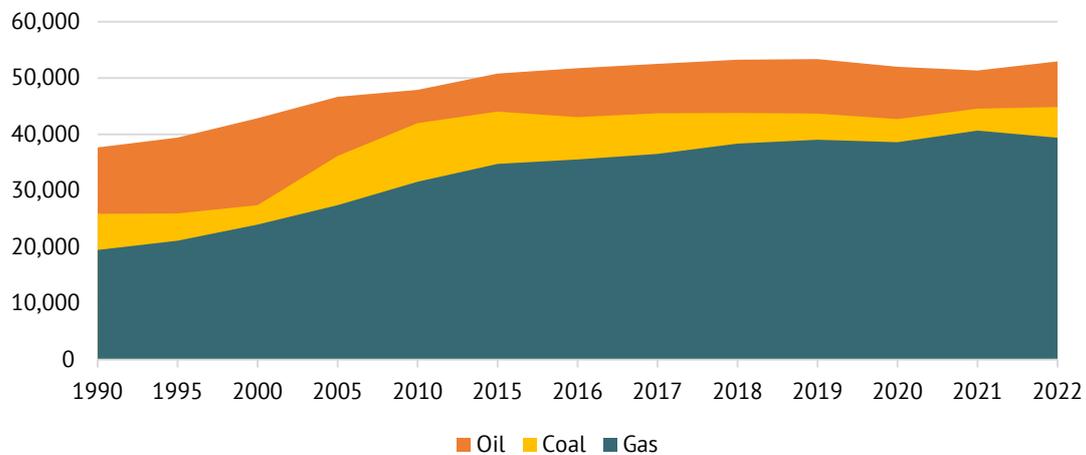


Figure 4. Global fossil fuel consumption by major types, TWh

Source: developed by the authors of this study based on data from Our World in DATA (2022)

The visualisation of fossil fuels broken down by coal, oil, and gas shows that coal production is currently partially declining in some parts of the world, but there is a significant increase in the use of oil and gas, which leads to adverse environmental impacts. Their excessive consumption leads to a shortage of raw materials (Fig. 5).

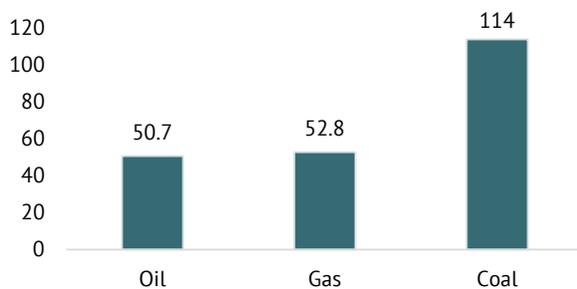


Figure 5. World reserves of major fossil fuels, year

Source: developed by the authors of this study based on data from Our World in DATA (2022)

According to published statistics, oil reserves for global consumption will last almost 60 years. Natural gas reserves are also limited. Humanity can live only 53 years with the existing gas reserves. The situation with coal reserves is much better, but their exhaustibility is undeniable, as the global average is 114 years. However, despite the considerable reserves of coal, which are much larger than those of gas and oil, its extraction and use in economic activities causes substantial environmental damage. Coal-fired power plants emit high levels of CO₂, and technologies to reduce emissions are too expensive to be used. Furthermore, coal mining has a substantial impact on the landscape and spatial infrastructure.

The exhaustion of global coal, oil, and gas reserves is driving up their prices, forcing developed countries to actively seek alternative solutions. In this environment, there is an increased focus on transforming the basic principles of business operations, with an emphasis on replacing fossil fuels with low-carbon energy sources, as the abandonment of fossil fuels will help minimise destructive global environmental impacts. Environmental problems can be overcome through the use of accumulated organic industrial and household waste in economic activities as an additional source of energy (Fig. 6).

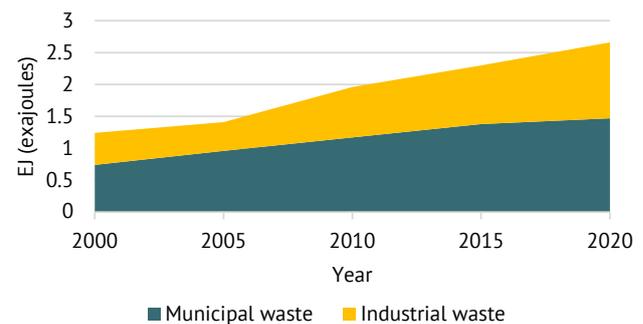


Figure 6. Global accumulation of organic industrial and municipal waste

Source: developed by the authors of this study based on data from the World Bioenergy Association (2023)

According to the World Bioenergy Association (2023), the energy supply from organic waste is 2.65 EJ, with municipal organic waste accounting for 55% of the total as of 2020, i.e., the majority, while industrial waste accounts for 45% of the total organic waste. Within 20 years, their volume doubled (by 98% and 138%, respectively). At the same time, the perception of household

and business residues as raw materials for further consumption in production allows for additional savings, minimising the consumption of fossil fuels and reducing the destructive impact on the environment.

The understanding of the feasibility of promoting organic waste conversion initiatives and bioeconomic activities has led to the creation of international focal points for the exchange of knowledge and practices. Thus, the key programme to support the European bioeconomy is Horizon 2020 (H2020) and, specifically, its aspect related to overcoming global challenges "Food security, sustainable agriculture and forestry, marine and inland water research, and bioeconomy" with a budget of EUR 3.8 billion for 2014-2020. At the initiative of the European programme, a major joint technology initiative, the BBI JTI, referred to in EU regulation as the BBI Initiative (public-private partnership) worth EUR 3.7 billion between the EU and the Biotechnology Industry Consortium (BIC) was launched in 2014, with mobilised contributions in 2020 reaching almost EUR 1 billion during 2014-2015, leveraging an expected EUR 2.7 billion in private funding. Established in 2014, the BBI JU joint venture aims to support the development of renewable resource-based industries by providing grants for research and innovation projects until 2024. Alongside grants and other initiatives (e.g., InnovFin) under H2020, programmes such as the European Fund for Strategic Investments (EFSI) and the European Structural and Investment Funds (ESIF) are helping to promote the bioeconomy. European programmes are complemented by national funding and various instruments offered by regional and/or local development agencies (e.g., Tekes in Finland, Invitalia in Italy, Netherlands Enterprise Agency in the Netherlands, Innovate in the UK, etc.).

For a long time, the bioeconomic model of sustainable development of society was only abstract, without

understanding of mass implementation in practice. The implementation of bioeconomic theory in the business environment took place only in the mid-20th century. Today, the bioeconomy is actively developing in the vast majority of developed countries. For instance, a company from Lower Saxony (Germany) uses milk that is not suitable for food consumption, colostrum from calving cows, or milk filtrate left over from cheese production to make protein and casein, and then forms it into fibres (the whey is dried, mixed with liquid and pressed through a fine sieve), which produces an antibacterial biopolymer that is easy to paint and has the advantage of saving water. Bioplastics are mainly used for vehicle interiors, including body parts and car seats. Car rubber tyres are made from dandelion and rubber tree. The advantage is natural rubber, which stays flexible even at low temperatures, and the disadvantage is the high price of natural rubber. The German company Biowert produces bioplastics and natural fertilisers from perennial grass plants. In the United States, a team of researchers from Yale University (2021) has developed and successfully introduced into production a sawdust-based bioplastic that can fully decompose within three months. The Netherlands is processing sugar beet waste into personal care products, detergents, paints, fibres, and biogas.

As the practices of foreign countries show, the key to the development of a sustainable bioeconomy is the availability of intellectual potential and the ability to implement scientific developments in practice. According to the World Intellectual Property Organisation (2022), Ukraine ranked 57th out of 132 countries in the Global Innovation Index, which has been calculated annually since 2007, in 2022, down 8 positions from 2021. This fact is associated with a weakening of human resources, a decline in the quality of education and science, and a deactivation of research and development (Fig. 7).

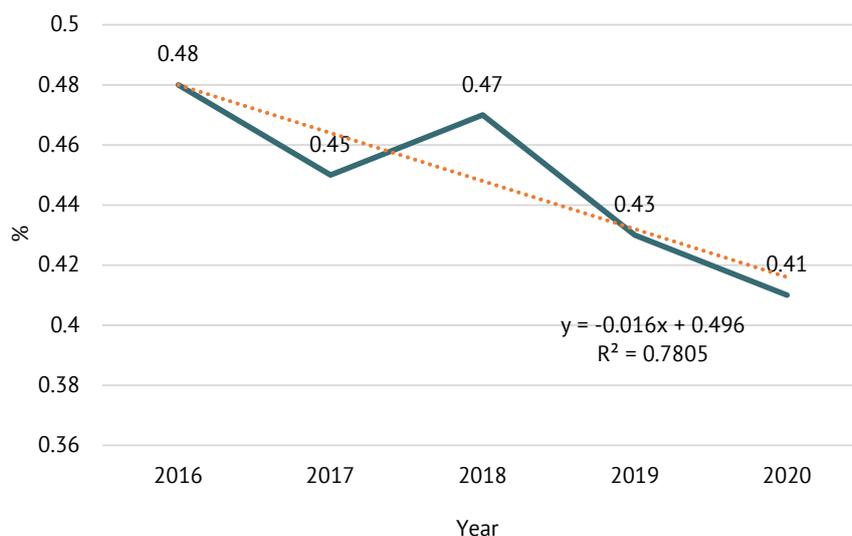


Figure 7. Share of R&D expenditure in Ukraine's GDP

Source: calculated by the authors of this study based on data from the State Statistics Service of Ukraine (2022)

The educational and scientific component plays a leading role in shaping the bioeconomic environment. Thus, according to the State Statistics Service of Ukraine (2022), in 2020, there were 619 higher education institutions in Ukraine with 1.4 million students, including 22 institutions that train specialists in biotechnology and bioengineering. In 2020, as a result of the activities of scientific organisations, the Ukrainian National Office of Intellectual Property and Innovation (UKIPI) granted 29 patents for inventions to national applicants and 190 to foreign applicants among applications for the issuance of industrial property rights in technical areas, including bio- and ecotechnology, and registered 221 utility models, which is evidence of the growth of scientific personnel capable of developing innovative ideas in Ukraine.

The main industries in Ukraine where modern biotechnological production methods are actively used include agriculture, food, woodworking, textile, chemical industries, and the energy sector. The innovative business environment is represented by technologies for the production of tableware (plates, cups, cutlery) consisting of 80% corn starch and additional non-chemical ingredients. The project of Valentyn Frechko, who proposed to make paper from fallen leaves and initiated testing of his technologies at the Zhytomyr Cardboard Factory, is well-known internationally. A Ukrainian startup (Tolstyykh, 2021) by the team of Daryna and Ilya Kichuk and Kostiantyn Shcherbyna signed a contract to produce Effa toothbrushes made of paper and corn starch that decompose in 2 months. The experimental experience of Yuriy Tostanovsky and Dmytro Bidyuk, who localised the Rekava business in Lviv to produce disposable tableware and flower pots from coffee grounds, is gaining popularity in Ukraine (Economic support of Eastern Ukraine, 2022). Tana company is known for its attempts to produce biodegradable tableware made from wheat, corn, and potatoes (Hnyyp, 2021).

An example of sustainable management is the agro-industrial holding Myronivsky Khlipoproduct (MKhP), which produces biogas for internal use from plant biomass, including sunflower husks, as well as animal by-products and wastewater; it also produces fuel briquettes from grain waste, which reduces the load on the local landfill. The Poultry Complex branch of Vinnytsia Poultry Farm operates on a full closed cycle basis, with the by-products from poultry processing being sent to the animal by-products processing shop, where they are used to make feed ingredients for the farm's own animals. The holding's enterprises regularly conduct laboratory tests, which also helps to control the quality of production (MKhP, 2022). Therewith, due to the adoption of the Law "On Restricting the Circulation of Plastic Bags in Ukraine" (Law of Ukraine No. 1489-IX, 2021), the production of corn and potato starch bags has intensified, specifically, Novis company (Dnipro),

Biosphere Corporation (Dnipro), GoGreen line of Freken Bok TM, Chystopes TM (Kyiv). An example of waste-free production on a biological basis is JSC Kokhavynska Paper Mill, which makes products from wastepaper exported to Ukraine from Moldova, Slovakia, Romania, Poland, etc.

This practice shows that the country's geographical location, favourable natural and climatic conditions for agriculture, the availability of fertile agricultural land and a considerable amount of forest and water bioresources contribute to the prospective development of bioeconomic activities in Ukraine. Over 40% of the territory is covered by high-quality soils, which makes it possible to develop agriculture and grow various crops. According to the State Statistics Service of Ukraine (2022), as of 1 January 2021, the total area of arable land in the country was 31.6 million hectares. The largest areas of arable land are in the Polissia, Forest-Steppe, and Steppe regions. The largest regions in terms of arable land are Chernihiv, Poltava, Kherson, Kharkiv, and Dnipro. Notably, between 2016 and 2020, the amount of arable land in Ukraine halved because of the ban on its sale and other transactions with it. According to the Ministry of Economy (2020), in 2020, only 0.1% of arable land was sold out of its total area. Ukraine's forest resources cover more than 15% of the country's territory, which makes it possible to meet the demand for timber and other forest resources. Thus, Ukraine has every opportunity to use its own biological renewable resources, i.e., plant and animal raw materials that are easily renewed to transform innovative ideas into new products, as well as to use accumulated residues of agricultural production, processing industry and household organic waste as a secondary raw material resource in economic activities.

Industrial and household waste in Ukraine is controlled by the State Environmental Inspectorate. At the regional level, waste management is coordinated by the local state administration, city and village councils, and public environmental inspectors. Activities to prevent and reduce the amount of waste generated are regulated following the Law of Ukraine "On Waste Management" No. 2320-IX dated 20 June 2022 (2023). The official waste coding system according to the current legislation is effective from 9 July 2023 (National Waste List and Waste Classification Procedure). Before the current list was adopted, Ukraine had the State Classifier of Waste (DK 005-96), which was approved by the Order of the Ministry of Ecology and Natural Resources No. 1201 "On Approval of the State Classifier of Waste" (2013). The State Classifier contains a hierarchical structure with 21 sections, 83 groups and more than 600 subsections describing different types of waste, including waste from industry, construction, medicine, household, and other areas of activity, etc. The structure of the generated waste is presented in Figure 8.

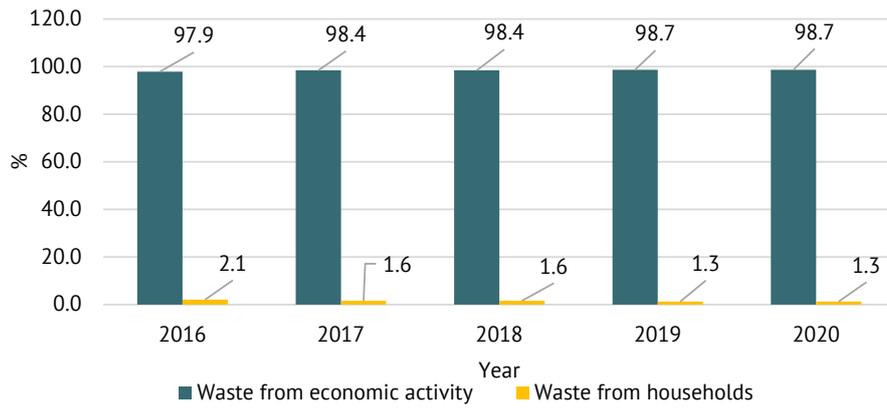


Figure 8. Structuring of household waste and economic activity, %

Source: calculated by the authors of this study based on data from the State Statistics Service of Ukraine (2022)

The total amount of waste generated in 2020 increased by 56% compared to 2016. The focus is on waste from economic activity, as their share is 98.7% of the total waste generated. Considering that the volume of waste increased by 58% in 2016-2020, the need for efficient and conscious waste management is becoming

increasingly urgent. Therewith, the share of waste used as a secondary material or energy resource increased by 18% in 2020 compared to 2016. At the same time, the volume of disposed waste is still a negative phenomenon, which increased by 64% in 2020 compared to 2016 (Fig. 9).

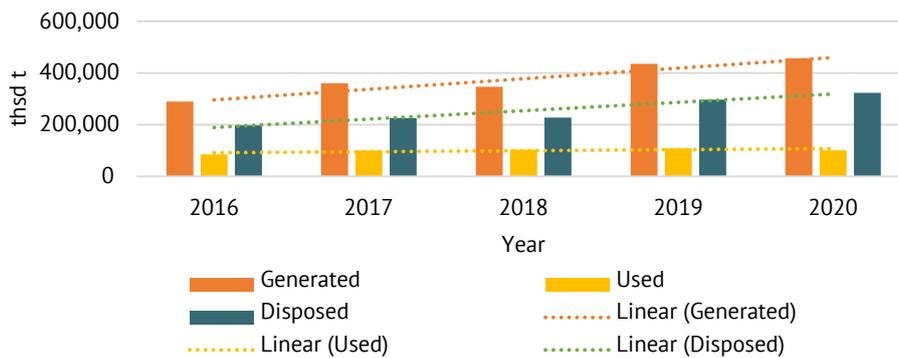


Figure 9. Management of waste generated from economic activities

Source: calculated by the authors of this study based on data from the State Statistics Service of Ukraine (2022)

In the context of sustainable growth, there is a need to find ways to minimise the amount of waste removed in favour of further recycling. Specifically, the development of the bioeconomic sector involves considering the uniqueness of organic residues processing,

which leads to their separation by material categories. Thus, agriculture, forestry, and fisheries (sector A according to NACE) account for a considerable share of waste generation, including 5,315.4 thousand tonnes in 2020 (Fig. 10).

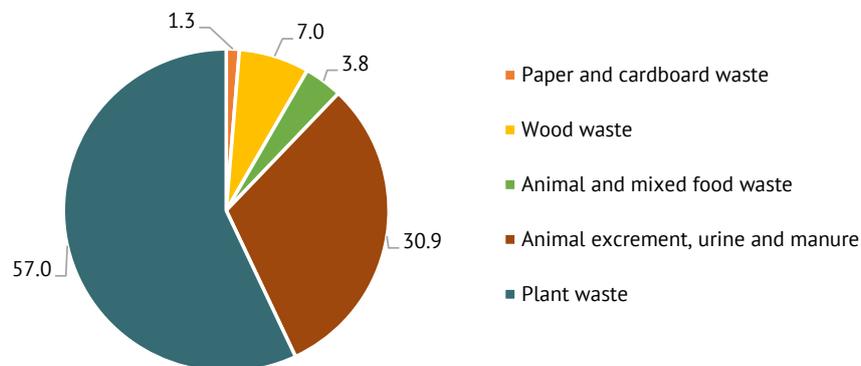


Figure 10. Organic waste generated by material category (2020)

Source: calculated by the authors of this study based on data from the State Statistics Service of Ukraine (2022)

The organic waste presented is mainly of plant origin, which accounts for 57% of the total organic waste generation by material category. The specific features of organic waste management from economic sectors in 2020 are visualised in Figure 11.

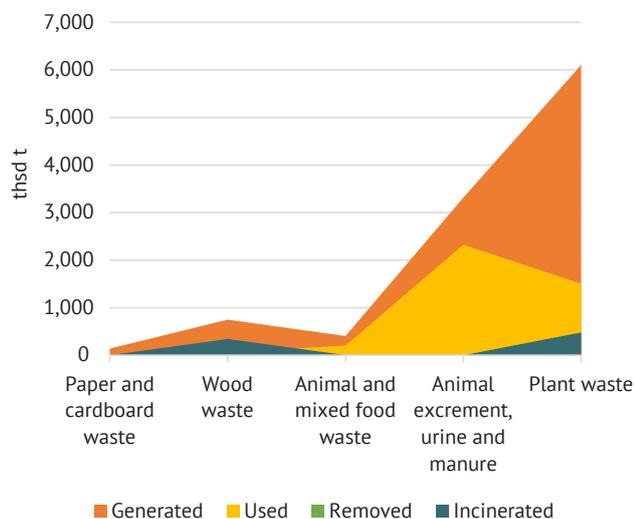


Figure 11. Waste management by material category in 2020

Source: calculated by the authors of this study based on data from the State Statistics Service of Ukraine (2022)

The study found that Ukraine has the potential to recycle vegetable waste, given the considerable share of its generation. Furthermore, food industry residues are actively exported to countries such as India, Italy, Turkey, Spain, etc. In 2020, the company exported waste worth USD 1,576,498 thsd, which is 3.2% of the total export structure, while commodity producers in other countries see such waste as raw materials for the production of goods, considering that residues such as sunflower oil cake, beet pulp, meat industry offal, and other waste have significant potential for further consumption in economic activities. This indicates the prospects of Ukraine in promoting sustainable bioeconomic activities, which will allow the development of the bioenergy sector to compensate for the shortage of natural gas in the production of heat and electricity, and the development of the bioindustrial sector will make it possible to consume waste as a raw material, while minimising production costs and reducing the area of land allocated for landfills, which is relevant in the context of expanded producer responsibility in the product life cycle. Considering the existing advantages in the development of a sustainable bioeconomy, it is important to outline promising areas for its development, which can be executed using the SWOT analysis method, as presented in Table 1.

Table 1. Matrix of SWOT analysis of sustainable bioeconomy development

STRENGTHS	WEAKNESSES
Favourable climatic conditions for agriculture	Lack of approved long-term goals and action plan for the development of a sustainable bioeconomy
Natural resource reserves provide high biomass potential	Weak effectiveness of state institutions and local governments in implementing regional waste management plans
High demand for alternative energy sources, including biofuels	Inferior quality of waste flow accounting and data analysis on the management of production residues
Globalised, fast-growing industry	Insufficient awareness of civil society of the separate collection system and the need to develop a culture of waste sorting
High intellectual potential, which allows involving educational institutions in the implementation of bioeconomic policy	The ineffective waste management system creates conditions for the expansion of landfills and the lack of monitoring of their environmental impact
Possible financing under government programmes	Weak ability of local governments to effectively cooperate and interact with scientific communities
Attracting external grant assistance under EU programmes (Norizon 2020, EU Life, EU4Business) and other available to Ukraine	Low level of innovation activity (Ukraine ranks 57th out of 143 countries according to the Global Innovation Index) due to weak opportunities for commercialisation of intellectual property
Specialisation in high-tech areas in education	Low level of awareness of opportunities to produce new products from organic waste and the benefits of treating or reusing it
Transition from globalism to national protectionism	Weak innovation ecosystems lead to the absence of a regional biomass market
OPPORTUNITIES	THREATS
Government support for innovative projects	Lack of a regional organisational and economic mechanism for industrial waste management
Positive institutional changes	Demographic crisis and low purchasing power of the population
Establishing cooperation (scientific, technological) with European bioeconomic platforms for academic transfer of ecobiotechnologies	Military escalation and high risks of political instability affecting the overall investment climate
Saving natural resources	Unattractive design of innovative bioproducts is possible

Table 1. Continued

OPPORTUNITIES	THREATS
Ability to quickly promote the development of sustainable business ecosystems	Imbalance in the economy – the country's transformation into a raw material appendage continues
Strengthening the competitiveness of the national economy (Ukraine ranks 85th out of 141 countries according to the Global Competitiveness Index)	Low consumer confidence in the quality of innovative bioproducts due to insufficient understanding of the principles of bioproduction and lack of awareness of sustainable consumption
Expediency of using agricultural land withdrawn from circulation	Low investment attractiveness of the biotechnology sector
Increasing the level of social responsibility through enhanced educational activities	Business distrust of government programmes is growing (due to the slow pace of reforms)
Streamlining the certification system for eco- and bioproducts	Outflow of qualified personnel abroad

Source: compiled by the authors of this study

The active use of own capabilities to transform innovative ideas by transforming renewable energy sources into food and industrial products requires the creation of a favourable investment climate to attract additional financial resources and introduce modern innovative technologies into production. As of 2020, the share of enterprises implementing innovations was 12-14% of the total number of operating enterprises, which is 3-4 times less than in the business communities of

developed countries. Innovation processes in Ukraine are not popularised, as almost a third of the funds allocated for innovative developments are spent by producers on updating material and technical support, while less is spent on acquiring intellectual property rights. About half of the enterprises do not finance innovation activities at all, despite the existence of effective state support programmes that could be used for their own development (Table 2).

Table 2. Innovation support programmes in Ukraine

Programme name	Subject	Areas
State Support Program "Affordable Loans 5-7-9%"	Entrepreneurship Development Fund	Development of entrepreneurship, including promotion of business entities, increase in production, exports, import substitution, high-tech production, energy efficiency, introduction of innovations, as well as promotion of creation of new jobs and enterprises, return of labour migrants to Ukraine
Programme "Ukraine: sustainable innovations in the bioenergy value chain"	The European Bank for Reconstruction and Development in cooperation with the Global Environment Facility (GEF)	Promotion of investment in innovative bioenergy technologies and practices related to the use of agricultural residues and waste by facilitating and developing sustainable bioenergy value chains
Pilot project to provide financial support to start-ups in Ukraine on a competitive basis	Innovation Development Fund	Financial support for start-ups in Ukraine, including in the field of information technology

Source: developed by the authors based on data from the Ministry of Economy of Ukraine (2023)

Considering the realities of the national economy, it is necessary to consider the complementary nature of the interconnection of constraints to the development of a sustainable bioeconomy, as their chain reaction significantly hinders the effective establishment of circular production processes at the enterprise and the functioning of the entire bioeconomic sector. Overcoming the barriers to the development of bioeconomic activities requires consolidation of joint efforts of public authorities, economic entities, and the scientific community, as the ability to interact effectively will minimise the impact of destructive factors.

The production process of business entities may be disrupted by limited access to bioresources, namely, the low level of organisation of bioresource supply and problems with its procurement, which encourages

producers to reorient and diversify their enterprises to achieve a closed cycle of their own production. This can be a challenging task for small producers, as it requires considerable capital investment. The resource dependence of suppliers and consumers of biomass can be reduced through the development of local competitive biomass markets and the launch of biomass auctioning in Ukraine.

The key barriers to the development of the circular bioeconomy at the national level are insufficient state support for business entities in the form of a taxation system and economic incentives for the development of the bioeconomic sector. The solution to this problem is to introduce additional economic methods of direct regulation, including additional targeted funding, targeted subsidies, setting state standards, regulatory

requirements for quality and certification of products, which will create additional material incentives for the development of a sustainable bioeconomy. Indirect regulation methods include preferential taxation of bio-products producers or differentiation of their taxes, provision of long-term and medium-term loan privileges, etc. All this will help create a favourable economic environment for the development of the bioeconomic sector.

The implementation of the bioeconomy goals is associated with the development of appropriate legislative and institutional frameworks that ensure sustainable growth and address a range of social, industrial, environmental, and demographic issues. The lack of regulatory framework for the bioeconomic system is a major obstacle that requires the transformation of existing environmental, civil, and administrative legislation in the field of waste management. Therewith, the system of extended liability of commodity producers and their capacity to reuse residues of economic activity is not sufficiently established, which substantially hinders the development of bioeconomic activity. The imperfect regulation of waste flow accounting and data analysis on the management of residues from economic activities underlies international disagreements in the formation of bioeconomic policy, which requires joint efforts and the search for ways to reach political consensus in this area.

CONCLUSIONS

Thus, the growing global environmental challenges necessitate the transformation of conventional business models with the reorientation of production to alternative energy sources that are low-carbon and low-cost. Therewith, considering the significant amount of organic industrial and household waste accumulated, the key to overcoming these problems is to operate on a biological basis, which minimises the destructive impact on the environment on the way towards sustainable

growth. In Ukraine, the geographical location, favourable natural and climatic conditions for agriculture, the availability of fertile agricultural land, and a significant amount of forest and water bioresources contribute to the prospective development of a sustainable bioeconomy. The main industries in Ukraine where modern biotechnological production methods are actively used include agriculture, food, woodworking, textile, chemical industries, and the energy sector.

A detailed review of the current state of development of the sustainable bioeconomy in Ukraine is proposed to be carried out using the SWOT analysis matrix, which helped to identify promising opportunities for the development of the bioindustry, considering strengths and weaknesses, as well as key threats, to find ways to minimise their destructive impact. Therefore, it is necessary to intensify innovation activities, expand research and initiate the implementation of eco-projects through state support, attracting external grant assistance, and strengthening the role of state institutions and local governments in implementing national and regional plans for the development of a sustainable bioeconomy. At the same time, the introduction of waste-free technologies into practice is hampered by a lack of awareness of the possibilities of producing innovative bioproducts, as well as the benefits of processing or reuse, which requires increased promotion of the idea of closed-loop bioeconomy among business entities, as well as raising consumer awareness of the importance of implementing sustainable consumption principles and enhancing environmental awareness through intensified educational activities.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Глобальні тенденції розвитку сталої біоекономіки для сільського зростання в Україні

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Анотація. Нарощення глобальних екологічних проблем змушує людство замислитися над трансформацією базових засад ведення господарської діяльності, оскільки традиційний економічний порядок призводить до збільшення обсягу викидів забруднюючих речовин і парникових газів у атмосферне повітря, надмірного виснаження основних видів викопного палива, значного накопичення промислових та побутових відходів. В окреслених умовах альтернативою вбачається застосування джерел енергії з низьким вмістом вуглецю, що дасть можливість мінімізувати деструктивні впливи на довкілля. Тому метою дослідження було обґрунтування теоретико-методологічних засад ведення біоекономічної діяльності та практичних рекомендацій щодо розвитку сталої біоекономіки в Україні. Для реалізації поставленої мети застосовано загальнонаукові та спеціальні методи теоретико-емпіричного рівня дослідження, зокрема на теоретичному рівні використовуються методи теоретичного узагальнення, абстрактно-логічні, гіпотетичні, історичні, методи сходження від абстрактного до конкретного тощо. Емпіричний рівень охоплює порівняльний, описовий, метод стратегічного аналізу SWOT, складання графіків та таблиць. За допомогою окреслених методів у процесі дослідження історичної ретроспективи здійснено моніторинг обсягу викидів парникових газів та забруднюючих речовин у атмосферне повітря через значне використання викопних видів палива, що провокує нарощування глобальних екологічних проблем у суспільстві. У зазначених умовах набуває популяризації господарська діяльність на сталих засадах, яка дозволяє виробляти відновлювальну енергію з поновлювальних ресурсів, залишків сільського, лісового та рибного господарства, а також органічних промислових та побутових відходів. У дослідженні окреслено зарубіжний досвід та українські ініціативи просування біоекономічної діяльності з урахуванням природо-ресурсного та інтелектуального потенціалу країни, а також фінансової національної підтримки біоіндустрії. Беручи до уваги результати дослідження, за допомогою SWOT-аналізу, систематизовано сильні та слабкі сторони сталої біоекономіки, передбачено ключові загрози її формування в умовах України та визначено конструктивні можливості для її розвитку. Практична цінність дослідження полягає у науковому обґрунтуванні пропозицій щодо перспективних стратегічних орієнтирів розвитку сталої біоекономіки з посиленням її можливостей та пошуку шляхів мінімізації деструктивного впливу ключових загроз

Ключові слова: викиди парникових газів; викопні види палива; органічні відходи; біоекономічна діяльність