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Circular economy in Ukraine – a chance for transformation in industry and services

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The monograph contains studies reflecting the processes of development of the modern circular economy model in Ukraine. The sources of the content of the monograph were the results of own authors research and the research of advanced scientists in the field of circular economy management. In the monograph, the authors prove that CE management is essential for the global community and for Ukraine it is a chance for transformation in industry and the service sector with new approaches. The transition to a CE will undoubtedly take place faster than previous transformations. This process has political support. The EU aims to move towards a CE to make Europe cleaner and more competitive. Ukraine is just beginning this path, and this monograph highlights the author's approaches to transformation in industry and the service sector.

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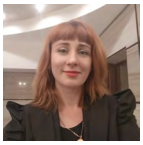

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Chapter I.

Formation of circular economy in Ukraine in the context of sustainable development

The primary levels of Ukraine's transition to a circular economy

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Abstract. It has been studied that the circular economy (CE) ensures the reuse of goods, reduces the negative environmental impact and allows efficient use of limited natural resources. It is substantiated that the transition to the CE can be done simultaneously at different levels: state, business, and the level of individuals, i.e. consumers. At the national level, governments play a leading role in implementing the principles of the CE by conducting public procurement of green services using the servitization model. Businesses can save financial resources and create opportunities in the CE business models. The areas of implementation of the CE are studied, among which the focus is on the use of zero waste, the stimulation of processing and recycling, the development of circular designs, the development of exchange and sharing models, and the implementation of ecological standards. In general, the CE's effectiveness consists of achieving economic, social, and environmental benefits by optimizing the use of resources and reducing waste, reducing raw material costs, stimulating innovation, introducing new business models (i.e RESOLVE, 9R) and creating social benefits. The CE offers the replacement of new raw materials with secondary ones, reducing the cost of purchasing raw materials and ensuring stable supplies of materials for production. It has been established that the CE requires the development of new technologies, processes, and business models. It stimulates innovation, creating new markets and opportunities for enterprises and creating new jobs in recycling, repairing, reusing, and maintaining products.

Keywords: circular economy, recycling, innovations, waste minimization, business models

Introduction

A CE is an approach to production and consumption that prioritizes resource conservation, waste minimization, and the creation of a closed cycle of material and resource use. It helps reduce the negative environmental impact by reducing energy costs and using resources more efficiently. The effectiveness of the CE provides new opportunities for businesses by reducing dependence on limited resources and price fluctuations. It promotes the development of innovative solutions, new products, and services and the creation of new markets and jobs. The CE generally aims to conserve resources by recycling, reusing, and repairing goods. This makes it possible to extend the service life of products, reduce the need for new raw materials and energy, and also reduce waste going to landfills.

Mc Donough W. and Braungart M. (2010) propose a cradle-to-cradle concept that considers production as a system that should be oriented toward the reuse of materials and energy. Murray Alan, Skene Keith and Haynes Kathryn (2017) examine various aspects of the CE, including economic, social, environmental, and technological dimensions. Webster Ken points out the CE's advantages and disadvantages and suggests ways to implement circular models.

Among the Ukrainian researchers who proved the need for the development of a CE in Ukraine are: M.M. Zalunin. (2019), Fedorchuk Ya., Servetnyk D. (2019), Varfolomeev M.O. (2020), Churikanova O.Yu. S.M. Lyholat and L.O. Semenyuk were engaged in researching the international experience of the circular economy (2021). Alekankina K. and Tkachenko Ya. indicated the necessity of a green course in the EU and Ukraine, with advantages and disadvantages. Overall, the CE has profound implications for production, employment, education, money, and finance, but it also drives changes in public policy and taxation. The economic benefit of this model is waste planning, allowing access to property, and promoting radical resource productivity, with the prospect of capital recovery and sustainability. Almost any waste must be reused in the production of new products. It reduces the negative environmental impact and allows efficient use of limited natural resources. As it has been repeatedly noted in many international documents, the concept of a CE is based on applying the principles of "reduce, reuse, recycle", namely, reduction of consumption, reuse, and recycling. It is important to note that this concept corresponds to the 17 UN Sustainable Development Goals and encourages countries and businesses to innovate.

Moreover, today, most EU countries, the USA, China, Japan, South Korea, and other countries have prioritized the development of the CE in their long-term strategies, according to D. Bayur (2021). At the same time, it means smart, rational use of available resources and the search for innovative ways to improve the environment and the economy. The transition to a CE can be made simultaneously at different levels: state, business, and individual (Fig. 1). At the national level, governments play a leading role in implementing the principles of the CE by conducting public procurement of green services using the servitization model. Some visionary leaders are already realizing this possibility.

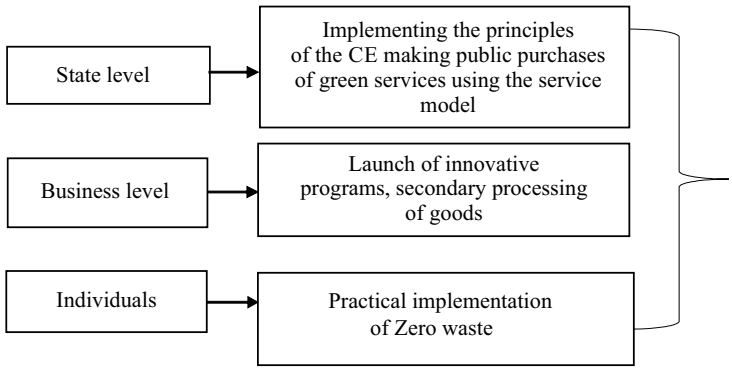

Fig. 1. Levels of circular economy formation in Ukraine*
formed by the authors

Anna Möller Wrangel, Head of Strategy and Acting Head of Business at the Swedish National Public Procurement Agency, called public procurement "a strategic tool that can lead to the rapid implementation of new technical solutions without the use of fossil fuels and circular flows" (The National Agency for Public Procurement).

Through servitization or PaaS, we can accelerate the deployment of green equipment and renewable energy sources and improve overall energy efficiency. This model allows countries to accelerate the energy transition while ensuring financial stability. For example, the Bogotá (Colombia) government has deployed 400 hybrid buses using a PaaS model for vehicle batteries, which are generally considered the riskiest component of hybrid and electric cars. Governments can create an enabling environment through policy levers such as fiscal measures – e.g., tax incentives for market mechanisms – and financial support, such as creating incubators for the private sector to create services needed by the public sector. It would also have a positive impact on the economy.

Businesses can save financial resources and create opportunities in the CE. For example, they can run buy-back programs and recover usable materials or create new materials from waste products, such as turning pulp and paper waste into renewable plastics or textiles. Implementing industrial symbiosis which connects industry sectors that typically work separately into collective company teams, increasing the possibilities of their development thanks to the effective use of common flows of energy and materials. Businesses can also develop products for long-term use, optimize system efficiency to increase margins and develop reusable and recycled products.

At the same time, enterprises can have a market advantage under the condition of using a circular business model, which can be focused on:

- business protection from risks caused by limited resources and price volatility;
- increasing productivity by reducing demand and costs for raw materials;
- innovation through product redesign – for example, redesign for durability, reassembly, reuse, and remanufacturing;

- creation of new products from secondary raw materials;
- improving relationships with customers and suppliers by developing new value propositions (features or services that make business more attractive).

Individuals/consumers can also use CE principles to reduce waste and save money by reusing or repairing items or sharing services such as tool libraries or car sharing. Such approaches are gaining momentum as governments, companies, and individuals adopt more cyclical approaches.

In general, different economic entities, natural persons, and the state, in the form of its authorities, can actively contribute to the development of the CE in Ukraine.

Note that within these levels, all participants adhered to the principles of sustainable development and carried out a set of activities aimed at practically implementing the digital economy (Fig. 2).

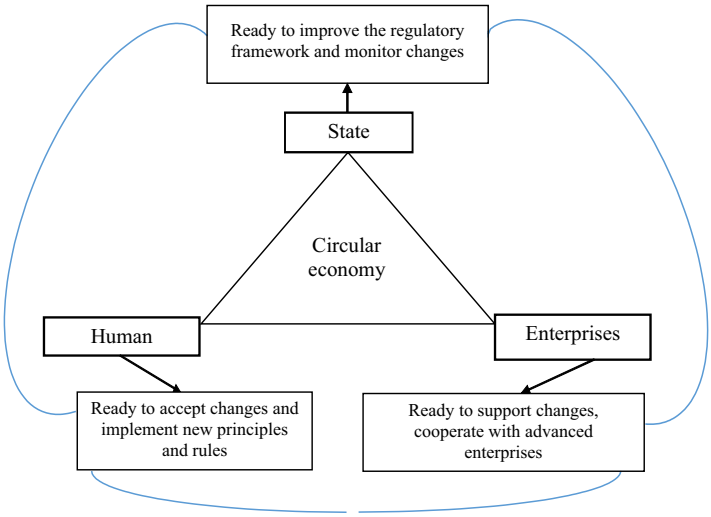

Fig. 2. Interrelationship of structural elements of the circular economy

The CE can have different directions of implementation, for example, the use of zero waste, the promotion of processing and recycling, the development of circular designs, the development of exchange and sharing models, and the implementation of environmental standards (Table 1).

One of the areas of practical implementation of the CE can be the use of zero waste. This direction can be used at all levels of the CE. It involves adopting specific strategies and practices to maximize the avoidance of waste and its recovery into new values. The main practical steps that can be taken to implement Zero waste are:

1. Use of waste as a resource. Instead of focusing on waste as garbage, it should be used as a resource. At the same time, alternative ways of using or processing waste can be

Table 1. Directions for implementation of the circular economy in Ukraine

Directions for implementation	Direction of use	Implementation actions	Result
Zero waste	State, enterprises, individuals	Development of strategies and application of practices for maximum avoidance of waste	Use of waste or minimal waste, reuse of goods, separate collection and recycling, composting
Stimulation of processing and recycling	State, enterprises,	Development and implementation of regulatory and legal acts, compliance with requirements and control over implementation	Strengthening the regulatory framework and creating favorable conditions for circular practices.
Development of circular designs	Enterprises, individuals	Manufacturing parts for products that can be easily disassembled into components and materials	Reduction of energy consumption
Development of exchange and sharing models	Enterprises, individuals	Secondary use and sharing of products and services	Effective use of goods
Implementation of environmental standards	The state, and international organizations	Efficient production, use of resources, eco-design, recycling and waste disposal	Strengthening the regulatory framework and creating favourable conditions for circular practices.

* Formed by the authors.

used to turn it into valuable materials or products – in this case significant obstacles are legal and technological aspects.

2. Production with minimal waste. Emphasis should be placed on designing products and packaging to minimize waste and apply principles of the recycling economy, such as design for disassembly or the use of biodegradable materials – the needs for changes existing process or lack of rules for implementing eco- and circular design.
3. Reuse. It is advisable to reuse products and packaging. For example, glass bottles or food storage containers can be reused – the cost and market as well consumer behaviors are the critical success factors.
4. Separate collection and processing. The separate collection of waste ensures its correct processing. Collect paper, plastic, glass, metal, and organic waste separately. At the same time, minimizing the amount of waste that goes to landfills is advisable – the investment cost plays the crucial role.
5. Composting turns organic waste, such as food or garden waste, into soil fertilizer. Recycling organic waste is vital in reducing waste and protecting the environment.

Organic waste includes food waste, grass, leaves, branches, stitches, and other plant and animal materials that can decompose naturally. Composting involves the natural decomposition of organic materials through the action of microorganisms under particular conditions. It can be carried out on a large scale (compost plants) and at home (garden compost or vermicompost using small worms). Composting results in a biodegradable material known as compost, which can be used as organic fertilizer for plants – correctly segregating food waste for collection.

6. Rejection of disposable products. Going single-use means making a conscious decision not to use or to reduce the use of single-use items and materials to reduce waste and the negative environmental impact. Disposable products, such as plastic bottles, disposable cups, plates, utensils, plastic bags, plastic straws, etc., have a severe negative environmental impact. They create considerable waste that remains in nature for a long time, especially plastic, which can decompose for hundreds of years. Using disposable products requires significant raw materials, energy, and water. Refusing them contributes to the preservation of these resources and their rational use. Also, single-use products generate a tremendous amount of waste that can end up in landfills or the natural environment. Rejecting them helps reduce the load on landfills and avoid environmental pollution. In general, rejecting single-use products helps reduce the use of plastic and other harmful materials in today's world – consumer behaviour.

In today's World, we can actively observe the spread of zero waste. In particular, in 2018, Vancouver (Canada) introduced a comprehensive long-term strategy – Zero-Waste 2040, which should push Vancouver to zero landfill waste over the next twenty years. In addition, Metro Vancouver also helped found the Canadian National Zero Waste Council, which hopes to support the transition to a CE through collaboration that promotes green designs and behaviours (Zero-Waste Communities Across the Globe). Europe's biggest zero waste success story can be seen in Flanders (Belgium). As of 2000, they had already achieved a 60% recycling rate, and today they divert about 75% of household waste from landfills. In 2005, with the participation of community groups, Buenos Aires, Argentina, passed a zero waste law that set goals for removing 75% of waste from landfills by 2017 and a complete ban on landfilling recyclables and organic waste by 2020 and also banned the incineration of municipal waste (Zero-Waste Communities Across the Globe). There are also zero waste online communities worth noting, including Reddit r/ZeroWaste, which brings together more than 400,000 people from around the World interested in sharing tips and asking for advice on everything from avoiding plastic bags to reusing hard-to-recycle materials. Also, many countries are striving to spread zero waste. The island of Bornholm has set itself the goal of becoming a waste-free island by 2032. However, several measures have been taken to achieve this goal, including a waste sorting system that eliminates landfills and incineration as waste management options. By 2032, all waste on this island will be treated as a resource. With proper sorting, recycling, and new technologies, the island should successfully transition to a zero waste society (6 Best Zero-

-Waste Projects in the World). Kamikatsu (Japan) is making impressive strides toward a zero-waste lifestyle. The city is currently over 80% on its way to becoming zero-waste by 2030. The city has implemented a strict waste sorting system that requires residents to separate their waste into 45 different categories; even paper is sorted nine ways (6 Best Zero-Waste Projects in the World).

The second direction of practical implementation of the CE can be the stimulation of processing and recycling. This direction is characteristic primarily at the level of states and enterprises. Governments ensure the development of regulations and control over their compliance, and they encourage enterprises to use processing and recycling. It can be done by introducing financial incentives, tax breaks or levies on secondary raw materials. In addition, governments and international organizations can set standards for resource use, eco-design, recycling, and waste disposal. It will help strengthen the regulatory framework and create favourable conditions for circular practices. For example, Sweden has been using the process of processing and recycling for quite some time. In particular, the country operates 34 waste-to-waste power plants that burn non-recyclable waste to generate enough electricity to power 250,000 households, contributing to significant reductions in waste and emissions. The level of recycling is so satisfactory that the country needs to import garbage from other countries (5 best recycling practices from around the world) 99% of garbage in the country is used either as fuel for power plants or as raw materials for production (No garbage: who in the world has learned to live without waste). In Vienna (Austria), 265,000 tons of garbage are converted into heat energy per year, which allows the heating of entire districts of Vienna. The Austrians use biotechnology that allows them to break down plastic. A particular fungal enzyme can split polymers into simple monomeric elements for this. It is how the "plastic cycle" is ensured: waste from one product is used to create another (no waste: who has learned to live without waste). In Singapore, power units are built on garbage. They burn more than 8 thousand tons of garbage daily, allowing them to reduce their volume by 90%. What does not burn (for example, metals) is sold. Thanks to "waste energy", Singapore produces 2,500 MWh of electricity per day (No Garbage: Who in the World Learned to Live Without Waste). However, with CE policy it is recommended to incinerate only the residual waste, to promote reuse and recycling of all valuable materials.

In 20 years, UK household recycling has increased from 5% to 64%, one of the highest rates in Europe, and is expected to continue to improve to become one of the world's leading countries in this field. A tripartite strategy includes the development of a simplified recycling structure to ensure citizens have easy access to a simple and efficient recycling system (5 best recycling practices from around the world). The third direction of practical implementation of the CE can be the development of circular designs. This direction is characteristic primarily at the level of enterprises and individuals. Companies can develop products with circular principles in mind. It means creating easily disassembled, repaired, and recycled products into the final product using standardized components and marking materials to facilitate further processing. The main critical aspects of developing circular

designs are that they aim to create durable, strong, and easy-to-repair products. They must be high-quality for long service life and possible use after repair or modification. The circular design assumes products are easily disassembled into components and materials used in other products or recycling processes. Standardized connections, marking materials, and easy access to components facilitate their further processing.

Also, secondary raw materials can be the primary source of materials. In general, circular design should reduce energy consumption and emissions by optimizing production processes and using energy-efficient materials and resources. In 2018, Chile launched the first CE program in Latin America with the support of promising companies and a plan to create a strategic roadmap and technology centre for the CE. China has incorporated the CE into its policies since the early 2000s. Initially, the main focus was on how one company's waste could become a source of income for another. Emphasis was placed on the three R's: reduce, reuse, and recycle. In 2019, the Finnish government updated the roadmap to stay on track, enable acceleration, and link the transition to a CE with other, broader national goals, such as Finland's climate goals (Circular countries), and in 2019 Poland implemented the Roadmap towards the Transition to the Circular Economy, and in 2023 the World Bank report about CE in Poland presented some recommendation for policy and implementations and in 2022 the Circular Gap Report for Poland was prepared by Circle Economy and Innowo, which calculated circularity in Poland at 10,2% https://www.circularity-gap.world/poland

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The fourth direction of practical implementation of the CE can be developing exchange and sharing models. At the same time, using "using the product" or exchange and sharing models is advisable, which do not involve purchasing the product but access to its functionality. For example, local communities can create a pool of goods that can be shared instead of purchasing individual copies for each user. An example could be the exchange or use of books.

Sharing and sharing models promote the efficient use of resources and the reduction of waste by sharing, reusing, and sharing products and services. The main aspects of the development of exchange and sharing models are exchange systems, which are provided by the development of platforms where people can exchange used goods, services, or resources. These include second-hand markets, platforms for exchanging clothes, tools, or other items, and business-to-business exchange networks. Creating shared access to resources or services instead of owning them privately. For example, sharing cars, bikes,

or tools. Joint ownership and sharing models characterize the development of models where groups jointly own and manage specific resources or assets. For example, it can be: shared ownership of solar panels, wind turbines, or sports facilities. It is also essential to understand the need to create systems where multiple users share resources or services, such as workspace, equipment, or infrastructure. Developing exchange and sharing models requires effective governance, including regulation, creating a legal framework, and ensuring trust. The fifth direction of practical implementation of the CE is the implementation of environmental standards established by governments and international organizations. Among the environmental standards are Directive 92/880/EC "On Eco Labels", British standard BS 7750 "Environmental Management System", and international standards ISO/TC 207 "Environmental Management". These standards may relate to production, resource use, eco-design, recycling, and waste disposal. This approach will generally strengthen the regulatory framework and create favourable conditions for circular practices.

Conclusions

In CE **maximizing resource efficiency**. is the main imperative and almost all waste must be reused in the production of new products. It reduces the negative environmental impact and allows efficient use of limited natural resources. The transition to a CE can be made simultaneously at the state, business, and individual levels. At the national level, governments play a leading role in implementing the principles of the CE by conducting public procurement of green services using the servitization model. Businesses can save financial resources and create opportunities in the CE. The CE can have different directions of implementation, for example, the use of zero waste, the promotion of processing and recycling, the development of circular designs, the development of exchange and sharing models, and the implementation of environmental standards. The effectiveness of the CE lies in achieving economic, social, and environmental benefits by optimizing the use of resources and reducing waste. The effectiveness of the CE lies in reducing the costs of raw materials, stimulating innovation, and creating social benefits. The CE offers the replacement of new raw materials with secondary ones. It makes it possible to reduce the cost of purchasing raw materials and ensure stable supplies of materials for production. The CE requires the development of new technologies, processes, and business models. It stimulates innovation, creating new markets and opportunities for enterprises and creating new jobs in recycling, repairing, reusing, and maintaining products. The CE can contribute to developing local economic systems and enterprises, ensuring greater regional self-sufficiency.

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Circular Economy Business Models and Region's Role in their Implementation

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Abstract. The theoretical and practical aspects of circular business models are studied. The need to transition from a linear to a CE in order to reduce the "ecological footprint" is substantiated. The importance of the main elements of the CE was analyzed: closed cycles, renewable energy, systems thinking. The international strategic documents on the development of the CE were studied. The key points and areas of implementation, which are defined in the Circular Economy Action Plan, have been studied. They are: make sustainable products the norm in the EU; expand the opportunities of consumers and state buyers; pay special attention to such industries as electronics, batteries and vehicles, packaging, plastics, textiles, construction, food products; reduce waste; make cyclicality work for people, regions and cities. The essence of the concept and elements of the business model are characterized: costs for product creation and development, sales organization costs and the way to make a profit. The main types of business models are highlighted: promotional, affiliate marketing, commission pay, trade, crowdsourcing, manufacturer, franchising, "low-touch", «razor and blades» and marketplace. According to interaction between business, private individuals and the state, there are such business models: business to business, business to consumer, business to government, consumer to business, consumer to consumer, consumer to government, government to business, government to consumer, government to government. The peculiarities of circular business models and their types are characterized: circular supply models, resource recovery models, product life extension models, sharing models, product service system models. On the basis of foreign experience, the peculiarities of the practical application of business models in various spheres and industries are analyzed; their advantages for the producer and the consumer are investigated. The problems of financial support for the development of the CE have been studied.

The necessity of strengthening the participation of regions in the development of the CE is justified; the main areas of activity of the region in this field are outlined.

Keywords: circular economy, linear economy, business model, resource efficiency, sustainable development of the region

Introduction

The implementation of CE becomes increasingly relevant. According to the definition of the World Economic Forum, the CE is "a renewable industrial system; it replaces end of service life with restoration, moves to use of renewable energy, eliminates the use of toxic chemicals that impair reuse and return to the biosphere, and aims to eliminate waste through the design of materials, products, systems and business models" (Circular Economy: Definition, Principles, Benefits And Barriers, 2020).

The publication of the report "The Limits to Growth" by the Club of Rome in 1972 became an important stage of formation of the CE concept. The publication was focused on the problems of resource depletion and pollution. The authors of the report substantiated the need for product reuse and recycling (Pavlikha, Korneliuk 2022).

The recognition of the importance of resource conservation and recycling is related to the concept of "ecological footprint", which indicates that the planet needs more than a year and a half to restore those resources that are consumed during the year. The concept of the ecological footprint emerged in the early 1990s and began to be used as an indicator of the rising tension between the economy and the environment. Before the emergence of the concept of ecological footprint, the IPAT formula was used to evaluate the human impact on the environment. It describes the interaction between the population (P), affluence (A) and technology (T): Impact (I) = P · A · T. The population factor is controversial because low-income countries have growing populations but relatively low ecological footprints. It is particular important after Covid-19 pandemic which was underlined by UNEP Resource Panel (International Resourse Panel, 2019). Many studies conducted by international organizations and various research institutions warn against the increasing climate instability, over-exploitation of important ecosystems and natural resources, and pollution, which causes significant damage to ecosystems and human health. Thus, there is an urgent need to transition to a CE, i.e. to the regenerative industrial system (Viikman, Skonberh 2017),

Definitions of a CE that focus on systemic change emphasize three elements: closed cycles, renewable energy, and systems thinking. Some researchers also consider social inclusiveness to be a necessary part of the CE. Closed cycles provide for the development of production cycles based on the example of an ecosystem, in which there is no concept of waste, as each the remainder can be used to make a new product. Producers take back their production after use and renew them for a new useful life, for which it is important to save the quality of products, components and raw materials as much as possible. The

use of renewable energy sources is one of the conditions of the CE. As with raw materials and products, energy is also stored as long as possible in the CE. It is impossible to recycle energy, so we are not talking about energy cycles, but about "cascading energy flows", for example, co-production of heat and electricity. System thinking means that every economic entity (company, person) is connected with other entities. Together, this forms a system in which the actions of one actor affect others (What is the definition of a circular economy, 2018).

In 2015, the European Commission adopted the first Circular Economy Action Plan, which included 54 points. Some of them have been completed, others are still being implemented. In March 2020, the European Commission adopted a new Circular Economy Action Plan (CEAP). It is one of the main components of the European Green Deal, new Europe's agenda for sustainable development. The EU's transition to a CE will reduce pressure on natural resources, promote sustainable development and create jobs, and it is a necessary condition to preserve biodiversity and to achieve climate neutrality by 2050 (Circular economy action plan, 2020).

The new Circular Economy Action Plan provides compliance with the circular principles throughout the entire product life cycle. The action plan is oriented on the way products are developed, promotes the sustainable consumption and aims to prevent waste and keep used resources in the economy for as long as possible. The Action Plan introduces legislative and non-legislative measures, and includes the following directions:

- make sustainable products the norm in the EU;
- expand the opportunities of consumers and state buyers;
- pay special attention to those industries that use the most resources and have a high potential for the development of the CE (electronics, batteries and vehicles, packaging, plastics, textiles, construction, food products, etc.);
- reduce waste;
- make cyclicality work for people, regions and cities.

The new 2020 Circular Economy Action Plan (CEAP) contains 35 initiatives. As part of the implementation of the Action Plan, the Global Alliance on Circular Economy and Resource Efficiency (GACERE) has been launched, regulations on persistent organic pollutants in waste have been updated, European Commission adopted proposals on green claims and right to repair and adopted a number of other initiatives under the Action Plan (Circular economy action plan, 2020; Tsyrkuliarna ekonomika. Plan dii, 2022).

Theoretical aspects of the CE and circular business models are studied by international structures and organizations (European Commission, Ellen MacArthur Foundation etc.), as well as domestic and foreign scientists (Jonker J., Faber N., Haaker T., Churikanova O., Mytsenko I., Shebanin V., Reshetilov H.).

Shebanin V. and Reshetilov H. investigate the theoretical aspects of the CE of the region, determine the advantages of implementing circular principles for the sustainable development of the region. Churikanova O. emphasizes the importance of innovation for circular business models, and also defines the role of regions in their implementation.

Mytsenko I. and Khadzhynov I. develop a conceptual approach to the study of circular business models in European companies. Pavlikha N. and Kornelyuk O. systematize the experience of foreign companies in implementing various types of business models and suggest using such experience to increase the level of regional development. Yednakovska K. justifies the role of investments in the CE. Tsymbaliuk I., Pavlikha N. examine the problems of balancing local budgets to ensure the sustainable development of local communities. Ruda M. and Myrka Ya. analyze the current state and prospects for the development of circular business models in Ukraine.

The purpose of this chapter is to summarize the theoretical and practical aspects of the development of the CE and, based on the successful practices of using business models, to determine the prospects for the implementation of circular business models at the regional level. To achieve this goal, EU documents, websites of leading companies for the introduction of CE, scientific works of Ukrainian and foreign researchers were analyzed.

To determine the advantages, directions and features of the introduction of the CE at the regional level, it is necessary to:

- investigate the essence and principles of the CE;
- analyze the benefits of implementing the CE;
- to analyze the peculiarities of the functioning of circular business models;
- to investigate the development of the CE in the countries of the European Union;
- to analyze the prospects for the introduction of the CE;
- to investigate the influence of various factors on the prospects for the development of the CE;
- to determine the problems of introducing the CE in the region.

The CE replaces the consumerist linear concept of the economy. In the linear economy, raw materials are mined, which is transformed into a product and then this product is thrown away after use, i.e the process takes place according to the principles of "take-make-dispose". The additional value is obtained by using more resources and producing more products. In contrast to the linear economy, the cycles of all resources are closed in the CE. This affects the way value is created and preserved, production sustainability is increased, and various business models are developed (How is a circular economy different from a linear economy, 2019) The business model is a conceptual description of the directions of the company's operation, features of interaction with customers and ways of obtaining profits by the company (Biznes-model: shcho tse take, yii osnovni vydy i yak vybraty optymalnu, 2020). Different types of business models have common elements that are common to all business models. We depicted it in Figure 1.

Note that when developing a business model, compliance with the main structure is important.

Changes in the competitive environment, individual needs of firms and enterprises led to the emergence of various business models. Well-known types of business models are (Biznes-model: shcho tse take, yii osnovni vydy i yak vybraty optymalnu, 2020):

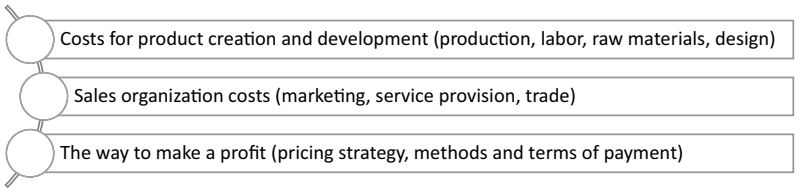

Fig. 1. The elements of the business model
(Business model: what is it, its main types and how to choose the best one, 2020)

- *promotional* (it has been used for a long time in the media space, in particular, to cover large volumes of traffic; for its effectiveness, it is important to find a suitable niche);
- *affiliate marketing* (the following schemes are used: trade-in banners on partner resources; payment for the transfer of a target potential client; payment for the user's performance of the target action. This business model is used by Ozon and Aviasales);
- *commission pay* (payment for the transactions of the participants of the agreement; it is used by real estate agencies, event companies, PR agencies, etc);
- *trade* (sales through distributors or using catalogs);
- *crowdsourcing* (when a large number of people unite; often this business model is combined with advertising);
- *manufacturer* (entrepreneur produces and sells goods on his own);
- *franchising* (using a proven, successful and effective business model of another company instead of creating your own);
- *"low-touch"* (minimum participation of the employee in the process of selling the product or service is provided, this allows for reduced prices);
- *«razor and blades»* (the sale of a durable good at a low price close or the cost price, and profit is made at the expense of the sale of disposable components for the product; for example, replaceable razor blades);
- *marketplace* (using of trading platforms for both goods and services with income from various sources).

A business model is a demonstration of the features of interaction between various entities (business, private individuals and the state). Local businesses that introduce circular initiatives in the organization of their production can use business models known in modern practice as the basis of their activities (Fig. 2, where B – *Business* (a commercial organization), C – *Consumer* and G – *Government* (state). The first letter of the abbreviation denotes the person who provides or sells services, and the second letter denotes the person who uses or buys them) (Osnovni vydy biznes-modelei z prykladamy, 2018).

The difference between circular business models and traditional ones is that circular models use already existing materials and products as inputs. The circular business models change the structure of product and raw material flows in the economy. They reduce adverse environmental impacts that arise from the extraction, use, and disposal of natural

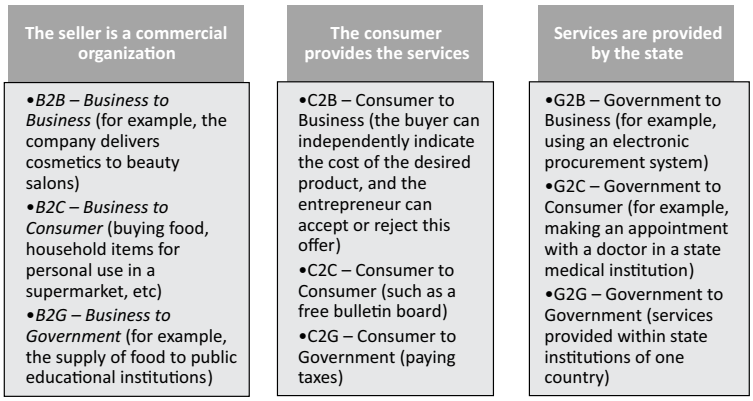

Fig. 2. Types of business models
(Main types of business models with examples 2018)

resources and materials. The use of circular business models helps to reduce the mining and use of natural resources and the accumulation of industrial and consumer waste. They are based on those activities that are necessary for the transition to a resource-efficient and CE. However, the environmental performance of circular business models depends on the scale of their use. OECD research results show that circular business models occupy a small share of the market. Areas such as processing, repair, joint use of reserve capacities and provision of services instead of products account for only up to 15% of production (Business Models for the Circular Economy: Opportunities and Challenges from a Policy Perspective, 2018).

M. Ruda and Ya. Myrka offer the following definition: "circular business model is a general term for completely different business models that seek to use fewer materials and resources for the production of products and services, and also want to extend the life of existing products and services through repair and recovery, end-of-life products through recycling, benefiting from the residual value of products and materials" (Ruda and Myrka 2020).

Figure 3 shows the classification of circular business models.

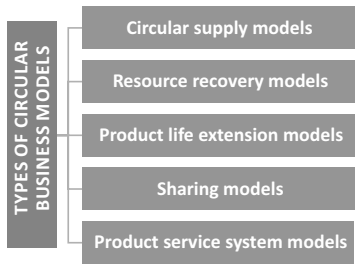

Fig. 3. Types of circular business models*
(Business Models for the Circular Economy: Opportunities and Challenges from a Policy Perspective, 2018)

Circular supply models use biological, renewable or reclaimed materials instead of traditional (often non-renewable) material resources. Thus, the demand for extraction of new resources and raw materials decreases (Business Models for the Circular Economy: Opportunities and Challenges from a Policy Perspective, 2018; Mytsenko, Khadzhynov 2022). An example of this type of business model is Renault, which became the first car manufacturer to start implementing the CE. In 2008, the Renault company created a subsidiary company, Renault Environment, which provides control over automotive waste and parts. As a result, their vehicles are 85% reusable and contain 95% end-of-life components. The share of recycled plastics in production must be constantly increasing. The company's profit from the application of the CE is 0.5 billion euros per year. In today's conditions of shortage of energy resources, it is useful to develop bioethanol production technologies. The raw material for this is agricultural waste. Such projects are used by the Finnish company North European Bio Tech Oy. This provides additional income, helps reduce emissions, create jobs, and strengthen national energy security (Ruda, Myrka 2020).

Resource recovery models recycle waste into secondary raw materials instead of disposal, thereby reducing the need to extract new resources. An example of successful implementation of such a business model is the company Van Werven (Netherlands), which works in the industry and production sector and is a service provider in the field of recycling secondary raw materials. The company processes construction waste, plastic and other waste into biomass. In 2019, the company processed 542,282 tons of waste, achieving a turnover of 100 million euros. The processing of this waste prevented CO_2 emissions by 216,974 tons. Another Dutch company, HKS, specializes in iron, metal and electronics processing. HKS processes 1.8 million tons of scrap per year; with annual sales of 500 million euros (data for 2020). RetourMatras works in industry and manufacturing and recycles discarded mattresses into new ones. The company recycles 1.5 million discarded mattresses a year that otherwise would have been burned. RetourMatras cooperates with companies such as IKEA, Renewi and Auping (Jonker et al. 2022).

Product life extension models are used by Fairphone and Peeze (Netherlands). Fairphone designs reliable phones that last longer by using replaceable modules that consumers can repair themselves. Peeze designs compostable coffee cups and bags, and makes coffee cups from sugar cane waste. Peeze's annual turnover is more than 16 million euros. Coffee is produced with a neutral CO_2 emission (Jonker et al. 2022). An example of product reuse is Algramo's system, which allows customers to refill household goods using smart dispensers and packaging with an RFID chip. In 2020, Algramo brought more than a quarter of a million packages to market, all of which were 100% reusable. Reuse is especially important for plastics because, unlike recycling, it preserves all the resources used in the production process (Pay for the product, not the packaging: Algramo, 2021).

Another good example of the CE is the experience of thredUP. Lots of clothes are thrown into landfills or burned every year. These are material losses, as well as energy, water and other resources used to produce textiles and clothing. The company thredUP

has created an online platform for buying and selling used women's and children's clothing. ThredUP buyers have access to high-quality clothing at low prices from over 35,000 brands. ThredUP sellers send clothing for free, and then thredUP employees process the goods, check quality, and perform price analysis, storage and placement. Customers can get access to brands that they would not otherwise be able to afford. They also earn money from clothes they no longer wear and feel good about reducing their negative impact on the environment. Keeping clothes in use as long as possible is a basic CE strategy in the fashion industry. In 2018, thredUP expanded its platform and provided access to brands and retailers (i.e. started to operate on a B2B model). The popularity of this business model is evidenced by the growth of the company's revenues from 129.6 million dollars in 2018 to 186 million dollars in 2020 (Keeping clothing in use to reduce waste: thredUP, 2022). Similar methods are used by the Vestiaire Collective resale platform for designer fashion. Vestiaire was founded in 2009 to allow individuals to buy and sell second-hand fashion items. The platform's developers also hope to cultivate circular thinking by encouraging their clients to buy better quality and take better care of their clothes to increase their resale value (A global peer-2-peer resale platform for designer fashion: Vestiaire Collective, 2022).

Company Teemill has developed a circular production process that turns old T-shirts into new T-shirts. Every product produced by Teemill is designed to be returned when it wears out or the customer no longer wants to wear it. Teemill's supply chain increases material usage, and reduces chemical and water consumption. Products are made in real-time. The customer makes an online order, specifying the color, size and design. The t-shirt is then printed and sent to the customer. Thus, the final product is produced only when it is needed (An open access, circular supply chain for t-shirts: Teemill, 2022).

Sharing models facilitate the sharing of underutilized products. Such a business model is useful for manufacturers with low utilization rates. It changed the relationship between producer and consumer through the use of C2C (consumer to consumer), B2C (business to consumer) models. Consumers interact directly with each other on online platforms. This model includes transport exchange platforms: the C2C relationship model is used by BlaBlaCar – an international online passenger search service, RelayRides – a car rental service, Airbnb – a platform for renting private housing (Business Models for the Circular Economy: Opportunities and Challenges from a Policy Perspective, 2018; Ruda, Myrka 2020). FLOOW2 is a platform where companies and organizations can share, rent and sell unused products, services, waste and materials or leftover materials. Together, users generated €129,154,864 in additional revenue in 2019. Peerby (Netherlands) is a consumer platform that allows you to borrow and lend items. 80% of items are used once a month or less. Peerby lists all the things you can borrow and rent in the area. Thanks to joint use, the need for production is lower (Jonker et al. 2022).

Rheaply uses a B2B model for efficient resource exchange. Rheaply's asset exchange manager allows users to track inventory, sell, donate, or lease items, and provides analytics in the form of a waste diversion report. Rheaply's founder, Harry Cooper, came

up with the idea of sharing equipment while still a student. In this way, he tried to solve the problem of underfunding of research departments of universities. Faculties that had surplus laboratory equipment or other things that were not used, gave it all to those departments that had needs. That's how he came up with the idea of creating an asset redistribution platform that would allow using excess resources. When the equipment is not in use, the Rheaply user can use the shared platform to place the items in another part of the enterprise, campus or school. Data on the platform is generated in the following ways: posting of messages by individual users on the site; batch processing and data loading through integration with ERP (enterprise resource planning) or AMS (automated manifest system). Since its inception, Rheaply's technology has enabled various organizations to save $1.5 million by leveraging valuable resources internally (Sharing valuable resources more effectively: Rheaply, 2021). Product service system models, where services are sold rather than products, improves incentives for more efficient use of the product, and thereby contribute to the frugal use of natural resources (Mytsenko, Khadzhynov 2022).

Signify, former Philips Lighting, is a multinational corporation that manufactures and sells electric lamps and lighting fixtures. Signify also offers Lighting as a Service (LaaS) to its customers. Under a LaaS contract, Signify installs, operates and maintains the lighting systems, and customers pay a monthly service fee for the lights. The lighting fixtures Signify uses under its LaaS contract are specifically designed to be easily repaired and reused. In this business model, the costs of purchasing equipment are replaced by monthly payments for productivity. Under the LaaS business model, Signify motivates to produce high-quality, durable and modular equipment that lasts much longer, thus conserving resources used in production. In addition, because the light is often professionally managed with the help of artificial intelligence and the Internet of Things, the system works more efficiently, resulting in significant energy savings. Signify's "circular" lights last 75% longer than conventional fixtures. Lighting consumes approximately 15% of global electricity demand and generates 5% of global greenhouse gas emissions. By implementing lighting-as-a-service business models, it is possible to increase the provision of light to those who need it, while avoiding large volumes of waste and greenhouse gas emissions. Signify has an annual revenue of €6.5 billion (2020).

The company MUD Jeans offers to use a pair of jeans for a fixed amount per month, after which the consumer is motivated to return the jeans. The company's turnover was 1.6 million euros (2020) and 45,000 pairs of jeans were sold (Jonker et al. 2022; Why buy light bulbs when you can buy light: Signify, 2021).

Gerrard Street has introduced a subscription service for its modular headphones. The modular design allows the reuse of 85% of components. The subscription model allows Gerrard Street to restore and recycle headphones at the end of their useful life. This business model aims to reduce the large amount of precious materials and electronic waste that end up in landfills. Gerrard Street can increase its revenue by maximizing the use cycles of each pair of headphones (Headphones as a service: Repeat, 2022).

Kaer supplies air conditioning systems for commercial and industrial properties in Asia. In 2013, the company shifted its business to Refrigeration as a Service (CaaS) with an offering called Kaer Air. Demand for space cooling is growing due to the expansion of the global middle class and rising air temperatures. According to the International Energy Agency, by 2050 air conditioning will account for 13% of global electricity consumption. To avoid this, the energy efficiency of buildings should be improved, and one way is to use product-as-a-service models such as Kaer Air. Kaer uses a modular design approach to add or remove air conditioning units as needed. The advantages of such a model are the reduction of electricity and installation costs. Thus, the CE can reduce electricity shortages (Cooling as a service: Kaer, 2021).

Circular business models are not separate from each other. Clear distinctions between the two are in theory, and practice firms may use combinations of business models. For example, use product maintenance, repair or remanufacturing system models at the same time. The successful implementation of certain types of business models by a firm can contribute to the adoption of corresponding business models by other firms. Recycling, reuse and repair have been around for a long time and are not a new phenomenon. But the diversity and complexity of these business models is growing. By closing resource cycles, circular business models can reduce the environmental footprint of economic production and consumption. Using the business model of resource recovery through recycling, it is possible to reduce greenhouse gas emissions by 90%. The recycling of end-of-life products will make it possible to reduce the extraction of natural resources and the generation of waste by up to 80% compared to the production of new goods.

Reducing the extraction, processing and transportation of natural resources also leads to energy savings. Sharing or renting existing products will reduce the environmental footprint. For manufacturers, retention of ownership may encourage the development of products that have a relatively long life and are more amenable to remanufacturing or recycling at the end of their useful lives. For consumers, paying for services instead of goods can lead to more careful use of things (Business Models for the Circular Economy: Opportunities and Challenges from a Policy Perspective, 2018).

As noted by M. Ruda and Ya. Mirka, circular business models introduce a clear differentiation between consumables and durable product components. In the traditional economy, producers often do not distinguish between them. But in the conditions of the new economy, the purpose of consumables is to use non-toxic and clean components. The purpose of durable components (such as metals and plastics) is to be reused or refurbished for other production applications. And the role of the consumer should be changed to the role of the user (for the long term). Business also requires a different way of thinking, which is not limited to the desire to sell a product (Ruda, Myrka 2020).

The development of the CE requires significant investment, both to support startups experimenting with new circular business models, and for large-scale projects. According to preliminary estimates, a minimum of $3.5 trillion per year will be needed to build

clean energy infrastructure by 2050. UNCTAD estimates that developing countries alone need $3.9 trillion a year to fully meet the UN's Sustainable Development Goals. Financial institutions are aware of their role in the development of the CE and provide the necessary investments and tools. By investing in the CE, they can gain a competitive advantage for themselves. For example, green bonds, which cover several key elements of the CE, have increased more than three hundred times. Companies can also issue "transition bonds" for financial technologies or new business models that support the transition to low-carbon alternatives. Financial services companies are consolidating their leadership positions by investing in the CE. As governments and other stakeholders increasingly recognize the importance of transitioning to a CE, they will put pressure on producers and encourage them to change the way they do business. A leader in the field of circular investments, ABN AMRO (one of the largest banks in the Netherlands) is actively looking for clients. At an early stage, ABN AMRO published a CE guide. The company has also released a set of tools to help facilitate the transition to these new business models. ABN AMRO, ING and Rabobank jointly developed and launched new financial guidelines that could serve as a standard framework for CE investments. These recommendations describe the new forms of necessary capital and explain the financial foundations of circular business models (Yednakovska 2022).

The obstacle is that traditional financing mechanisms and systems are often ill-suited to the transition to a CE. Banks may prefer conventional, more "safe" investments to financing circular projects that are considered more risky. Standards for defining circular companies, products or initiatives are insufficiently developed. One solution is to find partners to maximize the impact of cyclical offerings and share risks. This idea is the basis of the Circular Supply Chain Accelerator (CiSCA), which ING developed together with Accenture Strategy and Circle Economy to accelerate the circular economy. CiSCA supports large multinational companies as their small and medium-sized suppliers move towards circular business models (Yednakovska 2022).

Research by Bain & Company, conducted in conjunction with the World Economic Forum, shows that business leaders increasingly feel the need to adopt circular models. New entrants with innovative business models are emerging in many industries. They recognize that well-designed circular products and business models can accelerate growth, reduce costs and increase sustainability, preparing the enterprise for a low-carbon future. Developing cyclical products or strategies requires new ways of thinking. Most large companies have established broad sustainability goals, but not all have specific goals. And some managers believe that the costs for the transition to a circular way of production do not justify expectations about profits in the future. Despite the significant problems of the circular transition, leading multinational companies have notable successes in this. For example, consumer goods giant Unilever plans to produce 100% reusable or compostable packaging by 2025. Michelin plans to make 80% of its tyres from sustainable materials by 2048, and every tyre will be recycled. Leading companies also set specific revenue targets for circular products and services. Whoever builds a successful circular business model

now will gain a strategic advantage and be able to attract more new markets in the future (The Circularity Challenge: Expect Disruption and Get Out in Front of It, 2022).

Despite the significant environmental potential of circular business models, experts note the need to take into account certain risks (Business Models for the Circular Economy: Opportunities and Challenges from a Policy Perspective, 2018):

- increased production of biomaterials can cause soil changes and create additional pressure on ecosystems and biodiversity;
- as a result of recycling, the impact of harmful chemicals contained in secondary materials may increase;
- a consequence of shared consumption may be a shift away from ecological substitutes (for example, in the transport sector, where consumers may choose to share cars instead of public transport).

However, these warnings should not be seen as threats. To avoid negative consequences in the process of implementing circular models, a monitoring and control system should be followed, which will minimize risks.

Ukraine also joins the process of implementing the CE. Before the full-scale invasion of Russia, Ukraine had already made some progress in implementing circular business models. Ukrainian business models of circular supplies are not yet widespread, as their implementation requires significant investments, which only large companies have access to. It is difficult for smaller businesses to get financing. The regional investment policy envisages investing in innovation, but in practice, this is difficult to implement due to lack of funds. Business models of resource recovery are developing more successfully, in particular, the practice of using waste from some enterprises as raw material for others is used at manufacturing enterprises and processing factories. More common models are C2C (platforms for the sale of used goods), B2C (platforms for hotel and tourism reservation services), B2B. From the side of the region, in this case, a policy of support and stimulation of development is needed in order to cover the largest possible number of industries. European enterprises actively use business models to extend the life cycle of the product, are engaged in the restoration of household appliances, mobile phones, cars, and equipment. Ukrainian manufacturers of similar products do not use this practice, considering it time-consuming and expensive. Ukrainian business models of using a product as a service mainly use imported products, instead, in order to implement circular principles, domestic products should be used. To do this, it should meet European quality standards (Churikanova 2020).

Taking this into account, it is necessary to increase attention to the development of circular business models in Ukraine. This is relevant both for the post-war recovery of the economy and for the continuation of Ukraine's European integration course (Pavlikha, Korneliuk 2019). There is still no clear position on who should coordinate and stimulate the transition to the CE: the state, the region, or individual economic entities. In our opinion, the regional approach to the development of the CE should be deepened. Regions and communities that have received more powers as a result of decen-

tralization are characterized by greater homogeneity and have a better understanding of their own needs and capabilities (Antoniuk 2020; Pavlikha, Korneliuk 2019; Pavlikha et al. 2022).

In our opinion, an effective tool for the effective implementation of strategies and roadmaps for sustainable and smart development of regions and communities is the introduction of various CE business models. This is possible based on the development of public-private partnerships, the cluster form of labor organization and the stimulation of local business participation.

V. Shebanin and G. Reshetilov point out that the CE of the region cannot be implemented by a single institution or company on its own, because by its nature, CE promotes connections between individual stakeholders and sectors of the region (Shebanin, Reshetilov 2021). Therefore, the use of various forms of CE business models by local organizations will allow them not only to diversify their activities but also to take a direct part in achieving the goals of sustainable development of communities and regions in the form of public-private partnerships.

Churikanova O. emphasizes the need to develop the national and regional programs, taking into account the needs of the CE, and believes that the introduction of circular models is an issue that should be resolved at the state and regional levels (Churikanova 2020). The necessary financial resources providing is a prerequisite for business support on the way to circular development. Significant long-term investments are needed to carry out structural transformations in the regional economy (Tsymbaliuk et al. 2021).

The task of regional policy is also informational work to change the consciousness of producers towards the implementation of these business models to have a positive impact on regional and state environmental indicators. Support from the region can also take place by providing preferential business conditions to companies that choose circular development models (Churikanova 2020). For the implementation of circular initiatives, a solution option may be to find partners to share risks and focus on additional sources of funding. In particular, the creation of joint ventures with business entities from neighboring countries can create favorable conditions for the cCE of the regions. In the conditions of war, it is difficult to talk about investment attractiveness, however, the western regions of Ukraine are located relatively far from the war zone and can be considered safer. In addition, it is necessary to develop post-war recovery plans to rationally use future investments. Border regions have additional opportunities to attract investments using cross-border cooperation. An additional source of funding can be cross-border programs and projects, including the use of opportunities for Neighborhood Programs. Analyzing the projects implemented in Ukraine with the support of cross-border cooperation programs, it should be noted that some of them are aimed at ensuring sustainable development, in particular improving ecology, preserving forests and biodiversity, and restoring river ecosystems. However, it is necessary to work on the development of circular projects and business models in production activities. Significant long-term investments are needed to carry out structural transformations in the regional economy and to introduce

a CE in the production of industrial and consumer goods, construction, the transport sector, the food industry and the service sector. One of the directions should also be informational work to change the consciousness of producers towards the implementation of circular business models, spreading the culture of smart consumption and waste management among the population. This can be done by holding joint scientific and practical conferences, organizing training, publishing information materials, and working visits to enterprises in neighboring countries.

The successful implementation of the circular model of development of the national and world economy is possible under the condition of using various business models of the CE at the level of regions and communities, based on public-private partnership. We agree with the opinion of Shebanina V. and Reshetilova G. that the introduction of CE models will strengthen the sustainability of the region's development by reducing dependence on the inflow of resources. The development of the CE will allow the region to move towards a more sustainable, inclusive and low-carbon development model (Shebanin, Reshetilov 2021).

The transition to a CE requires systematic, joint actions of the consumer, business, state and government. The lack of state support at both the national and regional levels makes it difficult to implement circular initiatives. The presence of legal regulations, promotion of circular production and smart consumption, financing of projects, product quality improvement, monitoring and evaluation of progress and results are necessary conditions for the implementation of a CE.

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Public policy of forming pro-circular human behaviour

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Abstract. The object of the study is public policy of forming human behavior in the field of CE. The importance of implementing of CE is approved. Ukraine started waste management reform recently. It is investigated the main reasons of low level of recycling in Ukraine. One of them is low level of culture of waste sorting by the population. Many people don't have appropriate knowledge and habits how to sort waste. In this case, the formation of public policy, in which feedback awareness will be present, will make public services more effective. The main role of the government in this case is to find incentives and motivation to change people's behavior and reduce their impact on the environment. It explores the main groups of factors that make influence human behaviour regarding the CE principles. Economic factors have a significant influence on people's behavior. Social factors can be influenced or changed by public policy hardly. Since people's values and norms are created by the processes that shape their personality. The COM-B model was used to find appropriate undertaking which helps to change the behavior of the consumer of public services in the sphere of the CE.

Keywords: human behavior, circular economy, public policy, public service

Introduction

Today, the world is moving towards a CE. Products and materials, being in the last phase of their life cycle, can be transformed into new products and materials. The concept of a CE is based on the 4-R principles:

- Refuse:
- Reduce: the use of resources is reduced and the preference is given to renewable materials;
- Reuse: products are used as efficiently as possible;
- Recycle: by-products and waste are recovered for further use in the economy.

Thus, the effective use of limited natural resources is achieved, and environmental protection is also ensured.

Most of the countries of the European Union, the USA, China, Japan, South Korea and other countries have prioritized the development of the CE in their long-term strat-

egies. As a part of the Association Agreement between Ukraine and the EU, Ukraine undertook to harmonize national legislation with European legislation. This contributed to the adoption of the National Waste Management Strategy in 2017, which includes, in particular, the introduction of CE principles. And in June 2022 Verkhovna Rada of Ukraine passed a law on waste management reform. The main precondition of the waste management reform in Ukraine was the formation of a spontaneous landfill on a big territory of the country. Every year, Ukrainians throw away 400 million tons of municipal solid waste, of which only 3–6% are recycled. 93% ends up in landfills, which harms the environment and the health of residents. In Ukraine, only 7% of waste is recycled, while in most European countries it is at least 40% (Yevstigneeva 2022). The main reasons for such a low level of recycling are: the lack of proper infrastructure, the low level of participation of producers of goods in the recycling process (Hordiichuk 2021) and the low level of culture of waste sorting by the population. In addition, in Ukraine for the last 30 years there has been a system of "burying" waste, where there is a so-called monopoly of transporters who control the cash flow. But from the complex waste management service, which consists of collection, transportation, sorting, processing, and disposal of waste, only one is actually performed – removing waste (Yevstigneeva 2022).

The situation is significantly worsened by the waste of war. More than 325,000 tons of waste have been accumulated on Ukrainian land only from the destroyed Russian military equipment (Hubareva 2022). To this value is also added the waste of the destruction of residential and transport infrastructure, namely approximately 6,800 residential buildings were destroyed by Russian troops in Ukraine (Hubareva 2022). So, this problem of research is important today.

The theoretical and methodological basis of the research is statements of CE and behavioral economy. A CE turns goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. CE business models fall into two groups: those that foster reuse and extend service life through repair, remanufacture, upgrades and retrofits (Walter, Stahel 2016). It is suggested that a successful CE contributes to all three dimensions of sustainable development, economic, environmental and social. CE should adapt to the natural ecosystem cycles and utilize these in economic cycles by respecting their reproduction rates (Korhonen et al. 2018). Tools of CE implementation are developed by researches (Kalmykova et al. 2018). The first tool is a CE Strategies Database, which includes 45 CE strategies that apply to different parts of the value chain. The second is a CE Implementation Database, which includes over 100 case studies categorized by Scope, Parts of the Value Chain that are involved, as well as by the used Strategy and Implementation Level.

It explores operational behavioural factors that contribute to the adoption of CE practices in SMEs of emerging economies for the sustainable development of their societies. The study has developed an initial roadmap for identifying and examining the causes affecting the adoption of CE, along with the range and inter-relationship among the factors

instigating direct and indirect effects. Decision-makers and policymakers should consider the range of the factors' influence and should take appropriate actions on the identified significant causes and effect group factors for enhancing the adoption of CE in SMEs (Luthra et al. 2022).

The Pro-Circular Change Model is examined (Muranko et al. 2018). The Pro-Circular Change Model (P-CCM) is a novel theoretical framework, which uses a Theory of Planned Behaviour (TPB), Pro-Circular Values (P-CVs) and Persuasive Communication (PC) to identify and influence behaviors that can support the development of a CE. This model could help to change consumer and organizational behaviors to support the development of a CE.

The aim of this study is the formation of undertakings of forming human behavior in the field of CE. To achieve this goal, the following tasks were set: to investigate the role of consumer behaviour in forming of public service on environmental safety; to compare waste management and people's behaviour in Ukraine and other countries; to explore the particularities of population's behaviour on waste sorting; to examine the principals of public policy providing CE; to develop undertakings of forming the human behavior of public services in the field of CE.

The following scientific methods were used: analysis and synthesis, induction and deduction, modelling. Identification and analysis of relationships between factors and outcomes is studied.

Results and discussion

The state, also producers and consumers of products, play an important role in the development of the CE. The government can stimulate demand for circular products by adopting legislation, developing strategic programs and public services. Public policy makes an influence on businesses and consumers, in particularity how to operate and how to adhere to the principles of the CE.

Government and municipal authorities should take a comprehensive approach to waste sorting. Four factors that underlie the success of the CE: economic incentives, personalized tools, motivational communication and the application of legal norms. People need incentives to start and maintain proper waste collection, as well as the availability of appropriate means to do so. At the same time, there must be communication that explains why separate collection of waste is important. People must be aware of their responsibility in supporting the CE, in particular understand that if they do not comply, they will be punished.

For example, 87% of Canadian consumers recognize that their behavior has a direct impact on the environment. This understanding is reflected in their purchasing habits, since the same number of people prefers to buy products from companies that implement active CE measures (Gaetjens 2022).

There are many issues that need to be resolved on the way to achieving a high level of environmental awareness of Ukrainian citizens, residents of towns and villages. Among them, the most relevant are: finding incentives and motivation to change people's behavior and reduce their impact on the environment; the development of public policy with an orientation to the formation of a sense of joint responsibility of people or a sense of public duty to behave appropriately; forming the behavior of people who will respond positively to a certain environmental measure and will not return to their previous environmentally harmful behavior if it would be canceled. This will depend on the psychological processes involved in the individuals' response to the policy in question, on the extent to which the behavior is merely a response to external stimuli or is somehow internalized by the individual.

Obviously that the directive model of government management, in particular the mandatory norms for regulating environmental pollution standards, are becoming ineffective. People do not accept the calls of government bodies to reduce their consumption and start sorting garbage just because the government body asks for it. At the same time, the formation of public policy, in which feedback awareness will be present, will make public services more effective Therefore the possibility of using behavioral mechanisms in the CE should be considered. Behavioral mechanisms are a complex of behavioral tools that can be used to increase the effectiveness of the implementation and development of public policies (Kantsyr 2019). Incentive and behavioral public policy tools have been supported by governments in many countries around the world to improve the effectiveness of public policy. After all, at the point of contact between the person and the state, while the public service is received, that behavioral mechanisms and principles of behavioral economics can significantly improve this process, and as a result, the effectiveness public policy. Behavioral public policy is a policy that includes all methods and tools of public policy aimed at influencing individual and collective behavior using the principles of behavioral economics, psychology or neuroscience (Holger 2019). Behavioral economics is based on psychological features of human perception of economic processes. The world experience of environmental policies has examples of successful use of behavioral tools (in particular, stimulation and pushing in the right direction of choice) to increase their effectiveness. In Ukraine, behavioral tools are not sufficiently used in the development of public policy. As a result, the population of Ukraine at the level of behavioral perception is not ready to change their habits and the way they handle garbage, just because the government said so.

In Ukraine, the culture of the population regarding cleaning and sorting of waste has not yet been formed. On the one hand, eco-trends have become fashionable, and on the other hand, the number of landfills has increased. People continue to leave trash where they spend time without taking it to the trash can. Containers for sorting the most popular waste – paper, glass, plastic (PET), organics and hazardous waste (batteries, accumulators, mercury thermometers, lamps, medical waste, etc.) – are mostly used as a general tank for all types of waste. People do not want to sort, they do not know how, and they are not going to do it in the near future, because they do not understand the benefits for

themselves. Those who started sorting waste in the country became a little more. However, their share is quite small for achieving the desired results in sorting waste In order to determine the attitude of Ukrainians to waste sorting, a survey was conducted (National Research, 2021). 1,200 respondents living in Ukraine (with the exception of the occupied territories of Donbass and Crimea) were interviewed by the method of individual interviews. According to the results of the survey, it was found that an average of 40% of surveyed Ukrainians are ready to sort waste. Almost 46% of Ukrainians consider the lack of sorting tanks or their inconvenient location to be the biggest problem (Fig. 1). A third of those interviewed are convinced that there is no sense in sorting, since all garbage is mixed and taken to one landfill. More than 30% of respondents answered that they are not used to it yet. Almost half of the respondents believe that those who sort waste should pay less for its removal.

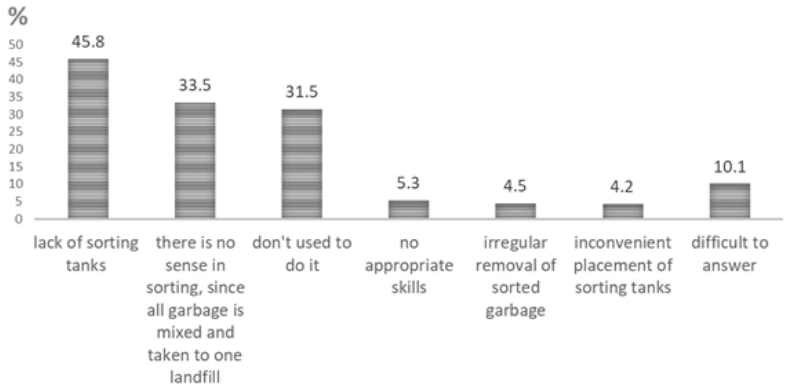

Fig. 1. Barriers for waste sorting in Ukraine (National Research, 2021)

Therefore, human behavior is often decisive in achieving set goals or implementing public policy. It is therefore important to identify, promote and leverage consumer behavior that supports the transition to a CE. Conversely, behavior that impedes circularity should be analyzed and the obstacles that people face in the implementation of public policy should be removed.

Based on the results of the survey on the readiness of Ukrainians to sort waste, it can be considered that the main directions of public policy for the formation of a CE are the development of infrastructure, information and educational activities, and the formation of a new habit of sorting waste among residents of villages and cities. Using basic incentive and motivation mechanisms, such as forming the right choice (various labeled bins) and dealing with expected errors (the specified information "don't put the following waste in this bin:...") would help public services of waste collection, sorting and disposal to be more effective (Kantsyr 2019). As an example, we can cite the experience of China,

where in 2019 they began to introduce mandatory waste sorting at the legislative level. For this purpose, the government placed sorting waste cans everywhere and volunteers who helped with advice. Fines were introduced for incorrect waste sorting, special mobile applications were created. And in order to popularize the collection of plastic, an opportunity was given to pay for travel in the Beijing subway with a plastic bottle. To do this, it was enough to collect about 20 used bottles, then to drop them into one of the machines in the subway – and you would receive a free ticket (Kachan 2020).

Economic factors have a decisive influence on consumer behavior. Social factors, preferences and beliefs make an impact on the individual psychology of the person. Therefore, they are the most difficult to be influenced or changed by public policy, since our values and norms are created by the processes that shape our personality (Fig. 2).

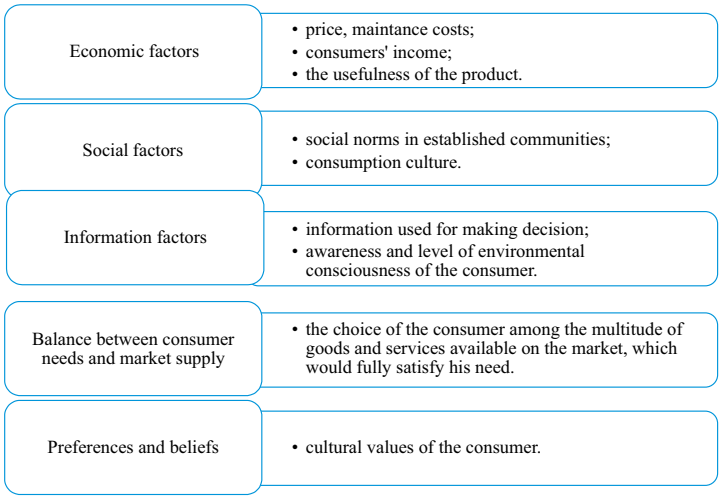

Fig. 2. The main groups of factors that determine human behavior regarding to the CE principles (European Environment Agency)

EU countries are already actively implementing measures to make consumer choices consistent with the CE. Recently, policymakers at both national and EU level have increasingly paid attention to economic factors and the match between needs and supply. Many countries have introduced tax credits for certain repair services in an attempt to make reuse options more economically attractive to consumers.

The potential options for inducing human behavior, which have to be explored, vary depending on the type of policy instrument and the level of intervention in consumer choice (e.g., from the simple information provision to restrictions and prohibitions). For a policy initiative to be effective, it must establish a clear link between the proposed measure and the factors that shape human behavior. For this purpose, the COM-B model can be used to change the behavior of the consumer of public services in the sphere of the CE.

The COM-B model for behavior change determines capability (C – capability), opportunity (O – opportunity) and motivation (M – motivation) as three key factors capable of changing behavior (B – behavior). Capability means a person's psychological and physical ability to participate in an activity. Opportunity refers to the external factors that make behavior possible. Finally, motivation refers to the conscious and unconscious cognitive processes that direct and inspire an individual's behavior (Fig. 3).

This model admits that behavior is influenced by many factors. Changes in behavior are caused by modification of at least one of these components. The COM-B model is particularly important when considering intervention methods because interventions must ensure the persistence of learned behaviors. We can educate, and inform in the purpose of building capability. We can persuade, and provide incentives and restrictions for the purpose of motivation boosting. We can change policies, rules, or something in the environment to enable of the opportunity (Tab. 1).

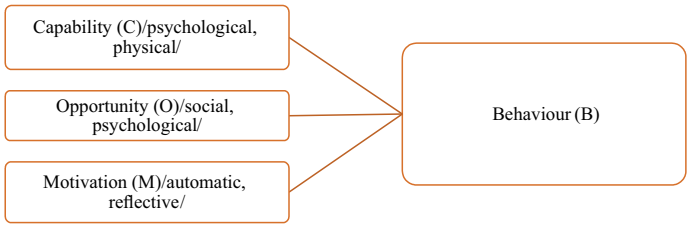

Fig. 3. COM-B model of human behavior formation

Table 1. Proposed undertakings to form the human behavior of public services in the field of CE

COM-B model	Undertakings
Capability (C)	1. Educational activities to increase general awareness of the impact of waste on the environment and human health. 2. Education of a thrifty attitude to the resources usage; clarification of the expediency of waste sorting and processing. 3. Providing information about types of waste suitable for processing, advantages, features and disadvantages of certain methods of waste management, consequences of their use in certain regions or communities. 4. Marking of containeri for collecting and sorting waste. 5. Organization of centralized removal of sorted waste.
Opportunity (O)	1. Formation of the regulatory and legal framework for ensuring the principles of the CE. 2. Introduction of financial incentives for residents' compliance with waste sorting rules.
Motivation (M)	1. Social advertising in mass media and outdoor advertising. 2. Motivational communication with people-leaders who inspire the desired behavior – to follow the rules of sorting waste. 3. The opportunity to see the real result of sorting garbage motivates people to change their bad habits.

Conclusions

In the field of waste management, Ukraine lags far behind developed European countries. Huge volumes of waste are generated in Ukraine every year, at the same time, there is currently no developed infrastructure for dealing with them. In addition, there is a very many other problems at different levels, such as a low waste sorting culture of the population, lack of appropriate knowledge and developed skills. The success of the CE is based on the understanding and conscious attitude of people to the collection and sorting of waste. The consumer behavior of public services in the field of the CE that is decisive in achieving environmental protection, compliance with the legislation on waste management, and the formation of the ecological culture of the country's population. Based on the COM-B model of the formation of human behavior, undertakings are proposed that would encourage the conscious handling of waste. The main tasks of offered undertakings are to change human behavior to reduce their impact on the environment.

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The experience of advanced countries in the use of circular economy and their practical implementation in Ukraine

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Abstract. The experience of advanced countries in using the CE and its practical implementation in Ukraine was studied. It was established that the results of the implementation of the CE should ensure the production of innovative products, the development and implementation of effective waste collection and sorting systems, the stimulation of the development of processing enterprises and recycling plants, the optimization of production, and the goal of zero waste.. It is well-founded that the CE stimulates the development and use of product designs that are easy to disassemble, repair, and recycle. It is also possible to stimulate the development of durable products using high-quality and wear-resistant materials. Furthermore, it has been proven that the CE stimulates the creation of favourable conditions for developing and implementing innovative circular enterprises and startups. It may include financial support, the development of special programs, and incentives for startups in the CE. Moreover, this, in turn, ensures the development and implementation of appropriate legislation, regulations, and standards that will contribute to the development of a CE and control over the use of resources and waste. In general, these areas of the CE can be implemented through cooperation between the government, the private sector, academic institutions, and civil society to promote sustainable development and conservation of natural resources.

Keywords: circular economy, cost of resources, recycling of resources, principles of circular economy, circular supply

Introduction

Circularity means efficient (re)use and processing of resources, materials, and products in closed cycles. It is an economic model that represents sustainable development: a transition from a linear model based on consumption and disposal to a model in which the lifetime of products is as long as possible and materials and waste are minimized. The CE can be implemented holistically, but at the same time, the features of the CE are at the core of every urban system.

The CE is about protecting our natural environment, waste disposal, and reducing emissions. It creates enormous opportunities for our economy by improving productivity and opening up new markets and for our communities by providing local jobs and access to the goods we need. A more CE is also more self-sufficient; it reduces our dependence on imported goods and materials and increases economic sustainability (Shynkaruk 2021). However, it requires political and legal support

According to Korhonen, Nuur, Feldmann, and Birkie (2018), definitions that focus on systemic change often emphasize three elements, which are further explained below: closed loops, renewable energy, systems thinking.

The CE involves the creation of so-called durable products and will practically increase the efficiency of resource reuse in the industrial sector.

Results and discussion

The CE is very important for the global community. The transition to a CE will likely occur faster than previous transformations. It has political support; for example, the EU is committed to moving towards a CE to make Europe cleaner and more competitive. Also, unlike previous changes that often faced public resistance, there is increasing societal pressure for companies to become climate-neutral (Henrik Hvid, 2022).

A CE, an economic system that eliminates waste and pollution by design, keeping materials in the system where possible through reuse, repair, and recycling, is an effective way to reduce emissions caused by cities without affecting the quality of life or harming business. Transitioning to a CE will create climate-resilient cities with economic, social, and environmental benefits. The transition to renewable energy sources will reduce greenhouse gas emissions by 55%. The transition to a CE could deprive the remaining 45% needed to achieve the UN climate goals (Karamitsos et al. 2022).

A CE preserves and recovers as much of the value of resources as possible by reusing, repairing, renovating, recycling, repurposing, or recycling products and materials (Circular Economy, 2022). The successful implementation of the CE is not an end in itself. However, it combines the protection of climate and resources with cultural changes, increasing competitiveness and independence from raw materials, as well as creating jobs and local value within the framework of the implementation of the concept of sustainable development.

The CE has become a vital priority of the policies of leading economies, as it solves the relevant systemic climate crises and ensures the rational use of resources, biodiversity, and global health at the same time, if it is implemented consistently and on time in the sense of a holistic, systemic solution. 2018 the European Union and China signed a Memorandum of Understanding on Cooperation in the Circular Economy. It helps pave the way for a global transition to a more inclusive economic system that works for businesses, people, and the environment. China implements the CE in establishing and developing new industrial parks, which must comply with the requirements of the CE, etc. 2018, the Circular Economy Promotion Law (first published in 2008) in China was revised and updated. The country has implemented a resource recycling system, one of the goals of building a prosperous society and implementing the national strategy by prioritizing internal circulation (for example, internal consumption). It is partly due to the instability of international trade and is the result of the traditional CE strategy (Bleischwitz et al. 2022). Therefore, there are already specific positive results of following the principles of China's circular economy, which are as follows: a reduction of energy consumption and water consumption per unit of GDP by 13.5%and 16%, respectively, compared to the level of 2020.

Germany is forming a CE due to the revitalization of material flows and the availability of materials for companies. Within the road map framework (Bochko 2022), a general and perspective structure of actions has been developed, which clearly defines the essential requirements for transformation in politics, business and science. Several concrete action recommendations of Germany's Circular Economy Roadmap are already reflected in the coalition agreement of the new federal government. In this context, the CE offers Germany a comprehensive system that can combine economic and environmental policies and significantly contribute to achieving the goals of the European Green Deal (especially climate neutrality by 2050). The roadmap focuses on forming a consistent shared target vision of the CE by 2030 and formulating specific recommendations for actions (Circular Economy Roadmap for Germany acatech, Circular Economy Initiative Deutschland, 2021).

Scotland implements CE projects thanks to a particular investment fund. Over the past 20 years, Scotland has made significant progress in reducing waste and resource recycling emissions. It has taken significant steps to tackle Scotland's throwaway culture and promote recycling. The draft law expands the levers at its disposal, and the Roadmap defines actions to accelerate progress within the existing competencies. We note that specific actions are necessary to transition to a fully CE. In particular, the National Strategy of Economic Transformation for ten years was published in November 2021 (Shynkaruk). The Strategy aims to maximise Scotland's economic potential to create a more prosperous economy and society, highlighting the opportunities a CE can provide. Finland was the first in the world to develop a national road map to transition to a CE (Bayra 2021).

The CE program of the Finnish government, published in early 2021, is an important milestone in Finland's CE work. Finland aims to limit the use of natural resources

by 2035 and has committed to achieving climate neutrality by 2035. Finland has world-class know-how in the development of innovative bioproducts and technologies. Modern Finnish pulp mills are versatile bioprocessing centers that offer attractive ecosystems and investment opportunities for developing new products and technologies. Such goals are possible only when economic growth and well-being are no longer based on the wasteful use of natural resources. According to a 2021 Sitra survey, 82% of Finns believe that the CE creates new jobs and prosperity in Finland. Countries willing to take a similar step can take Finland's example and develop their plan to move their people and resources to a more sustainable future (Järvinen, Riku Sinervo 2021).

Finland has world-class know-how in the development of innovative bioproducts and technologies. The industrial exploitation of woody biomass is transforming, creating compelling new business opportunities. Modern Finnish pulp mills are versatile bioprocessing centres that offer attractive ecosystems and investment opportunities for the development of new products and technologies. Today's biotechnology-based forest industry is focused on the production of biofuels and other value-added wood-based products. China – implements the CE in the creation and development of new industrial parks, which must comply with the requirements of the CE, etc. In 2018, China's Circular Economy Promotion Law (first published in 2008) was revised and updated. In China, a system of resource recycling has been introduced as one of the goals of building a moderately prosperous society. A comprehensive "Dual circulation" (domestic-international circulation) was proposed in 2020 as a national strategy to reorient China's economy by giving priority to domestic circulation (such as domestic consumption). This is partly due to the instability of international trade and is a result of the traditional CE strategy (Bleischwitz et al. 2022). Therefore, there are already certain positive results of adhering to the principles of China's CE, which are as follows: reduction of energy consumption and water consumption per unit of GDP by 13.5% and 16%, respectively, compared to the level of 2020.

Achieving a utilization rate of 86% for stalks, 60%for solid waste, and 60% for construction waste. Disposal of 60 million tons of waste paper and 320 million tons of steel scrap. Production of 20 million tons of processed non-ferrous metals. An increase in the value of the output of the resource processing industry to 5 trillion yuan (US$773 billion). Building a resource processing industry system and increasing the efficiency of resource use. Building a waste recycling system and developing a recycling-oriented society. Deepening the development of the agricultural CE and establishing circular agricultural production: a Chinese briefing on July 16, 2021 (China's Circular Economy: Understanding the New Five Year Plan, 2021). The Netherlands actively uses the principles of the CE. In particular, Amsterdam has been implementing a CE since 2015, developing the food and construction industries, and since 2019, it has introduced the "Doughnut Economy" (Raworth 2017).

The "doughnut Economy" concept in Amsterdam consists of nine ecological levels. Among them are climate change, air pollution and loss of biodiversity. In addition, there

are twelve social funds related to, for example, education, health care, and gender equality. Using the "doughnut model" for a city involves calculating the city's current impact on both these nine environmental sectors and twelve social factors (Ministry of Infrastructure and the Environment/Ministry of Economic Affairs, 2016). Focusing on three priority value chains (biomass and food, construction, and consumer goods), 17 circular policy initiatives were developed in Amsterdam. They cover a variety of ecosystems, including circular food production in urban and rural areas; prevention of excessive consumption and minimization of the use of fast-changing consumer goods; and the circular development of buildings through flexible zoning and regenerative design (the Netherlands is 24.5% circular). In Denmark, the industrial aggregation approach is used for CE. An industrial association or agglomeration is simply merging certain companies, mainly through joint venture-style cooperation (JVSC). The first step towards a CE in Denmark is industrial pooling, which includes processes in the biological and technological domains through which combined suppliers and consumers coexist to achieve material and energy efficiency through economies of scale and scope (Halog, Anieke 2021). Denmark is already an important player in the export of waste, technology and energy solutions. The Danish initiative was launched in collaboration with Industriens Fond, DI – Dansk Industri, DTU – the Technical University of Denmark Sustain, Teknologisk Institut, DDC – Danish Design Center, Lifestyle & Design Cluster and IDA.

One of the first steps was a project initiated and implemented by the Ellen MacArthur Foundation to create a toolkit for policymakers to describe a methodology for developing CE policies. The project examines the possibilities of the CE from the perspective of the country and politicians. It aims to provide politicians with a practical toolkit that will help accelerate the transition to a CE. The results showed that the introduction of cyclical economic principles in the Danish economy: increase GDP by 0.8–1.4%; reduce the consumption of selected resources by up to 50%; reduce carbon dioxide emissions in Denmark by 3–7%; create 7,000–13,000 jobs by 2035. In Denmark, more and more companies are realizing the significant growth opportunities in the CE. Danish companies develop innovative solutions for the CE that contribute to the environment, the climate and the economy.

Some companies improve resource efficiency and reduce their environmental impact by reducing the use of minerals and raw materials, ensuring responsible sourcing of raw materials and/or reorienting consumption towards renewable resources. Kaffe Bueno is a Danish bioscience company that processes coffee by-products into active and functional ingredients for personal care, nutraceuticals, biomaterials, food, and beverages. The world's largest marketplace for surplus food helps people fight food waste in their local communities by connecting them to restaurants and grocery stores with surplus food and ingredients through an app. Founded in 2016 in Copenhagen and now in 17 countries, Too Good To Go saves over 250,000 meals daily. The B Corp Movement is a non-profit network transforming the global economy to benefit all people, communities, and the planet. Based on their standards and certification process, their network drives economic

system change to support their collective vision of an inclusive, equitable, and regenerative economy. Although Ukraine still needs to develop a systematic strategic vision for the development of the CE, general declarative provisions such as increasing resource efficiency, stimulating innovation, implementing the provisions of the CE, and increasing effective waste management are characteristic.

Ukraine, too, has already taken specific steps toward implementing the components of the CE. In particular, the "Concept of Sustainable Development" was approved, which not only correlates with the 17 goals of sustainable development of the UN but also encourages the country and business to implement innovations and use the principles of "3R" (reduce, reuse, recycle). (United Nations Centre for Regional Development, 2005) However, it is worth noting that in Ukraine, in the last two years, there have also been the first effective projects in the private sector, for example, projects for the creation of biogas complexes, the processing of fallen leaves into paper, the production of meal from the waste of non-alcoholic beer production, the production of glass frames from coffee grounds, etc. However, new unique projects related to the CE in Ukraine are quickly being taken over by foreign partners and investors. Therefore, the state should, within the framework of implementing the sustainable development strategy, more systematically develop a clear plan for implementing best practices for the development of the CE in the country.

Therefore, for the introduction and development of the CE in Ukraine, we offer the practical implementation of the following business models:

1. Circular supply that aims to use fully recycled or biodegradable materials to replace single-use resources.
2. Recovery of resources ensures the recovery of valuable resources or obtaining energy from products of secondary raw materials.
3. Extending the product's life by extending the life cycle of products and components through their repair, modernization, or resale.
4. Development of a platform for sharing products and components through sharing, access, or ownership.
5. Application of servitization, i.e., supplementing products with service offers and/or implementation while remaining the owner of these services. The implementation of CE development directions for Ukraine is proposed to be carried out by the following entities: the Commission for the Implementation of Reforms, the Ministry of Economy of Ukraine, the Ministry of Energy of Ukraine, the Ministry of Development of Communities and Territories of Ukraine, the Ministry of Digital Transformation of Ukraine, the Ministry of Finance of Ukraine, the Ministry of Reintegration of Temporarily Occupied Territories of Ukraine, the Ministry of Strategic Industries of Ukraine, and the Ministry of Agrarian Policy and Food of Ukraine (Tab. 1)

Table 1. Implementation of CE development directions for Ukraine

Types of work / Subjects of implementation	Waste processing system	Complex disposal of solid waste	Recycling projects	Industrial park development projects	Innovative projects for economic recovery	Actions to improve waste processing	Special measures for the management of the chain of disposal and processing of waste	Actions on the promotion of green transformation	Income from the implementation of actions
Reform Implementation Commission									
Ministry of Economy of Ukraine									
Ministry of Energy of Ukraine									
Ministry of Development of Communities and Territories of Ukraine									
Ministry of Digital Transformation of Ukraine									
Ministry of Finance of Ukraine									
Ministry of Reintegration of the Temporarily Occupied Territories of Ukraine									
Ministry of Strategic Industries of Ukraine									
Ministry of Agrarian Policy and Food of Ukraine									

The activities of the above entities should contribute to the country's sustainable development by reducing the negative impact on the environment and improving economic indicators.

Conclusions

The results of implementing the CE should ensure the production of innovative products, the development and implementation of effective waste collection and sorting systems, the stimulation of the development of processing enterprises and recycling plants, the optimization of production, and the goal of zero waste. It will reduce the amount of waste, efficiently use resources, and create new jobs. The CE encourages developing and

using product designs that are easy to disassemble, repair, and recycle. It is also possible to stimulate the development of durable products using high-quality and wear-resistant materials.

It is also worth noting the stimulation of the development of platforms and networks that facilitate the exchange and sharing of goods, services, and resources. For example, the development of platforms for sharing used electronics, clothes, tools, etc., as well as cars or spaces.

The CE stimulates the creation of favorable conditions for developing and implementing innovative circular enterprises and startups. It may include financial support, the development of special programs, and incentives for startups in the CE. And this, in turn, ensures the development and implementation of appropriate legislation, regulations, and standards that will contribute to developing a CE and control over the use of resources and waste.

In general, these areas of the CE can be implemented through cooperation between the government, the private sector, academic institutions, and civil society to promote sustainable development and conservation of natural resources.

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Concept of circular economy in Ukraine

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Abstract. As a result of the implementation of the CE in Ukraine, the main principles of the CE became clear and the main advantages were determined. It was established that Ukraine significantly lags behind wealthy European states in terms of waste management. The policy of the EU and Ukraine in the sphere of the CE was approved, considered as a new one, recommendations were given to Ukraine regarding the transition to the CE, taking into account the best European practices. Implementation of the practice and principles of the CE in Ukraine will help preserve the potential of resource conservation, speed up the transition to a CE, protect biodiversity and stimulate innovation. The new safe model of the economy will provide an opportunity for Ukraine to increase economic indicators, improve the population's well-being and reduce the negative impact on the environment. The CE offers economical use of raw materials, efficient consumption of available resources, and reduction of waste generation.

Interesting opportunities for the CE of the agricultural sector of Ukraine are presented. The main component is greening in order to ensure the reduction of the load on the environment and to promote the innovative development of the agro-environmental sphere. The main points of the adaptation of the CE of Ukraine by the Circular Economy Action Plan (CEAP), which is aimed at accelerating the transformational changes necessary for the European Green Deal, are reflected.

The ideas of resource recovery, processing of used raw materials and transition to renewable energy sources are presented, which form the basis of CE. Management of resources, in particular waste, can be carried out in a new, more logical way according to the CE. In this regard, it is important to note that Ukraine lags far behind wealthy European countries when it comes to waste management. A huge amount of garbage is generated in Ukraine every year, but currently there is no infrastructure to deal with it. In general, the strategy of Ukraine in the field of CE should be developed and implemented thoroughly, taking into account global trends and focusing on local issues.

Keywords: economy, circular economy, adaptation of circular economy, waste

Introduction

The evolution of Ukraine's relationship with nature is a long and complex story. The number of the planet's population is constantly growing, and its needs are growing along with it. Humanity consumes more and more natural resources (ores, minerals and biomass) every year. Industrialization has helped people overcome poverty and improve the quality of life, but at the same time it has created conditions in which people cannot exist. It is necessary to create a system in which environmental protection will help economic growth. The world needs thorough transformations: safe production and rational consumption.

Today, in most countries of the world, prevails a linear system of economy – when resources are extracted, processed and turned into waste that has no further use. However, such irrational, incorrect, thoughtless use of natural resources and material resources created by man hurts the state of the environment and humanity as a whole. Such reasons have a significant impact on the need to transfer the linear system of the economy to newer, more progressive models, which are based on the rational use of the country's resource potential and nature management, the improvement of the quality of life of the country's population and the formation of a noospheric worldview at all levels of society in the context of ensuring sustainable development. Such changes take place by introducing a circular (cyclical, circular, circular) economy into the production practice of economic activity. And the CE is gaining momentum every day.

Research on the creation and development of the CE is particularly important in the current economic world, as evidenced by the attention of many experts and active scientists in this field.

According to Sauvé, S., Bernard S., Sloan P. the CE is an economy in which things are produced and consumed in closed systems of flows of material resources that take into account their impact on the environment, especially the production of waste. According to them, the main principles of the CE are the reduction of resource consumption and environmental pollution throughout the product's life cycle (Sauvé et al. 2015).

Authored by Peter Mitchell, Head of Economics at WRAP, for the London Sustainable Development Commission, London Waste and Recycling Board and the Greater London Authority, the CE is crucial to preserve resources as long as possible, as well as to maximize the value of goods and materials by using them as long as possible before recovery and reuse (Mitchell 2015).

The transition to this paradigm, according to Bastein T., Roelofs E., Rietveld E., Hoogendoorn A., is a crucial condition for a stable industrial system that promotes the formation of new types of economic activity, increases competitiveness and creates jobs (Bastein et al. 2013).

When defining the concept of CE, some scientists use the basis for the idea of managing material resources and include other factors. For example, P. Heck underestimates the use of renewable energy compared to waste management and recycling. He believes

that in order to ensure the sustainable production and supply of renewable energy, the transition to a CE will need to be resolved (Heck 2006).

Su B. and others point out that the scope of responsibility of the CE is increasingly expanding to include additional areas such as energy efficiency, land and water management in addition to issues, related to the management of the material base (Su et al. 2013).

According to Ghisellini P. and others, the radical reformation of all processes during the life cycle of goods with the help of advanced technologies has the ability not only to recover materials and energy, but also to increase the standard of living of the population as a whole (Ghisellini et al. 2016).

The E. MacArthur proposed one of the most common definitions, referring to the CE as an industrial system that is capable of self-renewal. Such a system aims to eliminate waste using the latest materials, products, systems and business models. This is achieved by replacing the idea of a limited period of use and transitioning to the use of renewable energy, reducing the circulation of toxic chemicals and making it impossible to reuse resources. Simply put, the interpretation of the CE involves the classification of materials into two different groups:

- materials of biological origin that can be reused as raw materials in the biosphere (for example, forestry products);
- technical materials that cannot be easily decomposed and reused as inputs in the biosphere (eg plastics and metals).

Through careful planning, administration and technical innovation, the CE aims to make the most of these two categories of materials in this gap. The main goal is to maintain efficient flows of resources, including labor, information, and energy, to continuously replenish social and natural capital (Ellen MacArthur Foundation, 2013).

Preston F. defines the CE as a method of changing how resources are used in the economy. Using these techniques, industries produce valuable materials that can be used in other operations such as upgrading, reusing, or repairing a product (Preston 2012).

Research methods were used to achieve the objectives: comparison, synthesis, and analysis, as well as system-structural, analytical, statistical and regression research methods.

Results and discussion

More than 30 years have passed since the "circular" economy was first mentioned, but it was only after its official launch in the European Union that its popularity grew rapidly and world leaders recognized its importance for achieving sustainable development. On March 11, 2020, the European Commission adopted the Circular Economy Action Plan (European Commission, 2020). The plan aims to reduce consumption in the EU and double the reuse of resources over the next few decades, while stimulating economic growth. The implementation of the measures of this Plan can increase the EU GDP by an additional 0.5% by 2030 and create about 700,000 new jobs (Circular Economy Action Plan, 2020).

The main expected benefits from the implementation of the CE are shown in Figure 1.

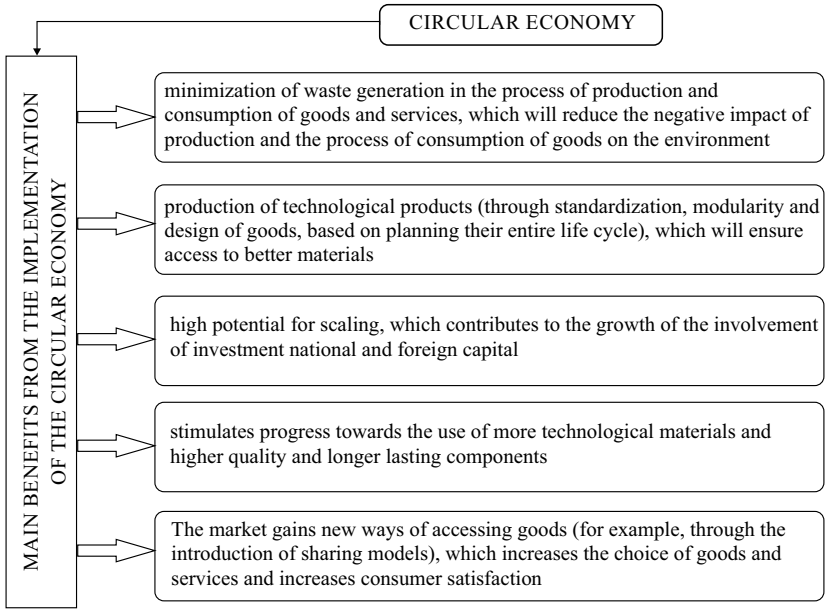

Fig. 1. The main benefits from the implementation of the CE

The CE is a model of production and consumption that involves sharing, renting, reusing, repairing, renovating and recycling existing materials and products for as long as possible (Mark 2018). In our opinion, the main vector principles of the CE are: reduction of the amount of waste, reuse of products and materials, and also, and what is very important, restoration of nature.

In this regard, the European Commission is considering the establishment of sustainability principles and other appropriate ways of regulating the organization of the CE in the following aspects:

- improvement of product durability, the possibility of reuse, modernization and repair, solving the issue of the presence of dangerous chemicals in products, increasing their energy and resource efficiency;
- increasing the content of processed products in products, while ensuring their effectiveness and safety;
- the possibility of repeated production and high-quality processing;
- reduction of carbon emissions into the environment;
- limitation of one-time use and prevention of premature aging;
- introducing a ban on the destruction of unsold durable goods;

- promoting product-as-a-service or other models where manufacturers retain ownership of the product or responsibility for its performance throughout its life cycle;
- mobilization of the potential of digitization of product information, including such solutions as digital passports, tags and watermarks;
- rewarding products based on their various sustainability indicators, including by linking high levels of productivity to incentives (Circular Economy Action Plan, 2020).

Industrial enterprises consume nature's resources for the production of products without caring about the further disposal of waste, which leads to the degradation of natural systems and environmental disasters.

To solve socio-economic and environmental problems, it is necessary to achieve sustainable production and consumption. There is an urgent need to switch to a CE model due to the economic consequences of environmental degradation or the lost economic opportunities of those industries that do not use recycled materials. The CE is a self-regenerating economic system that allows for the most efficient ecological use of resources at all stages of production and involves the entire value chain of goods and services to create a closed cycle. Methods of multiple use of materials are considered. All waste generated in the production process is reused in other links of the value chain, which avoids environmental pollution. The new safe model of the economy is an opportunity for Ukraine to increase economic indicators, improve the welfare of the population and reduce the negative impact on the environment. The CE offers economical use of raw materials, efficient consumption of available resources, and reduction of waste generation. The CE goes beyond the production process and is integrated into the country's economy, as the main strategy for finding energy in creating a closed cycle of resource use. The implementation of such an economy involves the construction of new business models based on the repair, reuse, and replacement of products to prevent the generation of waste as much as possible. There are five main components:

1. Product design – designing products so that they have a longer useful life and the possibility of repair, dismantling, reuse or remanufacturing.
2. Production processes – all resources are used as efficiently as possible.
3. Consumption of resources – promotes responsible consumer choice through product labeling with information on the impact on the environment.
4. Waste management – waste prevention, preparation for reuse, recycling and recovery, with priority given to prevention and reuse.
5. Transformation of waste into resources – expanding the market of secondary raw materials and reuse.

The motto of the CE is to ensure the maximum efficiency of each process in the life cycle of goods or services. When switching to such an economic model, maximum changes are expected: from the choice of raw materials, and methods of manufacturing products to the use of by-products of one production as a full-fledged raw material for another.

This will avoid the loss of the value of materials and products, scarcity of resources, sharp rise in prices, accumulation of waste, environmental degradation and climate change, and will contribute to the development of innovations, the growth of the number of jobs and the increase of the competitiveness of the economy. Ukraine chose a green course in which CE is the main component. It will continue to stimulate the development of the national economy, improve people's health and well-being.

Implementation of the practice and principles of the CE in Ukraine will help preserve the potential of resource conservation, speed up the transition to a CE, protect biodiversity and stimulate innovation. Economy, rational use and effective consumption of resources are the basis of a successful and sustainable business. Enterprises will receive several advantages by joining the green course of Ukraine.

In Ukraine, the development of the CE is hindered by several factors, the main of which is the lack of appropriate legislation and the support of investors who are ready to invest in waste processing projects. Therefore, there are very few Ukrainian enterprises operating on the principles of CE. In addition, they all, as a rule, work with the involvement of foreign capital. Important program documents in the field of climate policy in Ukraine are the National Waste Management Strategy until 2030 and the National Waste Management Plan until 2030, the State Environmental Policy Strategy of Ukraine for the period until 2030, the Concept of State Policy Implementation in the Field of Climate Change for the Period until 2030 and the plan for its implementation. The National Waste Management Strategy (On the approval of the National Waste Management Strategy in Ukraine until 2030, 2017), approved in 2017, is a document to initiate the waste management reform in Ukraine, the aim of which is to approach the EU directives in the field of waste management, and includes several measures, starting with the development and adoption of relevant legislation, for specific types of implementation of the system of extended responsibility of the waste producer, the development of technical regulations for waste management, ending with the development of regional plans for waste management and the construction of waste processing facilities. The National Waste Management Plan until 2030, adopted in 2019 (the approval of the National Waste Management Plan until 2030, 2019), is a detailed "roadmap" for the implementation of the national strategy of creating a waste management system in Ukraine based on EU standards. This document contains a package of tasks for each type of waste – from the adoption of the necessary legislative framework to specific measures for collection, treatment, and disposal.

The Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period Until 2030" (About the Basic principles (strategy) of the state environmental policy of Ukraine for the period up to 2030, 2019) adopted in 2019 is an updated document designed to help overcome not only the consequences of environmental problems but also the causes of their occurrence. This system of strategies and measures is the basis for its creation, it functions successfully in the EU countries, and is the basis for the formation of new environmental policies, the carrier of which is a resource-saving, cyclical and low-carbon economy.

In 2016, the Concept of the implementation of the national policy in the field of climate change until 2030 (the approval of the Concept of implementation of state policy in the field of climate change for the period up to 2030, 2016) was approved to improve the national policy in the field of climate change for the sustainable development of the country, legislative activity and ensuring economic, energy and environmental security. and improving the well-being of citizens. Institutional prerequisites for the gradual transition to low-carbon development under the conditions In 2017, the Action Plan for the Implementation of the Concept was adopted, which provides measures for the formation, regulation and implementation of national policy in the field of climate change and the gradual transition to low-carbon development.

However, all the displayed legal acts on the regulation of the CE in Ukraine do not comply with the EU directive on waste management, the use of spent batteries, accumulators, waste electronic and electrical equipment, and waste oil products. There are also no clear rules and laws regarding waste disposal, mining waste disposal, decommissioning of vehicles. The existing regional environmental plans provide for the construction of new landfills, which contradicts the principles of CE. According to the Circular Economy Action Plan (CEAP), which is aimed at accelerating the transformational changes necessary for the European Green Deal, based on the principles of the CE, which have been actively implemented since 2015, Ukraine should adapt to the CEAR. The main points of adaptation are shown in Figure 2.

The most well-known both in foreign and national practice of companies providing services in the field of strategic management of by-products and waste is the company Recycling Solutions, which began its activities in 2012 with a pilot project to study the possibilities of reusing microspheres (a by-product of burning coal at TPP) in the oil and gas and chemical industries, as well as in the production of refractories. Recycling Solutions is a company for strategic management of by-products and waste. The main mission of Recycling Solutions is to implement the principles of CE. With the help of advanced practices, the company strives to ensure the cyclical use of natural resources and industrial waste, taking care of the environment and improving ecology. Recycling Solutions offers its customers a service for the effective management of their secondary resources, implementing the principles of the CE in their daily activities. This approach involves the maximum extraction of secondary resources from existing by-products and waste for further processing and sale in the areas of consumption.

Today, Recycling Solutions helps more than 20 enterprises to earn from waste. Every year, the company processes more than 2.2 million tons of waste from the Ukrainian industry and sells them in 22 countries. The company studied promising directions and over ten years of work invested more than 15 million US dollars in the creation of processing enterprises for waste from the thermal power, metallurgical and coke chemical industries (Recycling Solutions, 2022). For many years, crystalline ammonium sulfate (a by-product of Ukrainian coke plants, which can serve as a raw material for effective mineral fertilizers) was exported for processing to Turkey, Bulgaria or Serbia, after which it was partially

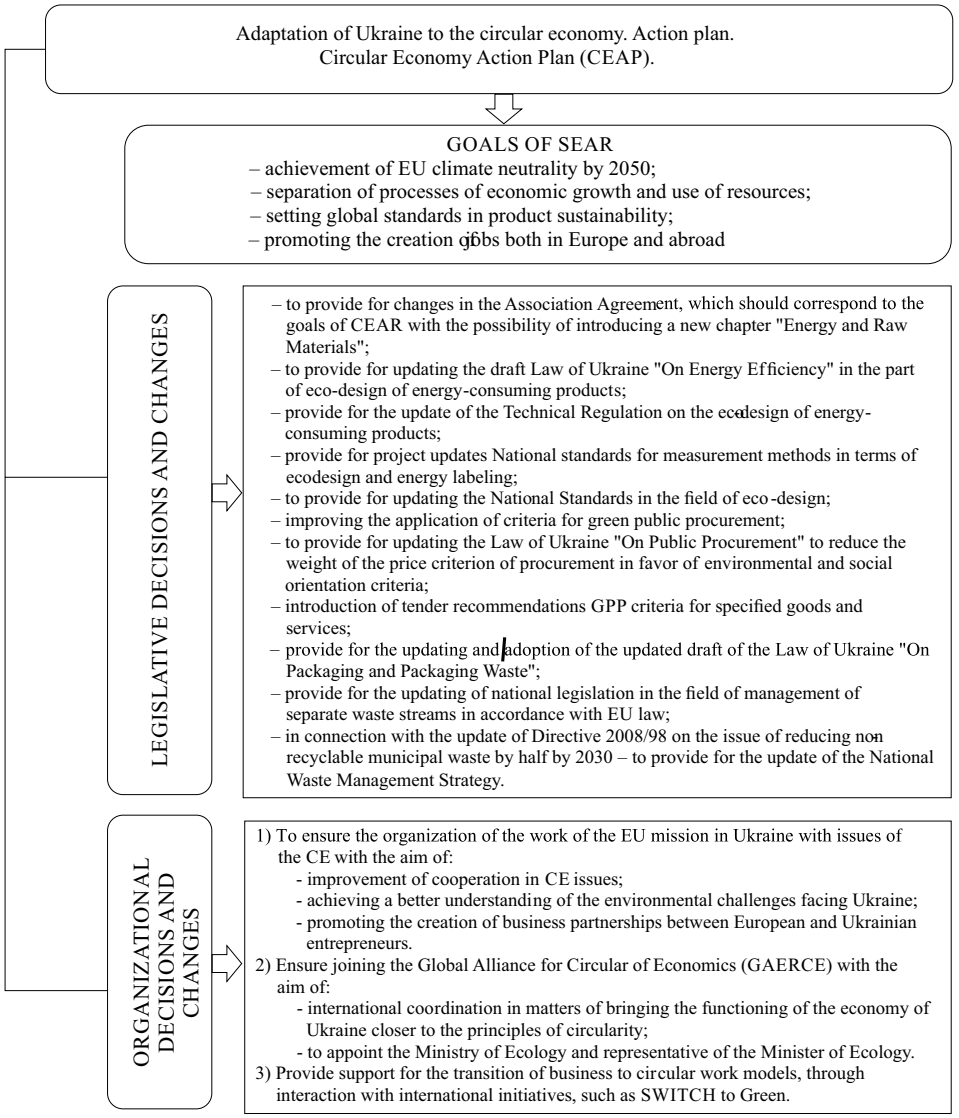

Fig. 2. Adaptation of Ukraine to the circular economy in accordance with CEAR (Circular Economy Action Plan, 2020)

imported back to Ukraine as a finished fertilizer to meet the demand of farmers. Recycling Solutions built a plant in Kryvyi Rih to process this by-product into ready-to-use granular ammonium sulfate. The plant not only supports the principles of a CE, ensuring the processing of by-products of the main industrial process of coke chemicals, but also reduces the resources spent on their movement around the world.

The agricultural sector also opens up interesting opportunities for the CE. For domestic agribusiness, the main component of greening should be the creation of closed production cycles at the meso and micro levels, which would not only ensure the reduction of the load on the environment, but also contribute to the innovative development of the agricultural sector (Kovalchuk, Lukiianenko 2020). One of the spheres of activity in circular agriculture is the conversion of streams of food residues into animal protein as efficiently as possible.

Again, a vivid example of this business model in Ukraine is the company Recycling Solutions, which also works with agricultural resources. Thus, in 2021, Recycling Solutions and its partners opened the largest factory in Ukraine for the production of high-protein feed additives and animal fats for farm and domestic animals FEEDNOVA. The construction of FEEDNOVA is an investment project of the group of companies "Effective Investments" in partnership with the Dutch company "Mada Participations B.V." and the Ukrainian investment company UMG Investments. The construction of the enterprise is a joint project of foreign and Ukrainian investors. Investments in the project amounted to more than 20 million dollars. The capacities of the FEEDNOVA plant are located in the city of Busk, Lviv region. The complex has four state-of-the-art production lines and five boilers from a Dutch manufacturer. The capacity of the enterprise is more than 220 tons of raw materials and 90 tons of finished products per day. The company's priorities are innovative technologies, strict adherence to international quality standards, and transparent terms of cooperation. FEEDNOVA is the first innovative production of this scale in Ukraine. FEEDNOVA is the first independent operator in Ukraine that will process raw materials from external suppliers and produce high-protein products. And this is also a unique feature of this enterprise, because at the level of international processing standards that FEEDNOVA adheres to, no one else in Ukraine does this, which makes this company the first in terms of capabilities, volumes of processing and production of finished products.

High-protein feed additives are made from by-products of animal origin, which are not suitable for human consumption. The plant produces products from the second and third categories of raw materials. Products of the third category are used as feed additives for agricultural and domestic animals. These products include meat and bone meal, feather meal, and fat from red meat and poultry. Products of the second category are used as organic fertilizers. They also include technical fat. The scope of application of FEEDNOVA products is as follows: supplements – an additional source of protein in the diet of farm and domestic animals; processing products are used as highly effective organic fertilizers, and processing products unsuitable for feed are used as an alternative fuel, as well as for the production of biodiesel. Adhering to high standards, the plant will produce high-quality feed additives for both Ukrainian consumers and customers on international markets. More than 20% of finished products will be sold on the domestic market. At the first stage, FEEDNOVA will export to the EU markets, then move on to sales to consumers in Africa and Asia.

The advantages of high-protein supplements are:

- Nutrition: additives enrich the diet of animals, and increase the nutritional value of feed and the quality of the final livestock products.
- Safety: all products of the complex are divided by categories and origin, they pass all stages of analysis and control in our laboratory.
- Environmental friendliness: safe processing and disposal of animal waste is the key to preserving the environment. In addition, it prevents the development of epidemics.
- Economic efficiency: the processing of livestock by-products allows to return to the production process those resources that would otherwise simply be thrown away.

In addition to production, the FEEDNOVA enterprise provides services for the collection, transportation and preparation of by-products of animal origin. The team of the "Fidnova" company works to provide comprehensive solutions for epidemiological safety. FEEDNOVA will solve the problem of environmental threats – the high-tech plant will guarantee veterinary and sanitary control and environmental safety of the region. Agricultural enterprises will have the opportunity to fully follow the legal and safe processing of animal waste. For the agricultural sector, this is a significant, particularly significant event, because it is the first independent production, which is built on the secondary processing of raw materials from other industries. The problem with the processing of livestock products has both ecological and economic dimensions. With the launch of FEEDNOVA, these problems begin to diminish.

In Ukraine, there is a practice of organizing the All-Ukrainian forum "LEADERSHIP AND ECOTRANSFORMATION – 2021", where leading companies that have implemented the best solutions in preserving natural resources are awarded and celebrated. The organizers of the forum chose the most significant projects of the current year. It was the FEEDNOVA company that received the award for its significant contribution to the eco-transformation of the state, business and society.

Conclusions

The CE is increasingly attracting attention as the most potential way to increase well-being while reducing the demand for final raw materials and minimizing negative externalities. This transformation requires a systemic approach that goes beyond existing ones to improve economic models, as well as to develop new mechanisms of cooperation between states, businesses and society. It should be noted that the transition to a CE will be long and difficult, taking into account the economic realities of Ukraine, especially in the conditions of full-scale aggression by Muscovites. This is due to the lack of a single implementation mechanism or financial support from the state. Therefore, enterprises that do not have sufficient financial resources for restructuring and modernization are looking for potential sources of financing. In addition, there is no culture of waste man-

agement (potential raw materials) among the population, which seriously hinders their access to the enterprise.

In addition, all the necessary levers and factors to achieve the goal are resource-intensive and require developed mechanisms. But such a modern approach will reduce the burden on the environment and create many additional benefits for product manufacturers and society. A gradual or complete transition to a CE will allow not only enterprises but also entire countries to become more environmentally responsible, which in turn will lead to further economic growth. For this purpose, the Government of Ukraine should take into account the provisions of the Circular Economy Action Plan (CEAP) regarding the CE of the EU when preparing and finalizing the National Energy and Climate Plan and other strategic documents.

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The circular economy transition: the challenges of innovative change for sustainability

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Abstract. CE is an alternative vision for growth according to Sustainable Development Goals (SDGs) by 2030. The overall objective of this paperwork is to discuss several challenges encountered when pursuing sustainable innovative change, considering innovation as a significant and positive effect on performance in organizational economic sustainability. The European Commission aims to ensure coherence between industrial, environmental, climate and energy policies to create an optimal business environment for sustainable growth, job creation and innovation. The Commission has developed an ambitious program to transform the EU economy into a CE, where the value of products and materials is preserved for as long as possible, which brings great economic benefits. For businesses, working together to create a basis for sustainable products opens up new opportunities in the EU and beyond, including Ukraine.

We are talking about business reorganization, changing the business model, and taking into account values and innovations. Circular business model is an umbrella term for completely different business models that seek to use fewer materials and resources to produce products and services, and to extend the life of existing products and services through repair and restoration, recycling and reuse. Thus, innovative business models of the CE arise and develop, first of all, in an urbanized and environmentally responsible environment and are aimed at reducing dependence on material resources, increasing efficiency and increasing profits. Innovation is a continuous process that involves delivering innovation as a service to customers by bringing together the right people, processes and tools. Disruptive innovations are innovations that change the relationship of values in the market environment. In this context CE involves the construction of dynamic structures (often combining enterprises of different industries) and stimulates the process of transformations at each link of business processes. Therefore, for the implementation of the product strategy, enterprises in the context of sustainable development can use such tools as DISRUPT framework.

Keywords: circular economy, sustainable development, business model, disruptive innovations, product strategies, DISRUPT framework

Introduction

Under the vector of sustainable development, modern approaches to business are changing significantly, and environmental and social aspects are taken into account. At the same time, the need to adjust (or develop a new) business model based on innovation is becoming more urgent. The CE, which aims to minimize waste and increase resource efficiency, is most in line with modern environmental trends. It is the implementation of the principles of the CE that can today provide a synthesis of economic, social and ecological mechanisms for achieving the company's goals in the conditions of sustainable development.

The relevance of the chosen topic is due to the growing role of the environmental factor in the construction of business processes of companies all over the world. To ensure sustainable development and increase the balanced potential of the enterprise in the modern conditions of globalized economy, it is necessary to constantly improve the methods and mechanisms of management of the supply, production and sale of goods (services), accepting the need for ecological approaches to business as much as possible.

Enterprises and companies that determine the dynamics of economic growth in each industry can serve as the main drivers of transformation when implementing circular business models. In the conditions of increasing production rates, it is most appropriate to implement strategies of a circular form of interaction in industry and the service sector. At the same time, gradual adaptation in the conditions of internal and external support can improve the functioning of enterprises at the micro- and macro-level, strengthening their response to environmental challenges. Today, it is extremely important to develop a company's business model based on innovation and to focus on global goals of sustainable growth. This will contribute to the transition of the economy of Ukraine from a raw material model to a CE, as has been happening in the EU countries for the past decades (European Commission, 2023). It should be noted that the implementation of the principles of the CE is based not only on innovative solutions, but also on cooperation with other companies, market participants and state authorities to implement joint projects. However, it is the DISRUPT Framework (a business model based on disruptive innovation) that can provide significant economic benefits in the long term for both the enterprise and the industry, and of course, for society. A significant slowing factor in the activation of processes of environmental strategies adaptation and circular scenarios of business units modification are numerous barriers. They can be caused by many factors: the insufficient potential of the enterprise according to external assessments, unjustified risks, changes in the level of profitability, and others. In general, the following obstacles can be identified as:

- technological (innovative technologies);
- economic (high investment costs and a long payback period for the development of circular business models);
- legal (lack of developed environmental legislation and requirements for product certification, especially when entering EU markets).

We must realize that the use of the DISRUPT toolkit in the process of manufacturing products within the framework of circular business processes is relevant, but not available to all enterprises due to the lack of knowledge and experience. Managers need clear guidance on design, input decisions, product use and end-of-life, business model viability and global supply chain collaboration, and the use of digital technologies to ensure circularity. Basic sustainable development strategies should be directly linked to performance indicators that reflect the physical volumes of materials, water or emissions used. During the research, as a result of theoretical generalization, analytical comparison and modeling, the foreign and domestic experience of designing circular business models based on disruptive innovations, and adaptation of business processes to the principles of sustainable development was considered.

We are talking about business reorganization, changing the business model, and taking into account values and innovations. A.Osterwalder and Y.Pigneur, authors of innovative business models (Pinye, Ostervalder 2022), claim that the value proposition (as the core of the business model) is the reason why consumers turn to one company, preferring it to another. Such an offer solves a certain problem of the client, and satisfies his need. Each value proposition consists of an optimal package of products and/or services that helps satisfy the requirements of a certain market segment. And the market today actively demands innovative products in the assortment of companies, although consumers at the same time monitor the social responsibility of business. Instead, the circular business model is an umbrella term for completely different business models that seek to use fewer materials and resources to produce products and services, and to extend the life of existing products and services through repair and restoration, recycling and reuse. Thus, innovative business models of the CE arise and develop, first of all, in an urbanized and environmentally responsible environment and are aimed at reducing dependence on material resources, increasing efficiency and increasing profits (Shpak et al. 2020).

Practitioners say that to be competitive in today's market, companies need to shape an innovation infrastructure, including tools, systems, people, culture and business processes. The rapid pace of technological innovation and competitiveness in our global economy is best illustrated by this stunning fact: only 52 companies have remained on the Fortune 500 list (a list of the 500 largest companies by annual revenue) since its inception in 1955 (Ottinger 2021). However, many organizations struggle to get effective results from innovation efforts. Teams expend resources and managers watch as other firms increase their competitive advantage by innovating in their industry or new markets. When innovation efforts fail, it can be difficult to build organizational momentum to reinvest in future endeavors. Innovation is a continuous process that involves delivering innovation as a service to customers by bringing together the right people, processes and tools "Quality" and "reengineering" were the most important components of the business world of the 80s and 90s of the last century, but disruptive innovation has become one of the main paradigms of the modern world. Efficiency, productivity and adaptability remain the most important characteristics of business process reengineering, which involves the

achievement of new goals by restructuring the enterprise's business processes based on innovation (Harrington 2006).

Results and discussion

In general, it is necessary to understand that such industry leaders as Netflix, AiRBnB, Amazon or Apple successfully implement the theory of disruptive innovation in practice, but at the same time, the founders of these companies often did it unconsciously, simply implementing creative ideas. Disruptive innovations are innovations that change the relationship of values in the market environment. At the same time, the existing products become uncompetitive simply because the parameters based on which the competition used to take place become less important (Kylliäinen 2019). Such innovative technologies, which eliminate or reduce dependence on non-renewable natural resources, significantly increase the quality of life or provide a technological transition in the use of a certain product (service). The main criteria are: high potential need of humanity or a large number of users; high availability for everyone; and relatively low cost. The differences between disruptive and sustaining innovations are shown in Figure 1. It should be noted that the term "disruptive" is mistakenly equated with a one-time, new, bright event. Instead, it is explained (Christensen et al. 2015) that disruptive innovation is a process of redistributing resources, changing tastes and preferences of consumers and potential customers, and constant changes in technology. The author of the theory summarizes that as a result of this process, more accessible and cheaper goods are produced. A new product first gets a small share of the market, which, growing gradually, displaces the big players. Thus, the theory of disruptive innovations helps the company to correctly choose a development strategy, and predict the behavior of competitors and its own company.

It is discovered (Christensen et al. 2019) the phenomenon of how it happens that large companies that may be using good business practices lose their market leadership

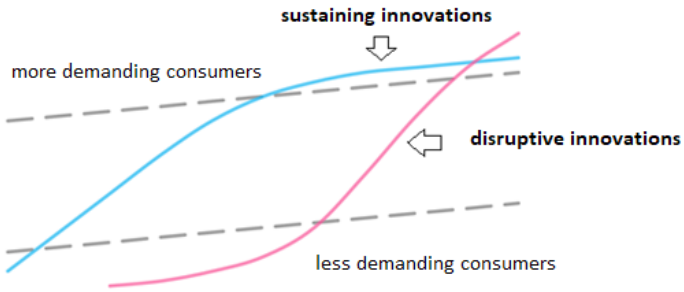

Fig. 1. Differences between disruptive and sustaining innovations depending on the level of consumer demand (Kylliäinen 2019)

and lose their positions in the market as new players that actively implement innovations appear. The researcher lists and explains two key parts of this dilemma:

1. The value of innovation does not bring money in the short term: improving a product takes time and research.
2. The innovation advantage belongs to small companies: large companies benefit from having a large number of customers, but this leads to the need to meet their high sales expectations. Instead, small businesses don't have to match the annual sales volume of existing businesses, so they have more agility and more time to focus and develop new products and services.

Responding to new competition only with innovative technologies is often not enough, as the market participant has had a lot of time to improve the offer and business model. Furthermore, product development takes time and multiple iterations, making catch-up unlikely, even with additional resources. The characteristics of disruptive innovation are as follows: lower margins, at least initially; higher risks; destruction of the existing market, or creation of a new market segment in the existing one; sales arguments and measures of value usually fundamentally change; new technologies and/or a new business model; at first the process is slow until it reaches the mainstream and then grows exponentially. It should be noted that the pursuit of such solutions often creates additional problems for the business. And the thing is that disruptive innovations are not something that can be tracked in the process of implementation, they are only evident in retrospect. The theory of disruptive innovation is useful for understanding the role technology plays in shaping business and the environment. But when the theory itself becomes dominant and entrepreneurs are obsessed with the idea, then, as a rule, fiasco awaits them (Kaplan 2022). Scientists have proven that sustainable development should be established at the stage of business model design (Pinye et al. 2019), and for this, innovative solutions in the field of technology, new approaches to management, and investment mechanisms of cooperation are needed. Therefore, a clear strategy should be developed and the essence of the 4P innovation concept used in the development of an innovative business model should be determined (see Fig. 2). That is one should clearly understand the idea underlying

Fig. 2. The essence of the 4P innovation concept used in development of innovative business model (based on (Tidd, Bessant 2015; Kampmann 2021))

business development (mission, vision); characteristics of the product sold by the company, opportunities to expand the range, ways to improve the product; how the company creates value, what types of activities it focuses on; how the product and/or company is positioned.

It is interesting that according to the classification of innovations by the level of technological novelty and impact on the market, it is disruptive innovations that involve the use of such technologies or the development of a new business model that radically changes the market (Fig. 3). And this approach can change those industries that need to be rebooted and function in conditions of sustainable development. The newness of technology in each business shows whether the innovation is based on new or well-proven technologies. Ideas that have a low market impact are easier to implement, and the effect is amplified over time. Ideas that have a large market impact tend to be complex, expensive and risky to develop, but bring high potential value. So, let's describe 4 types of innovations in detail:

Disruptive (breakthrough) innovation is often the most well-known type of innovation that provides effective use of new technologies and tangible results. Although breakthrough innovations are extremely bright and exciting, they come with many nuances and challenges. The most common organizations that exhibit the characteristics of breakthrough innovation are startups.

Incremental innovation involves the gradual continuous improvement of existing products and services. Although they are the least flashy of all the categories, they offer the most obvious advantage for achieving the prescribed rate of return. By continuously improving products, services, and business operations, organizations can reduce stagnation and continuously increase market share.

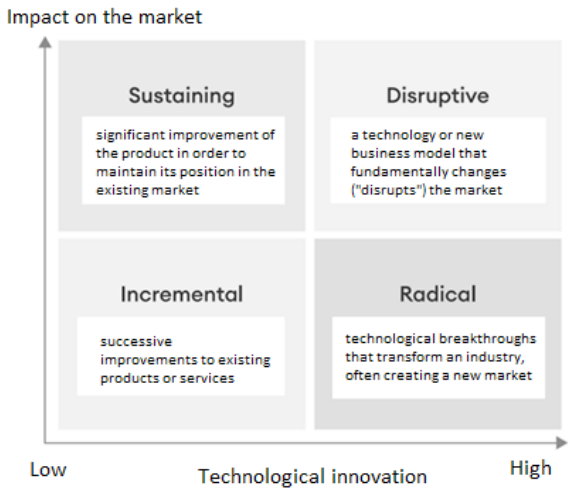

Fig. 3. Classification of innovations according to the level of technological novelty and impact on the market (based on (Ottinger 2021))

Sustaining innovation is the best way to protect the company's position in the market. Whereas incremental innovation focuses on small improvements to existing products and services to increase value or customer satisfaction, sustaining innovation focuses on larger changes to gain or maintain market leadership. This category focuses on creating new features or services that differentiate the product from all its competitors.

Radical innovations typically use a technological breakthrough that transforms industries and creates new markets. This type of innovation completely changes the way an organization interacts with the market. The success of the major technological transition that drives this type of innovation is often linked to the organizational behavior and capabilities of the firm that create the right conditions for the successful commercialization of new ideas.

Each of these categories has value, and a system that combines all four creates robust and effective innovations while identifying blind spots for potential market or consumer change. Without incremental innovation, products and services can fall behind. Both existing and potential customers suffer. Without sustaining innovation, a company will have to work harder to achieve market leader status and win the majority of the market. And without radical or disruptive innovation, a company is missing out on enormous potential value while at the same time running the risk of being disrupted by new methods or technologies. By implementing all four types of innovations, a company ensures short-term success by optimizing its current products and differentiating them from competitors, while protecting long-term sustainability. Correctly applied innovations can become the basis of a circular business model and be embodied in a strategy for success both now and in the future.

The CE involves the construction of dynamic structures (often combining enterprises of different industries) and stimulates the process of transformations at each link of business processes. Therefore, for the implementation of the product strategy, enterprises in the context of sustainable development can use such tools (Table 1). Speaking about the types of circular business models that function effectively in the EU (Circle Economy, 2020), their basic characteristics should be singled out. To strengthen the competitiveness of the EU, the 10-year Europe 2020 strategy was developed, the main directions of which include:

1. Smart growth (development of the economy based on knowledge and innovation).
2. Sustainable growth (promotion of more efficient use of resources, environmental friendliness and separation of economic growth from the use of resources).
3. Inclusive growth (promoting an economy with high employment that ensures social and territorial cohesion).

In Figure 4 types of circular business models in the context of sustainable development, which can be applied by Ukrainian enterprises, are depicted.

The choice of a circular business model should be situational, based on research of the market environment and an adequate assessment of the company, and only then will it be possible to achieve goals and strategic advantages. Circularity and sustainable de-

Table 1. Necessary components of the DISRUPT FRAMEWORK for designing an innovative business model

Designation in abbreviation	Essence of the component	Content of measures for each component
D	Design For the Future	Apply a systematic perspective to product design based on durability and benefit for future generations
I	Incorporate Digital Technology	Strengthen the interaction between the participants of the supply chain based on the implementation of digital technologies, online platforms and software solutions.
S	Sustain and Preserve What's already There	Use resources as long and efficiently as possible, give products a second life (in particular by extending life cycle phases or implementing "take&back" strategies) where possible.
R	Rethink the Business Model	Consider the possibility of rethinking the business model by finding ways to create more value for all stakeholders, including due to the integration of products and services.
U	Use Waste as a Resource	Dispose of waste by using it as a resource due to incineration, reuse and recycling of waste; to create a full-fledged market for recycled materials.
P	Prioritise Regenerative Resources	Prioritize the use of renewable and reusable resources, as well as non-toxic resources that are converted into materials and energy in the most efficient way possible.
T	Team Up to Create Joint Value	Work together to achieve set goals in the supply chain, both internally between organizations and with the public sector to increase openness and create shared value.

Source: based on (Talin 2022; Circle Economy, 2020).

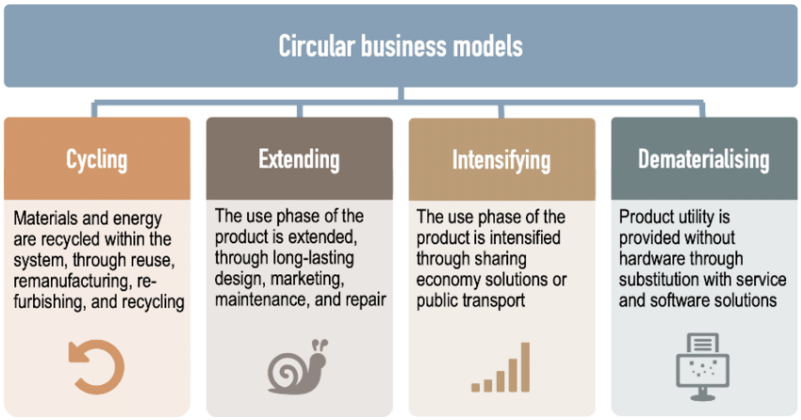

Fig. 4. Types of circular business models in the context of sustainable development of the enterprise (Geissdoerfer et al. 2020)

velopment means separating economic growth from resource consumption. For companies, this involves conserving materials, extending product life through repair and reuse, and ultimately recycling. It is also about improving product usage through new business models, including those that offer products as a service and collaborative engagement platforms (Markard et al. 2020).

Conclusions

The application of DISRUPT framework, which is the basis for shaping innovative product strategies, involves a wide range of tools: design guidelines, input decisions, business models and collaboration in the supply chain, and digital technologies to support circularity. Implementation of this approach in practice makes it possible to actively implement innovations and follow the principles of sustainable development. After all, such strategies relate to activities that directly affect material flows: for example, by choosing alternative input resources or cyclically returning materials back into the system. They should be directly linked to performance indicators that reflect physical volumes of materials, water or CO_2 emissions. At the same time, strategies based on circular business models will stimulate the choice of alternative materials and reduce environmental pollution by minimizing waste.

Prospects for further research on the topic will consist of detailing the impact of the new business model on increasing the company's efficiency in the long term, as well as in the formation of specific recommendations regarding the implementation of circular business models based on innovations by Ukrainian enterprises in the context of sustainable development.

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Chapter II.

Innovative approaches to the circular economy in industry and services in Ukraine

Impact of war actions on water resources of Ukraine

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Abstract. The military aggression launched in Ukraine has caused a large number of catastrophic events that have negatively affected all spheres of life in Ukraine, including the condition of water resources. The destruction and damage of hydraulic structures on rivers and reservoirs, as well as water infrastructure facilities that regulate river flow and provide water supply to many sectors of the economy are significant and critical. As a result of war actions, dams, pumping station buildings, hydrotechnical structures of canals, bridge crossings, and regulatory gates were destroyed and damaged, equipment and machinery were stolen, and power supply was interrupted due to damage to power grids and power systems of transformation and transmission systems of electricity. In the territory of Kyiv, Chernihiv, and Zhytomyr regions, regulating hydrotechnical structures were damaged. Weirs, protective dams, pumping stations and other hydrotechnical structures were destroyed and damaged in Kharkiv, Donetsk and Dnipropetrovs'k regions, which led to water losses and flooding of settlements. As a result of the violation of the operating regimes of water bodies, an estimated volume of 732.1 million m^3 of water was withdrawn or discharged, and it is constantly increasing as a result of destruction. The purpose of the section is to consider the ecological state of water bodies and to investigate the problems caused by military actions and to develop measures to achieve "good" ecological conditions of waters, including post-war recovery measures.

Keywords: war actions, water resources, hydro-economic infrastructure, hydrotechnical structures, pollution, damage, armed aggression

Introduction

In the first weeks of the full-scale war, hydrotechnical structures at the Oskil reservoir on the Oskil River in the Kharkiv region were damaged. Due to the impossibility of reg-

ulating the operation mode of the reservoir and the lack of access to the structures, there was an unproductive loss of water in the estimated volume of 60% of the total volume of the reservoir, which created risks in the provision of water to populated areas of the Donetsk region. As a result of directed shelling by artillery shells, the dam of the Pecheneg reservoir on the Siverskyi Donets river, which provides drinking water to the city of Kharkiv and settlements of the Kharkiv region, was damaged. Therefore, there was an uncontrolled discharge of water at a rate of approximately 22.0 m^3/s and a decrease in the volume of water by 39.7%. At the end of May 2022, the Raigorod Dam on the Siversky Donets River in Donetsk Region was damaged, which led to an uncontrolled discharge and a decrease in water levels in the river by approximately 1.5 m at drinking water intake sites in Donetsk Region, which led to problems in guaranteed water supply to consumers in Donetsk Region. As a result of a rocket strike in September 2022, the hydrotechnical structure of the Karachuniv Reservoir on the Ingulets River in the city of Kryvyi Rih, Dnipropetrovsk Region, was damaged. Within two days, the water level in the reservoir dropped by 42 cm. The estimated water loss was 16.9 million m^3. All this led to the impossibility of providing water supply and drainage services and caused significant damage to the environment, which caused both temporary and long-term consequences for the ecosystems of river basins.

Because of the breach of the Kozarovytska Dam, which separates the Dnipro Reservoir from the floodplain of the Irpin River, there was flooding of the floodplain area and water pollution due to the inflow of agrochemicals from reclaimed land, flooding of street toilets, cesspools, places where livestock are kept, cattle burial grounds, and other areas with toxic waste. Additionally, remnants of fuel, technical lubricants, and ammunition got into the surface water from the destroyed enemy equipment. Subsequently, the emergency situation was localized, the flow of water was stopped, and work is being carried out to restore the damaged hydrotechnical structures (Starodubtsev 2022). The uncontrolled withdrawal of water from the North Crimean Canal, which occurred as a result of the seizure of the main water intake facility and the destruction of barrier structures, leads to negative consequences of the arbitrary withdrawal of water from the Dnipro to the Crimea.

Consequently of constant hostilities and the occupation regime, the situation in the east of Ukraine has already led to serious consequences, the elimination of which will require a very significant amount of time with the involvement of a large number of resources and the demilitarization of territories to prevent a full-scale ecological disaster (Kozishkurt 2022). As a result of the damage and destruction of infrastructure facilities, and unstable electricity supply, communal sewage treatment facilities work inefficiently, which leads to the entry of untreated sewage into water bodies. According to the monitoring results, there is a trend towards an increase in the content of biogenic compounds (nitrogen and phosphorus) and indicators of organic pollution in the surface water bodies of the Dnipro, Don and Southern Bug basins.

In the event of an emergency impact, the nitrogen group comes to the fore in the list of priority pollutants at the point of wastewater discharge, in addition to organoleptic indica-

tors, which is explained by the ingress of untreated wastewater into the river. The increased content of nitrates in water is dangerous for public health. This is due to the role of nitrates in the synthesis of nutrients, both in the environment and in the human body. Since nutrients are mutagenic and carcinogenic, the increased nitrate content in water increases the risk of oncogenic disease in the population. In addition, the increased content of nitrogenous substances encourages the processes of eutrophication of water bodies (Bezsonnyi 2022).

According to the Ministry of Development of Communities and Territories of Ukraine, 33 objects of water treatment and drainage facilities were damaged, resulting in damages with an estimated cost of UAH 4,005.48 million (USD 109.53 million). Significant and critical damage to hydrotechnical structures on rivers and reservoirs, as well as land reclamation facilities. During rocket and artillery attacks, water management facilities in populated areas, especially sewage treatment plants of communal and industrial enterprises, did not escape devastating destruction (Shevchuk 2022). At the same time, the consequences and risks for water resources from the invasion of the Russian Federation into the territory of Ukraine are significant for both people and the environment. It is worth noting that the consequences of military actions for the environment cause risks and threats to the safe functioning of both society and environmental components. Water resources in wartime require saving and protection. This problem is urgent and requires scientists to carefully analyze and assess the situation, and determine ways and means of neutralizing the consequences of Russian aggression (Strokal 2022).

Water management organizations that belong to the sphere of management of the State Agency of Water Resources of Ukraine and enterprises suffered damage in the form of destruction and damage to hydrotechnical structures and water management systems. As a result of the hostilities, the bases of operational areas (administrative buildings, production shops, boxes, warehouses) were damaged, pump station buildings were destroyed and damaged, canal structures, dams, bridge crossings, regulator locks were damaged, equipment and machinery were stolen, electricity supply was stopped due to damage to power networks and systems transformation and transmission of electricity. All this led to the impossibility of providing water supply services for irrigation of irrigated lands and the removal of drainage water from drained lands, and caused an urgent need for restoration. Based on the results of processing literary sources and analytical reviews, it was established that a number of dangerous environmental situations arose during the military operations on the territory of Ukraine, among which the destroyed water management infrastructure, in particular, aggravates the impact, namely:

- damage or destruction and subsequent shutdown of water supply and drainage systems in the areas of hostilities poses a threat of accidental contamination of surface water bodies due to uncontrolled discharge of untreated sewage;
- pollution of water intakes due to the inflow of untreated and insufficiently treated sewage, as well as the presence of spontaneous burials of the dead, leads to large-scale eutrophication of water bodies and the complication of the sanitary-epidemiological situation by increasing the risk of infectious diseases;

- pollution of surface and underground waters as a result of the ingress of oil products with fuel and lubricants due to explosions and accidents at oil depots and the destruction of military equipment;
- ingress of dangerous and toxic substances contained in the remains of ammunition. Risks come from ammunition-related heavy metals, energetic compounds such as trinitrotoluene (TNT), hexane (RDX), and rocket fuel;
- soil and water pollution occur as a result of the ingress of toxic perfluoroorganic and polyfluoroalkyl compounds during firefighting. These compounds are not of natural origin, they are extremely stable both in the environment and in the human body;
- accidents on ships and port infrastructure along the coast of the Black and Azov seas lead to the pollution of coastal sea waters with oil products and the spread of pollutants throughout the water area;
- damage and destruction of dams cause the emergence of large-scale emergencies of man-made and natural nature associated with inundation and flooding of territories, and also leads to the loss of valuable fresh water.

Taking into account the fact that the water management infrastructure includes hydrotechnical structures and artificially created water bodies, as well as the fact that the disruption of water management systems can lead to negative consequences related to the deterioration of the environment and negative consequences caused to health people and sectors of the economy, the provisions of the Methodology for assessing losses from the consequences of man-made and natural emergencies (KMUM, 2022) are applied in the calculation. The calculation of damage to the infrastructure is partially based on the inventory of damage to all irrigation, drainage and anti-flood facilities, which is carried out by water management organizations of the State Water Agency in all regions on an ongoing basis. The calculations cover the period from the beginning of armed aggression (February 24, 2022) to June 1, 2022. Thus, the amount of compensation for damages to water infrastructure facilities can be determined by the formula:

$$D_{wm} = F_p + F_u + R_c \quad (1)$$

where:

F_p – total losses from the destruction and damage of fixed assets of production purposes, UAH;

F_u – total losses from the destruction and damage of fixed assets of non-production purposes, UAH;

R_c – total costs for restoring the functioning of the infrastructure facility, UAH.

Total losses from the destruction and damage of fixed assets of industrial purpose consist of losses from the complete or partial destruction and damage of buildings, structures,

housings, machinery, equipment and other types of fixed assets of industrial purpose and are calculated according to the following formula:

$$F_p = \sum_{i=1}^{n} \left(\Delta P^i \cdot K_a^i \right) - L_b \tag{2}$$

where:

ΔP^i – decrease in the balance sheet value of the *i*-th type of fixed assets of production purpose as a result of complete or partial destruction, taking into account the relevant indexation coefficients;

K_a^i – depreciation coefficient of the *i*-th type of fixed assets of production purpose;

n – the number of types of fixed assets of production purpose that were partially or completely destroyed, pcs.;

L_b – liquidation value of received materials and equipment, UAH.

Total losses from the destruction and damage of fixed assets of non-production purpose (housing, communications, structures and auxiliary buildings, etc.) are calculated based on the residual book value of the destroyed objects according to the following formula:

$$F_u = \sum_{i=1}^{n} \left(\Delta P^i \cdot K_a^i \right) - L_b \tag{3}$$

where:

ΔP^i – decrease in the balance sheet value of the *i*-th type of fixed assets of production purpose as a result of complete or partial destruction, taking into account the relevant indexation coefficients;

K_a^i – depreciation coefficient of the *i*-th type of fixed assets of production purpose;

n – the number of types of fixed assets of production purpose that were partially or completely destroyed, pcs.;

L_b – liquidation value of received materials and equipment, UAH.

Adhering to the RDNA (Rapid Damage, Loss and Needs Assessment) methodology, a group of experts from the World Bank, together with specialists from the State Agency of Water Resources of Ukraine and with the support of the "Hydrosolution" company using satellite data, conducted a preliminary assessment of damages, losses and needs of irrigation and reclamation systems and water management facilities from the start of the war until June 1, 2022. The work was carried out in several stages, accompanied by the collection of information about damaged or destroyed objects of water management infrastructure. Water management organizations that belong to the sphere of activity of the State Agency of Water Resources of Ukraine conducted an inventory of property assets

on the balance sheet in the liberated territories and assessed the damage caused, as well as the need to restore the damaged water management infrastructure. In addition, the expert group checked the level of damage to water infrastructure facilities in the territories that were under occupation, and the access of representatives of water management organizations to their infrastructure facilities was impossible or had a dangerous effect. During the determination, it was taken into account that damage is considered to be the complete or partial destruction of physical assets located in the affected area. Damage caused by war was measured in natural units (square meters of buildings, kilometers of canals and roads,

Table 1. Losses by asset type as of June 1, 2022
(The Ukraine Rapid Damage and Needs Assessment – August 2022 report (RDNA, 2022))

Type of assets	Total quantity, pcs.	Completely destroyed, pcs.	Partially damaged, pcs.	Estimated damages (million USD)
Flood protection and water storage				**4.72**
Dams (pcs.)	232	2	18	4.63
Embankments (pcs.)	775	0	13	0.90
Irrigation				**19.30**
Main canals (km)	10,238	0	43	5.86
Secondary canals (km)	164,218	0	0	
Operational Pump stations (pcs.)	1,312	6	42	10.30
Other hydraulic constructions (pcs.)	18,033	6	22	3.13
Drainage network (km)	1,177	0	0	
Drainage				**6.76**
Main collectors (km)	7,639	0	0	
Lower collectors (km)	91,566	0	0	
Operational Pump stations (pcs.)	170	0	5	0.38
Other hydraulic constructions (pcs.)	17,489	12	5	6.39
Buildings and equipment				**7.04**
Administrative buildings an garages (pcs.)	49	5	22	2.47
Repairing shops and production sites (pcs.)	62	1	8	0.76
Other buildings inc bridges (psc.)	0	3	8	0.69
Cars and other machinery (pcs.)	1,606	9	57	3.13
Total	314.566	44	243	37.83

etc.). The results of the damage assessment were highlighted in the World Bank report The Ukraine Rapid Damage and Needs Assessment – August 2022 report (RDNA, 2022), and provided to the Government of Ukraine for further work on attracting investments to restore damaged and destroyed water infrastructure facilities.

Table 2. Damages determined by region as of June 1, 2022
(The Ukraine Rapid Damage and Needs Assessment – August 2022 report (RDNA, 2022))

Regions	Category of priotarization	Infrastructure Damage based on oblast inventory method	Infrastructure Damage case by case method (severe underreporting)	Total infrastructure Damage by hybrid method
Vinnytska	0	0	0	0
Volynska	4	0.55	0	0.55
Dnipropetrovska	3	0.05	0	0.05
Donetska	2	5.50	45.51	51.00
Zhytomyrska	4	0.37	0	0.37
Zakarpatska	0	0	0	0
Zaporizka	3	0.01	6.42	6.44
Ivano-Frankivska	0	0	0	0
Kyivska	1, 4	11.07	0	11.07
Kirovohradska	0	0	0	0
Luhanska	2	4.40	20.13	24.53
Lvivska	0	0	0	0
Mykolaivska	2	6.61	1.48	8.09
Odeska	0	0.02	0	0.02
Poltavavska	0	0	0	0
Rivnenska	4	0.37	0	0.37
Sumska	1	0.37	0	0.37
Ternopilska	0	0	0	0
Kharkivska	1, 2	6.96	0.06	7.02
Khersonska	2, 3	0.07	42.93	43.00
Khmelnytska	0	0	0	0
Cherkaska	0	0	0	0
Chernihivska	0	1.47	0	1.47
Total		**37.83**	**116.52**	**154.38**

When summarizing the results, a classification distribution of water infrastructure facilities by types of assets was carried out, namely, facilities for protection against the harmful effects of water and reservoirs (dams, dams, embankment structures, regulated sections of rivers), irrigation (main canals, pumping stations, pipelines, other hydraulic engineering structures for irrigation networks), drainage (main collectors, transfer pumping stations, other hydraulic engineering structures for drainage networks), buildings and equipment (administrative buildings, repair shops, operational stations, other infrastructure objects, including bridges, road and other machinery and equipment). The results of damage assessment by asset types were obtained according to the inventory method, which is used at the regional level by water management organizations belonging to the State Water Agency, and show a total amount of damage of 37.8 million USD (Table 1). Of the total amount of 37.83 million US dollars, 4.7 million US dollars are allocated to structures for protection against the harmful effects of water, namely from floods and floods, as well as artificial reservoirs, irrigation systems, and structures for supplying water for irrigation of irrigated lands – 19.3 million US dollars, for drainage systems and facilities for drainage from drained lands – 6.76 million US dollars, and for production bases, buildings and auxiliary equipment of operational sites – 7.04 million US dollars for buildings and equipment (Gopchak 2022).

For greater coverage of water infrastructure facilities, a hybrid method is used, based on taking into account priority categories depending on the degree of damage caused by hostilities. With this in mind, regions (oblasts) of Ukraine were divided into priority categories and five categories were defined. Losses were determined as a ratio of the irrigated area according to the method of the Kyiv School of Economics. This method assumes that the amount of damage is a linear function of the length of time the region has been in active combat or occupied. The Table 2 presents calculations of damage caused to water infrastructure facilities for each region (region). Total damage to infrastructure facilities is calculated using the hybrid method.

The distribution of losses by asset categories is presented in Figure 1.

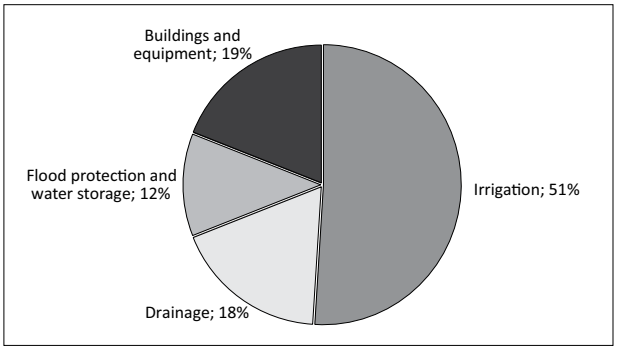

Fig. 1. Distribution of losses by asset type as a share of total losses
(The Ukraine Rapid Damage and Needs Assessment, The World Bank, August 2022)

Results and discussion

As a result, losses in the irrigation, drainage and water management sector of the regions are estimated at 154.38 million US dollars, including damage to dams, irrigation canals, embankments, buildings and departmental premises (KSE, 2022). This amount partly reflects losses in territories previously occupied by Russian forces and now under the control of Ukrainian authorities, in territories that were not occupied but suffered as a result of the bombing, including territories that were flooded to protect against the occupation. Serious negative consequences inevitably arose as a result of the use of weapons, which can cause long-term effects on the environment (NTU KhPI, 2012). In the places of hostilities, water bodies are polluted with remnants of military equipment, and various ammunition, and leaks of fuel and lubricants are observed. Already now, the content of oil products, heavy metals and dangerous chemicals is recorded in the surface water bodies of the de-occupied territories.

Diagnostics of the ecological state of river basins should show the direct and indirect impact of military actions on water ecosystems and prepare evidence of the commission of war crimes against the environment for further assessment and compensation of the damage and losses caused to Ukraine as a result of the armed aggression of the Russian Federation as a result of pollution, littering, depletion and other actions regarding water resources, which can worsen water supply conditions, harm people's health, cause a decrease in fish stocks and other objects of water fishing, deterioration of living conditions for wild animals, decrease in soil fertility and other adverse phenomena due to changes in the physical and chemical properties of water, decrease in their ability to natural purification, violation of the hydrological and hydrogeological regime of waters (KMUP, 2022).

In cooperation with the Ministry of Environmental Protection and Natural Resources of Ukraine and the State Environmental Inspection of Ukraine using methodological tools (KMUV, 2022) approximate losses for unauthorized use of water were calculated, which amounted to 32.63 million UAH/day (1.0 million USD/day). For the pollution of water resources by polluting substances, which are daily discharged with waste water, the losses amount to 10.44 thousand UAH/day (285 USD/day). In just 10 months of Russia's full-scale invasion of the territory of Ukraine, the total amount of damages due to pollution, clogging of water and arbitrary use of water resources amounted to more than UAH 55.7 billion. Of these, UAH 15.5 billion in losses were calculated as a result of the seizure of hydraulic facilities of the North Crimean Canal (DEI, 2022).

In order to respond promptly and make management decisions in the field of protection and rational use of water resources, the State Agency of Water Resources of Ukraine monitors the condition of surface waters, in particular at the places of drinking water intakes, according to physico-chemical, radiological, hazardous chemical and basin-specific indicators. With the restoration of safe access to the de-occupied territories, the number of water samples is gradually increasing. The State Agency of Water Resources of Ukraine monitors surface waters in accordance with the Procedure for State Water Monitoring

(KMUD, 2018) and the State Water Monitoring Program (in terms of diagnostic and operational monitoring of surface waters for 2022 (Prohrama, 2022).

Due to the impossibility of taking water samples at water bodies located on the territory of hostilities, as well as due to the tense military situation in March-June 2022, it was possible to take water samples at only 35 percent of monitoring points. Already in July 2022, taking into account the deoccupation of the territories, it was possible to take water samples at 398 monitoring points, which was 68 percent of the total number of 583 monitoring points (Khilchevskyi 2022).

Table 3 presents the distribution of the number of monitoring points by river basin district, taking into account the possibility of sampling in different periods.

Table 3. Number of surface water monitoring points where water samples were taken in 2022 (State Agency of Water Resources of Ukraine, July 2022, (Khilchevskyi 2022))

The area of the river basin	Total number of monitoring points		The number of actually monitoring points	
	total	including drinking water places	total	including drinking water places
The Visla river basin	23	23 (100%)	1	1 (100%)
The Dnipro river basin	210	129 (61%)	40	28 (70%)
The Dniester river basin	92	92 (100%)	19	19 (100%)
The Don river basin	72	8 (11%)	6	1 (16%)
The Danube river basin	101	98 (97%)	11	11 (100%)
The Pivdenny Bug river basin	50	37 (74%)	15	9 (60%)
The Crimean rivers basin	–	–	–	–
The Azov Sea rivers basin	19	0 (0%)	3	0 (0%)
The Black Sea rivers basin	16	11 (69%)	0	0
Total	**583**	**398 (68%)**	**95**	**67 (71%)**

To ensure the implementation of the surface water monitoring program, the redirection of water samples for the determination of priority and basin-specific substances to the water monitoring laboratory of the Western Region in the city of Ivano-Frankivsk, which meets the requirements of ISO/IEC 17025:2019 in the field of chemical and physicochemical test methods, was ensured surface, wastewater, underground water and soil and is technically equipped to measure the relevant indicators. During the development of the Surface Water Monitoring Program for 2023, proposals were considered for the

inclusion of additional indicators of pollutants associated with the armed aggression of the Russian Federation, namely: oil products, chemicals contained in ammunition depots and missiles, if it is possible to identify them, as well as additions additional water monitoring points in the de-occupied territories to identify the impact of military actions on the state of water resources The most relevant are investments in the restoration of destroyed hydrotechnical structures and water reservoirs in territories recently freed from occupation and territories where hostilities were not conducted (Levkivskyi 2006). The implemented measures will also protect communities from risks associated with floods and restore the work of state institutions, which will ensure their effective support for the restoration and modernization of reclamation systems and water resources management

Conclusions

Military actions by the occupiers worsened both the ecological condition of water bodies and lead to problems related to the water factor. In the face of climate change, water security comes to the foreRestoration of the environment to its natural state in part of the water sector is considered in the context of river basin management plans, which are restoration plans for river basins. These plans will include measures to achieve "good" environmental conditions of the waters, including post-war recovery measures.

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Unauthorized landfills of the Ukrainian Transcarpathia: reasons for the appearance and prospects of use in the context of circular economy

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Abstract. Some regions are facing a problem of solid household waste disposal, which could become raw material in the context of the circular economy. Purpose: to conduct an inventory of unauthorized landfills within the limits of the test site in Transcarpathia region (Ukraine) and work out recommendations on ways to use the advantages of recycling to improve the ecological state of the environment. Results. The article considers the state of solid waste management in Transcarpathia region. Each landfill has a passport with a description of the morphological composition of the waste in percentage terms, size and photo fixation of its appearance. The paper analyzes main indicators that make up the passport. It emphasizes that the specific disposal of solid waste in unauthorized landfills is about 0.52 m^3/ha, which is quite high among the regions of Ukraine. Despite the good coverage of the population with solid waste collection services (77%), illegal dumpsites are widespread. The paper also considers ways of landfills evolution in time. Conclusions. Disposal of solid household waste in the study area not only affects the population, but also has a negative impact on landscapes. The investigated unauthorized landfills contain resource-valuable solid waste components: wood (29%), construction materials (18%), rags, shoes (13%), plant remains (9%), paper (7%), plastic, polyethylene (7%), glass (6%), rubber (3%), metal (3%), etc. When processing them, the population of the community could gain an economic effect exceeding the cost of garbage removal. The materials of the work contain recommendations of the transition to the circular economy.

Keywords: Landscape, ecology, waste management, waste disposal, landfills, Transcarpathia

Introduction

The amount of solid household waste is continuously increasing due to the growth of large and small cities and their population, creating more and more problems for local municipal authorities and utility services.

Solving this problem, modern society at this stage of its development faces the disposal of solid household waste, which becomes a difficult task. The reason for this is the appearance of various modern packages, new types of plastics and glass that decompose in nature. Getting into the soil and water environment, decomposing under the influence of external physical and chemical factors of the environment, solid household waste becomes dangerous for the environment and threatens human health.

In order to satisfy the needs of one citizen of the planet, 40 tons of mineral raw materials are extracted annually from the depths of the Earth. People use only 3–5% of it, at best, the rest pollutes the environment. However, humanity can benefit from this type of pollution. An example of this is processing of mine waste, extraction of useful substances from tericones, not to mention the secondary processing of various polymers.

This problem has another aspect: Ukraine has already accumulated more than 27 billion tons of solid waste alone, having absorbed more than 1.6 million square km of territories (for example, this is 1/10 of Ivano-Frankivsk region), generally suitable for economic use.

The problem of solid household waste disposal is a problem of national importance. In the list of types of activities and objects that pose a high environmental hazard (Decree of the CM of Ukraine dated June 27, 1995 No. 554 «On the list of types and objects that pose an increased ecological hazard»), the problem of destruction, processing, preservation, burial and disposal of all types of industrial and household waste takes third place after those of nuclear energy and nuclear industry.

The problem of solid household waste disposal in Transcarpathia has not been completely solved until now. There are overflowing landfills that require the construction of waste processing or waste incineration plants. The regional authorities have voiced such plans more than once, but so far, the situation in the region is rather unfavorable. There is also a low environmental awareness of the population, which traditionally throws garbage on the banks of rivers, which carry everything downstream during floods. This creates serious problems for reservoirs, making the banks look ugly and forms spontaneous landfills on rapids or bends of the river. A large part of the river valleys in Transcarpathia are in the protected zone, which worsens the situation.

The purpose of the work: to conduct an inventory of unauthorized landfills within the limits of the test site in Transcarpathia region (Ukraine) and develop recommendations on ways to use the advantages of recycling to improve the ecological state of the environment.

Literature review

An officially registered solid waste landfill is dangerous if there is no waste sorting equipment or a waste processing plant on its territory. However, a natural landfill is many times more dangerous due to the lack of control, and, therefore, – any environmental protection measures, as well as the payment of taxes (Landfills...). There are almost 6,000 official (controlled) landfills in Ukraine. Moreover, according to various estimates, there are up to 30,000 natural (uncontrolled) landfills, occupying approximately 7% of the entire area of Ukraine. Consequently, the total volume of waste at all landfills, including industrial ones, is more than 450 million tons per year, much of it is hazardous (Landfills...).

A natural landfill can contain various types of waste with an extremely high level of danger. In addition, their locations disregard any sanitary rules and regulations. These are usually the areas of forest strips closest to settlements, ravines along highways, reservoir coasts, and steppe zones, affecting large areas by poisonous substances.Consequently, rare species of flora and fauna die, and settlements receive polluted water and acrid stench from vapors in the air. Therefore, a few years ago, the Ministry of Ecology and Natural Resources created an interactive map of landfills of Ukraine on its website, where you can leave a message online about the coordinates of a spontaneous landfill (Landfills...).

A review of scientific publications on unauthorized landfills can help understand the problem of environmental pollution and its consequences for human health and ecosystems.

Scientific publications on illegal dumping are quite diverse and may include journal articles, books, studies and reports. Here are some examples of such publications.

In his work, Mahajan Rinnie (Generation... 2020) states that in recent years, the topic of solid waste management has attracted the attention of the whole world. This problem is more severe in the developing countries than in the developed countries due to lack of capital and resources. Solid waste generation, sorting methods, storage facilities, collection frequency and disposal methods have proven unsustainable in developing countries. In these countries, uncontrolled dumping and open burning are a common thing. Open dumping and incineration of waste poses serious risks to the environment and health. This has led to serious forms of air, water and soil pollution. Solid waste pollution increases mortality and morbidity. Therefore, this study (Generation... 2020) examines the environmental consequences and potential health hazards of improper and inefficient solid waste management. It also focuses on the environmental sustainability of solid waste management rather than economic and social sustainability. Thus, a paradigm shift towards sustainable and clean solid waste management is vital to preserve ecosystems while maintaining a green economy and social equity among current and future generations.

Despite the fact that Ukraine has developed a National strategy for waste management until 2030 (Safranov 2020), this has not resolved many issues in this area yet.

Our scientists pay considerable attention to the problem of unauthorized landfills. Thus, a group of scientists from Odesa State Ecological University in (Prykhodko 2019),

while studying the amount of plastic accumulation in the waters of the northwestern Black Sea region, conducted a survey of the territory of Odesa and Mykolaiv regions and created a map of existing solid waste landfills, both organized and unauthorized. They established that «A significant part of plastic waste, primarily from unauthorized landfills of solid household waste, is carried by air currents into the river network, and in the case of their proximity to the coastal strip – directly into the Black Sea water area» (Prykhodko 2019).

These are just a few examples of publications that can be useful in studying the problem of illegal dumping. It is important to use research and publications from responsible sources to obtain the most reliable information.

Here are some key aspects found in such publications:

- Causes of Unauthorized Landfills: the research analyzes the factors leading to the occurrence of illegal dumps, such as insufficient waste management infrastructure, lack of alternative methods of waste disposal, lack of understanding of illegal dumping consequences, etc.
- Environmental Impact: studies assessing the environmental impacts of illegal dumping, including soil, water and air pollution, as well as impacts on biodiversity and ecosystems.
- Health Effects: studies examining the human health effects of illegal dumping, including respiratory health risks, cancers, infectious diseases, etc.
- Social Consequences: studies analyzing the social consequences of illegal dumping, such as job losses, increased inequality, and the impact on life quality of local population, particularly children and vulnerable strata.
- Management Strategies and Problem Solving: studies suggesting strategies and policies for waste management, as well as effective methods for cleanup and remediation of contaminated sites.
- Publications in these areas help deepen understanding of the problem of illegal landfills and develop strategies to overcome this serious environmental challenge.

Methods

To obtain data on various socio-ecological indicators of the territory, the authors used specific means of collecting information.This enabled us to conduct a qualitative analysis of social problems, including complex ones: the state of public opinion, features of social and group consciousness of people. There are four main means of empirical, sociological and socio-economic research, document analysis, observation, survey and social experiment.

Field studies are, as a rule, large-scale research with a detailed survey of individual enterprises, settlements, the territory of administrative districts as a whole. This is the main method of cognition in social ecology. Here, we reveal the deepest relationships, develop

and test new concepts, collect original primary material for subsequent systematization and generalization.

Large-scale field research includes the study of primary objects. Large-scale inspections also include recording of unauthorized landfills. For this, we use methods of camera processing of statistical data.

The authors carried out the inventory of unauthorized landfills on an experimental site with fixed dimensions for the convenience of further calculations. For this purpose, we drew a map with a clear reference to each point, using a photo fixation and description of garbage composition in percentage (Fig. 1). The observation was carried out during the spring-summer period of 2023.

Results and discussion

According to the Ministry of Communities and Territories Development of Ukraine, more than 25 thousand unauthorized landfills are recorded annually in Ukraine on an

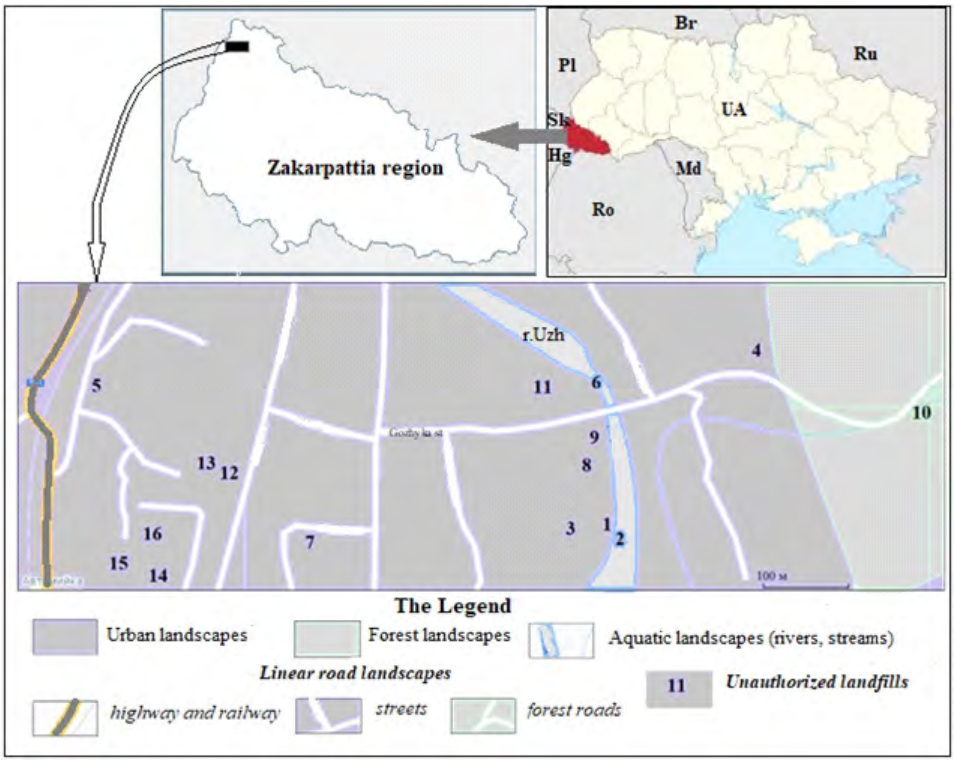

Fig. 1. Location of unauthorized landfills on the experimental site

area of about one thousand hectares, the emergence of which obviously relates to the lack of centralized solid waste collection (22% of the country's population are not covered by solid waste collection services).

One of the objectives of the National Waste Management Strategy for Ukraine until 2030 (Landfills...) is to increase the level of solid waste recycling to 50% by 2030 and to abandon a large number of existing landfills, while launching new regional landfills.

Transcarpathia region is characterized by relatively low values of specific solid waste disposal (4.3 t/person), while the specific disposal of solid waste in unauthorized landfills is about 0.52 m^3/ha, which is quite high among Ukrainian regions (Generation... 2020). It has one of the lowest proportions of land area in Ukraine (0.0075%) and one of the highest proportions of overloaded landfills – about 11%, while in the neighboring Chernivtsi region it is less than 2% (Generation... 2020).

In general, in Ukraine, the coverage of the population with solid waste collection services is, on average, 77% (Generation... 2020), but this does not reduce the problem, as the private sector traditionally takes garbage outside the village and dumps it on the side of the road, on the river banks, at the edge of the forest, etc. This creates spontaneous landfills, which occasionally either burn or compact. Most often, grass grows through the garbage and it naturally decomposes or mixes with plant debris.

The inventory of unauthorized landfills was carried out on an experimental site with fixed dimensions, located within two settlements: the village of Velykiy Berezny and the village of Zabrod. The Uzh River flows between them. There is a wide floodplain around it, which is periodically flooded in springs and after rains. This is an important fact, since some of the landfills are washed by the river and moved downstream, littering the surrounding landscapes. On the map, all landfills are plotted with the help of a GPS navigator, which simplifies the assessment of their density on the location. We found 19 locations of unauthorized landfills. For each landfill, we created a passport with a description of the morphological composition of garbage in percentage, dimensions, and a photograph, as well as a general photo catalog, part of which is shown in Figure 2 as an example.

In early spring, garbage dumps appear due to the spring-cleaning of the estate. It is at this time that most of the garbage is plant remains, stones picked up from the soil, and household junk. However, new dumpsters occurred containing construction waste, glass, including glass containers, plastics, including plastic bottles, which private enterprises quite successfully process for special disposal. Such examples testify to the low environmental education of the population, which instead of sending them for disposal, simply throw them away and litter large areas.

Analysis of the morphological composition of garbage at each landfill has showed that they are quite heterogeneous (Table 1, Fig. 3). Some of the landfills (Nos. 4, 9, 12, 13, 16) consist of 70–90% of wood – tree branches, firewood, sawdust. This is the material that does not require additional processing for re-use, as it can be used for premises heating. At the same time, using recycling, this waste can become raw material for chipboard production.

Fig. 2. Photo documentation of unauthorized landfills

Construction waste prevails in some landfills (Nos. 8 and 14) (Fig. 3). It is also possible to reuse it – for example, to fill in bumps on the roads, reusing it on construction sites for backfilling,etc.

There is a predominance of rags and shoes on the first and second sites – 65% and 40%, respectively, while paper and cardboard dominate on site site No. 3 (Fig. 3). Traditionally, recycling plants use this waste to create a new product, but under these disposal conditions, it only pollutes landscape components.

The rest of the unauthorized landfills have a diverse morphological composition. In this case, we recommend separate collection of garbage on private estates and send it in portions for targeted processing.

The studied unauthorized landfills generally contain resource-valuable solid waste components: wood (29%), construction materials (18%), rags, shoes (13%), plant remains (9%), paper and cardboard (7%), plastic and polyethylene (7%), glass (6%), rubber (3%), metal (3%), etc. (Fig. 4).

Thus, research at the test site established the predominance of plant remains (branches, wood, sawdust, grass), rags and building materials (Fig. 4), which are valuable raw materials for waste processing enterprises.

Table 1. Garbage composition of unauthorized landfills at the test site in %

№ № landfills	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Paper, cardboard, chipboard			70		10		20			10		5		5				5	
Rags, shoes	65	40	5		30	30				5	10	10			5			15	25
Glass					5					20	20			5			30	15	10
Building materials	5		5				30	85	10		20			60	40	5	30	30	20
Rubber	10	10			5		10			5	10						5		10
Tree branches, firewood, sawdust	5	20		85	25	5	10		75	20	10	70	90	5	20	80		10	20
Grass, vegetable garden	5	15	5	10	15	40	30	10	10		10			5	20	5			
Plastic, polyethylene	5	5	5		5	25				20		10	5	5	10	5	20	10	10
Metal, wire		5	5							10	10			10			10	10	
Other	5	5	5	5	5			5	5	10	10	5	5	5	5	5	5	5	5
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

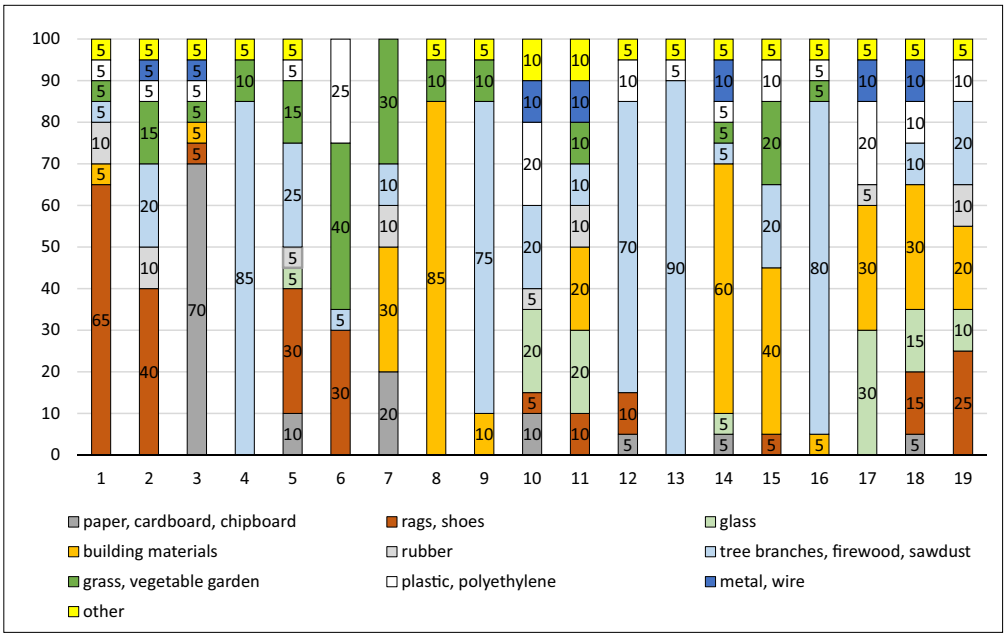

Fig. 3. Garbage composition of unauthorized landfills at the test site in %

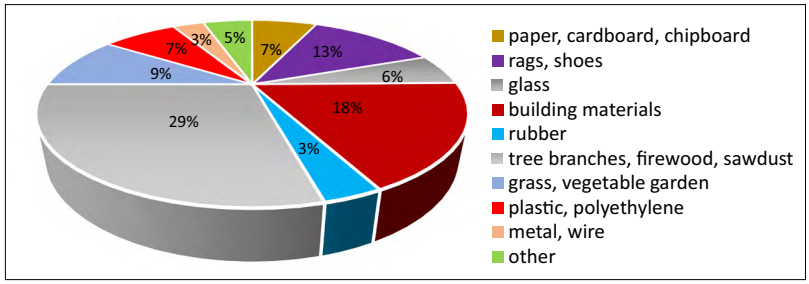

Fig. 4. Average morphological composition of waste at the test site

To ensure circularity, we have to increase the level of waste collection and recycling. Thus, one should know the categories of waste that go to recycling (Prykhodko et al. 2020):

- Textiles, taking into account the complexity of the textile value chain, the impact of rapid fashion changes, the current limited reuse of textiles, the significant contribution to waste accumulation and greenhouse gas emissions from industrial wastewater, and the need to stimulate demand for environmentally friendly clothing;
- Electronics, which, with proper and safe handling practices, also present an opportunity for reuse and remanufacturing, leading to an increase in the supply of OPSYS TK template – affordable products, as well as opportunities to recycle valuable materials present in e-waste;

- Construction and reconstruction, which will gain special importance during the post-war reconstruction process of Ukraine;
- Plastics, the consumption of which is growing unsustainably, constituting the main share of imports of chemical industry products to Ukraine. Increasing the consumption of recycled plastic, reducing the amount of plastic waste and microplastics in the environment;
- Accumulators, where new value chains arise as a result of the electronic mobility development.

The new draft Law on Batteries and Accumulators addresses the issues of recycled content, recovery of valuable materials and safe disposal. We will need further measures to combat single-use batteries and align with the new EU regulatory framework being developed (Prykhodko et al. 2020).

Agriculture is an important part of the Ukrainian economy. There is a significant potential in this sector to improve food handling, storage and distribution to prevent losses. This sector can also be a supplier of by-products to feed industrial and energy processes (Prykhodko et al. 2020).

Minerals and metals are the most important raw materials for society used in almost every sector of the world economy. Their extraction and further processing will be key to providing clean technologies, mobility and digital solutions necessary for the transition of all industrial sectors to climate neutrality and a circular economy.

The Law of Ukraine «On Waste», Resolution of the Cabinet of Ministers of Ukraine No. 1212 dated August 3, 2000, Law of Ukraine «On Licensing of Certain Types of Economic Activity» No. 1775-111 dated June 1,2000 establish the legal, organizational and economic foundations of activities related to the prevention or reduction of waste generation volumes, their collection, transportation, preservation, processing, utilization and removal, disposal and burial, collection and processing of resource-valuable solid waste components, as well as prevention of negative impact of waste on the natural environment and human health on the territory of Ukraine. Such waste includes:

- polymer waste;
- waste paper;
- glass;
- metals;
- rubber waste, including worn tires;
- textile waste materials (rags);
- other types of waste.

The company's Charter, a license for the right to collect and process solid waste, other permitting documents (working project, comprehensive examination of the working project for the right recycling, EIA project) should mainly determine the status of the activity of state, commercial enterprises, legal entities and private individuals engaged in the collection and processing of resource-valuable components of solid waste.

However, in violation of legislation in the field of waste management, a number of companies, especially commercial firms, collect and process valuable solid waste components without permits in full, with a gross violation of processing technology (in particular, processing of polymer waste).

Commercial firms and private individuals carry out work on the polymer waste processing in unsanitary conditions with a gross violation of production technology, in unequipped premises and without the approval of regulatory authorities.

Prior to the issuance of Resolution of the Cabinet of Ministers of Ukraine No. 1197 dated August 3, 2000 «On the approval of the list of certain types of waste as secondary raw materials, determination of services for the collection and procurement of which are exempt from taxation», enterprises, firms, legal entities and private individuals engaged in business activities for the collection and processing of resource-valuable waste, allowed the above-mentioned violations.

Ukraine had developed the Waste Management Strategy until 2030 (Safranov et al. 2020), which was approved by the Decree of the CMU dated November 8, 2017 No. 820. It determines the main directions of state regulation in this area for the next decade, taking into account European approaches to waste management.

Such a situation in the removal of solid waste in Velykiy Bereznyi, Transcarpathia Oblast, occurred, in our opinion, for the following reasons:

- lack of proper coordination by the sanitary conditions management of the township in connection with different forms of ownership of organizations engaged in the removal of solid waste;
- weakening of inspection and sanctioning of inspections, compliance with schedules and sanitary regulations for the removal of solid waste;
- lack of control over the regular application of transport for the removal of the daily accumulation of solid waste;
- lack of a unified centralized system of solid waste disposal, as a single management body;
- control weakening of district, city and regional sanitary bodies, ecological police, department of ecology, on the implementation of sanitary cleaning rules;
- lack of control over the drawing up and execution of application schedules by customers for the removal of daily solid waste accumulation;
- absence of a single document confirming the amount of garbage actually removed from the customer and the amount that arrived at disposal sites.

Conclusions

Disposal of solid household waste in the study area does not benefit the population. Moreover, it has a negative impact on landscapes. The investigated unauthorized landfills contain resource-valuable solid waste components: wood (29%), construction ma-

terials (18%), rags, shoes (13%), plant remains (9%), paper and cardboard (7%), plastic and polyethylene (7%), glass (6%), rubber (3%), metal (3%), etc. When processing them, the population of the community could gain an economic effect exceeding the cost of garbage removal. The materials of the work recommend the transition to the circular economy. Recycling can give new life to old things or waste. The circular economy promotes the full use of all consumed raw materials. Therefore, it is important to develop the practice of recycling in household conditions as well.

Moreover, the ecological consequences of such a transition are obvious. The basic strategy in Transcarpathia Oblast should focus on reducing negative visual impacts, as well as the impacts on the local landscape. Considering potential negative influence on water resources, associated with the migration of infiltration runoff, we should pay special attention to landfills with accumulated plant remains.

Finally, the last stage includes measures to reduce residual negative impacts, such as improving the environment in the area of landfill location, required necessary measures for landscape planning, improving and restoring the condition of the sites and the surrounding area as a habitat for local species of plants and animals.

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Managerial information technologies to increase efficiency of energy willow growing

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Abstract. The chapter studies the impact of managerial information technologies on the increase of efficiency of energy willow growing by agricultural enterprises. The research analyzes problems and prospects of power engineering development in Ukraine. It is confirmed that growing and use of energy crops in Ukraine demonstrates a positive impact on development of bioenergetics, economics and agrarian sector. The work considers agro-ecological peculiarities and prospects of using alternative sources of energy in the current conditions, defines problems and prospects of technological and technical solutions in the field of alternative power engineering. The authors substantiate expediency of energy crops growing on the lands of low fertility and assess it as one of the most promising sectors of bioenergetics in Ukraine. The sector development provides great advantages because of the opportunity to get all kinds of biofuel (solid, gaseous, liquid) to substitute traditional energy carriers, a positive impact on soil conditions (increase of the content of organic matter, phytoremediation of polluted lands), development of local economy and creation of new job places in the regions. It is stated that global increase in the demand for energy crops contributes to the rise in prices that causes growth of supply. Agriculture of Ukraine, therefore, has all chances to become a branch that is capable to ensure both food and, to some extent, energy security of the country. Development of the biofuel market can be stimulated and supported by the state by applying a wide range of tools. The chapter outlines directions to increase economic efficiency of energy willow (Salix) growing. It is noted that efficiency of energy willow growing and capitalization of the proper quality chips depends on application of advanced methods of management, mechanization and automation of the accounting and production processes, use of innovative digital technologies. The research describes the effect made by digital technologies on the stages of energy crop production, outlines digital information tools to manage the process of energy crop production, including software for automated accounting. The work sets tasks for the complex automation of the process of energy willow growing management.

Some science-based strategies of bioenergetics development grounded on the impact of digital accounting and production processes are proposed.

Keywords: energy willow, biomass, chips, costs, production, bioenergy crops, management, automation, digitalization

Introduction

Nowadays, biomass is considered the main kind of renewable sources of energy in the world. Burning wood does not deteriorate the thermal balance of our planet and therefore, wood biomass is viewed as an environment-friendly kind of fuel. Moreover, the process of the renewable source production can be managed that is, however, impossible with the traditional sources (coal, oil, gas). Europe is actively developing the branch of energy crops, like willow, poplar, miscanthus, switchgrass, etc. It is a profitable business for farmers that provides new job places, more revenues to local budgets, as well as energy independence, improvement of environmental conditions, particularly land conditions, for the country. Energy crops can be grown on agricultural lands of low fertility, which occupy almost 4 million ha in Ukraine. According to the forecasts, the area under energy crops will increase in the European Union up to 26.2 million hectares until 2030 (Ppv.net.ua, 2018). Thus, new objects of management, i.e. bioenergy agricultural crops and biomass, have appeared. It forces the necessity to find out the methodological peculiarities to increase efficiency of the technological process of energy willow growing and to develop the theoretical and practical context of the information support for management of the bioenergy crop production.

The present research studies objects of the biomass and energy crops management, particularly some kinds of trees and plants, which are purposefully grown to produce solid biofuel. They are divided into three groups (Saee.gov.ua, 2015): fast-growing trees (energy willow, acacia, poplar, etc.); perennial grasses (miscanthus, Uteusha Rumeks); annual grasses (sorghum, triticale). Biomass is used in several ways, particularly it is processed for solid (retting) and liquid (biodiesel and bioethanol) biofuel. Thereby, agrarian economy is viewed as a "live" economy, i.e. the economy which is characterized by economic processes with living organisms, namely animals, plants, agricultural land, environmental complexes, food and energy reserves (Zhuk 2008). Scientists have concluded that biomass is the largest renewable source of energy. Identification of biomass is based on its unique characteristics, particularly non-fossil nature, organic (plant or animal) origin, capability to biological decomposition, intention of biomass producers to use it for energy purpose (Tomchuk, Fabiianska 2018).

The analysis of literary sources certifies that it is hardly possible to achieve economic growth based on the wood biomass and, for that reason, it is necessary to concentrate efforts on growing energy crops and utilization of agricultural by-products. Using renewable sources of energy is one of the principal directions of the energy policy in Ukraine,

focused on saving traditional fuel and energy resources, reduction of the dependence on imported energy carries and improvement of the environmental conditions. In Ukraine, the branch of bioenergetics has one of the greatest potential of development. Prospects of bioenergetics development are fueled by the powerful agrarian sector, sufficient labor forces and favorable climatic conditions of the country. The greatest potential is shown by such kinds of biomass as wood waste, agricultural and energy crops (Denysenko 2019; Energy efficiency and energy independence of rural territory: prerequisites of establishment and performance, 2020). Some Ukrainian scientists are sure that growing and using energy crops in Ukraine has a positive effect for development of bioenergetics, economics and agrarian sector. Moreover, it creates new job places, increases revenues to local budgets. Burning biofuel made of energy crops produces organic fertilizers which can be used in agriculture (Babyna 2018; Green investments in sustainable development: world experience and Ukrainian context, 2019).

Results of the research confirm that global increase in the demand for energy crops contributes to the rise in prices that causes growth of supply. Agriculture of Ukraine, therefore, has all chances to become a branch that is capable to ensure both food and, to some extent, energy security of the country. Development of the biofuel market can be stimulated and supported by the state by applying a wide range of tools (Kravchuk 2013). Although growing and using energy crops is one of the most promising sectors of bioenergetics in Ukraine, some researches prove that the projects of growing such energy crops as willow, poplar, miscanthus show economic indicators on the margin of profitability which are not very attractive for investors (Tryboi et al. 2021). Theoretical and methodological basis of the research is made by the fundamentals of economic science concerning the features, essence, principles and peculiarities of the impact made by managerial information technologies on the increase of efficiency of energy willow growing by agricultural enterprises. To conduct the research, the scientists used a set of general scientific and special methods of economic research, particularly: analysis the synthesis, logical, dialectic – to deeply study the research object and to improve the conceptual framework; generalization – to describe theoretical and methodological basis; comparative method and systematization – to study foreign experience; graphical – to visually demonstrate the research findings; abstract and logical – to consolidate the results and make conclusions and suggestions.

Results and discussion

Solution of the problem of energy shortages and rise in prices can be found in the use of biomass for energy purpose. All agricultural by-products and biomass of wood waste can be generally used to produce heat or electric energy. All these resources are, however, non-renewable. In some European countries, energy raw material has been long cultivated by growing energy crops. Energy crops are characterized by very fast initial rates of growth. The raw material which is processed to produce fuel can be obtained already in

three years after the plantation start. Thus, energy crops create a permanent renewable source of energy. The yield (growth of biomass) variates from 10 to 30 t/ha of dry mass. Fuel chips of energy willow are made of tree biomass cut into tiny pieces by a special crusher. The common feature is that the carbon dioxide balance is equal to zero, that means that the amount of carbon dioxide emitted into the air during burning is equal to the amount absorbed during photosynthesis by energy crops while they grow. Furthermore, comparing to the gas heating systems, modern boilers running on the biofuel made of energy willow four time reduces the costs of housing heating.

In Ukraine, specialists have been working for ten years to increase efficiency of using biofuel and bioenergy. It shrinks the national economy's dependence on the import of energy carriers, ceases energy consumption, contributes to economic development. Most countries are only at the start of their way of applying their resource potential, whilst Sweden, Denmark, Finland, Norway have already created highly technological industrial sectors for bioenergetics and intensively use them. In particular, there is an effective system of cogeneration based on biomass. New member-states of the UN, like Moldova, Romania, Bulgaria, Poland, Baltic state, as well as Ukraine possess significant amounts of raw material, but that potential is almost not engaged or is used inefficiently because of the lack of investments in advanced technologies of biomass growing and processing. Nevertheless, Ukraine has recently experienced positive changes in the energy policy focused on promotion of biomass as a fuel which is acknowledged to be a technically rational process of burning biomass made of fuel chips and pellets. The market of solid biofuel is being actively developed and creates demand for high-quality raw material. New varieties and hybrids of energy willow (Salix) provide high yields of biomass used to produce biofuel and demonstrate much better indicators of dry biomass yield, efficiency of solar energy accumulation and ecological technology of planting than the common Ukrainian kinds of trees.

The interest to energy willow has been aroused by the sharp energy crisis in the world that has forced many countries develop special national energy programs intended to reduce consumption of fossil fuels and substitute them with other sources of energy, particularly biomass of fast-growing varieties of trees. After deep chemical processing, wood biomass is used to produce fuel for internal combustion engines. The sufficient amount of wood is supplied by special energy cropping areas of poplar, alder, acacia and willow. It is important that the plantations can be made on the lands of low fertility. Thus, Finnish researchers develop the technology of launching willow plantations on the worked out peatlands and on the lands which cannot be further used for agricultural purposes. In Sweden, they study the opportunities to create similar plantations on dried sphagnum swamps, as well as assess the impact of fertilizers and mycorrhizae on the living and growth of shrubby willow cuttings (Green investments in sustainable development: world experience and Ukrainian context, 2019).

Development of green energy has resulted in fast expansion of the area of bioenergy crops in the European countries. The leaders are Sweden (20 thousand ha of willow 550 ha

of poplar, Poland (9 thousand ha of willow and 300 ha of poplar), Denmark (5.7 thousand ha of willow and 2.8 thousand ha of poplar) and Ukraine (almost 5 thousand ha of willow and 300 ha of poplar). Today, the global consumption of energy made of renewable sources on the basis of biofuel accounts for 15% as compared to other kinds of energy. In some European countries, the contribution of biofuel into the total consumption of primary energy carriers takes a significant share, namely in Denmark – 8%, Sweden – 19%, Finland – 22%, in spite of the substantial reserves of fossil hydrocarbons. According to the available estimates, in Ukraine, the share of renewable sources of energy does not exceed 2.7% of the amount of produced energy. The Energy strategy of Ukraine till 2030 expects its growth up to 10%. In Ukraine, energy crops growing is at the initial stage, about 4000 ha of marginal land are under energy crops. Mostly, it is energy willow, poplar and miscanthus which provide the annual average yield of 20 t/ha. The branch has a huge potential being capable to increase 250 times. According to the scientific estimates, one million ha of land can produce 11.5 million tons of energy crops yield which can substitute 5.5 billion m^3 of natural gas, or two thirds of the country demand for gas.

Introduction of highly effective technologies of energy willow growing is the condition for economic progress of the bioenergy complex. It will provide an increase of energy willow yield and reduce costs of its growing. Any technology is intended to save resources. It is a complex of biological, agro-technical, technical, organizational and economic measures to ensure high yield and high quality of biological materials. One of the important conditions to increase economic benefits from growing willow is to conduct proper cost management in order to take leading positions at the market of biofuel producers operating on eco-friendly biomass. Thus, Ukrainian agricultural enterprise SALIX ENERGY LLC defines its strategic goal of development, aims to expand plantations of energy willow and to create a vertically integrated company, i.e. agro-energy holding, which will have a plant of producing fuel pellets of its own eco-friendly biomass and a power plant in its structure. In case a vertically integrated business organizes processing of biomass into pellets and briquettes, and it is equipped with modern boilers, the business is able to supply heat and electric energy. Findings of the research prove that 450 ha of energy willow produce sufficient amounts of biomass for a settlement with 7000 residents is completely switched to alternative energy supply (Hnatyshyn et al. 2022).

The concept of energy efficiency and energy saving, as well as its practical implementation require some improvement of the system of management in the field of renewable energy. Nowadays, biomass is considered to be the main kind of renewable sources of energy in the world. Burning wood does not deteriorate the thermal balance of our planet and therefore, wood biomass is viewed as an environment-friendly kind of fuel. Moreover, the process of the renewable source production can be managed that is impossible with the traditional sources (coal, oil, gas). Production of high-quality energy willow at the lowest cost can be achieved by applying modern methods of management and automatic technological processes, using innovative digital technologies. Digitalization significantly influences each stage of energy willow growing (procurement, production,

sale). In particular, when applying advanced digital Internet-technologies at the stages of procurement, the enterprise saves much cost, because different online services, mobile platforms, specific agrarian digital sites of suppliers (planting material, raw material, commercial and material values, protection means, etc.) can be normally used for free or at minimum cost for subscription. The best price proposals and conditions of product delivery provide substantial savings for agrarian enterprises. The process of energy willow production is influenced by digital technologies through introduction of digital tools into some technological and managerial processes. In crop production, a technological process consists of a complex of agro-measures which should be performed according to the optimal (approved) sequence in the determined agronomic terms in order to provide the most favorable conditions for energy crop growing, high yield of plants in compliance with the economic, technological, natural and ecological requirements. High yields of energy crops are currently provided by advanced intensive technologies which are based on findings of the agrarian science, technics and highly efficient system of agrarian production management.

Figure 1 demonstrates the ways the advanced digital technologies influence some stages of energy willow production.

The research findings confirm that Smart farming, precision agriculture is effective and achievable if a land bank of minimum 500 ha is available. Today, almost 30% of agrarian enterprises are on the way of introducing technologies of precision agriculture, but they mostly apply only one innovation, i.e. an autopilot or course pointer to avoid gaps

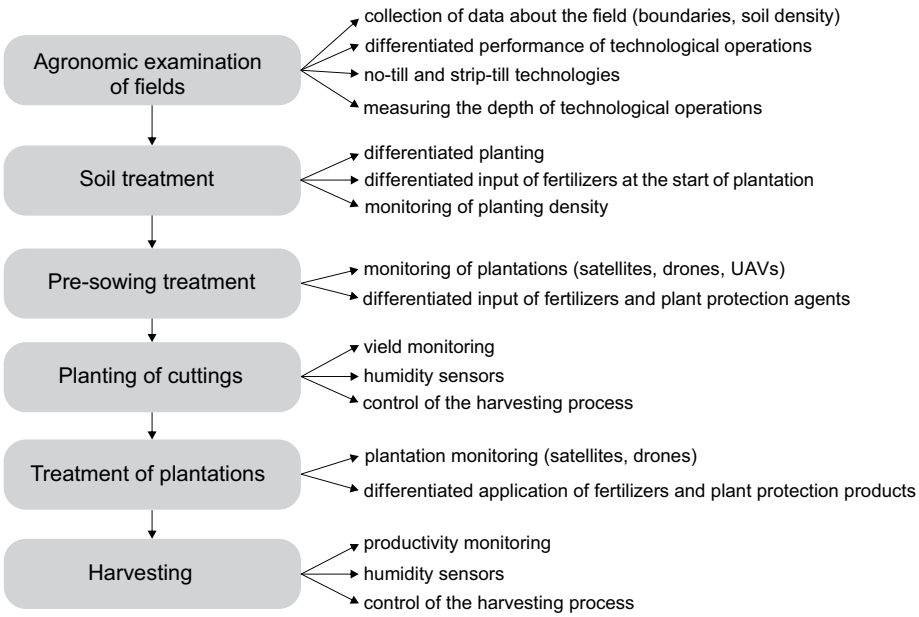

Fig. 1. Impact of digital technologies on the stages of energy willow growing

or overlaps on fields during the chemical treatment of agricultural crops. To introduce technologies of precision agriculture, it is necessary to gradually fulfill the following steps: first, to develop a clear plan of measures which should describe the processes that should be optimized, to define who will be responsible for the results; to make an algorithm of the result measuring. To launch precision agriculture, the primary task is to provide parallel driving which can significantly accelerate performance of field works, reduce cost and need of machinery. Thus, the enterprise should buy an autopilot or course pointer with RTK-signal or without it. The second step is to set a basic RTK-station, which can send a corrective signal (corrections) through the PRS-connection. It will improve accuracy of the GPS-coordinates up to 2.5 cm. Such options help to avoid overlaps and gaps. In practice, elements of precision agriculture are often introduced according to the recommendations of the dealing company managers to buy some digital assistants. Apparently, managers can be interested in selling some elements of precision agriculture having no system knowledge of the expediency of their use in each specific case that can result in inefficiency of the digital technology. To grasp the idea of applying digital technologies at each stage of the technological chain of energy willow growing, it is necessity to specify constituents of all technological processes. Afterwards, some elements of digital technologies can be added to those constituents (Fig. 2).

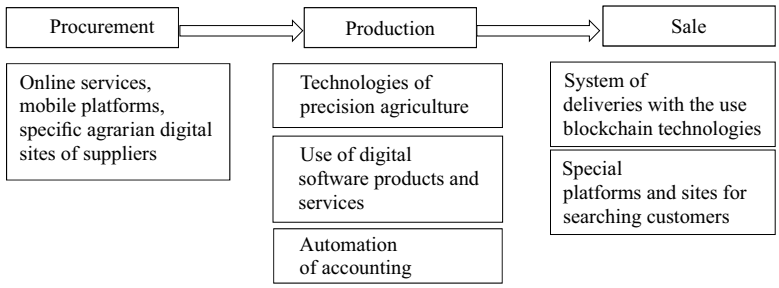

Fig. 2. Digital assistants in the technological process of energy willow growing

Using specialized software products and services, agricultural enterprises engaged in energy willow production can get more information, can perform appropriate and adequate technological operations and managerial processes with consideration of available information from satellite monitoring, systems of farm-management, meteo-services, etc. Software for production and managerial activity strengthens the information constituent of management, increases efficiency of the system of enterprise management generally, whilst appropriate analytics can help to make the best managerial decisions and contribute to the rise of the enterprise profitability.

Satellite monitoring helps to observe changes of crop conditions during vegetation. The data are obtained due to satellite shooting of each field. To conduct satellite monitoring, the performer (specialized company) should be provided with the field coordinates.

It can be done by using special program set on a phone or tablet, GPS or Google Earth Pro. One needs only to identify the field, sign it, save and send the message by Viber or e-mail. The service of satellite monitoring with the analytics of the cropping conditions costs 5 UAH/ha on average.

At the stage of sale, blockchain technologies can significantly accelerate and provide transparency of deliveries. Blockchain systems can reduce time for payments. Digital platforms and sites can be used for searching clients to sell the produced products of energy crops. Today, a new instrument of online commerce called Tradomatic (https://www.tradomatic.io) has become very popular. That platform brings together the leading producers and buyers, transnational and local traders, agroholdings and large farms. Its success is ensured by the client-oriented and transparent approach, focus on running agrarian business in compliance with international standards.

Agricultural producers need to register and create a proposal of their products following tips of the online operator, discuss and change terms of agreement online, conclude contacts for delivery. Using that instrument, agricultural enterprises get more opportunities to find partners and new customers. The enterprises can also use the agribusiness development platform called AgroTalk that comprises information on technological innovations. It also provides tools for searching partners and new clients.

Meteo-services are important assistants of agricultural enterprises as they provide weather forecasts and assess risks of diseases and pests. For instance, the company meteo.farm proposes free use of the service for a month, and afterwards, a paid tariff should be chosen. By using meteo-services which provide the data about precipitation and temperatures, producers can optimize terms of the field work start, can get adequate information about frosts to protect yield, estimate soil moisture, relative air humidity, accurate temperature, possible precipitation, wind speed, etc. without visiting fields that saves a lot of resources. However, it is necessary to assess efficiency of that instrument at each enterprise with consideration of the actual need of the proper data.

Thus, production of energy willow is positively influenced by digital software products and services used by agricultural enterprises (Fig. 3).

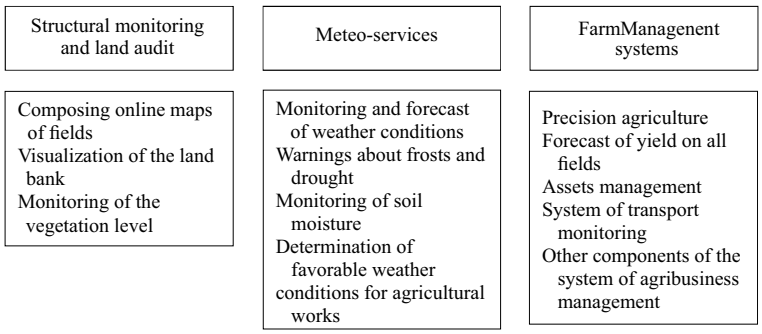

Fig. 3. Digital software products and services which are worth using in the process of energy willow production

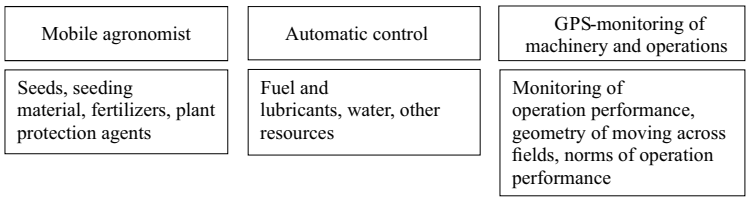

Fig. 4. Constituents of the system of automated accounting and debit of inventory items in management of the technological process of energy willow growing

Efficiency of the management of energy willow production by agricultural enterprises is immediately influenced by the available automatic system of accounting and debit of inventory items (Fig. 4). Properly arranged automated accounting is of great importance in pricing of the energy willow biomass. Automated accounting and debit of inventory items will help the agricultural enterprise managers to identify a list of inventory items, to control correspondence of their accounting and actual amount, as well as to justify the use and debit of inventory items. It will provide the managers with the appropriate and complete information about the items move within the enterprise.

Hence, complex automation of the process of energy willow production includes:

- soil and agrochemical mapping;
- composing task-maps for a variable rate of sowing and differentiated fertilization;
- keeping the history of fields with coordinate reference;
- creation of the multilayer maps of fields with consideration of different indicators;
- agro-chemical estimates;
- machinery dispatching by using satellite navigation and data of remote sensing;
- planning the work of agricultural enterprises;
- planning yields;
- creation and updating of technological maps of crops and references to fields according to crop rotations;
- planning cost of products, current and total budgets;
- planning and accounting of technological operations according to the technological maps;
- accounting of harvested products, worked daily hours, used pesticides and fertilizers;
- operational plan/fact analysis of the completed works and production indicators;
- operational plan/fact analysis of financial indicators;
- factor analysis.

Conclusions

The interest to energy willow has been aroused by the sharp energy crisis in the world that has forced many countries develop special national energy programs intended to

reduce consumption of fossil fuels and substitute them with other sources of energy, particularly biomass of fast-growing varieties of trees. The objective necessity to identify biomass and chips of energy willow as the specific objects of agrarian enterprise management has been fueled by fast development of renewable energy both in the world and in Ukraine. All principal functions of enterprise management are performed basing on the information about cost of bioenergy crops (particularly energy willow) growing and the following use of biomass and chips for energy purpose. Such information is composed in the system of automated accounting of agricultural enterprises. Since cost accounting is conducted in terms of fields, cost of the products harvested from different fields can be different and it will influence the product price.

Hence, effective management of the bioenergy development and high efficiency of growing bioenergy crops by agricultural enterprises need proper management of the technological process of energy willow growing. Improvement of the managerial information technologies in order to increase efficiency of energy willow growing and development of science-based strategies of bioenergy development is revealed in the impact made by digitalization of the accounting and production processes. Moreover, proper assessment of the mechanisms of information technology implementation at each stage of energy crops production ensures stability of the agribusiness object operation.

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Responsible management of Ukraine's export supply chains during the Russian-Ukrainian war

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Abstract. The most significant factors restraining the development of Ukrainian commodity exports before the modern Russian-Ukrainian war are described. These factors include the insufficient development of domestic certification systems, financial challenges, low global reliability ratings, and a lack of harmonization with European legislation in export activities. It is substantiated the theoretical necessity of usage the responsible management principals in export supply channels of Ukraine that involves managing environmental, economic, social, and informational impacts during export activities. The priority tasks of the recovery and development of the export system of Ukraine in the context of the responsible management of export supply chains are defined.

The approach to building a model of responsible management of export supply chains from the point of view of creating long-term environmental, economic and informational value is proposed. The Five-level (5PL) and six-level (6PL) export supply chain management solutions are important elements of this model. According to this model route optimization in export supply channels based on the Clark-Wright algorithm is developed. This optimization method takes into account the analysis of the geographical structure of foreign trade in goods of Ukraine with the countries of the European Union, territorial distance from the capital of Ukraine to the capital of the proposed country, technical characteristics of transportation and characteristics of wartime logistics. The proposed optimization of transport routes can significantly reduce costs and increase the eco-efficiency of export transportation.

Keywords: Russian-Ukrainian war, circular economy, export supply channel, responsible management, transport route, optimization

Introduction

In the conditions before the beginning of the modern Russian-Ukrainian war, the most significant factors restraining the development of Ukrainian commodity exports were:the insufficient development of domestic certification systems, in particular, eco-certification and export product quality control; the complex financial condition and insufficient level of innovative development of most enterprises; the low global rating of reliability on the market and the level of investment attractiveness of Ukraine; insufficiently harmonized and unified Ukrainian legislation in export activity following European legislation (Dedyaeva 2012).

In the conditions of the Russian-Ukrainian war, the factors restraining the development of exports were expanded by the factors of ecocide and a significant decrease in the logistics system's efficiency level. Among the priority tasks of the recovery and development of the export system of Ukraine are the introduction of responsible management of export supply chains, which involves the management of environmental, economic, social and informational impacts during the implementation of export activities; motivating suppliers to implement responsible management practices throughout the entire life cycle of goods and services; solving tasks of optimizing the movement of material flows to ensure sustainable development and successful access to world markets.

Results and discussion

In the context of the responsible management of export supply chains, the critical tasks in wartime conditions are:

- the choice of a model of international supply chain management,
- improvement of transport and logistics support processes, and
- optimization of goods transportation within the ten largest partners of Ukraine regarding export operations.

Management of export supply chains today can be represented by six models 1PL, 2PL, 3PL, 4PL, 5PL, and 6PL (Table 1).

In addition to the above, responsible management of export chains should be cost-effective and aimed at increasing the level of economic and environmental sustainability of the chain, which in turn involves:

- the emergence of financial and economic effects at the micro level (providing competitive advantages due to cost reduction (fuel savings, fewer trips, and bilateral/multilateral transport fullness);
- the occurrence of external effects that can be determined using environmental sustainability indicators and the achievement of sustainable development goals (environmental protection, prevention of adverse effects on it, continuous improvement of environmental indicators; control of carbon emissions, reduction of direct and indirect carbon footprint; efficient management of the use of water

Table 1. Management models of export supply chains

Supply chain management model	The essence of the model	Outsourcing/insourcing of logistics services
Outsourcing of logistics services is the transfer of all processes related to the storage, movement and delivery of goods to a third party (company or group of companies). Insourcing of logistics services is the creation of its own autonomous structural units (companies) that provide specialized services to both company divisions and external contractors.		
Single-level (1PL)	the manufacturer independently ensures the storage, movement and delivery of the goods to a third party	–
Two-level (2PL)	transport mediation is used between the producer and the consumer	transport outsourcing
Three-level (3PL)	the manufacturer does not independently provide transportation, placement and storage of products in the warehouse	transport outsourcing, warehouse outsourcing
Four-level (4PL)	the manufacturer does not independently provide transportation, placement and storage of products in the warehouse. At the same time, another business entity appears – a logistics company that ensures the coordination of transport and warehouse processes	the logistics company manages transport and logistics processes
Five-level (5PL)	integrated supply chain (a set of subjects: suppliers, producers, consumers and intermediaries who are in economic relations and united by participation in a single reproductive cycle of goods/services)	insourcing
Six-level (6PL)	integrated supply chain using Industry 4.0 technologies (Internet of Things, robotics, artificial intelligence, process automation, etc.)	insourcing, logistics company manages transport and logical processes with the help of artificial intelligence

Developed based on: (Mondher et al. 2012).

resources and other resources, their cleaning and circulation; disposal of hazardous waste);

- increasing the level of quality, maximizing the speed and timeliness of deliveries due to innovation.

Financial and economic internal effects of responsible export management are cost reduction due to fuel savings, fewer movements, and bilateral/multilateral transport fullness. The following indicators can be used to evaluate internal efficiency at the micro level:

- profitability ratios (return on capital, profitability of total investments in the enterprise);
- indicators of inventory turnover and their structure;

- shares in the structure of assets;
- the ratio of overdue export supply contracts (if the supplier, the carrier and the manufacturer are one subject of economic activity);
- the transport quality factor, measured by cost indicators, etc.

Coefficient of deferred export supply contracts (C_{dc}):

$$C_{dc} = (V_{dec}/V_e) \times 100\% \quad (1)$$

where:

V_{dec} – export value of unfulfilled agreements during some period (6 months, a year);
V_e – export value of all export operations during some period (6 months, a year).

The external effects of responsible export management can be determined with the help of indicators of environmental sustainability, achievement of sustainable develop-

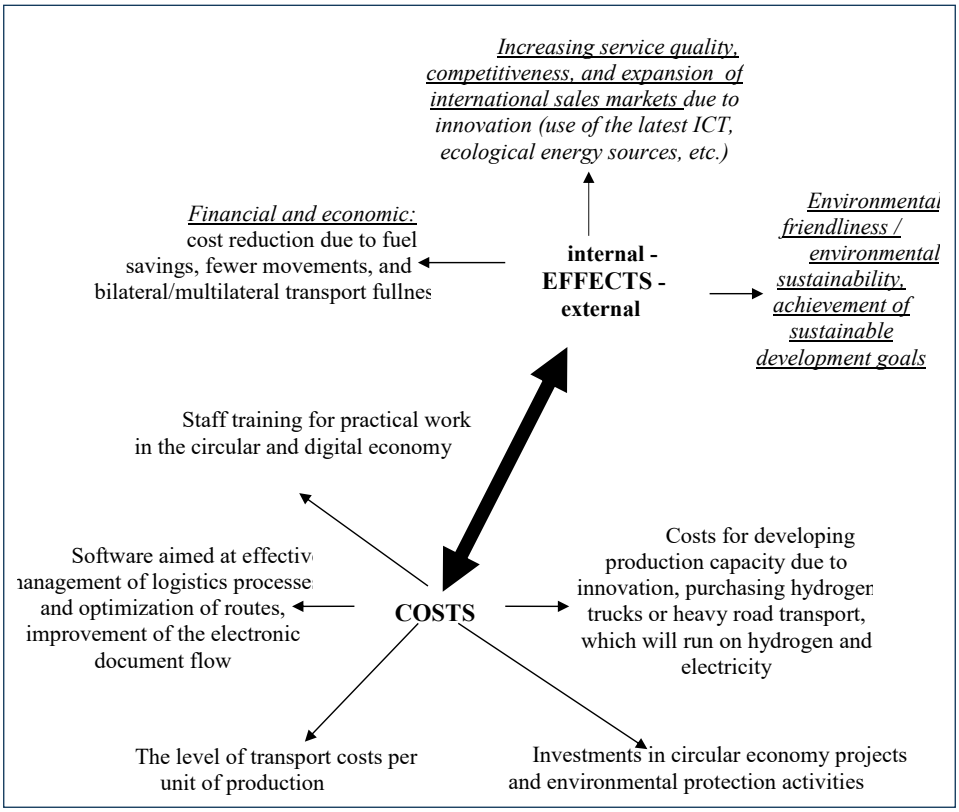

Fig. 1. «COSTS-EFFECTS» in the system of responsible management of export supply chains
Author's development

ment goals, in particular, the specific weight of the use of land transport for transportation with hydrogen fuel cells, the number of accidents that affected the environment, the level of processing of materials used for packaging (Fig. 1).

Thus, responsible supply chain management aims to create, protect and grow long-term environmental, economic, social and informational value for all groups of influence involved in bringing goods and services to the external market (Mykhaylenko, Lutsenko 2021).

This approach to building a responsible management model of export supply chains is a component of the CE model. It considers the creation, protection and growth of long-term environmental, economic and informational value for all groups of influence involved in delivering goods and services to the foreign market. A vital aspect of this model is route optimization and optimal use of vehicles in export supply chains. In the conditions of the Russian-Ukrainian war, significant volumes of import and export of

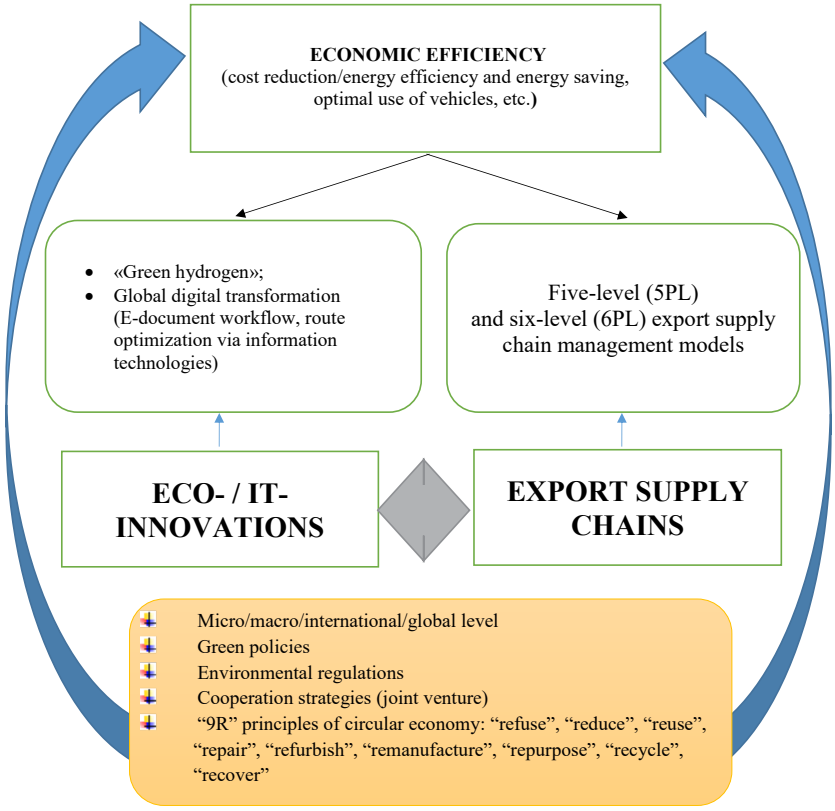

Fig. 2. The approach to building a model of responsible management of export supply chains from the point of view of creating long-term environmental, economic and informational value
Note: "Reduce" – for example, electronic documentation in export transportation;
"Refuse" – for example, refusal/partial refusal of trucks, as they work on diesel

Ukrainian goods are carried out by ground transport through the territories and checkpoints of the western region. According to the data of the National Institute of Strategic Studies, during March–December 2022, the share of international transportation by land transport in the total volume of cargo turnover (91.2 million tons) was 59.5% (54.2 million tons), seaports – 38.6% (35.2 million tons). At the same time, almost three-quarters of all imports came to Ukraine through the western border crossings – by road (48.5%) and railway (25.9%) modes of transport. It is advisable to optimize the transportation system of goods by road transport, considering the complication of sea logistics routes and the overlap of air space due to Russia's full-scale invasion of Ukraine's territory.

Based on the analysis of the geographical structure of foreign trade in goods of Ukraine with the countries of the European Union as of January 1, 2022, it is possible to single out those countries with the most significant export volume (Table 2).

Table 2. The largest trading partners (EU countries) of Ukraine by export of goods as of January 1, 2022

Name of country	Legend	Export volumes, thousands of dollars, USA	Specific weight in the structure of total export of products, %	Territorial distance from the capital of Ukraine to the capital of the proposed country, km
Ukraine	M_1			
Poland/Warsaw	M_2	390,392.4	6.48429	774
Italy/Rome	M_3	327,423.5	5.43840	2,351
Germany/Berlin	M_4	186,746.6	3.10180	1,350
Netherlands/Amsterdam	M_5	257,655.9	4.27959	1,920
Spain/Madrid	M_6	328,537.2	5.45690	3,638
Hungary/Budapest	M_7	150,684.5	2.50282	1,113
Romania/Bucharest	M_8	139,843.8	2.32276	914
Slovakia/Bratislava	M_9	75,101.8	1.24742	1,317
Austria/Vienna	M_{10}	66,209.9	1.09973	1,326
Bulgaria/Sofia	M_{11}	64,808.8	1.07645	1,300

Transportation can mainly be carried out through the territories of Ukraine's western region, which is a basis for building the optimization model. Also, the initial data for building an optimization model is the presence of a road vehicle with a length of 12 meters and an average transportation weight of 10 tons.

It is advisable to determine the structure of the routes by building a "minimum tree" (the shortest network) that connects all points without closed contours. The shortest

network is constructed as follows: starting from C_0 (the warehouse), the minor possible distance $\min(l_{ij})$ and the corresponding point M_j are determined at each step. Points not included in the initial network (for example, M7) are connected to the point with the shortest distance.

Then, starting from the point farthest from the initial one (taking into account the "minimum tree"), we group the points on the route, considering the need for each cargo and the carrying capacity of the rolling stock unit.

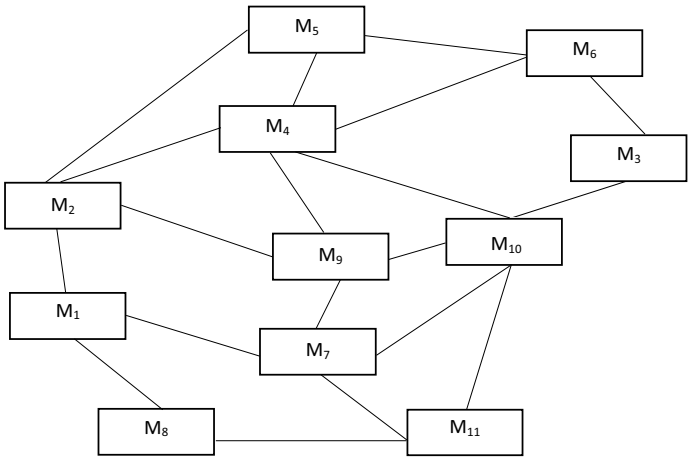

Fig. 3. Scheme of placement of trading partners of Ukraine by the export of goods

Using the Clark-Wright algorithm, we will compile optimal delivery routes considering the vehicle's carrying capacity. The proposed algorithm consists of 6 steps.

Step 1.

We find the cell (i*, j*) with the maximum kilometr gain S_{max} on the matrix of kilometr gains. At the same time, the following three conditions must be observed:

- points i* and j* should not be part of the same route;
- points i* and j* are the initial and/or final points of the routes of which they are a part;
- the cell (i* and j*) is not blocked.

If we find a cell that satisfies the three specified conditions, we proceed to the next step. If not, go to step 6.

Step 2.

The route, including item i*, will be designated route 1. Accordingly, the route that includes item j* will be designated route 2. We will introduce the following notations:

- N = {1, 2, …, n} – many suppliers;

- N1 (N1 ⊂ N) – a subset of points included in route 1;
- N2 (N2 ⊂ N) is a subset of points included in route 2.

It is evident that i* ∈ N1, j* ∈ N2 and N1 ∩ N2 = Ø (according to step 1 and condition 1).

Then we calculate the total volume of deliveries on routes 1 and 2 according to the formula:

$$q_1 = \Sigma_{k \in N_1} q_k \, i_{q2} = \Sigma_{k \in N_2} q_k \quad (2)$$

where:

q_k – the volume of delivery of the k-th item, kg.

Step 3.

The total volume of deliveries must meet the condition

$$q_i + q_j \leq c \quad (3)$$

where:

c – carrying capacity of the car, kg.

If this condition is met, then we proceed to the next step, and if not, to step 5.

Step 4.

We combine routes 1 and 2 into one common circular route. We will assume that point i* is the final point of route 1, and point j* is the starting point of route 2. When combining routes 1 and 2, the following conditions must be observed:

- the sequence of the location of points on route 1 from the beginning to point i* does not change;
- point i* connects with point j*;
- the sequence of locations on route 2 from point j* to the end does not change.

Step 5.

We repeat steps 1–4 until the next iteration fails to find S_{max} that satisfies the three conditions from step 1.

Step 6.

We calculate the total vehicle mileage.

Having substantiated the possible traffic schemes, we can form examples of the two shortest routes considering the data in Table 2 (Fig. 4 and 5).

The proposed optimization of transport routes will significantly reduce costs and increase the eco-efficiency of export transportation.

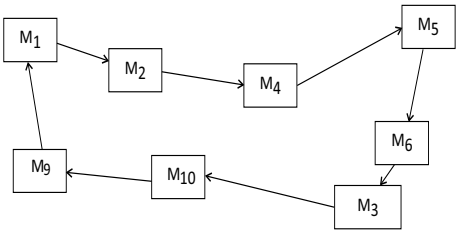

Fig. 4. Traffic scheme according to the first route

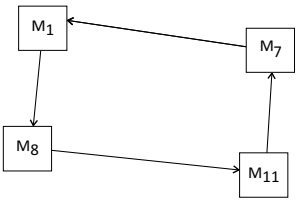

Fig. 5. Traffic scheme according to the second route

In addition, expanding the capacity of the western border of Ukraine is the essential aspect in optimising Ukraine's supply chains. This expansion can be achieved thanks to the following:

- increasing the number of checkpoints and control points;
- development of modern infrastructure of existing checkpoints, acceleration of procedures through electronic document flow;
- creation of an "e-Customs" system harmonised by EU regulations.

Conclusions

Therefore, in order to rebuild and restore the export system of Ukraine in the conditions of war and post-war times, it is necessary to carry out the following measures and actions on the micro- and macro levels:

- to implement a model of responsible management of export supply chains from the point of view of creating long-term environmental, economic, social and informational value for all groups of influence involved in the delivery of goods and services to the foreign market;
- to create logistics centres and electronic services that facilitate and optimize the movement of goods based on and by EU standards;
- to improve the logistics system for servicing export commodity flows based on the five-level (5PL) and six-level (6PL) international supply chain management models by the European Green course and the concept of sustainable mobility;
- to use the "COSTS-EFFECT" approach in the responsible management of export supply chains and draw up optimal supply route schemes using the Clark-Wright algorithm by foreign economic enterprises.

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Use of geoinformation technologies as a tool of digitalization in the sphere of waste management

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Abstract. The chapter provides an overview of ecological, economic and social problems, waste handling, management strategies, programs, legislative approaches, namely: Household Waste Management Program "Smart Environment. Khmelnytskyi", Project of modernization of solid household waste infrastructure in the city of Khmelnytskyi, digitalization of waste management processes, use of geographic information systems in the field of waste handling, etc. The management tools listed above will increase efficient use of natural resources and provide an opportunity to minimize generation of waste and emissions, they are based on the use of cleaner production tools, they are the implementation of the concept of "CE" according to which waste turns into raw material for further production. Suggested approaches and the use of geographic information technologies as a tool of digitalization in the field of waste management in particular, will make it possible in the future to monitor the state and changes in the physical parameters of the solid household waste landfill, forecast change trends, control the volumes of waste accumulation, create conditions for ensuring a safe technogenic and ecological situation, they will be able to become an integral tool of ecological management of the region.

Keywords: geographic information technologies, digitalization, waste management, management, circular economy

Introduction

The ecologic, economic and social problem of waste management is extremely acute in the world, and especially in Ukraine. It is expected that in 2050 the population will generate more than 13.1 billion tons of waste, which is related to an increase

in the standard of living of the people and their incomes. This is 20% more than over the last 10 years, considering the fact that only 25% of all waste today is disposed of or recycled.

Such world institutions as UNIDO and UNEP believe that resource-efficient and cleaner production is the way to improve production efficiency, which involves the use of preventive management strategies that increase the efficient use of natural resources, minimize generation of waste and emissions, and are based on the use of cleaner production tools: production efficiency; environmental management; human development (Circular economy and agribusiness development, 2021; Annual report, 2021). Such methodological approaches correlate with the vision of "green" cities, namely: green spaces, urban infrastructure, implementation of modern, efficient, technologically improved digital solutions in the communal sphere, waste sorting, quality of water and atmospheric air, transport, emissions from enterprises, etc. (The role of bioenergy in the clean energy transition and sustainable development, 2021; Antoniuk 2022). The issue of waste management is regulated by the Law of Ukraine "On Waste" which defines legal, organizational and economic principles of activities related to the prevention and reduction of the volume of waste generation, its sorting, processing, utilization, removal and burial, etc. (Decree No. 1073, 2022).

Camana, D., et all. developed informational waste lifecycle dashboards, waste management tools, etc. (Camana et al. 2021; Joensuu et al. 2022; Rogge, Reichardt 2016; Rufí-Salís et al. 2021; Visentin et al. 2020) and others explored the principles of waste management in cities, position of the circular economy, policy and applied issues of its implementation were studied in the works.

Waste handling is regulated by international standards ISO, 2017. ISO 14044:2006/ AMD 1:2017. Environmental management – Life cycle assessment – Requirements and guidelines. International Organization for Standardization, Geneva, Switzerland, ISO, 2006. ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations – Principles and procedures, ISO, 2020. ISO 20887: Sustainability in buildings and civil engineering works – Design-for- disassembly and adaptability – Principles, requirements and guidance.

Geoinformation technologies (hereinafter GIS) for the design and operation of landfills were studied by: Citation: Nguyen et al. 2022; Shahabi et al. 2014; Athena, Hassan 2014; Wang et al. 2009), et all. In particular, the peculiarities of waste handling at different levels were considered by national scientists: Blyzniuk A.M., Bieliaieva S.S., Horobets O.V., Hubanova O.R., Ihnatenko O.P., Viatkin P.S., Orlova T .O., Samoilik M.S., Khyzhniakova N.O., Shuntova S.G., Povnyi S.M. and others. Certain aspects of waste management have been highlighted in the publications of such national researchers as Andreichenko A.V., Derykolenko O.M., Kerzhakov V.I., Dovha T.M., Popova O.Yu., Rudenko O.V., Shulaieva Yu.E. Foreign scientists considered waste management in the context of CE, in particular: B. Mais, Qiang Yi, Tang Xiao-Yang, Geyser K., Wen-Hong Zhang, and others.

The following research methods were used in the study: systematic analysis of information about the lack of handling in Ukraine and the use of world experience; analysis of literature in the field, modelling of environmental, production and technological operations in the waste collection and processing system; analysis of experience and its application for the city of Khmelnytskyi, strategic management (project management and logical matrices of business processes in the work of city hall). There have been used modern applied tools for waste processing (GIS technologies, portals for logistics and training, electronic labelling of containers and packaging, monitoring of transportation, legislative and regulatory documents for organization of CE, etc.), which are relevant in the system of their handling worldwide.

Results and discussion

The waste management system in Ukraine is at the level of the poorest countries. During the years of independence, the amount of solid household waste (SHW) in Ukraine has increased by 25%, but approaches to waste management have not fundamentally changed. Just like it used to be, almost all SHW is taken for disposal to household waste landfills, often to unsanctioned ones. Solid household waste landfills require significant areas and lead to serious environmental problems and have a negative impact on human health.

An example of bringing waste management legislation in Ukraine in line with EU legislation was the approval of the Household Waste Management Program "Smart Environment. Khmelnytskyi" for the years of 2021–2022 (2021). One of the main principles of the National Waste Management Strategy in Ukraine until 2030, approved by the order of the Cabinet of Ministers of Ukraine No. 820-p dd. November 8, 2017, is the hierarchy of waste management.

Figure 1. Change of approaches to waste management and transition from disposal to prevention, reduction of waste generation and implementation of waste sorting, recycling, and reusing are essential for achieving positive results in solving urgent waste related problems not only in the cities, but in Ukraine on the whole.

Household Waste Management Program. Smart Environment. Khmelnytskyi for 2021–2022 was developed and implemented in accordance with the laws of Ukraine "On Waste", "On Environmental Protection", "On Local Self-Government in Ukraine", the Order of the Cabinet of Ministers of Ukraine No. 820-r dated November 8, 2017 "On approval of the National Waste Management Strategy in Ukraine until 2030", the Order of the Cabinet of Ministers of Ukraine No. 117-r dated February 20, 2019 "On Approval of the National Waste Management Plan until 2030" (Fig. 2).

The purpose of the development and implementation of the Program is to create conditions that will contribute to ensuring the complete collection, transportation, utilization, processing and burial of solid household waste (hereinafter SHW), reducing the impact of

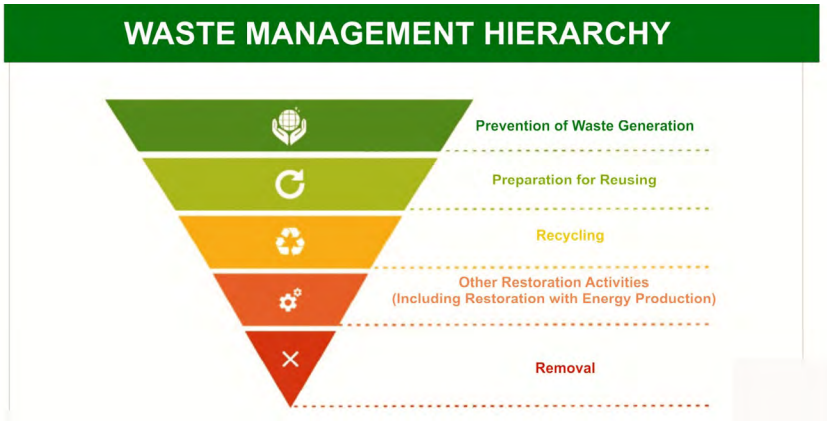

Fig. 1. Hierarchy of waste management ("Smart Environment. Khmelnytskyi" for 2021–2022 years 2021)

Fig. 2. National Waste Management Plan until 2030
("Smart Environment. Khmelnytskyi" for 2021–2022, 2021)

solid household waste on the environment, improving the sanitary condition of the city and improving the epidemiological well-being of the population.

To achieve the goal of the Program, the local government set the following main tasks:

- to reduce the volume of household waste burial through the introduction of new, modern, highly efficient methods of waste collection, transportation, storage, processing, utilization and disposal;
- to ensure the introduction of mechanized sorting of household waste with extraction of recoverable residues;
- scientific and research work on the safe disposal of household waste with manda-

tory compliance with the requirements and rules of operation of the landfill, to organize monitoring and control of the landfill in order to prevent harmful effects on the surrounding natural environment and human health.

The problem of solid waste generation in Khmelnytskyi is really acute, the city is a typical regional center in the west of Ukraine with a population of up to 300,000 people. The daily amount of waste taken to the landfill is about 32 tons. For example, in 2019, Spetskomuntrans (in charge of waste removal) transported solid household waste in the amount of 848.6 thousand cubic meters. m., 31.8 thousand cubic meters of bulky waste, 5.1 thousand cubic meters of liquid waste.

However, all generated household waste was buried at the solid household waste landfill. The morphological composition of solid household waste in the city of Khmelnytskyi is shown in Figure 3.

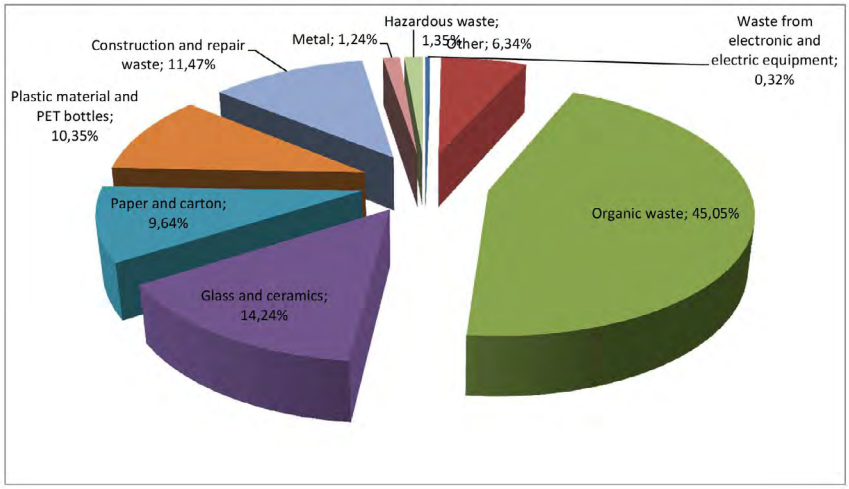

Fig. 3. Morphological composition of solid household waste in the city of Khmelnytskyi ("Smart Environment. Khmelnytskyi" for 2021–2022, 2021)

The city's existing solid waste landfill is at the edge of reaching its maximum capacity, and the generation of municipal waste in the city of Khmelnytskyi is going to increase in the coming years from approximately 94,000 tons per year (registered in 2017) to 107,000 tons per year by 2027. That is why Khmelnytskyi Communal Enterprise "Spetskomuntrans" jointly with the European Bank for Reconstruction and Development has developed a Project for the modernization of solid household waste infrastructure in the city of Khmelnytskyi. The main goal of the project is to provide waste processing facilities within the city of Khmelnytskyi. The project also aims to improve waste man-

agement operations and introduce processing and recycling capabilities for this this city's waste management infrastructure and reduce the volume of waste transported only to the landfill. In addition, it is assumed that the implemented Project will be integrated into the regional waste management plan of Khmelnytsky region. Expected outcomes are as follows: improvement of the system of handling and management of solid household waste in the city. The implementation of the Project is planned jointly with the European Bank for Reconstruction and Development in the post-war period. In order to implement the project of solid household waste infrastructure modernization in the city of Khmelnytskyi and the introduction of the system of integrated management of household waste in the city there has been founded the Office "Smart Environment. Khmelnytskyi", which is a structural subdivision of Khmelnytskyi Communal Enterprise "Spetskomuntrans". The Waste Management Center has been operating in the city since September 2020. This is a place where every resident of the city of Khmelnytskyi can leave waste free of charge for further processing or disposal. The center accepts 13 fractions of waste (paper, plastic, polyethylene, combined packaging, metal, household appliances, construction waste, "green" waste, furniture, clothing, hazardous waste). Today, such types of waste as batteries and accumulators, fluorescent and energy-saving lamps, thermometers, expired medicines, containers from household chemicals, paints, varnishes, solvents and glues, electrical and electronic equipment are collected separately by Khmelnytskyi Communal Enterprise "Spetskomuntrans" by means of mobile station (Ekobus) and are further transferred to specialized enterprises that have received licenses to carry out operations in the field of hazardous waste management. The main goal of the collection of hazardous and specific waste is to prevent it from entering the solid household waste landfill. There have also been proposed measures to reduce the amount of organic ("green" waste), which is the main generator of unauthorized landfills, entering the landfill. Local authorities are conducting awareness-raising activities among city residents as for managing "green" waste. Owners of private households are advised to compost leaves and garden waste in compost pits on their own plots of land, take them to the territory of the solid household waste landfill by their own transport, and order special equipment to transport leaves to the solid household waste landfill.

In general, the implementation of the Household Waste Management Program "Smart Environment", Khmelnytskyi will make it possible to:

- implement the Infrastructure Modernization Project for collection, logistics and processing of solid household waste in the city of Khmelnytskyi;
- reduce the scope of household waste burial at the city's solid household waste landfill;
- ensure the maximum extraction of secondary raw materials by implementing a more effective system of separate collection of solid household waste;
- increase the level of environmental awareness and responsibility of citizens regarding household waste management;
- attract investments in the field of waste management;
- ensure urban land improvement and sanitary condition of the city;

- reduce harmful impact of household waste on the natural environment and human health („Smart Environment. Khmelnytskyi" for 2021–2022, 2021).

Another argument in the field of waste management was signing of the Association Agreement with the European Union in 2014 which obliged Ukraine to bring its legislation more in line with the EU legislation. Ukraine needs to fully implement the provisions of Directive 2008/98/EU of the European Parliament and the Council dated November 19, 2008 "On Waste..." (Voytsikhovska et al. 2019). As for Ukraine, namely the city of Khmelnytskyi, the Directive introduces a five-level hierarchy of waste management:

1. Prevention of waste generation (the best option because of a number of tools: environmental audit, cleaner technologies, best practices, environmental management systems, etc.).
2. Reuse of sorted waste.
3. Economically expedient processing of waste (secondary resources) (glass, waste paper, metal, plastic).
4. Introduction of the ban on waste incineration.
5. Disposal of waste that cannot be processed at a landfill.

Harmonization and implementation of European requirements for waste management in Ukraine also involves the implementation of such tools as Good Rules and best practices for waste management. For the future, the Khmelnytskyi City Hall is advised to implement the experience of the Non-Governmental Organization "Green Initiatives of Rivne" concerning recycling of organic waste, namely (Skripchuk 2018a, b, c, 2020):

- taking into account the terms of operation of household waste landfills (the normative term of operation of household waste landfills in all cities of Ukraine expired more than 25 years ago and they are actually overfilled);
- processing of fallen leaves, mowed lawn grass, gradual involvement of sorted food waste will solve the issue of sanitation in cities and save space at the landfill for other waste;
- implementation of modern technologies for handling sorted organic waste to organize its cost-effective processing;
- obtained compost, biohumus, soil mixtures or liquid fertilizers are suitable for growing seedlings, fertilizing lawns, flower growing in cities, traditional agricultural production;
- the formation of the first stage of a civilized system of separate collection and logistics of organic waste – from biomass to a gradual increase in the share of sorted food waste through the creation of an online platform and the attraction of waste from shops, cafes, etc.

As for GIS technologies and digitalization of the waste management system, these are systemic and multifunctional, ecologically necessary, economically beneficial, socially expedient solutions, for example (Skripchuk et al. 2020, 2021):

- IT support and constant monitoring of the determination of the volume of leaves and mowed lawn grass, the state of green plantings disease;

- introduction of ecological technology for processing organic waste into biohumus (inceniration leads to repeated pollution of the atmosphere and it is prohibited);
- scientific and technological substantiation of technologies, machines and mechanisms for the full cycle of processing organic waste into compost and (or) biohumus;
- design and engineering of a waste processing site for launching a modern system of grinding, composting, sifting, loading and packaging of finished products (compost and (or) biohumus);
- obtaining biohumus as a valuable ecological fertilizer;
- engineering arrangement of a waste processing site for launching a modern system of grinding, composting, sifting, loading and packaging of finished products (compost and (or) biohumus);
- the task is implemented in accordance with the best world practices, the provisions of the "green" economy, the standards of DSTU ISO 14 000 "Environmental Management", Directive of the European Union 2008 /98/EU, etc.;
- informatization will be implemented through IT support for accumulation, logistics and constant monitoring of defining the volume of leaves and mowed lawn grass, diseases of green plantings;
- the implementation of the project will improve the sanitary and epidemiological situation in the cities owing to the established system of informing the population about the time of garbage removal via SMS messages, planning the days and times of the systemic logistics by regions (routes) for the removal of organic waste and gradually sorted food waste;
- in the future, the program can be expanded to all types of waste, which will make it possible to sort, and therefore to start separate removal and processing of waste.

In total, Khmelnytskyi City Hall implements the above approaches and best practices of EU countries, namely:

1. Implementation of the concept of CE according to which waste becomes raw material for further production. Biotechnologies are used to break down plastic products, which ensures a closed cycle of business processes – waste from one product is used to create another product.
2. A set of business processes for processing organic waste into compost and biofertilizers is applied.
3. There is a system of business processes of refunds for containers. Buyers are refunded after they return used cookware. Funds from this deposit price are distributed as follows: 85% – for arranging container collection, 15% – for processing.
4. Special legislation helps to close illegal landfills, and economic instruments (fines) have resulted in waste sorting.
5. Digitalization of business processes in the field of waste management. For example, in France, every garbage bin has a microchip, which automatically records the time of filling and the time of garbage removal. Garbage trucks are equipped with

reading devices and on-board computers that automatically read the information and make it possible to organize the optimal routes the trucks (Voytsikhovska et al. 2019).

Another relevant type of work in digitalization processes in the field of waste management is going to be application of geographic information systems in the waste management sphere. In our opinion, geoinformation systems in terms of digitalization of the waste management system are a system of devices, programs, organization of handling of all types of waste, appropriate computer technologies that provide modelling of business processes, design, monitoring of the territory of cities and landfills (electronic display of maps, charts, space and aerial images of the earth's surface) together with analytical information (statistical data, lists, economic indicators, etc.). It is reasonable to carry out all the above types of work in the system of ecological audit of territories, communities, cities, regions and the system of nature management. Also, a spatial data management system and appropriate software can be used for a geoinformation system.

The geoinformation system of waste management is a module of the geoinformation system of a community or region, which serves as a decision-making tool in the field of solid household waste management, the means of visualizing the current state and phasing of the implementation of local and regional waste management programs. GIS of waste management is designed to solve a number of problems related to the collection of information on the current state (inventory) of dump sites and landfills, their certification, visualization of schemes for sanitary cleaning of populated areas, development and optimization of logistic schemes for the routes of waste collection equipment for the collection and removal of waste in the relevant area, elaboration of ecologically and economically optimal waste management practices (MagnetikVan Municipal Technologies, 2022).

We offer the following possibilities of modern geoinformation systems:

- the availability of tools for making inventory of the condition of dump sites and waste landfills using real-time mobile technologies and unmanned aerial vehicle (UAV) technologies, creating on their basis a data bank (including 3-dimensional models) of waste storage sites;
- certification of landfills and dump sites, creation of databases of waste storage sites and morphological features of landfills;
- formation and display of optimal logistic schemes of waste collection equipment routes;
- planning specific prospective measures regarding technical and operational equipment of waste landfills, forecasting the future condition of areas and other geometric parameters of landfills, developing a strategy for optimal concentration of waste storage and disposal sites;
- visualization on an interactive map of existing and prospective vector schemes for sanitary cleaning of populated areas in combination with urban planning documentation and land cadastre, a system of cartographic services (Google Maps, OpenStreetMaps, etc.), which allows approaching waste management comprehensively;

- availability of a subsystem of citizens' electronic appeals and a platform for their prompt analysis;
- provision of information support function of local self-government bodies when making decisions in the field of environmental safety of the population, risk management, automation of reporting on the results of environmental works.

The implementation of the geoinformation system in the work of Khmelnytskyi City Council deserves special attention. The project is implemented within the framework of cooperation in the Project "Supporting Organizations-Leaders in Combating Corruption in Ukraine "VzayemoDiya" (SACCI) with the support of the United States Agency for International Development (USAID). Implementation of the Project will improve the quality of work with databases and the access of city residents to geospatial data of the urban cadastre, city land cadastre, and sector-specific registers. In such documents, it is advisable to show such layers as socio-cultural objects (various objects to choose from, for example, pharmacies, health care facilities, bus stops, playgrounds); base layers (different maps to choose from, for example, a topographic plan 1:2,000, orthophoto, Google Map, Open Street Map, Aerial Bing Map); general plan of the city of Khmelnytskyi; detailed plan of the area of "Zaricchia" (it includes other layers, for example, schemes of engineering networks, project plan, plan of red lines); the detailed plan of the central part of the city (it includes other layers similar to the previous one); documents of a permissive character (passports of land plots, as well as town planning conditions and restrictions); historic and architectural reference plan; historic cartography (about 20 maps since 1,800); adjustment of the master plan; zoning plan of the city; public cadastral map (it includes other layers, for example, cadastral division, soils, disposal of agricultural land); register of advertising means; temporary structures, etc.

The authors offer such proposals together with the project, in accordance with the Law of Ukraine "On Access to Public Information" and the implementation of the Law "On the National Infrastructure of Geospatial Data", which assumes public disclosure obligation (Law of Ukraine "On Access to Public Information", 2011; Law of Ukraine "On the National Infrastructure of Geospatial Data", 2020). To analyze the current situation at the solid waste landfill, we have analyzed the web resource "Geo-information systems of the city of Khmelnytskyi" and suggested adding a block of 3-D modelling of this waste landfill to this database. With the purpose of analysis of the current situation at the solid waste landfill of the city of Khmelnytskyi, in our research we used the unmanned flying quadcopter DJI Phantom 4 Pro, being an integral component of the analysis and construction of the modern geoinformation system of the city. Below, Figures 4–8 show the stages of construction of the 3-D model of the Khmelnytskyi SHW landfill.

Figures 4–8 show the steps and fragments of creating a three-dimensional model of the Khmelnytskyi solid household waste landfill. The use of geoinformation technologies as a digitalization tool in the field of waste management has resulted in:

- finalization of the GIS of the city of Khmelnytskyi,

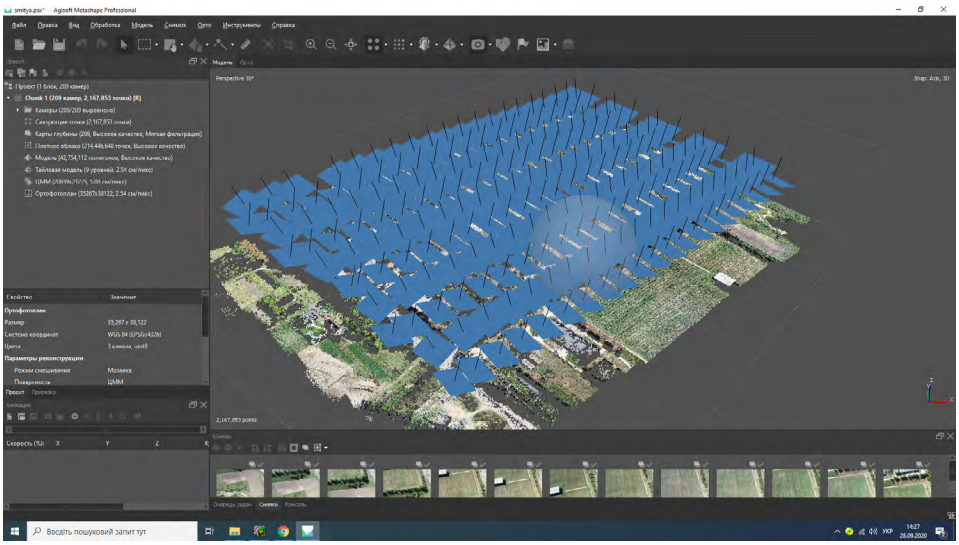

Fig. 4. Adjustment of aerial photographs

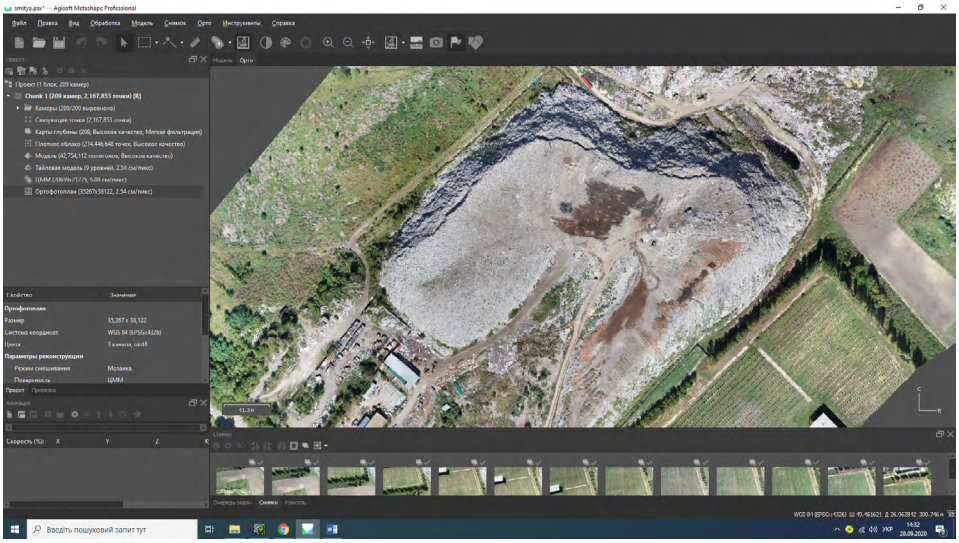

Fig. 5. Orthophoto of the area of photographing

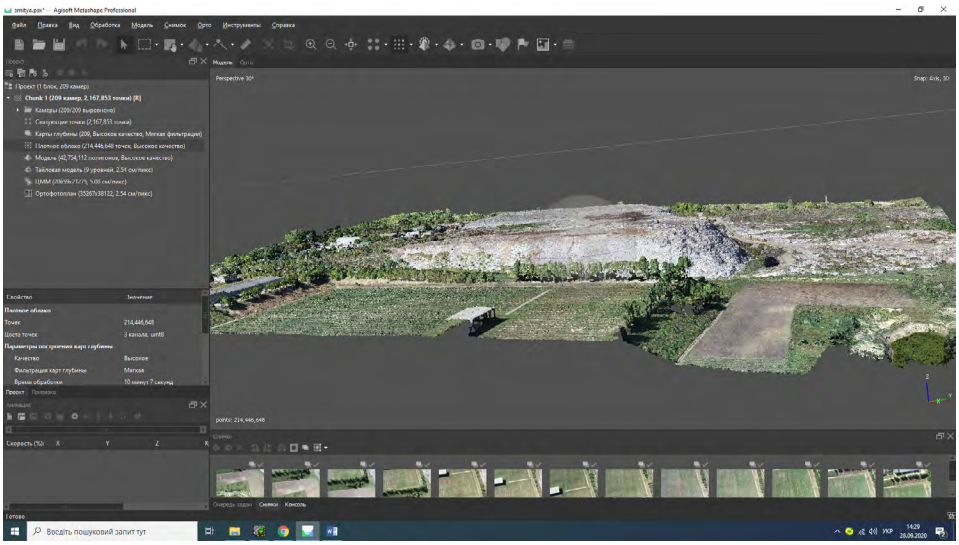

Fig. 6. The first zoom-in of a three-dimensional model (a clustered cloud of points)

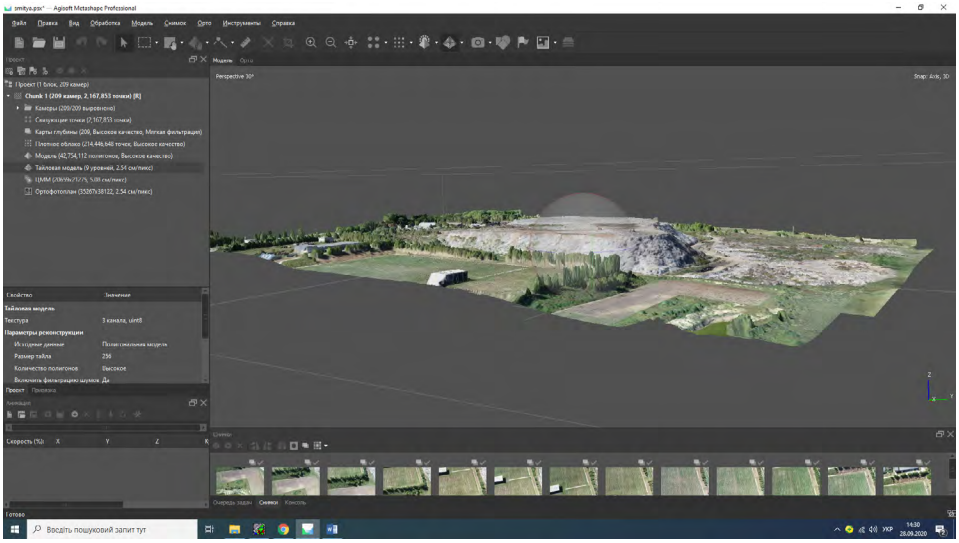

Fig. 7. Tile model of the area of photographing (3D – model)

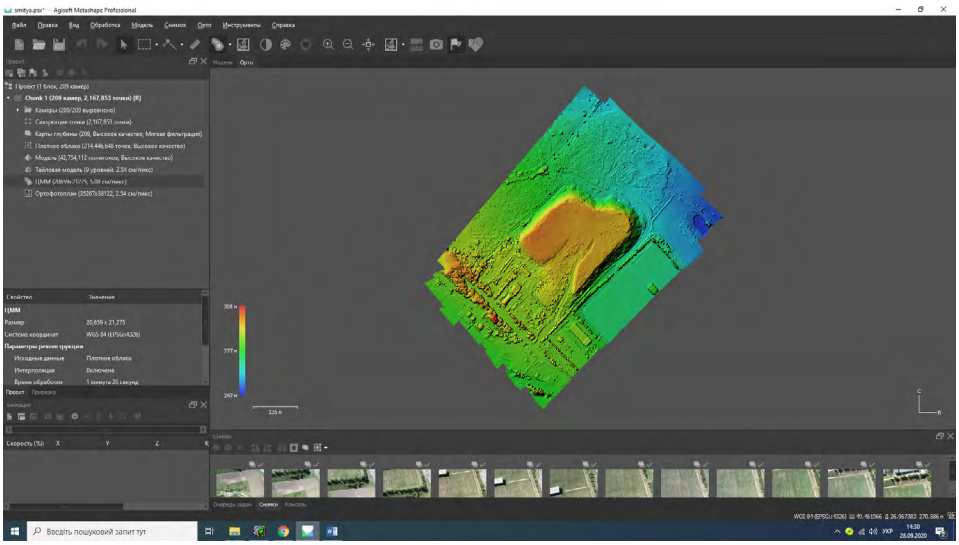

Fig. 8. Digital model of the area

- construction of a 3D model of the Khmelnytsky solid household waste landfill, which in the future will make it possible to carry out observation of the condition and changes in the physical parameters of the object under research,
- forecasting trends in landfill size changes,
- control of volumes of waste accumulation,
- creation of conditions to ensure a safe technogenic and ecological situation,
- justification of the importance of environmental management tools for cities, communities, and regions.

Conclusions

Thus, the scientific and methodological developments will be useful for cities all over Ukraine and throughout the world, namely: accounting for the locations of solid household waste landfills and dump sites; improvement of the ecological condition of the territory and its upgrading; application of the concept of CE; strengthening interaction between the authorities and the community, involving community members in solving environmental problems, in particular those of waste accumulation and management; logistic control; savings costs through rational management of sanitary service of the respective areas; implementation of the program of public access to environmental information concerning management and disposal of solid household waste; implementation of environmental education programs for the population. Thanks to the introduction

of the city's geoinformation system, the Aarhus Convention on public access to environmental information will be implemented.

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Chapter III.

The model of investment attractiveness of the circular economy in Ukraine

Processing renewable biomass in cities: biomass treatment technology case studies

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Abstract. The purpose of this study is to provide an overview of the use of biomass in various applications. It discusses biomass in the global carbon cycle and describes biomass-related projects funded by the EU. The study presents biomass management systems involving leading applications such as Landfilling, Gasification, Incineration, Thermal Conversion, Torrefaction, Biodegradation, and Composting. Furthermore, it outlines the advantages and disadvantages of biomass. The study concludes by providing a scientific and practical basis for decision-making towards a more sustainable application of biomass in the growing bioeconomy.

Keywords: Poland, biomass, municipal solid waste management, bioeconomy, EU funded project

Introduction

The biomass-producing and converting sectors of the EU bioeconomy created up to EUR 657 billion of value added and employed 17.4 million people in the EU-27 in 2019 (Economy, 2022). According to Biomass Energy (2022), "Biomass is organic, meaning it is made of material that comes from living organisms, such as plants and animals. The most common biomass materials used for energy are plants, wood, and waste. These are called biomass feedstocks. Biomass energy can also be a non-renewable energy source. Biomass contains energy first derived from the sun: Plants absorb the sun's energy through photosynthesis and convert carbon dioxide and water into nutrients (carbohydrates)."

The definition of biomass (see Biomass – advantages and disadvantages 2023) can also be found in the Polish Act of February 20, 2015, on renewable energy sources. According to this act, biomass should be defined as biodegradable waste or residues of biological origin, including plant and animal substances related to:

- Agriculture,
- Forestry,
- Fishing,

➟ Aquaculture,
➟ Industry.

Biomass can also include biodegradable municipal waste as well as sewage and sludge from sewage treatment plants. Pellets, briquettes, and agrichar (torrified biomass) are made from these natural raw materials (Act on Renewable Energy Sources, 2015).

Results and discussion

1. Biomass in the Global Carbon Cycle

According to "Biomass in a Low-Carbon Economy" (2018), biomass is an integral part of the global carbon cycle. Carbon is absorbed from the atmosphere as plants grow, and then it is released as biological matter decays or burns. This process has played an important role in regulating Earth's climate in the past, and the careful management of biomass stocks will play a critical role in limiting the rise in global temperatures over the next century (Biomass in a Low-Carbon Economy, 2018).

The role of biomass provides two main routes to mitigating climate change. First, its growth removes carbon dioxide from the atmosphere and stores it for long periods in soils, trees, and other plants. Second, biomass can be used to reduce fossil fuel emissions

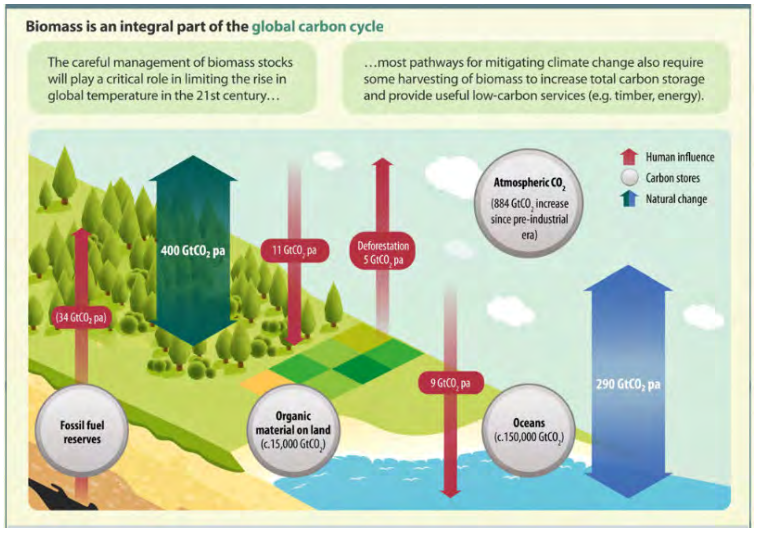

Fig. 1. The potential role of sustainable biomass within the global carbon cycle (Source: Biomass in a low-carbon economy, 2018)

Notes: The values depicted in the carbon cycle diagram are based on the IPCC 2014 report and the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, as well as data from Le Quéré et al.'s (2016) Global Carbon Budget 2017 in Earth System Science Data. This information is drawn from the Royal Society and RAEng's (2018) Greenhouse Gas Removal report

into the atmosphere by directly replacing oil, coal, and natural gas use or by displacing high-carbon materials such as steel and cement (Biomass in a Low-Carbon Economy, 2018). Figure 1 illustrates the potential role of sustainable biomass within the global carbon cycle.

Some of the leading biomass feedstocks, as presented in Figure 2, include: (top row) switchgrass, copra (coconut), cotton, and jatropha; (middle row) municipal solid waste (MSW), sunflowers, palm nuts, and canola; (bottom row) wheat, sugar cane, wood, and rice. These feedstocks are discussed in "Biomass Energy" (2022).

The authors responsible for the respective biomass feedstock pictures for the U.S. Department of Agriculture (USDA) are: V. Zutshi, S. Beaugez, M. Hendrikx, S. Heydt, M. Oeltjenbruns, A. Munoraharjo, F. Choudhury, G. Upton, O. Siudak, M. Gunther, and R. Singh.

Fig. 2. Leading biomass feedstocks
(Source: Biomass Energy, 2022)

People have been using biomass energy – energy derived from living things – since the earliest "cave men" first made wood fires for cooking or keeping warm. Biomass is organic, meaning it is made of material that comes from living organisms, such as plants and animals. The most common biomass materials used for energy are plants, wood, and waste, which are collectively referred to as biomass feedstocks. Biomass energy can also be derived from non-renewable sources. It contains energy initially derived from the sun: Plants absorb the sun's energy through photosynthesis and convert carbon dioxide and water into nutrients (carbohydrates). This energy from organisms can be transformed into usable energy through direct and indirect means. Biomass can be burned to create heat (direct), converted into electricity (direct), or processed into biofuel (indirect).

According to the World Bioenergy Association (WBA, 2019), fourteen percent of renewable energy consumed globally in 2017 came from biomass, making it the largest form of renewable energy (96% for heat and 9% for electrical production). The International Energy Agency (IEA) estimated that more than 85% of this biomass came from forests or the forest sector. It is predicted that bioenergy use will increase significantly in the coming decades to meet the rising demand for renewable energy sources, particularly from forestry (European Commission, 2021; Titus et al. 2021).

Bioenergy, derived from bio-based sources, is the largest among renewable energy sources. In 2017, bioenergy accounted for 70% of renewable energy consumption (WBA, 2019). However, its contribution has been gradually decreasing due to the reduced use of traditional biomass sources. In 2017, electricity from biomass-based sources was the third-largest renewable electricity source globally after hydropower and wind, generating 596 TWh of biopower (WBA, 2019). Biomass is widely used for heating and constitutes 96% of the renewable heat market globally (WBA, 2019).

Renewables, largely based on biomass sources, provide about 13% of the global energy supply, with biomass contributing more than three-quarters of renewable energy, primarily from woody biomass (Biomass flows, 2022). Sankey diagrams, such as those in the BIOMASS Assessment study by the Joint Research Centre (JRC), present the flows of biomass for each sector of the bioeconomy, from supply to uses including trade, enabling deeper analysis and comparison across different European Union sectors and countries (JRC Biomass flows, 2022). These diagrams, presented in Figure 3 and Figure 4, show biomass flows in 1000 T of dry matter (net trade) as of 2008.

Biomass resources commonly used in a traditional manner to provide energy for cooking, hot water, and residential heating (especially in colder climates) include wood, animal dung, and agricultural wastes and residues (IEA and FAO, 2017).

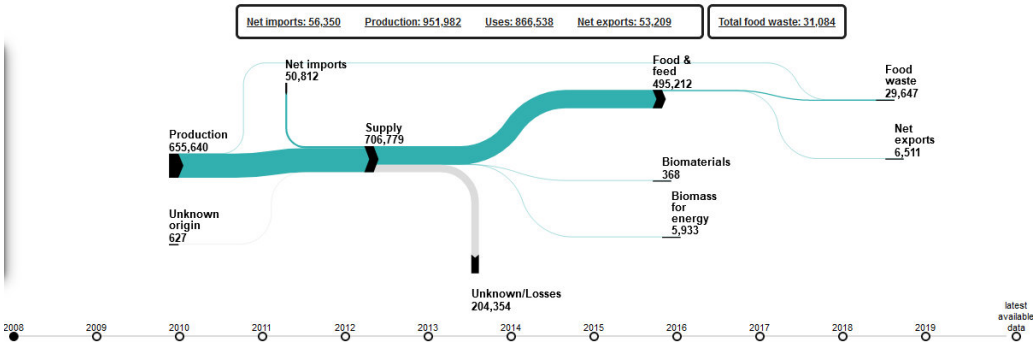

Fig. 3. The EU Biomass Flows tool is a visualization in the form of Sankey diagrams depicting the flows of biomass for each sector of the bioeconomy, based on available data from 2008
(Source: Data from the BIOMASS project, European Commission – Joint Research Centre)

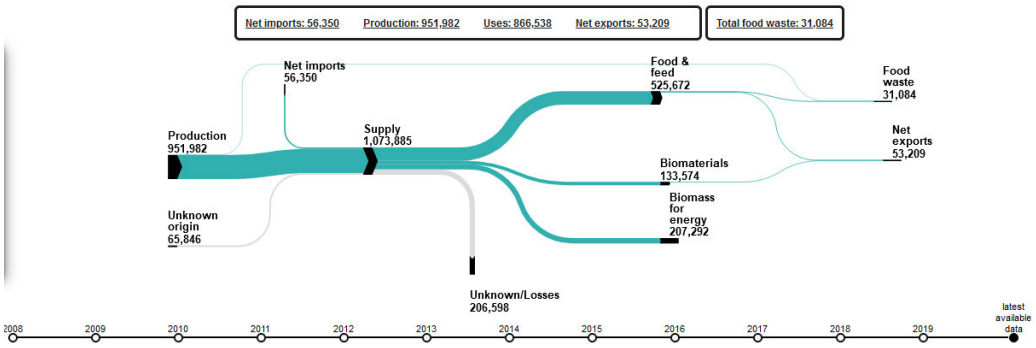

Fig. 4. The EU Biomass Flows tool is a visualisation, in the form of Sankey diagrams, of the flows of biomass for each sector of the bioeconomy, available data 2019
(Source: data from the BIOMASS project, European Commission – Joint Research Centre)

Biomass feedstocks serve as sources of bioenergy and encompass a wide range of materials. According to IEA and FAO (2017), these biomass feedstocks include:

- Wet organic wastes, such as sewage sludge, animal wastes, and organic liquid effluents, as well as the organic fraction of municipal solid waste (MSW).
- Residues and co-products from agro-industries and the timber industry.
- Crops grown specifically for energy purposes, including food crops like corn, wheat, sugar, and vegetable oils produced from palm, rapeseed, and other raw materials.
- Non-food crops such as perennial lignocellulosic plants (e.g., grasses like miscanthus and trees like short-rotation willow and eucalyptus) and oil-bearing plants like jatropha and camelina.

These diverse biomass feedstocks play a crucial role in the bioenergy sector, offering sustainable alternatives to fossil fuels and contributing to renewable energy production.

Figure 5 illustrates the specification from biomass feedstock to final energy use, showcasing the most common pathways used to date. These pathways include:

- Production of heat and power from wood, agricultural residues, and the biogenic fraction of wastes.
- Conversion of maize and sugarcane to ethanol.
- Utilization of rapeseed, soybean, and other oil crops for biodiesel production (IEA and FAO, 2017).

Biomass and waste already serve as a significant global energy source, accounting for over 70% of all renewable energy production. In 2015, their contribution to final energy consumption was roughly equivalent to that of coal (IEA and FAO, 2017; IEA, 2017). The consumption of biomass and waste resources is primarily prominent in the heat sector, although the bioenergy sector for electricity and transport biofuels is growing rapidly, largely due to higher levels of policy support (refer to Figure 4).

IEA and FAO (2017) classify biomass resources into three main groups based on their origin (as depicted in Figure 6):

- Residues and waste: Biomass derived as a by-product, residue, or waste from other activities and product streams.
- Forestry: Biomass harvested from forestry activities.
- Crops and fast-growing grasses: Biomass intentionally grown for energy production purposes.

These classifications provide insights into the diverse sources of biomass that contribute to the bioenergy sector and play a vital role in renewable energy production.

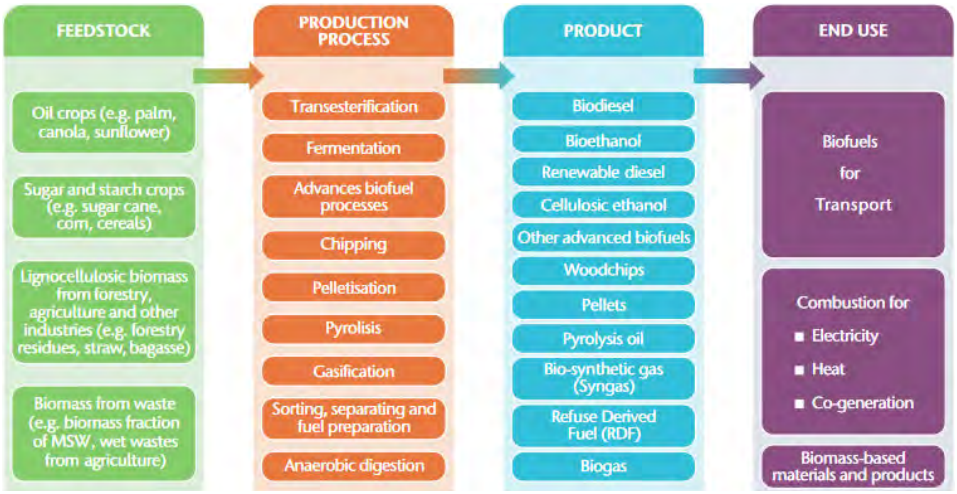

Fig. 5. Potential bioenergy pathways: From biomass to final energy use
(Source: IEA and FAO, 2017)

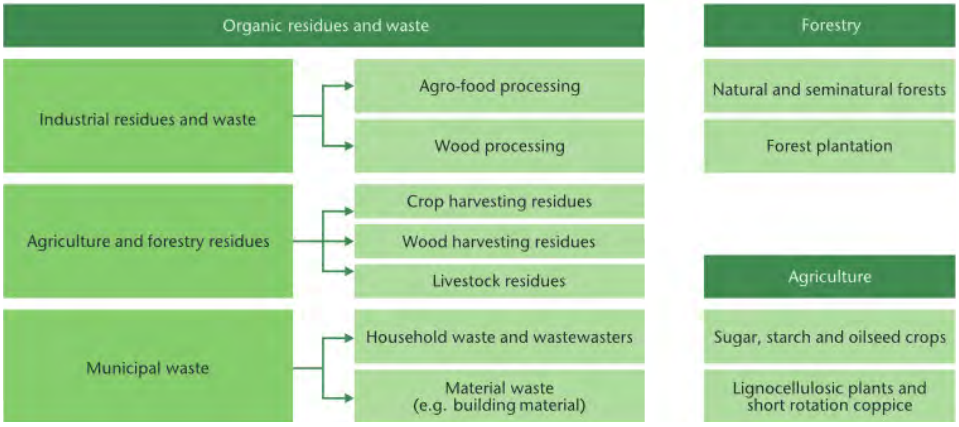

Fig. 6. Biomass types according to origin
(Source: FAO, 2017)

2. Biomass Treatment Technology: Case Studies

Biomass in EU-Funded Projects

The utilization of raw materials, such as biomass, has been extensively studied in several EU-funded projects. One notable initiative is the Ultra-Low CO2 Steelmaking proposal within the EU-funded ULCOS project (ULCOS, 2004). ULCOS, launched by major players in the European Steel Industry and their partners in other industries and academia (47 partners across 15 European countries), focuses on the availability and use of biomass in the steelmaking industry. Biomass species selected for the Electric Arc Furnace (EAF) process include forest residues, grapewine, corn stalks as agricultural residues, as well as miscanthus and sorghum from cultivation (GREENEAF, 2013). The GREENEAF project aims for sustainable EAF steel production through biomass selection. Additionally, the Biochar for Sustainable EAF Steel Production project (GREENEAF2, 2019) demonstrates the feasibility of using char from biomass as a substitute for coal in the EAF.

Another relevant project under RFCS is the Flexible Production of Coke Using Alternative Coals – Effects on Coke Properties under Blast Furnace Conditions (FLEXCOKE) (Lundgren, 2019). This project explores the use of biomass as alternative carbon sources in coke production for blast furnaces.

Among the LIFE projects, the LIFE Smart project aims to develop an innovative steelmaking approach by replacing fossil resources with alternative reductants, including waste biomass or renewable, end-of-life non-recyclable resources in the form of AlterCoal® pellets (The LIFE SMART project, 2022).

On a different note, the Market Uptake Support for Intermediate Bioenergy Carriers (MUSIC) Horizon 2020 project focuses on assessing technical and non-technical aspects of biomass feedstock mobilization. Its goal is to develop dedicated feedstock mobilization strategies and improve biomass logistics (Music, 2019).

The EU-funded HyperBioCoat project (High-Performance Biomass Extracted Functional Hybrid Polymer Coatings for Food, Cosmetic, and Medical Device Packaging) addresses the challenge of developing biodegradable hybrid organic-inorganic coatings for use in food, cosmetics, and medical device packaging (Grant Agreement N 720736, 2020).

"We developed a coating material based on biopolymers extracted from lignocellulosic biomass, a renewable resource derived from plants primarily composed of polysaccharides (cellulose and hemicelluloses) and an aromatic polymer (lignin). These biopolymers were combined with the material class of bioORMOCER®s," stated project coordinator Stefan Hanstein from Fraunhofer IWKS (refer to Figure 7). The bioORMOCER® coatings are bio-based, biodegradable, high-barrier coatings suitable for various packaging applications. They are developed from a class of materials with glass-like structural units by the Fraunhofer Institute for Silicate Research (see Emmert et al. 2021).

The HyperBioCoat project offers environmental benefits such as a lower CO_2 footprint and conservation of natural resources. This is achieved as the supply chain does not require additional plant cultivation areas or additional supplies of water, fertilizers, and pesticides.

Fig. 7. Coating material based on biopolymers extracted from lignocellulosic biomass by combining them with the material class of bioORMOCER®s- Fraunhofer IWKS
(Source: HyperBioCoat project coordinator)

Biomass Management Systems

In China, over 1 billion tons of biomass solid waste containing lignocellulose, such as stalks, straws, and landscaping waste, are produced (Li et al. 2011). This essay analyzes the advantages and disadvantages of landfilling, gasification, incineration, and biodegradation as biomass management systems. Despite being studied for several decades, efficient treatment processes are not widely adopted. Among these methods, only biodegradation stands out as an environmentally friendly technology.

The discussion presented in the essay highlights the view that "Although we have found several methods to deal with biomass (for example milling manure, feeding, industrial utilization and construction materials etc), the efficiency is not high and all those methods will produce pollutants more or less. Biomass solid waste will be the hindrance

Fig. 8. Energy form: UK biomass plants use wood pellets of leftover material from managed forests
(Source: Ravilious, 2020)

to the rapid economic develop ment some day in the future if there are still no efficient treatments without pollution. Also with the technology developing on how to treat and/or degrade biomass solid waste, process equipments should be mat ched with the treating and/or degradation technology" (Lietal 2011).

The conversion to biomass energy, which played a key role in reducing our dependence on fossil fuels is discussed in Ravilious (2020). Figure 8 presents the wood pellets of leftover material from managed forests used to biomass plant in UK (Ravilious, 2020).

Landfill

Landfill is the most common method of dealing with solid waste. Solid waste is transported to remote areas with sparse population. Initially, landfills caused groundwater and air pollution. However, modern landfills in China are developed with impermeable bottoms and sealed with clay, addressing some pollution concerns. Despite these improvements, the volume of solid waste, including biomass, is rapidly increasing, leading to the proliferation of landfills around Chinese cities. Landfills require extensive land areas and pose risks of leachate leakage. It's evident that landfilling does not reduce or decompose solid waste efficiently.

Over time, landfills can lead to secondary pollution issues such as groundwater contamination, air emissions, and soil degradation. Some instances have shown that landfills can become breeding grounds for pests and diseases. Economically, landfilling involves transporting waste from various locations and maintaining facilities for extended periods, incurring significant costs (Cheng, Hu 2010).

Historically, landfilling has been the primary waste management method, providing insights into current technologies and future challenges (Christensen et al. 2011). Christensen et al. (2011) categorize landfill types as follows:

- Open dumps: Basic disposal sites, often clay or gravel pits, accepting various waste types without regulation.
- Sanitary landfills: Improved sites with restricted access and waste coverage with soil, maintaining a neater appearance.
- Controlled landfills: Implement liners, collection systems, and treatment facilities to control leachate and gas, with restrictions on hazardous waste.
- Dry tombs: Aim to prevent water infiltration and gas generation by covering landfills, with full gas collection.
- Bioreactor landfills: Introduce technologies like semiaerobic and flushing bioreactors to enhance waste degradation and shorten stabilization times.

Management of landfill gas (methane) significantly impacts environmental sustainability (Willumsen, Barlaz 2011). Capturing and utilizing methane generated from waste fermentation for electricity and heat production reduces environmental impacts. The illustrated landfill area (Figures 9–10) covers approximately 36 hectares (SOKB).

The case study of sanitary landfill and Municipal Solid Waste (MSW) Management Systems in Kosodrza, Community of Ostrów, Poland, is detailed by Sala and Bieda (2019b).

Fig. 9. Aerial view of the Landfill in Kraków in Poland
(Source: Barycz municipal waste landfill, 2023)

Fig. 10. Aerial view of the Landfill in Kraków in Poland.
(Source: Barycz municipal waste landfill, 2023)

Gasification

With the rapid advancement of technology, gasification has emerged as a viable solution. Biomass can be converted into gas fuel through thermochemical processes in a method known as gasification. During this process, long-chain biomass molecules are broken down into low molecular weight gases such as methane, hydrogen, and carbon monoxide through pyrolysis (Demirba 2001).

While gasification research has a long history, its industrialization has only recently begun. One drawback is the high tar content produced during pyrolysis when gasification temperatures are insufficient, resulting in low carbon conversion efficiency. Gasification facilities also incur relatively high costs due to the need to withstand temperatures of up to 1200 degrees Celsius (Wu et al. 2000).

Furthermore, as noted by Biomass Energy (2022), slag forms as a glassy, molten liquid during gasification. It can be utilized in various applications such as making shingles, cement, or asphalt. Industrial gasification plants are being established worldwide, with Asia and Australia leading in construction and operation. Notably, one of the largest gasification plants is under construction in Stockton-on-Tees, England, with the capacity to convert more than 350,000 tons of MSW into energy to power 50,000 homes (Biomass Energy, 2022).

Biomass can also be directly converted into energy through gasification. For instance, the gasification plant in Maui, Hawaii, converts sugar cane into electricity, as depicted in Figure 11 (Biomass Energy, 2022).

Fig. 11. Gasification plant in Maui, Hawaii, converts sugar cane to electricity (Source: Biomass Energy, 2022. Photograph courtesy Warren Gretz/NREL (National Renewable Energy Laboratory, NREL)

Incineration

Incineration is a waste treatment process that involves the combustion of organic substances present in waste materials (Knox 2005). This process transforms waste into ash (inorganic constituents), flue gas (comprising gaseous and particulate pollutants), and

heat. In ancient times, people burned biomass to generate heat. They later discovered that the ash produced had high fertility, improving crop yields.

However, burning biomass in urban areas or farmlands can lead to air pollution and adverse health effects. This is due to the dramatic increase in dust, particulate matter, and other pollutants, resulting in rapid deterioration of air quality. Additionally, it can reduce visibility and obstruct traffic, especially on highways. The low calorific value of biomass leads to short burning times in boilers and necessitates a large quantity of raw material for the boiler, increasing production and storage costs.

While incineration can generate heat that may be used to produce electricity, biomass's low calorific value makes it less suitable for thermal power plants under these conditions. Nonetheless, in some cases, the heat generated from incineration can be harnessed for power generation.

Thermal Waste Treatment Plant in Krakow (Ecoincinerator), Poland

The Thermal Waste Treatment Plant (TWTP), also known as Ecoincinerator, in Krakow was constructed in response to the ecological needs of the city as part of the "Waste Management Program in Krakow" project under the Operational Program Infrastructure and Environment 2007–2013. Construction of the Ecoincinerator commenced on 6 November 2013, and final tests at the plant were conducted from 3 December 2015 to 27 June 2016. The total net cost of the project was approximately PLN 666 million (grossing approximately PLN 819 million). Funding from the European Union amounted to approximately PLN 372 million, covering around 55.8% of eligible expenses. Krakowski Holding

Fig. 12. The Thermal Waste Treatment Plant in Kraków
(Source: Waste conversion process. How does the Krakow eco-incineration plant work? 2022)

Komunalny SA (KHK) contributed approximately PLN 294 million, sourced from its own funds and a loan from the National Fund for Environmental Protection and Waste Management (NFEP&WM). The plant is situated in the south-eastern part of Krakow, specifically in District Nowa Huta (Sala, Bieda 2019a).

The TWTP has a processing capacity of 220 thousand tonnes of municipal waste per year. It handles mixed municipal waste chosen by residents, as well as other waste resulting from mechanical processing of municipal waste (post-recovery processes like material waste, bulk waste, and rubble). The waste processed originates solely from the municipality of Krakow (Sala, Bieda 2019a; TWTPK).

The facility is a modern installation that adheres to the Best Available Techniques (BAT), ensuring the highest environmental protection standards (Sala, Bieda 2019a). A general view and longitudinal section of the TWTP are depicted in Figure 12.

Torrefaction

Before biomass can be efficiently burned, it undergoes a drying process known as torrefaction. Torrefied biomass is then shaped into briquettes, such as those made from wood waste in Nairobi, Kenya, as shown in Figure 13 (Biomass Energy, 2022). Torrefaction of biomass aims to enhance its properties (Wild et al. 2022) and produce advanced solid fuels or biocarbon products. Both woody and non-woody biomass can undergo torrefaction, resulting in a biogenic carbon carrier that can be utilized as fuel or for other process applications (Wild et al. 2022).

Wild et al. (2022) highlight that even non-woody biomass, like agricultural residues, can be converted into acceptable fuels through torrefaction. Torrefied biomass can be used in power plants and various industrial sectors such as steel, cement, and others that traditionally rely on carbon from fossil fuels for their energy needs. Currently, different production processes are testing torrefied biomass as semi-finished by-products or input materials (Wild et al. 2022).

Fig. 13. Torrefied biomass is shaped into briquettes in Nairobi, Kenya (Source: The National Renewable Energy Laboratory <NREL> Photograph courtesy, Chardust LTD, Biomass Energy, 2022)

Biodegradation

Composting is the most common method used to biodegrade solid biomass waste. Composting effectiveness depends on factors such as air volume, pH levels, heat, and moisture. Microorganisms play a crucial role in composting, with fungi like white rot fungi being extensively studied. Bacteria and actinomycetes also contribute to the process. Research has shown that enzymes produced by microorganisms are the primary agents of biodegradation. The heterogeneous nature of biomass requires a range of hydrolytic enzymes to cooperatively break down hemicellulose (Sánchez 2009).

Lignin, made up of phenyl propane units, is biodegradable by only a select few microorganisms capable of secreting three key enzymes: LiP, MnP, and Lac. Cellulose, composed of glucose units, is comparatively easier to biodegrade, with enzyme systems categorized into β-glucosidases, endo-glucanases, and cellobiohydrolases (Kögel-Knabner 2002; Wu et al. 2000). Following biodegradation, biomass waste such as landscaping waste, straws, and stalks can be converted into valuable products like fertilizer, feed, and energy.

Despite its advantages such as no new pollution, energy conservation, and material recycling, biodegradation has limitations hindering its widespread adoption. Firstly, waste must be sorted by type due to enzyme specificity. Secondly, additional power is required to reduce biomass particle size, necessitating equipment with higher specifications. Thirdly, the biodegradation process is time-consuming, leading to higher costs compared to chemical or physical methods. Fourthly, efficient microorganisms are challenging to isolate, and even when found, the process is complex and requires strict conditions. These challenges impede the practical application of biodegradation technology. Recently, the cost of implementing biodegradation technology has outweighed the benefits for enterprises (Cheng, Hu 2010).

Container Composting Plant for Green Waste in Barycz, Krakow, Poland

According to Stentiford and de Bertoldi (2011), compost is defined as a stabilized and sanitized product resulting from the composting process, which is beneficial for plant growth. Composting, as described by Stentiford and de Bertoldi (2011), is a microbial aerobic transformation and stabilization of heterogeneous organic matter under aerobic conditions and in a solid state. Composting systems have been established worldwide, with thousands of facilities in operation. Krogmann et al. (2011) provide estimates of the number of composting facilities for different feedstocks in countries such as the United States, Germany, and regions like Flanders in Belgium.

The Barycz container composting plant for green waste is located in Krakow, Poland (Barycz). The composting system comprises 8 composting containers, each equipped with aerobic composting systems, air blowers, biofilters, condensate management systems, air pipes, and heat processing air heaters. The plant commenced operation in September 2005, with expansion taking place between 2012 and 2015. The Barycz composting facility in Krakow is depicted in Figures 14–16.

Fig. 14. Picture of Barycz composting facility, Kraków, Poland
(Source: BCCP, 2023)

Fig. 15. Compost storage in Barycz composting plant in Kraków, Poland
(Source: BCCP, 2023)

Fig. 16. Barycz composting containers yard in Kraków, Poland
(Source: BCCP, 2023)

The Key Advantages of Biomass

Biomass stands out as one of the most sustainable raw materials for the future (Biomass – Advantages and Disadvantages, 2023). Bio-waste is inherently natural and environmentally friendly, and the resulting ash serves as an excellent organic fertilizer. Additionally, biomass derived from post-production waste during wood processing represents

an ecological method of obtaining biomass, with its most significant advantage being its renewable nature without the need for mining – it is entirely renewable and widely accessible. It is generated through various means, including municipal waste disposal or animal excrement (Biomass – Advantages and Disadvantages, 2023). An intriguing example of a valuable biofuel source is the cultivation of special energy crops on wastelands or sterile post-industrial soils, using fast-growing plant species like energy willow or Jerusalem artichoke. This not only produces oxygen but also enhances soil conditions.

Biomass serves as a clean and renewable energy source, with its primary energy derived from the sun, and the regrowth of plants or algae biomass occurs relatively quickly. Trees, crops, and municipal solid waste remain consistently available and can be sustainably managed (Biomass Energy 2022). Many biomass feedstocks, such as switchgrass, can be harvested from marginal lands or pastures where they do not compete with food crops. Similar to other renewable energy sources like wind or solar, biomass energy is stored within organisms and can be harvested when demand is highest (Biomass Energy 2022).

Disadvantages of Biomass

According to Biomass – Advantages and Disadvantages (2023), several drawbacks of biomass as a raw material should be noted. These include:

1. Lower Calorific Value: Biomass possesses a lower calorific value compared to coal or natural gas. This means that more biomass is required to generate the same amount of energy. As a result, biomass combustion in boilers produces large amounts of ash, necessitating frequent removal and cleaning of heating installations.
2. Ash Generation and Maintenance: Combustion of biomass in boilers leads to the generation of large amounts of ash, necessitating frequent removal and cleaning of heating installations. This increases maintenance costs and effort (Biomass – Advantages and Disadvantages, 2023).
3. Increased Energy Prices: The growing demand for biomass can lead to an increase in energy prices, particularly due to the rising costs of raw materials. This can pose economic challenges for biomass recipients.
4. Land Use Competition: Most biomass requires arable land for development. If the same land is utilized for biofuel crops such as corn and soybeans, it can result in competition for land resources, impacting food availability or natural habitats.
5. Dependency on Fossil Fuels: Many biomass plants rely on fossil fuels to maintain economic efficiency. This reliance contradicts sustainability goals and contributes to greenhouse gas emissions.
6. Lower Energy Density and Water Content: Biomass has a lower energy density compared to fossil fuels, and a significant portion of biomass is water, which is lost during energy conversion processes.
7. Environmental Impact: Unsustainable harvesting of biomass, especially from forested areas, can lead to deforestation, habitat loss, and carbon emissions. Combustion of

biomass also releases pollutants such as carbon monoxide, carbon dioxide, nitrogen oxides, and particulates, contributing to air pollution and environmental degradation (Biomass – Advantages and Disadvantages, 2023).

Conclusions

This study underscores the significant role of biomass in the bioeconomy and global carbon cycle. While biomass offers numerous advantages, including its renewable nature and contribution to energy production, careful consideration of its drawbacks is essential for sustainable application. The study highlights the need for informed decision-making and scientific approaches to maximize the benefits of biomass while mitigating its environmental and economic challenges.

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Eco-industrial cluster in the circular economy

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Abstract. The creation of industrial clusters is an effective way of combining industry with commerce and the necessary infrastructure. However, industrial clusters can have both positive and negative impacts: they contribute to a community's economic growth and can act as focal points for environmental and social problems. In particular, they can become sources of greenhouse gas emissions and pollution, deplete natural resources, establish low standards in the labour sphere, lobby for legislative acts beneficial to them, and communities can suffer from their neighbourhood. This study aims to formulate the main requirements and efficiency indicators for an industrial cluster to be considered eco-industrial. Research has shown that smart eco-industrial clusters are the most powerful tool in achieving Sustainable Development Goals, and clusters can help achieve more than 60% of the Goals, especially if the cluster is agro-industrial and focuses on cooperation with science and universities. The author proposed the basis of establishing benchmarking norms and standards for the introduction and operation of a smart eco-industrial cluster, which establishes the norms according to which an industrial cluster can be considered a smart eco-industrial cluster and which, unlike others, prevails over the principle of choosing the most stringent norms and standards of compliance in the ecological, economic and socially inclusive spheres.

Keywords: circular economy, cleaner production, eco-industrial cluster, sustainable development, Sustainable Development Goals

Introduction

A cluster is a sectoral, territorial and voluntary association of organizations that work closely with each other and with other actors in the value chain to increase the competitiveness of their products and their exports and promote economic development in the region. Clusters as network structures focus on creating new value within the network or reducing transactional and economic costs. They complement each other in production and marketing chains or in implementing innovative projects.

Industrial clusters are a relatively new form of economic organization. In many developed countries, they have proven their significant role in shaping and ensuring the economic security of the country and its territories, improving the welfare and safety of people (Bashynska et al. 2021a).

It is essential to distinguish clusters from other business associations, particularly from industry business associations. Most industry business associations aim to lobby for the common business interests of their members, such as fiscal and other industry preferences. With rare exceptions, they do not have on the agenda and strategies provisions for increasing competitiveness through better production cooperation, international cooperation, exports, innovation and digitalization. All of the above distinguishes clusters from other business associations. However, effective long-term functioning of industrial clusters is possible only if the strategy is based on the principles of sustainable development, namely greening, CE resource management, renewable resources, smartization of business processes and more (Bashynska 2020). Green industrial growth is one of the most critical issues for sustainable development; in particular, industrialization and urbanization usually interact. It is well known that the industrial sector is the engine of the growth of the national economy. At the same time, it contributes to most global environmental impacts, such as carbon and resource emissions, as well as emissions of critical pollutants. It is essential that neglect of preventive means of ecological safety management of individual entrepreneurs can lead to irreparable damage to human health and life. Thus, the present requires creating a new economic system – an ecological industrial cluster.

In addition to the above, two factors have a significant impact on the world economy, changing existing laws and principles:

1. The war in Ukraine led to significant population migration, including small and medium enterprises. The most significant number of migrants was received by Poland (on 11.06.22, about 4 million people) (Straż Graniczna, 2022). This migration can be seen as an opportunity to obtain a synergistic effect, as Ukrainian SMEs have brought highly liquid financial resources, qualified personnel and experience to Poland. However, to scale their business in Poland, they lack knowledge of the law, established connections (logistics) and the peculiarities of doing business.
2. The COVID-19 pandemic has led to business profitability loss and even many businesses closure (McKinsey & Company, 2022). Many SMEs will never return to business, but studying in a cluster can help them start a business without significant financial investment. Thus, it is necessary to outline the state of industrial parks (clusters) in Ukraine, the ways of their greening and their legislation based on leading foreign experience. The increased interest of scientists in clusters was formed after the publication of the works of Michael Porter and which is given a leading role of clusters in shaping the competitiveness of states and regions.

Sufficiently in-depth IC studies are available from foreign scientists. The Japanese authors (Tsujimotoa et al. 2018) review 90 previous studies using the ecosystem concept and explain four main research approaches. The first approach is the perspective of industrial ecology, which is based on the idea of industrial ecosystems. The second approach is considered in terms of business ecosystems. This approach is based on the theory of organizational boundaries. Some influential scientists are paying attention to platform management, which is the third approach. The fourth approach is a multi-stakeholder network

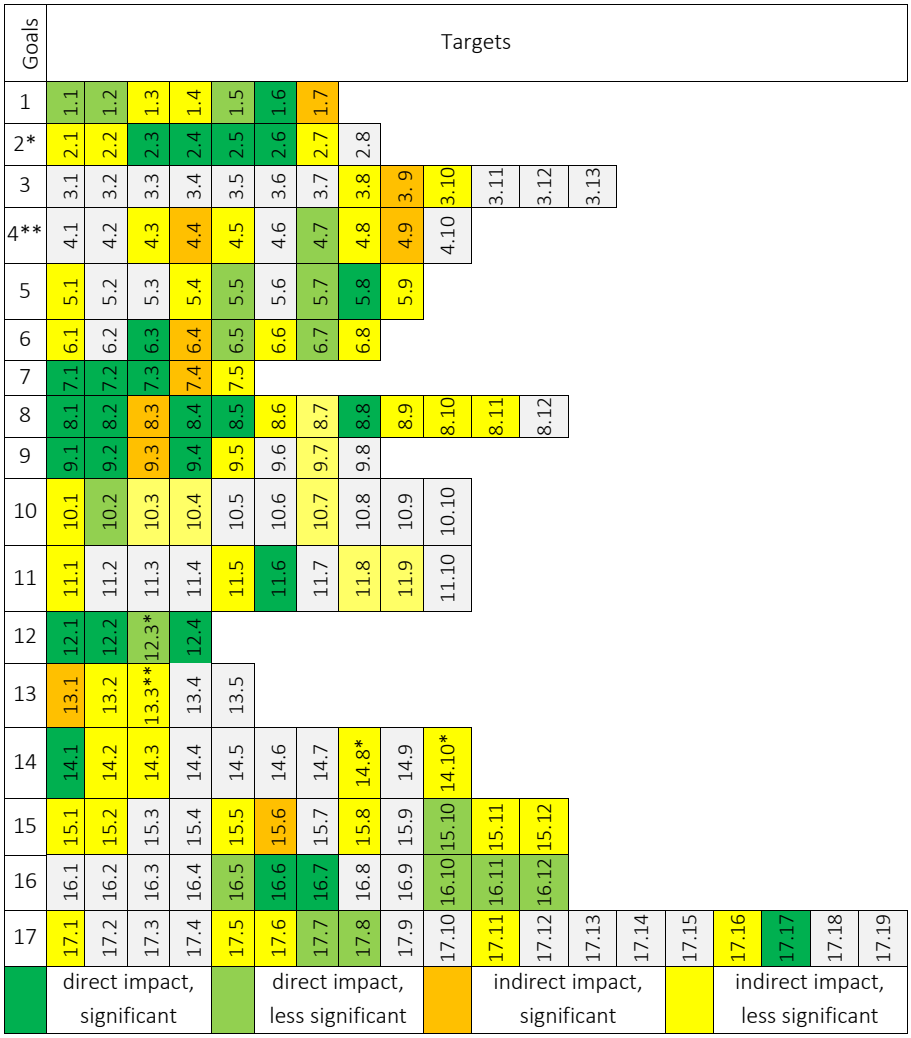
that facilitates dynamic analysis of behavioural relationships based on social media theory. The publication (The World Bank, 2021), which is the result of cooperation between the United Nations Industrial Development Organization (UNIDO), the World Bank Group and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, outlines a rethinking of industrial eco-parks based on the experience gained since the start of the framework project in 2017, as the creation of industrial eco-parks has proven to be an effective way to combine industrial activity with commercial and infrastructure services.

A group of scientists from Finland (Halonen, Seppänen 2019) defines the industrial eco-park as a business community of enterprises in the real sector of the economy and services that seek to improve environmental and economic performance through cooperation in solving ecological and resource problems. Emphasis is placed on the pursuit of collective benefits, which outweigh the number of individual benefits, which each realizes only by optimizing the activities of each participant. Recent studies by foreign authors are increasingly concerned with the greening of eco-clusters as a tool for introducing a CE (Xie, Lu 2022) or the development of eco-industrial parks (Genc et al. 2019; Ong et al. 2021). In turn, such issues as the participation of companies in the IC and the calculation of the feasibility of making management decisions are not paid attention to, except in terms of the impact of COVID-19 (Mengistu 2020).

For the first time, the concept of an eco-industrial park (clusters) was presented at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 (The United Nations, 1992). At this point, other states have already initiated various planning processes to introduce eco-industrial production, which was considered a way to transition to sustainable production and CE practices. Since then, the concept has evolved to take into account other aspects, such as resource-efficient and clean production, industrial symbiosis, climate change, pollution, greenhouse gas emissions, social standards, infrastructure sharing, effective risk management and shared resources, use of land resources and ecosystem services, use of artificial intelligence, etc. Sustainable development goals are the key development directions of countries, which were adopted at the UN Summit on Sustainable Development. They replaced the Millennium Development Goals, which expired at the end of 2015. The SDGs were adopted from 2015 to 2030 and count 17 Global Goals, which continue and deepen the stimulation of inclusive, sustainable industry.

The author believes that smart eco-industrial clusters are the most powerful tool for achieving Sustainable Development Goals (Fig. 1).

It is worth noting that in order to define a smart eco-industrial cluster, the author considers direct influence – this is what the cluster can directly influence (for example, target 7.2 – to significantly increase the share of renewable energy in the global energy balance), the indirect influence was considered more like lobbying for specific goals at the regional, state and global level as a tool that sets certain standards (benchmarks) and has a significant impact (for example, target 11.8, 15.1, 15.2 and so on). Thus, only through the prism of achieving the Sustainable Development Goals a smart eco-industrial cluster



* in case of organization an agro-smart eco-cluster

** in case of organization a smart eco-cluster focusing on collaboration with science and universities

Fig. 1. Impact of the Smart Eco-Industrial Cluster Achievements of the Sustainable Development Goals (author's development)

can help achieve more than 60% of the Goals, especially if the cluster is agro-industrial and focuses on cooperation with science and universities.

The research aims to form new knowledge to develop the concept of creating the eco-industrial cluster based on sustainable development, cooperation, risk resilience and smarting of its participants. To implement the tasks will be used scientifically sound re-

search methods and tools, new methods: systematization and empirical research – in the study of current world legislation on industrial clusters, in studying the theoretical foundations of world experience in creating and operating industrial clusters, its conceptual apparatus, scientific basis; classification-analytical – for the classification of technology and approaches to global smarting; graphical, statistical and comparative analysis, Microsoft Excel analysis tools – in the analysis of the current state of the existing leading industrial parks (clusters); dialectical and comparative – to summarize global trends in intelligent innovation and the use of information technology; systematic and logical – to develop the basic principles of an eco-industrial cluster based on instrument and requirements to sustainable development, namely greening and cleaner production, CE, resource management, renewable resources, smartization of business processes and more; benchmarking – to determine the reference smart eco-cluster.

Results and discussion

There are about 2,950 clusters in Europe, i.e. defined as regional concentrations of participants in the relevant industries. Economic activities related to European clusters cover up to 39% of jobs and up to 55% of EU wage funds. In contrast to the relationship of industrial cooperation in traditional industries, which was practised long before the emergence of clusters, clusters are much more innovative – 87% of all EU patents are produced by companies that are members of clusters. In addition, the contribution of clusters to foreign economic activity is significant – 50% of export industries also belong to clusters. According to the European Cluster Panorama 2021 (Franco et al. 2021), for the period 2010–2013, in some sectors and regions of the EU 33.3% of cluster firms showed employment growth of more than 10%, while outside the clusters, such results were achieved only 18.2% of firms.

The first industrial parks in China were established in the 1980s (UNIDO, 2020). There are currently 375 of them, and about 25% of all foreign direct investment accumulates there. In turn, parks provide China with about 15% of merchandise exports and more than 4 million jobs.

There are 1,200 industrial parks in South Korea. They provide 80% of national exports, 70% of industrial production and 50% of employment in the industry (Park et al. 2008).

In Turkey, 346 industrial parks have been established in the last 30 years, and more than 80% of foreign direct investment is concentrated in them. The development of Eco-Industrial Parks is an emerging concept being spread in Turkey as a sustainable development model (Dolgen, Alpaslan 2020).

There are more than 50,000 resident companies in Turkey's industrial parks. According to expert estimates, they created more than 1 million jobs and provided GDP growth and exports more than 3 times. As a result, in 2013, Turkey, which had been a debt to the IMF for decades, returned the last tranche to the organization, fully repaying its debt.

Poland has 77 industrial and technology parks in 14 special economic zones. Almost all were founded in the second half of the 1990s (KPMG, 2009). Over the next ten years, the country's real GDP grew by 50%, and exports almost tripled. The total number of jobs created in the SEZ reached 186 thousand. At the same time, more than 20 billion euros were invested in parks. According to the European Observatory for Clusters and Industrial Change (The World Bank et al., 2021) on cluster support in 29 European countries, which includes an in-depth analysis of 30 national and 55 regional programs, tailor-made cluster support policies and strategies are widespread in Europe and around the world.

Despite the economic feasibility of clustering the economy, clusters have not yet become widespread in many countries, in contrast to highly developed countries. As of October 2021, there are 64 industrial parks in Ukraine (Fig. 2), and in Kazakhstan – up to 10, but there is not a single industrial park or cluster that would be, in total, functioning to some extent the way that such leading clusters work.

In 2012, Ukraine adopted the law "On Industrial Parks", and in September 2021, it adopted amendments. Their predominant activities are engineering, processing, and light (Fig. 3).

Statistical and analytical research showed that Ukrainian industrial parks do not ensure the region's sustainable development. However, ensuring sustainable economic growth and increasing the territory's competitiveness was one of the goals of creating more than 70% of industrial clusters (Fig. 4).

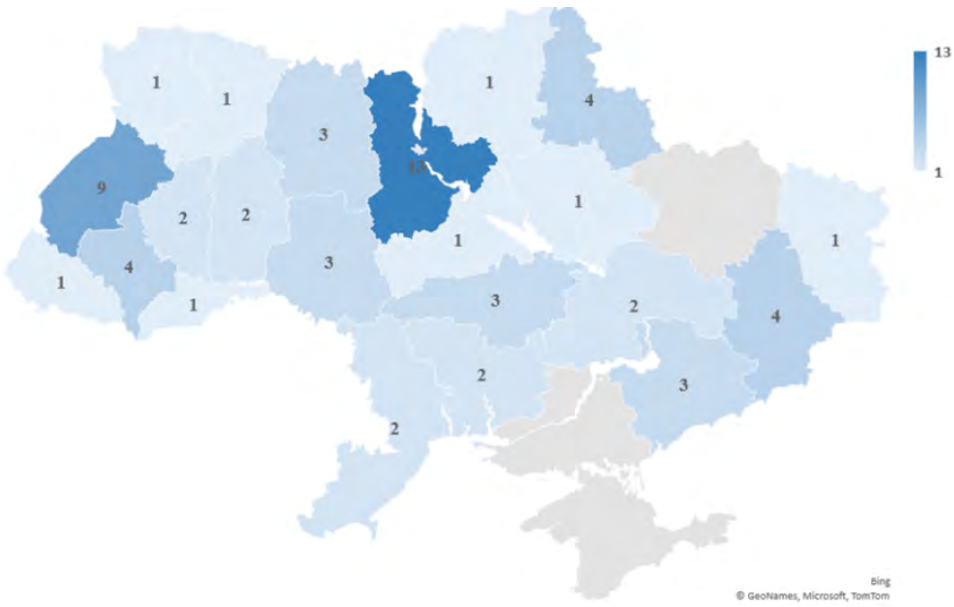


Fig. 2. The territorial distribution of industrial parks in Ukraine
(compiled by the author according to the data of the Ministry of Economics of Ukraine, 2021)

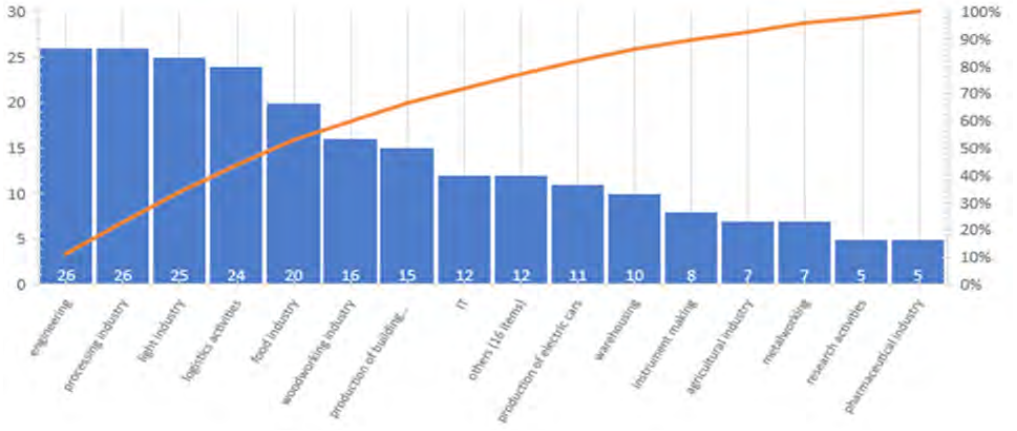


Fig. 3. Branch distribution of industrial parks
(compiled by the author according to the data of the Ministry of Economics of Ukraine, 2021)

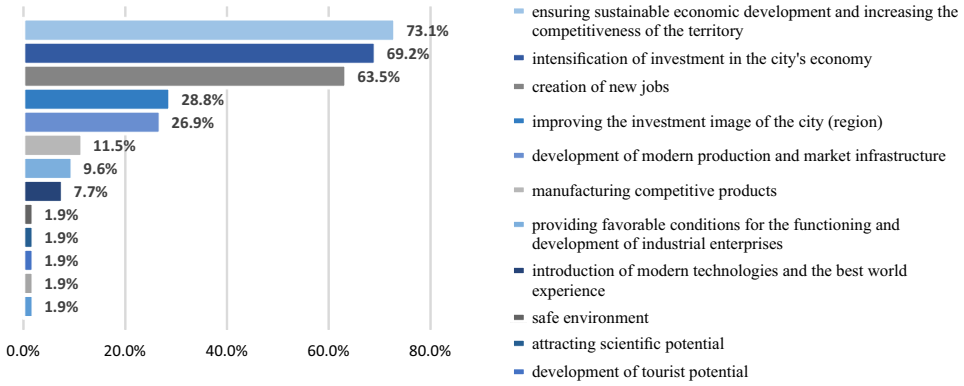


Fig. 4. The goals of creating industrial parks
(compiled by the author according to the data of the Ministry of Economics of Ukraine, 2021)

However, only four high-quality infrastructure facilities with residents with operating plants are fully operational. It:

- Bila Tserkva Industrial Park (Kyiv region);
- Vinnytsia Industrial Park (Vinnytsia region);
- Solomonovo Industrial Park (Zakarpattia region);
- Korosten Industrial Park (Zhytomyr Region).

There are many reasons, but the main one is the lack of total funding. According to the Ministry of Economics (Minister of Economy of Ukraine (2021) from 2016 to 2019,

the State Fund for Regional Development financed only four projects related to creating an infrastructure of industrial parks, for a total of 7.2 million hryvnias.

Most of Ukraine's border industrial parks are located in the Lviv region, which borders Poland, whose economic structure is similar to Ukraine's. At the same time, the experience of development and efficiency of Polish industrial parks is much higher than in Ukraine.

However, unlike Ukrainian legislation, no single law in Poland regulates industrial parks' activities. For the first time at the legislative level, support for the development of industrial parks was included in the program of the Council of Ministers of July 11, 2000, "On strengthening the innovative economy in Poland until 2006." However, this was preceded by the Law of May 12 2000, "On Principles of Support for Regional Development" (Internetowy System Aktów Prawnych, 2022), which provides local governments with the opportunity to develop an active spatial development policy (strategic planning and financial support at the local level, etc.), which promotes investment in their territory. The law outlines the basic principles and forms of support for regional development and defines the interaction mechanisms between executive bodies and local governments.

In particular, in Art. 3 identifies the main priorities of regional development:

- development of each region, improving the quality and living conditions of residents and the level of satisfaction of the needs of territorial units;
- creating conditions for increasing the level of competitiveness of territorial units;
- reduction of asymmetry between regions.

To do this, local governments can create preferential conditions on the territory of a particular administrative unit. For example, reduce local taxes and rents, organize training for entrepreneurs, reimburse the cost of employment of the unemployed, facilitate entrepreneurs' access to technical infrastructure, and so on. One of the tools that local governments can use is the exemption from the real estate tax, which is subject to land tax, residential buildings or parts thereof, and buildings or parts related to economic activities. They acquired this right by adopting the Law "On Taxes and Local Taxation" of January 12, 1991, which gave local councils the power to set tax rates and establish certain benefits. The community council may, through a resolution, exempt entrepreneurs from paying real estate tax, using this as a form of state aid. Such assistance is equivalent to a tax benefit and must be provided following the conditions set out in Polish law (Polska Agencja Inwestycji i Handlu, 2018).

The Concept of the Regional Industrial Park (2002) once again emphasizes the possibility of local governments creating preferential conditions for enterprises and outlines the role of the industrial park as a tool for strengthening regional development and creating quality conditions for entrepreneurship (Krawczyk 2007). In addition, the placement of new investments within industrial or technology parks is one of the conditions for providing public financial support to enterprises, as stated in the said law No. 1537 (Article 3). However, enterprises applying for public investment must meet at least two other criteria

specified in Art. 2 item 1 of the law "On financial investment support" from 20.03.2002 (Internet System of Legal Acts, 2002):

- investments will affect the economic development of the region;
- investments will be located in the support zone;
- investments focused on technological innovations;
- investments will promote the development of cooperation with the national research base;
- investments will affect the local labour market. At the same time, the company's share in investment costs should be at least 25%.

Later, the partnership agreement "Programming the Financial Perspective for 2014––2020" defined a strategy for attracting funds from the European Structural Funds under the three EU policies (cohesion, standard agricultural, and common fisheries policy). It focuses on the need to support small and medium-sized businesses to increase their competitiveness and innovation, as well as industrial and science clusters to reorient, expand and better adapt to the needs of entrepreneurs in the services they provide. However, it is noted that to increase the efficiency of public spending; aid should cover those projects that would not have been implemented without public support or where state support would help increase or accelerate the project (European Funds Portal, 2014).

The Strategy for Responsible Development until 2020 (with a perspective until 2030), adopted by the Council of Ministers on February 14, 2017, already emphasizes the development of innovations. To this end, support is provided to business environment institutions that increase the efficiency of the "innovators" service system and professionalize their services (Ministry of Funds and Regional Policy, 2020).

The Industrial Development Agency, established in 1991, also plays a vital role in supporting industrial and innovative activities. Its main goal is to keep the restructuring of Polish economic entities and their adaptation to the conditions of international competition. The Agency initiates the creation of technology incubators and industrial technology clusters; provides access to high-quality services provided by business institutions, public online services and external sources of funding; contributes to the creation of a modern infrastructure for doing business, strengthening the links between the research sector and enterprises, as well as improving the efficiency of implementation and commercialization of innovations. Another factor contributing to developing industrial clusters and attracting significant investments in infrastructure is access to European funds.

Today in Poland, industrial parks are in the process of finding more effective tools for their activities, mainly through the Golden Triad (cooperation between government, business and research centres), operational programs 2014–2020 and 2021–2027, and international projects (Prawo.pl, 2016). International cooperation is necessary for developing industrial parks, which provides the exchange of knowledge in the effective management of parks and their operation, as well as helps attract foreign investors and find foreign partners.

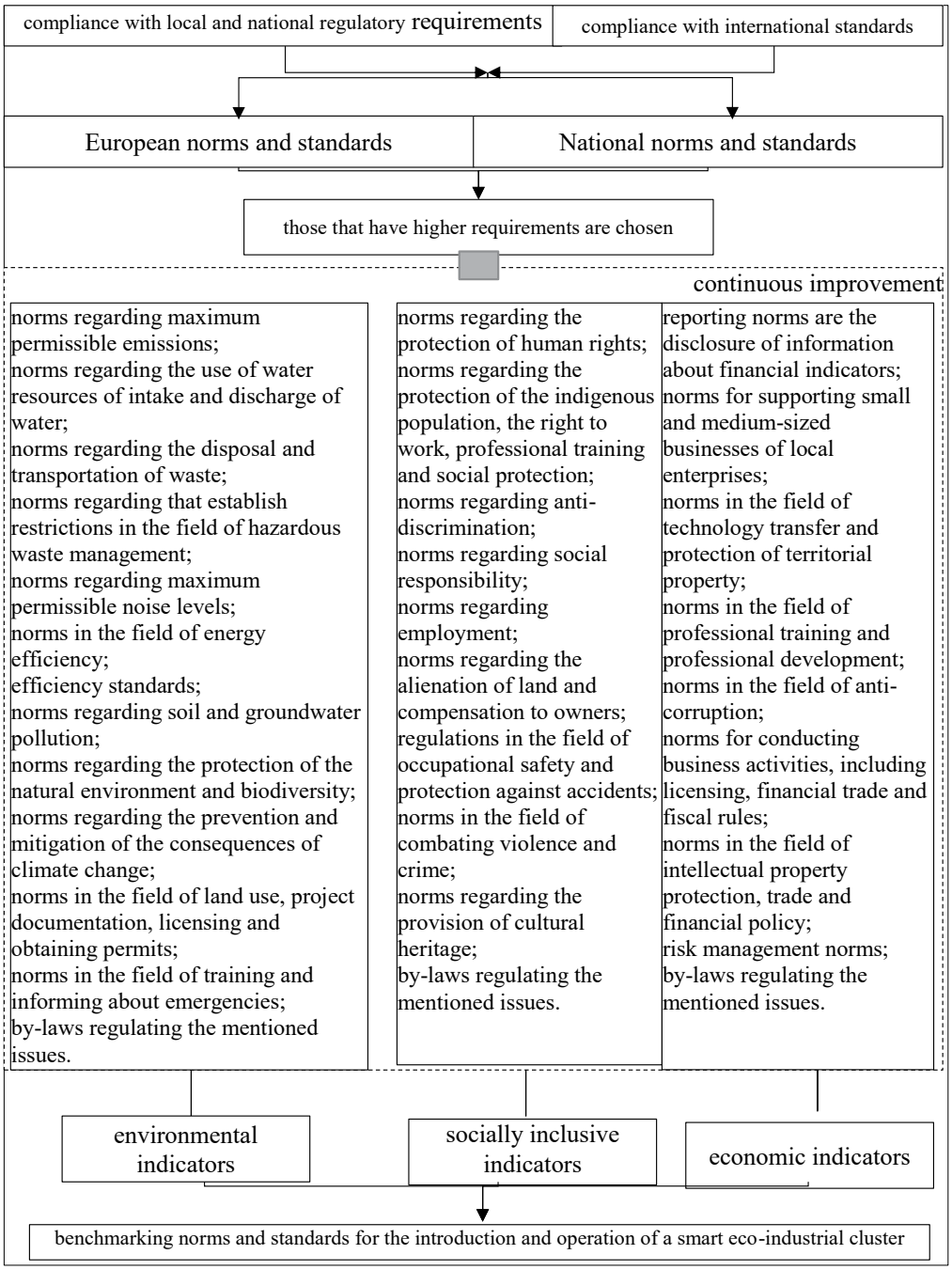


Fig. 5. The basis of establishing benchmarking norms and standards for the introduction and operation of a smart eco-industrial cluster

At the EU level supporting and encouraging the development of industrial parks is stated in the opinion of the European Socio-Economic Committee, "The role of technology parks in the industrial transformation of new member states" of 11.02.2006. provide a comprehensive structure and tools to promote, stimulate and develop innovation and regional development". In addition, it is noted that in legal texts and terminology, such organizations are referred to differently in different EU member states. However, the basic idea remains the same: to promote synergies between science, technology and economic development and to create synergies through cooperation between business and research institutions, thus facilitating market access (Bashynska et al. 2021b, 2022). At the same time, the creation and development of industrial parks in EU member states should be based on compliance with environmental principles and standards (EUR-Lex, 2006; European Investment Bank, 2018; UNIDO, 2019).

Thus, the analysis showed that Poland is one of the European leaders in the effectiveness of industrial parks and can be the basis for developing an industrial reference cluster. Still, compliance with environmental principles and standards is not fully implemented by law, in addition, to European and Ukrainian experience, parks will develop the concept of eco-industrial cluster and management of participation of enterprises in it.

The global process of socio-economic relations has been mainstream since the second half of the XX century and advocates the concept of sustainable development. Realizing the negative consequences of uncontrolled entrepreneurship and innovation chaos, the world community is trying to introduce international and national law norms that will protect the environment and eliminate humanitarian problems and socio-economic disparities.

Thus, based on the analysis of literature and legislation, it is possible to form The basis of establishing benchmarking norms and standards for the introduction and operation of a smart eco-industrial cluster (Fig. 5).

The proposed mechanism forms the basic principles according to which requirements are formed regarding, first of all, the environmentalization of the industrial cluster in order for it to be considered a smart eco-industrial cluster. The proposed mechanism is quite transparent and straightforward, but a critical thing should be noted, namely the choice of standards by which the indicators are generated. Indicators are selected according to the highest requirements. Thus, if the state has set a higher value for greenhouse gas emissions into the atmosphere, and the European standard provides for a lower value, European norms are applied in this case. Conversely, if the country has national standards or norms that are somewhat stricter than European norms, then the national standards are considered. The same principle is applied in the absence of regulation of this issue, in which case the only existing option is taken into account.

Conclusions

The eco-industrial cluster is an effective tool for sustainable development and prosperity of the country and people and provides companies with significant benefits from participating in it, namely the synergy effect, saving resources, primarily financial; for attracting foreign direct investment and intensifying the process of integration into global value chains. Inclusion in such chains allows companies to increase their technological level, expand innovation to gain more significant competitive advantages, and increase the depth of product processing and added value. Such factors facilitate this as acquiring and implementing the latest equipment and technologies, gaining access to modern methods of management and organization of production and special knowledge, and gaining adequate opportunities to enter international markets.

The ways of developing this research are the formation of a system of indicators of a smart eco-industrial cluster.

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The risk of behavior with elements of chairing and its elimination

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Abstract. The study presented by us touches upon some aspects of the phenomenon called chairmanship. This is a clearly unethical phenomenon in organizations that needs to be stopped. Our goal is, first of all, to take on the risks arising from the victory of an individual in the selection procedure or in another selection process for a leading management position. In the next part, we try to find ways to prevent the victory of a person who shows signs of chairmanship. The appearance of such a person in a leadership position can be dangerous for the company and stakeholders. The danger itself may lie in many ethical errors. Of particular danger is the alignment of organizational culture and command. A strong organizational culture should protect against this type of manager. Other tools are control mechanisms within the ethical management of people.

Keywords: chairmanship, prevention, managerial position, organizational culture, democracy

Introduction

If, in a competition of several candidates for the position of senior manager, a person wins who has used other means in the struggle than competence, knowledge, experience, etc., then this may mean the germ of several types of danger. for the organization. First of all, there are doubts about whether the knowledge and competencies of the winner are sufficient to perform the function. If this is not the case, then the unprofessional, incompetent approach of the management of the organization, organizational unit, subdivision can cause great damage to the organization and the interested parties entering into relationships with it. Incompetent management can cause enormous economic damage. Its impact may not be felt immediately, but it may be long-term. "Incompetent management, insufficient planning, minimal strategy and unwillingness to change can all be described as insufficient business education" (Komárková 2007, p. 40). An incompetent approach can certainly mean a big setback for the organization or part of it. Although there are several resources and services to support business, such as a business incubator, but in

this case, the only adequate step is the immediate replacement of an incompetent person. Sometimes it does not have to be a comprehensively incompetent person, these competencies can only be limited and weaker than those of competitors who have not succeeded due to ethically incorrect circumstances. An example would be the possible lack of a general overview if the supervisor is a subspecialist. Speeches of so-called Fahidiotism should not be compatible with higher management positions. First of all, this would be an obvious danger in senior positions of heads of scientific institutions, since science needs interdisciplinarity and multidisciplinarity.

The ethical risks that such a victory brings with it are also obvious. As long as the stool and its manifestations have been hidden, the risks are not known or obvious, but they are present. The main ethical risk lies in the fact that the personality of such a senior worker has weak, unstable ethical principles, is not ethically principled, and if it is, it is ethically incorrect. In such a case, further unethical steps may follow. An ethically polluted person without strong principles has the potential to engage in ethically harmful activities. Unethical behavior constantly threatens the internal integrity of the company, the organization and its relationship with the external environment. The institutionalization of ethics in society is an important and decisive means of eliminating and preventing unethical behavior. Therefore, an unethical manager can become an obstacle to his introduction into the institution.

A direct product of the manager's unethical behavior can be all sorts of ethical blunders, as well as their admission and even approval. Corruption is a very common type of ethical misconduct. "Corruption can be the promise, offer or giving of a bribe to influence someone's actions or decisions, or the request for or receipt of a bribe" (Almašiová 2014, p. 9). It does not have to be a financial or even material bribe. This form can also be given as a certain benefit, a counter service, the provision of classified information. Clientelism can be considered a form of corruption. Its result is mutual dependence on the basis of mutually provided unjustified benefits. "Corruption has both a demand side (where there are those who take bribes) and a supply side (where there are often entrepreneurs who offer or give bribes). Intermediaries may also appear among them" (Zemanovičová et al. 2003, p. 25). This negative phenomenon thrives in conditions where it is difficult to detect and provides relatively large opportunities for illicit enrichment. Another form of unethical behavior that a manager can exhibit is lobbying. Initially, lobbying had a neutral connotation (Žáry 1995). In the modern sense, this is the promotion of group interests. Supporting political parties through the business sector is usually motivated by counter-services, which some entrepreneurs rely on.

The winner of a competition for a managerial position who has won illegally may exhibit other violations of the norms of ethical behavior. It can inefficiently allocate public funds, illegally manipulate economic competition. It should not be forgotten that corruption on a large scale often precedes organized crime.

A manager with unethical patterns of behavior is often a person with low reflection of the gatekeepers of economic liberalism. "Liberalism in economics and politics without

responsibility to Europe and its future, the priority of momentary gain even at the cost of future multiple losses, manipulation of society, abuse of power, corruption, privatization of profits and socialization of losses – these are the consequences of illusions about the unlimited growth of consumption and life over real economic opportunities. some nations, states, as well as individuals within the framework of hedonistic morality, regardless of the future" (Bilasová 2012, p. 180). Of particular danger is the unethical handling of public finances. This is associated with negative economic consequences. "If decisions about public funds are made on the basis of private motives, then resources are not optimally distributed, economic competition is distorted" (Zemanovičová 2003, p. 186). Corruption and economic growth are negatively correlated. Corruption in public financial resources reduces the economic wealth of the state. Even in the case of public resources, corruption can take several forms. "The misuse of public resources and the misuse of public power for personal gain can be concentrated in the form of well-defined bribes, but can also take the form of dispersed benefits for a large number of people" (Beblavý 2007, p. 701).

Another significant danger lies in the fact that the leader will be engaged in a leader who does not have ethical principles. This undesirable phenomenon may occur primarily in connection with potential competition. In some cases, however, it may also be the bosses in relation to those employees who, at least from the point of view of this leader, are perceived negatively in some way. As a rule, this happens if the manager is not going to remain in the managerial function for more than until the end of the period or feels that nothing threatens him in his post. In the second case, it is a low organizational culture from an ethical point of view. The emergence of superiors is not, at least in the Slovak environment, a widespread phenomenon. An example is the research conducted in Slovak schools, which brought certain concrete results. "The emergence of mobbing or bosses in the educational environment of Slovak schools is 15%" (Kariková and Nabelková 2010, p. 12). This is a figure (unfortunately, undifferentiated) along with mobbing, which means that bossing is somehow not very common in our conditions. This is not a tragedy because, for example, it is said that research from Africa, power structures in academia, and "reluctant complicity in bullying" may tend to support bullies, affecting employee performance, productivity, health, and well-being (Mhaka-Mutepfa and Rampa 2021).

Another obvious danger is the potential degradation or leveling of the company's organizational culture. An ethically objectionable manager can have a significant destructive impact on the company. Although a high organizational culture can lead to his rapid or even gradual removal from office. Sometimes it happens that, despite significant pressure from employees, the manager withstands this pressure and remains in his post. The organizational culture of the company may pay for this. In this case, its gradual degradation can easily occur.

Perhaps the last danger is a possible increase in staff turnover. Due to the unethical behavior of the leader, some employees may quit of their own free will. First of all,

a job change for elite knowledge workers (as defined by Drucker) can mean far-reaching consequences for the company in the form of reduced product quality, reduced workload, etc.

Thus, there are several dangers that threaten a pleonectic person in the position of a senior worker. First of all, it is a threat of further unethical behavior, which can take various forms (corruption, lobbying, lust for power, inefficient distribution of public funds, etc.). At the same time, corruption has a direct negative impact on the economy of a particular company and ultimately on the state, so this is not just an ethical impact of actions. Such a person can reduce the quality of organizational culture, as well as be a direct cause of staff turnover in the company. Secondly, the use of the chairmanship as a tool to achieve a leadership position carries a significant risk that this position will be occupied by a person who is professionally and organizationally unsuitable for its full performance. This dual potential threat is a rationale for the need for defense in the sense of preventing such situations or resolving them quickly should they occur.

Possibilities of prophylaxis against behavior showing signs of chairing

Results and discussion

As can be seen from what we have already said, the chairmanship is a phenomenon that is not only unethical in itself, but can also give rise to a number of other negative phenomena. Therefore, we consider it necessary to present several proposals aimed at preventing this phenomenon.

First of all, we see significant protection against such behavior by a strong organizational culture in the company. This condition itself, if reliable, may prevent potential behavior meeting the above characteristics. In this case, only the hidden, sophisticated form of the chair will remain as an option. This would also be associated with the risk of exposure, which in this situation would mean disqualification in the struggle for a leadership position.

Author Grashkova discusses organizational ethics in an interesting study. He notes that there is a significant difference between business and organizational ethics. "Organizational ethics can also be understood as the intersection of individual applied ethics, i.e. we can mention business ethics, management ethics, economic ethics" (Hrašková 2015).

Organizational culture must have strengths that provide behaviors that are considered desirable. Organizational culture "determines the basic relationships of superiority and subordination and determines the overall system of functioning" (Minarová, Čierna 2008). The maturity of an organization's culture also reflects how it can handle deviations from its stated models. "Organizational culture and human labor potential, abilities and skills of employees are the most valuable capital" (Frianová 2007). A mature organizational culture is accompanied by several characteristics. Some believe that it is the organization of events in the external environment that contributes to the formation of informal

relations. However, they can also occur in the case of a weaker organizational culture. Good informal relationships are not excluded even with the worst organizational culture, although, conversely, maintaining a good organizational culture with poor interpersonal relationships is more difficult. It can be argued that the active approach of leaders to the problems of other colleagues is one of the signs of a mature organizational culture. Such an organizational culture should influence employee loyalty. It should be noted here that the reasons for loyalty are different and the necessary correlation may not exist even with a strong organizational culture and an ethically competent employee.

"A safe corporate climate means not only the absence of conflict, cynicism, frustration or slander, which are a suitable environment for mobbing, but also an environment in which individual employees can work well, be positively motivated and enjoy the work done" (Jašková 2013).

Basically, there are several types of organizational culture. The socio-psychological model is one way of dividing organizational culture. From this point of view, the following types can be distinguished: the humanistic culture is significantly relaxed, prefers informal relationships, the rules are more relaxed. This organizational culture is common in the art world. Mother culture, on the other hand, is largely formal. Work in it is strictly standardized and formalized. Everyone has a fairly clear work schedule. This type of organizational culture is characterized by formal relationships. It is associated with stability and confidence. It usually exists in organizations of state or strategic origin. The mother culture pays attention to the quality of work. The company's goal is to use experience and competencies in the work process. Relationships are more formal. The environment typical of such an organizational culture is the research environment. An authoritarian organizational culture is the concentration of power in the top boss. Such an organization is distinguished by high discipline and order. Disciplined workers with no side interests tend to be recognized. Mostly this type of culture exists in small organizations. Within the framework of the presented typology, we see the best opportunity for the development of chairmanship in a humanistic organizational culture. It is the most benevolent and has the fewest elements that contain some control. By far, the least chance of charing is given by an authoritarian culture, followed by a highly formalized maternal culture. From our point of view, even in the stepmother culture there is not much room for the opportunity to preside. In these types of organizational cultures, there is relatively little chance of engaging in unethical activities because the control mechanisms are relatively more powerful.

A strong organizational culture contains most of the control mechanisms that can influence ethical behavior in an organization. It has a positive effect on the leadership of the employees of the organization. The mechanisms of organizational culture have an obvious influence on ethical behavior in the organization. Failure to recognize the power of corporate culture in an organization will undoubtedly lead to the death of the business. Ethical management is an extremely important component in a company. "The power of organizational culture lies precisely in the fact that subordinates follow the behavior

of their leaders; if managers behave unethically, their subordinates copy this behavior and do not attach much importance to ethics in the workplace" (Remišová, Lašáková 2013). In essence, authors Trevino, Brown, and Hartman began to theorize about the moral leadership of humans (Trevino et al. 2003). The mentioned authors rely on two concepts: a moral person and a moral manager. According to Remišová and Lašáková, a moral manager is someone who rewards ethical behavior and punishes ethics violations in the workplace. A moral person is a person with good ethical qualities, with good ethical decision making and good ethical behavior. As part of the ethical management of people, a moral manager, among other things, is obliged to observe certain value orientations, such, first of all, as "orientation towards justice (making fair and consistent decisions and non-discrimination of others) ... orientation towards moderation (i.e. self-reflection, balance, self-control, avoidance of emotional stress, humility, deviation from personal desires in favor of the needs of other stakeholders)" (Remišová, Lašáková 2013). As mentioned authors recall, only a leader with ethical moral qualities can lead people ethically. These qualities should be manifested through the constant performance of ethically positive actions. The concept of ethical people management, implemented in the organizational structure of the company, can definitely be considered as one of the tools that will help eliminate the occurrence of the chairmanship in the company.

Combining a strong and powerful organizational culture with ethical people management is indeed a powerful chairing prevention tool, but it is certainly not enough without the use of other means. It is necessary to use means of control so that this phenomenon does not occur, or is already nipped in the bud. Various information should be verified, with transparency being the main principle. Anonymous information cannot be understood as information; on the contrary, it is necessary to look for its originator and apply sanctions to him. Transparency is absolutely essential. In the mentioned context, it is necessary to document every information provided during the selection process. With regard to documents on stay in foreign institutions or events, we suggest that the submitted confirmations be supplemented with photographs, as this may be a fake or fictitiously obtained confirmation.

As part of the verification, it is not only about verifying the reliability of information. The person who should strive to coordinate the ethical management of the company should be independent. "Practice shows that the independence of the entity responsible for managing ethics in an organization can, as a rule, be achieved only if its activities report directly to the top manager or the board of directors of the organization" (Remišová et al. 2021). Control in the sense of ethics means, according to Remišová, the conduct of ethics through an ethical program. Management processes have the task of moving the ethical level of the organization in such a way as to eliminate ethical inconsistencies. The goal is also to identify ethical issues in the organization. Remišová perceives her own ethical program as a complex and systematized structure. It functions in the life of the organization as an active structure. An ethical program must be created by several people, then it must be more effective. The ethics program cannot be reduced to just a code of

ethics. However, it is a key element of the ethics program. Within the ethical program, one of its three main components is the ethical infrastructure. It consists of ethical institutions in the organization, ethical advisory line, ethical education and, finally, forms of control. Activities and services also include whistleblower protection.

It's great if the ethics committee is part of the program. It acts as an advisory body for the management of the company. Control means own control and monitoring systems that evaluate how the ethics program works. In addition, it is necessary to master the system of protection of those who report unethical actions and circumstances. The basis of control is the identification of ethical deficiencies, especially in management. Such ethics "is therefore focused not only on quantitative indicators in the management of ethics, but mainly on qualitative ones, i.e. J. about what ethical issues the company and its employees are concerned about, what unethical actions occur in the organization and what are their causes, as well as the quality of ethical communication or ethical education" (Remišová et al. 2021).

Self-monitoring of employees' ethical behavior can be critical to preventing presiding behavior. The fact is that the activity of the employee is controlled. This monitoring must be preceded by the consent of the workers, who will state that they are aware of this type of control. Remišová and others introduce innovations in this area. They are "ex. the use of mystery shopping techniques and so-called research interviews with employees" (Remišová et al. 2021). The mentioned authors argue that it is not enough to have only one hotline for a company, but it is good to have a parallel system for receiving information from both internal and external environments. In this case, whistleblowing should be complemented by outsourcing. External hotlines will not be used to create a domino effect, namely to reveal the identity of the whistleblower and relay this information to the person directly affected by the notification. Remišová and others point out the possibility of undesirable influence on the further fate of the informer within the organization in this case. It is good if the technical side of ethical lines is handled by an external organization.

Ethical behavior in a company can be assessed both positively and negatively. This is where the connection between organizational management and ethical management can come into play. The values of labor productivity and their measurement have already been extrapolated by the selected companies into the ethical area. A slightly different way is the implementation of the ethical area in the general spectrum of activity reflection. One might ask if this is a confirmation of Drucker's belief that regular performance quantification is a source of performance improvement. Poor results can be punished, at least by a reprimand to a superior employee. It is important to praise good results and reward them. Sociometry is used to assess the behavior of employees in the face of interpersonal ethical conflict. This should mean part of setting up the system so that people behave ethically.

In large enterprises there is no possibility of direct personal control on an individual basis. Therefore, the individual approach should be replaced by a systematic approach. The system must have its own ethical rules. "In case of violation of the rules, the company

must consistently punish unethical behavior and then show that the undesirable behavior was punished" (Remišová et al. 2021). In this case, it is good if decision-making and control powers are separated within the organization. Remišová et al., they draw attention to the systematic short-term replacement of vacancies, which may carry the risk of various ethically incorrect behavior. There is simply a system that defines the principle of short-term personality in such a risky function.

We have already mentioned the code of ethics, which is a kind of skeleton of ethical business conduct. Recall that this may not always be ethically significant. We will deal with the issue of chairmanship in a separate chapter. In addition to a code of ethics, an excellent ethical tool is for employees to discuss ethical issues. If a half hour of the meeting is devoted to this, it is enough to discuss any ethically questionable issues (Remišová et al. 2021). At the same time, this half hour can also be used for the possible statement of employees or members of management about the appearance of ethically unacceptable behavior, which is a contribution to control.

Our authors draw attention to an institution called the Ethics Ambassador. Certain employees of the company have a task in the company to promote ethical principles and ethics in general. Basically, these are people with strong moral authority. Hierarchically, these may be ordinary employees, but they, as a rule, are called upon to resolve ethical issues in terms of the need to resolve them.

Checking and auditing the ethical behavior of employees is certainly an important tool to prevent chairmanship. We believe that a very good contribution to the prevention of the aforementioned ethical malaise is several factors in controlling the ethical performance of the manager's function, which are associated with sanctions to the extent that a more serious ethical error would lead to the removal of the manager from office. If a particular function were to depend on many factors, while it would be difficult for a manager to influence the aforementioned factors other than through professional activities and ethical approach, for individuals with various less ethical secondary interests, this would mean a significant loss in the profitability of a leadership position. We believe that one of the reasons why a person could be relieved of a leadership position would be proven bosses. In the event of a combination of bosses and chairmanship, which would take particularly significant forms, such as threats, unjustified withdrawal of a variable part of the salary, or even unjustified dismissal, the leader who combined bosses and chairmanship should not only be relieved of his position, but also dismissed from organizations without the possibility of appealing this decision.

Another important factor that may affect the above warning is disqualification from the competition in justified cases. If there is a causal relationship with unethical ethical behavior related to the selection procedure itself or its preparation, intimidation of persons entitled to participate in it, intimidation of candidates, direct exclusion from the competition should follow. We believe that this measure will directly contribute to the elimination of this type of behavior and, at the same time, the elimination, in some cases, of candidates in respect of whom it would be reasonable to assume that they would continue this or that

activity that is contrary to ethical principles. We should also not forget about the possible elimination of conflicts of interest during the selection procedure.

In the end, we offer several ways to prevent behavior that we might call chairing. First of all, it is a strong organizational culture combined with ethical personnel management. Due to the strong organizational culture, controls are a focal component of pre-chairing prevention. These are system control, which includes verification of information, the ability to report an ethically undesirable action so that the identity of the whistleblower remains secret, an ethics commission, systems for monitoring and monitoring the ethics program. We believe that an important element of such control is the presence of several factors that can effectively decide on the dismissal of an executive based on proven unethical behavior. If there are multiple options for effectively dismissing an executive in a justified case, possibly excluding a person with ethically negative behavior from the selection process, we see this as an opportunity to successfully prevent the chairmanship. In the most severe cases, we offer complete dismissal from the organization as a sanction.

Conclusions

Chairing in organizations is one of the current and relatively frequent ethical problems. Unethical methods of leadership struggle are not rare. In our article, we said goodbye to give part of the calculation of the frequent with pediological models, home-building bells, typical of the chairing. An important barrier that will help detect and eliminate such behavior is the organizational culture. A strong organizational culture of the company can effectively and promptly eliminate such behavior. A strong organizational culture contains control mechanisms that can influence compliance with ethical behavior in the organization. A strong organizational culture should be linked to ethical people management. In particular, effective control through ethical infrastructure is necessary – information verification, ethical management program with control from the ethics committee, control over compliance with the ethical code, ethical and consultation lines. Don't forget about whistleblower protection. Control of ethical behavior can lead to disqualification of participants who clearly show signs of using unethical means to obtain a leadership position.

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