

Mining sustainability and circular economy in the context of economic security in Ukraine

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Abstract

Purpose. The paper is devoted to the theoretical and methodological solution of the scientific problem of substantiating the relationship between the sustainability of mining and the implementation of the circular economy model in the context of the economic security of the state, with an emphasis on the importance of mineral resources. In addition, scientific and practical recommendations have been developed for regulating the circular economy in Ukraine in the context of ensuring economic security.

Methods. The paper focuses on various experts and scientists' positions regarding environmental challenges, circular economy, mineral resource management, and economic security. Using the proposed approach of contour analysis of the relationship between the circular economy and the system-forming components of the economic security of the state, the place and role of the circular economy in the system of economic security have been determined.

Findings. The research presents the results of a circular economy with the emphasis on mineral resources in the context of the economic security of the state. It has been determined that the circular economy concept combines the peculiarities of various system-forming economic security components (environmental, industrial, energy, mineral resource, social, food). It has been revealed that a circular economy is associated with various scientific trends of the ecological and economic system formation.

Originality. The duality of the connection between the implementation of the circular economy model and the components of economic security has been proved, which opens up opportunities for strengthening economic security both through positive effects and certain short-term negative effects.

Practical implications. A comprehensive analysis of using mineral resources in the circular economy in the context of the economic security of the state allows forming a number of scientific and practical recommendations for the sustainable management of economic security in Ukraine. This makes it possible to create a multi-level system for managing the circular economy in Ukraine, taking into consideration mineral resources.

Keywords: circular economy, economic security, resource efficiency, mineral resources, mining, waste recycling

1. Introduction

The topic of ecology has become acute in diverse scientific and analytical research. Nature has evolved to provide people with energy and resources according to the needs of the environment. However, human intervention has disturbed this balance. Over the past decades, the demand for resources in the world has increased sharply due to rapid industrialization and population growth. The population is expected to increase to 10 billion people in 2060, with a large income growth, and accordingly, in demand. According to OECD estimates, if current trends continue, global use of natural resources will increase from 79 billion tons in 2011 to 167 billion tons by 2060 [1]. The world is consuming natural resources twice as fast as they can be replenished. Moreover, their extraction and further consumption have a great impact on the environment (especially CO₂ emissions) and energy use. For instance, the energy used to produce food that will spoil in the future is approximately 10% of the world's total

energy consumption [2]. At the same time, the irrational use of natural resources can lead to their depletion, as well as to excessive mining, environmental pollution, and ecological imbalance. So now the challenge is to find ways to restore the balance, and among the possible ways are recycling of materials and the concept of remanufacturing.

The transition from the traditional "linear" model of economic growth is becoming a new global trend worldwide. With the gradual transition to a circular economy, the basic principle – "take, make, waste" – is transformed into the principle of "take, make, reuse", thereby increasing environmental efficiency by preventing the depletion of significant amounts of resources during underground disposal. The circular economy creates closed technological cycles with the full use of raw materials without waste generation and allows for harmonious coordination of sustainable development, accelerating economic growth, strengthening social stability and ecological balance.

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According to The Circularity Gap, only 8.6% of materials in the world are reused. However, many businesses have already joined the transformation of the economic model [3]. For instance, about 50% of companies from the top 100 on Fortune Global have chosen a circular economy strategy. The leaders in this area are the wholesale and retail sector, the automotive industry, while the oil industry, healthcare do not yet have a wide practice in a closed technological cycle.

The circular economy is one of the directions of the green economy, offering modern approaches to resource efficiency through producer responsibility, as well as reducing the ecological footprint of production. This type of economy underpins the implementation of the green economy and offers an effective business model to ensure the efficient use of resources, contributing to the achievement of the Sustainable Development Goals (SDG). The transition of a circular economy is possible through the development and implementation of legislation that helps to prevent waste generation, to use in the production of components and materials suitable for reuse, and to ensure deeper and better recycling of waste.

The main principle of the circular economy is to decouple, on the one hand, the consumption of natural resources and raw materials with the generation of waste and pollution, and, on the other hand, the production of final products and services [4]. Firstly, a circular economy aims to optimize and reuse products. Secondly, it introduces a differentiation between the use and durability of the product. The priority of a circular economy is the lower resources consumption, as well as their lower return to the environment in the form of waste. At the same time, insufficient attention is paid to the circular component of the green economy, both from the state and from business. This predetermines the relevance of this research.

Along with the long-term benefits of the circular economy, there are a number of limitations to the implementation of the concept [5]-[7]: the lack of a unified global approach, unanimous for all countries and businesses, leads to a big “contrast” in this area; the lack of correct measurement of the circular economy; the inertia of the technological base; the unprofitability of the circular economy in the short term; lack of necessary infrastructure, knowledge and skills in the sphere of the circular economy; lack of adequate funding at the national and local levels.

A large number of scientific studies on existing barriers confirm the complexity, multi-level, and multi-dimensionality of this process and require different actions at the national, regional and local levels, depending on the nature of the barrier.

2. Literature review

2.1. Circular economy concept: Emergence and evolution

Awareness of the ecological crisis severity poses before most countries the necessity of a detailed doctrinal research. For the first time, the development of products' efficient use and recycling was identified as a promising direction for economic development in the Report of the Rome Club “The Limits to Growth” [8]. This research contains an analysis of the possible advancement of civilization in view of the potential growth, the scale of natural resource use, environmental problems, etc.

A little later, experts from the European Commission [9] noted that the circular economy, unlike the production of new goods, allows creating new jobs and reducing resource consumption, greenhouse gas (GHG) emissions and waste.

From the point of view of a combination of theoretical and business-applied aspects, the circular economy is defined as “an economy that is regenerative and circular in nature, involving the creation of a continuous cycle of development that preserves natural capital and increases its value, enhancing the return on resources by optimizing their use” [10]. At the same time, there are several concepts in the scientific literature that interpret the circular economy. Their systematization made it possible to identify fundamental approaches:

1. Resource-oriented [11]-[14] – can be achieved through reuse, repair or refurbishment at the product level; at the component level – through reuse in production; and at the material level – through recycling.

2. Economically oriented [15]-[17] – is based on the materials reuse and the natural resource conservation. At the enterprise, it becomes possible to use not only primary, but also secondary material resources, while it becomes possible to choose resources at each stage of the production cycle, depending on the existing technology [18].

Currently, the definition of “circular economy” is becoming more and more popular in theory, and the principles of such an economy are being successfully implemented in practice in many countries. Its significance is often associated with sustainable development, which has become a paradigm for human development in the 21st century. The circular economy model today is contrasted with the “linear” economy, with its negative environmental impacts, large volumes of waste and pollution. To a certain extent, the circular economy is considered the next stage of the waste-free and low-waste economy.

D. Pearce and R. Turner were the first to introduce the definition of “circular economy” into scientific circulation in 1990 [19]. Among recent studies, it is important to note the works of D. D'Amato [20], J. Kirchherr [21], D. Korhonen [22], S. Ritzén [23], A. Heshmati [24]. General aspects of the circular economy are studied by many foreign scientists: N. Millar, T. Berger, D. Karrez, M. Geisdorfer, N. Boken, P. Savage, V. Haas, H. Nguyen, E. McLaughlin, F. Krausman, and others. S. Ingebrigsten and O. Jakobsen have made a significant contribution to the development of theoretical and methodological framework for the formation of the circular economy. Experts from international organizations, such as IMF, OECD, ILO, FAO, focus on the impact of the circular economy on social-economic and ecological development.

A. Lazebna points out that waste management should consist of:

1) ensuring the gradual and effective implementation of the measures enshrined in the National Waste Management Strategy in Ukraine until 2030;

2) systematizing the legislation in the field of waste management and implementation in practice [25].

By contrast, N. Kordiy and O. Lozo draw attention to the problems of legal regulation of e-waste management. The authors are convinced that only the formal aspect of this issue is taken into account at the legislative level. The consequence of this is abuse in the implementation of practical activities related to sorting, processing, recycling and disposal of waste [26].

At the level of individual countries, programs and roadmaps for the circular economy have been developed. The objectives of the circular economy are reflected in the United States' Strategic Plan for the Environmental Protection Agency's Sustainable Materials Management Program. In France, this concept is reflected in the national law on

“Energy Transition for Green Growth”. China in 2013 adopted an economic program of circular development.

At the regional level, since 2014, the EU countries have been implementing various strategies and policies aimed at a gradual transition to a circular economy. In 2015, the European Commission adopted its first circular economic action plan, developing a system of production process recommendations for 32 economic activities. In order to support businesses, the EU has adopted various economic measures such as a simplified permit system, tax cuts, green public procurement, subsidies for pilot projects, etc. In March 2020, under the European Green Deal, the EU adopted a new circular action plan [27] that will reduce pressure on natural resources and expand sustainable growth, as well as create new jobs.

In turn, the resolution adopted by the European Parliament on the use and consumption of materials by 2030 focuses on the necessity to improve waste management and reduce it [28].

At the international level, the SDGs adopted in 2015 at the UN General Assembly indicate the necessity to replace the outdated traditional production model based on the principles of “get, use, throw away” with a circular economy. It is a process of the materials’ rational use (from production to consumption), when all materials are disposed of or recycled and can be returned to the production cycle.

The circular economy concept at the micro-level implies environmental aspects in the development of production processes (eco-design), organization of cleaner production with low emissions, implementation of waste prevention systems by manufacturers, as well as increasing consumer responsibility through the introduction of eco-labeling systems and green public procurement. At the meso-level, the circular economy includes the development of eco-industrial

parks and agrarian ecological systems, complemented by environmentally friendly design and smart waste management. At the macro-level, its implementation is aimed at creating eco-cities, eco-communities and eco-regions [29].

The conducted analysis allows setting forth a definition: “A circular economy is a system based on the principles of reduction, reuse, recycling and recovery in the production/distribution/consumption of goods/works/services”. From the authors’ point of view, the condition for the circular economy consists of the reorganization of business processes related to the material resource management.

The European Investment Bank indicates the main reasons for the transition to a circular economy [30]:

1. Global demand for resources has been growing very rapidly, resulting in an ever-growing shortage of raw materials and water.

2. New technologies allow implementing new “green” business models.

3. Circular models play an extremely important role in the context of growing urbanization. Urban areas can easily implement and maintain systems that can collect and return different goods, materials, and other resources in a cost-effective manner.

4. Non-recyclable production and consumption of waste occupy large territories, its spraying and erosion lead to environmental pollution and harm the population, agriculture, soil, water resources, etc.

A circular economy can provide sustainability, create additional economic opportunities through effective environmental management, strengthen competitiveness in world markets, and reduce the costs associated with environmental degradation. Below, the authors present the general conclusions regarding the circular economy in the SWOT analysis (Table 1).

Table 1. SWOT analysis of circular economy

Advantages	<ul style="list-style-type: none"> – popularization of the concept at the international level; – promoting stakeholder engagement; – promoting new high-tech technologies; – support environmental standards and implementation of cleaner production; – human resources availability and advanced scientific research results for the promotion of circular economy; – development and production of the green food industry (develop agriculture sector). 	<ul style="list-style-type: none"> – lack of an internationally accepted definition; – unclear and uncertain measurement systems; – “situational” concept, its implementation depends on the individual place/country/region; – lack of understanding of losses for economic entities (for instance, jobs); – lack of venture capital; – lack of project financing and government subsidies; – investment constraints; – lack of necessary private lending. 	Disadvantages
	<ul style="list-style-type: none"> – creation of skilled jobs; – promoting energy independence, as well as food security; – changing the model of economic growth that is based on creating resource-saving and environment-friendly society. 	<ul style="list-style-type: none"> – challenges in consumer and production patterns, as well as lifestyles; – the threat of asymmetric information concerning circular economy; – the threat of resource endowments; – the threat of lagging institutional innovation. 	
Opportunities			Threats

The importance of research is conditioned by the fact that there is still no regulatory consolidation of the circular economy category. Legislation should have a clearer interpretation of the concept, based on recognized international standards and agreements. Countries need clear actions and indicators to monitor gaps on the path to circular economy implementation.

The transition to a circular economy should consolidate the tendency towards increasing people’s well-being and social equality, reducing environmental risks and deficits. And its success must be ensured by the conscious formation of favorable conditions, necessary for each country.

The transformation associated with the transition to a circular economy requires considerable resources and reorgani-

zation of the country’s financial system. The capital itself (both national and foreign) should be directly involved in projects aimed at further developing the capacities of renewable energy resources, recycling household waste, implementing energy-saving measures, spreading “circular” technologies and improving the efficiency of natural resources.

2.2. Importance of mineral resources in implementing the circular economy concept

The sustainability of the national economy is determined by the supply of raw materials, especially mineral resources. Mineral resources serve as a powerful accelerator of social-economic progress. Moreover, they are an important prere-

quisite for the state prosperity. Historically, a high level of economic development in most countries has been achieved through the intensification of mining and processing of mineral resources:

The process of minerals' exploration, extraction, and processing influences on the decrease in the available reserves, increasing the negative impact on the environment. The extraction of mineral resources is an energy- and resource-intensive process, as well as labor-intensive, which has a negative impact on the environment due to the reduction of biodiversity and adverse working conditions.

Habitat destruction or damage and, in some cases, reduction of ecosystems for rare and endangered species.

The impact of technology on the topography of the ocean bottom can change or destroy deep-sea habitats, resulting in loss of species richness, fragmentation or loss of ecosystem structure and function.

Since mining is often associated with significant negative environmental and social impacts, companies need to take control of the ESG contribution and the readiness to move towards a circular economy. Limiting the carbon footprint of mining has the dual benefit – boosting economic growth and reducing environmental risks in resource-rich developing countries. This will also allow moving towards enforcement of commitments under the Paris Agreement and SDGs (No. 7 and 13).

Despite the vast global reserves, competition will be severe as states seek to ensure their energy independence and security. At the same time, the mining industry is under increasing pressure on sustainability requirements. According to the Circularity Gap Report, only 9% of the 92.8 billion tons of minerals [3], fossil fuels, metals and biomass are reused per year. In the context of circular economy, recycling or alternative use can ensure the resource supply sustainability and potentially reduce waste generation, pollution and GHG emissions.

As a result of mining operations, huge amounts of waste and dumps have been generated over the years, which contain valuable raw materials. Due to the exhaustion and depletion of the resource base in a number of deposits, as well as the development of new technologies for the extraction of mineral raw materials, such waste should be considered as a new mineral resource base.

It is legitimate to assume that with the depletion of natural resources, deterioration of conditions and reduce in deposits, interest in the circular economy as a way to efficiently use the available resources of mining industry will grow. The realization of circular principles in the mining industry can occur through the creation of waste-free production in the mining industry.

Recently, in the scientific literature, the term “technogenic deposit” can be seen, which is understood as “the accumulation of mineral raw materials in the form of waste generated as a result of past economic activities, primarily mining enterprises”. Such resources of technogenic raw materials should be considered as an additional source of mineral raw materials in the extraction of minerals. Reportedly, the volume of components accumulated in such deposits over the past decades can be comparable to the amount of components mined annually in ores. In this case, the main efforts will be focused on the integrated use of ore, the involvement of low-grade ores, the reduction of emissions and the optimization of production processes, as well as the reclamation of areas.

Wastes from mining and beneficiation of metal ores, chemical raw materials and metallurgical production have significant potential in the context of extracting the rare-earth metal. Components in the wastes of mining and processing, as well as metallurgical complexes often exceed the content in the ore extracted from the bowels. The most volume type of metallurgical waste is waste slag. The slag storage leads to gradual leaching of copper, nickel and cobalt, which pollute the natural waters around the copper-nickel plant with heavy metals. Processing of one million tons of waste slag per year would provide raw materials for the production of 100 thousand tons of magnesium.

The formation of a market for secondary mineral resources is necessary in order to replace the “Cradle-to-Grave” consumption model, which describes a linear, unidirectional flow of materials in the process of transformation from raw materials to waste, with a new “Cradle-to-Cradle” consumption mode. The latter is focused on the use of industrial systems in which material flows are involved in closed cycle processes.

The use of secondary mineral raw materials ultimately provides:

- firstly, significant savings in material, natural, financial, energy and labor resources due to the involvement of low-grade raw materials, substandard ores, waste in the economic circulation. This eliminates large capital costs for new mining operations or the creation of new quarries, reduces the costs for the formation and maintenance of special dumps, tailings, transport and reclamation work, and also reduces the payment for the natural resource use;

- secondly, environmental protection and solving environmental problems (sharp reduction in GHG emissions and mass production waste) through the efficient use of secondary mineral raw materials both in the reverse technological cycle and in related sectors of the national economy (in construction, land reclamation in agriculture, etc.). This can be done through effective design and administrative decisions that eliminate the negative impact on the environment.

As part of environmental sustainability, mining enterprises during the minerals' extraction and processing should focus on reducing their carbon footprint, protecting the environment and supporting the local community. To sum up, sustainable mining should be based on [31]:

- sustainable development of proper mineral resource base (i.e. stimulating the inflow of foreign and national investments into mining industry, implementation of innovative mining and geological surveying technologies) to meet the needs of the national economy in mineral raw materials;

- transparent mining process and production cycle;
- expansion of export supplies of both surplus mineral raw materials, finished minerals and raw material products;
- participation in the development of mineral resource bases of other countries to provide the national economy with strategic raw materials.

The main problem of the circular economy at the mining enterprise is the technological capability and economic feasibility. In addition, despite the fact that the introduction of circular economy principles into the production process can have a positive economic effect by reducing costs, this effect is still not essential (because of huge capital costs).

2.3. The essence of economic security as a scientific category: Research analysis

Along with the importance of the circular economy implementation, one of the priority tasks for most countries in the world is ensuring economic security. Neglecting it can lead to catastrophic consequences: economic downturn, the bankruptcy of national enterprises (including private ones), and subversion of the life support system with further economic sovereignty loss. The essence of economic security as a scientific category at different times is formed under the influence of political, economic, social and other realities. It has been gaining meaning in the process of comprehensive analysis, systematization of factors, adaptation to the social conditions, etc. From a scientific point of view, “economic security” is considered in a narrow and broad sense: a “narrow” interpretation means protecting the economic interests of individuals and certain social groups, while a “broad” one means ensuring stable conditions for economic relations.

Modern understanding of “economic security” is based on the scientific works of both foreign and Ukrainian scientists. A significant contribution to the study of theoretical and practical aspects of this economic category, classification of threats and mechanisms for their prevention has been made in scientific research of B. Buzan [32], M. Tsereteli [33]; C. Murdoch, K. Knorr, F. Trager [34], Y. Zhalilo [35], S. Pirozhkov [36]. According to them, economic security generates innovative shifts in the economy to ensure sustainable economic development, as well as resists economic threats and destabilizing factors, and also contributes to ensuring the competitiveness of the national economy.

B. Buson connects economic security with access to resources (financial, human, natural) necessary to maintain an acceptable level of the state wealth [32]. M. Tsereteli [33]; C. Murdoch, K. Knorr, F. Trager [34] apply a similar approach and note that the concept of economic security is closely related to the security of a country’s access to economic resources (human capital, money, energy resources, technologies), as well as to support of a living standard and its further improvement. One of the biggest threats, according to the definition of economic security, is the lack of necessary resources – the mismatch of the critical level of food, production, financial, investment, innovation and other sources of material existence with the needs of individuals and the state. This can not only cause negative consequences (for example, the collapse of production processes, social tensions, impoverishment, strikes), but also jeopardize the normal functioning of the state.

Today, there is no unified approach to understanding the category of “economic security” in the scientific literature that acquires a new comprehensive interpretation and substantiation through social-economic and political processes affected by globalization and regionalization, digitalization, and sustainable development. Taking into account the scientific substantiations of scientists in the field of economic security, the authors propose the following definition: “Economic security is a set of conditions for the functioning of the economy, which ensures the protection of national economic interests from external and internal threats in the short and long term and is provided with the necessary resources, as well as competitive positioning in international markets”.

The lack of resources leads to the fragmented management of the country’s economy, weakening the influence on production, as well as social, demographic and other areas. Resource

supply as a factor of economic security determines the stability of the economy due to the presence of a stable supply of resources in spite of their depletion and uneven distribution. One of the biggest threats to economic security is the lack of necessary resources, including mineral resources. This, most likely, can have not only negative consequences, but also jeopardize the functioning of the state. One of the main economic security factors is resource provision. Therefore, a substantiated model of sustainable mining of minerals and resource supply, as well as the mining industry management in conditions of economic security, are extremely urgent tasks of the state.

3. Methodology

Despite the important scientific expertise in the field of circular economy and economic security, the circular economy impact on the economic security of the state (through its components), based on a holistic, systematic and thorough analysis, remains unexplored. This confirms the importance of scientific task – action-research understanding of the circular economy influence on economic security, the development of methodological and practical recommendations for strengthening economic security through creating conditions for the circular economy development.

Despite the existing scientific achievements in the field of the circular economy and its impact on a country’s ecological and economic situation, the role and place of the circular economy in the economic security system lack integrity, systematics, and thorough analysis that would reflect multifacetedness (through analysis of economic security components). In order to achieve the goal set by this scientific research, it is necessary to answer the question: through what channels and in what way the transition to a circular economy can affect economic security. The answer to this question can be the basis for further policymaking. Thus, the authors conduct a contour analysis of the structural and functional relationships of the circular economy and individual components of economic security.

With respect to the structural components of economic security, some authors distinguish external economic and internal economic security. Another subdivision in one of the research focuses on raw materials, energy, as well as financial, military-economic, informational, technological, food, social, demographic and environmental components of internal economic security [37]. Also, according to researchers [38], [39], the main structural components of the economic security are energy, financial, social, innovation-technological, food, as well as foreign economic, demographic and environmental components.

A detailed analysis of the circular economy in the system of economic security makes it possible not only to substantiate the effects, but also to formulate in detail the necessary steps for its transition. In order to conduct this study, the authors identify the following economic security components: environmental, industrial, mineral resources, technological, energy, foreign economic, food, social, demographic (Fig. 1).

4. The linkages between the circular economy and the system-forming components of economic security

Environmental security. The global environmental challenges, including the consequences of climate change and inevitably affecting the life and health of people, have become a tangible threat to the well-being of the population and sustainable development. One of such environmental challenges is increasing waste generation with a low level of its recycling.

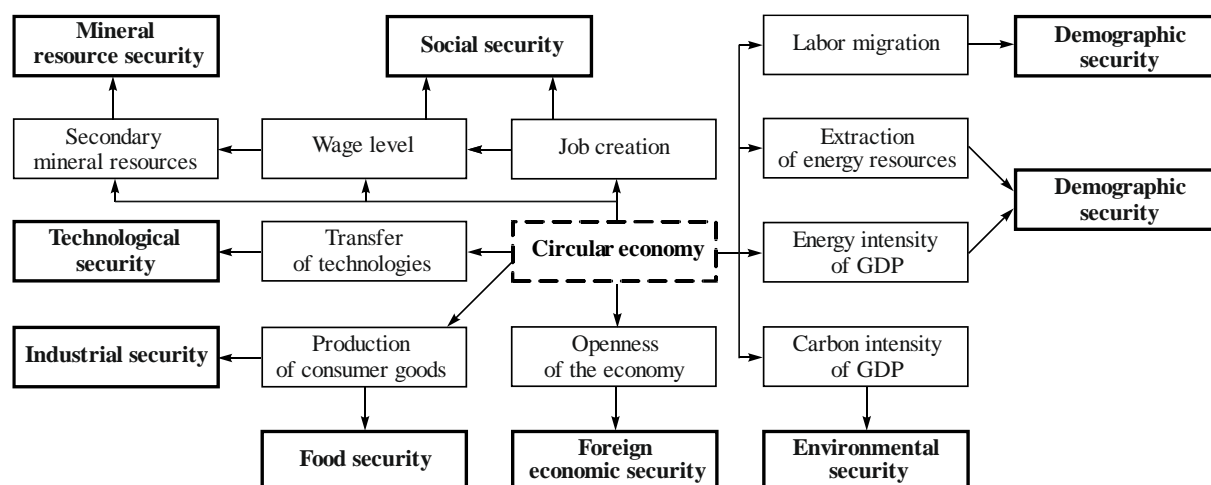


Figure 1. Linkages between the circular economy and the components of economic security

The scientific and theoretical basis of environmental security has objectively changed in connection with new threats in the environmental area. It should be noted that the threat to the environment may not be felt immediately, but the risks can accumulate and lead to environmental disasters, the consequences of which will require money and time.

Through the following channels, the circular economy can influence the environmental security: (1) implementation of “clean” technologies – more efficient and less polluting; (2) implementation of recycling technologies; (3) CO₂ emission reductions; (4) reduction in the area of landfills and waste burial sites; (5) reducing consumption of scarce and limited resources; (6) decrease of environmental taxes (Fig. 2).

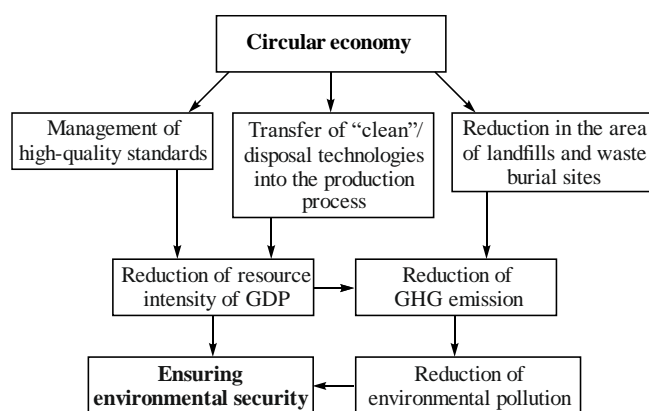


Figure 2. Circular economy influence on environmental security

As mentioned above, the circular economy is also characterized by regeneration, which minimizes resource costs, as well as waste, pollutant emissions and energy losses. It is worth noting that the manufacturing sector produces about 45% of all emissions that cause climate change. The circular economy reduces waste, for example in the production of steel, aluminium, plastic and cement, which account for 60% of industrial emissions worldwide [40]. For instance, increasing plastic recycling helps to reduce dependence on imported fossil fuels and reduce CO₂ emissions in line with commitments under the Paris Agreement.

Here it is important to raise the issue of electronic waste (e-waste) disposal, which is one of the most acute problems, since greenhouse gas emissions from the production, operation and disposal of digital devices and infrastructure can amount up to 3% of global emissions. At the same time, the circular economy can have a negative impact on environmental security.

Firstly, it is possible to increase the toxicity of waste with a decrease in its volume due to the deepening of processing. Secondly, the areas for storing secondary material resources at enterprises in the production process will be increased.

Industrial security. With the introduction of the circular economy principles, new methods of organizing business processes appear – import of technologies, informal institutions in the field of organization, etc. The circular economy qualitatively changes the production system and directly affects the production process: increasing the degree of product processing and quality, the emergence of high value-added products and the development of related industries. Circular economic growth is no longer achieved through production, but through long-term preservation [40]. The economic model reduces the economic importance of resource extraction and optimizes waste management, as well as reduces the environmental damage through the reuse and resale of goods, thereby extending the life of goods, recycling waste and downgrading the secondary resources. Consequently, the transition to “circularity” plays an important role in the transformation of industries.

This can create significant resource savings within production processes, expansion of value-added and economic opportunities for industrial enterprises. Industrial security can be achieved through the industrial complex development. In addition, the contribution of the circular economy is significant (Fig. 3). The impact is manifested in (1) creation of the material base accumulation (in the form of capital investment and reinvestment of profits in equipment and production technologies); (2) organization of production of previously imported products; (3) gradual increase in labor productivity and the production share of scientifically and technologically capacious products; (4) decrease in demand for primary material resources; (5) stable demand for secondary material resources; (6) cost reduction for warehouses and land for waste storage. The circular economy creates many economic opportunities and minimizes all types of waste, converting it into a new resource or raw materials that can be used for other purposes. For instance, waste can be used in industry as a secondary raw material, since waste is a significant resource for the end-use product residuals. The high level of waste generation and the low level of its use as secondary raw materials lead to the formation of significant volumes of solid waste in industry. Only a small part of it is used as secondary material resources, most of it goes to landfills.

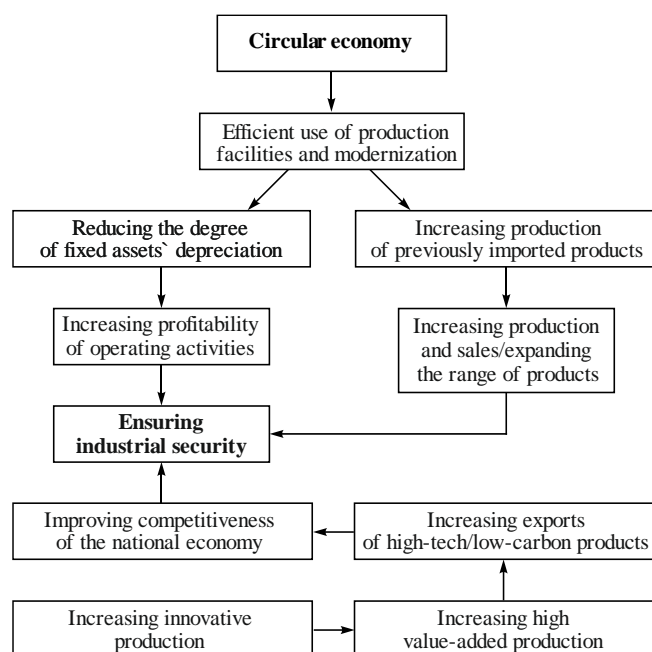


Figure 3. Circular economy influence on industrial security

Technological security. Ensuring technological security for any country in the civilized world is extremely topical and is possible through the introduction of new technologies and innovations, increasing the level of scientific and technical potential, rational use of technological and intellectual resources, active participation in international scientific and technological progress, which guarantees the country's ability to apply the newest technological solutions in national production. Assessing the potential effect of the circular economy on technological security, the authors take the view of the necessity of changing the technological structure and the importance of technology transfer (Fig. 4).

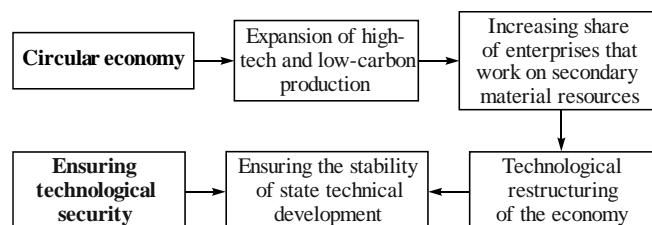


Figure 4. Circular economy influence on technological security

The latter is the transfer of systematic knowledge of production with a subsequent introduction into the manufacturing process. By implementing technological solutions, companies increase the competitiveness of manufactured goods and services in the international market, and thus – the share of high-tech exports. A circular economy can facilitate a country's transition from less efficient and highly polluting phase of development to "clean" and resource-efficient one.

Foreign economic security. For a country that decided to integrate into the world economy, it is extremely important to support foreign economic security, which is focused on minimization of state losses from the effects of negative external economic factors on the one hand, and creation of favorable conditions for economic development through its active participation in the global division of labor on the other hand. In most cases, the level of openness of the economy is important, which is a positive scenario that should be accompanied by the excess of export growth over

import growth. In this context, the activities of enterprises that focus on recycling contributes to (Fig. 5): (1) achieving a surplus of foreign trade; (2) expanding the range of goods and services; (3) diversifying the export geographical structure, entering new markets, previously not available to domestic producers due to the relatively low level of competitiveness of products; (4) ensuring the competitiveness of products in foreign markets that allow receiving a profit and the opportunity to reinvest it.

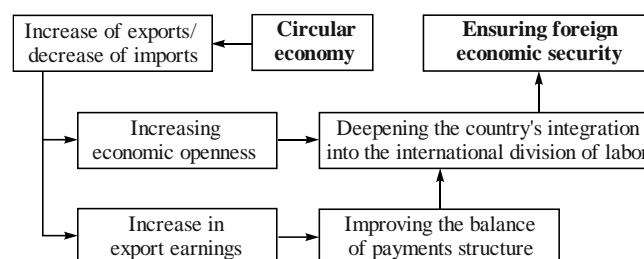


Figure 5. Circular economy influence on foreign economic security

The transition to a circular economy can eliminate the risk of a lack of resources. In the circular model, the materials and waste that are used again become raw materials. This solves the problem of natural resource shortage, high prices for raw materials, and reduces dependence on imports. This model of economy can eliminate the threat – a significant country's dependence on market condition.

Food security. Ensuring food security, which is indirectly linked to industrial security, is achieved by maintaining food production and ensuring the population with high-quality and affordable food products. Food industry enterprises in the circular economy are guided by the need to comply with established regulatory requirements and technical regulations, as they may fall under the penalties (heavy fines). Investing in processing with the subsequent production of environmentally friendly products is an additional competitive advantage. In general, the circular economy's influence on this component of economic security is positive (Fig. 6).

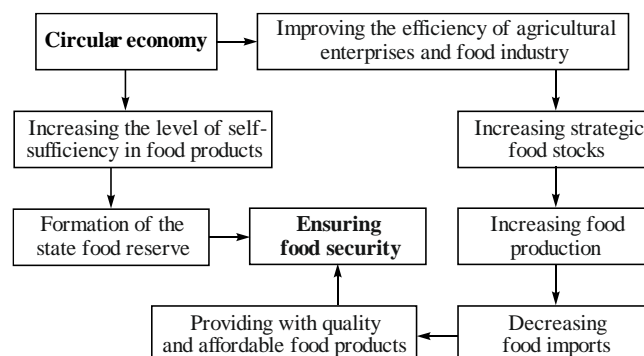


Figure 6. Circular economy influence on food security

The circular economy contributes to the formation of innovative solutions for inclusive and sustainable development, helping to tackle the global food waste problem by shortening food value chains and making them more efficient in terms of resource use. Currently, more than 30% of all food produced is spoiled or wasted, which not only harms food security, but also increases the pressure on natural resources. According to FAO, food waste accounts for 8% of GHG emissions or generates up to 4.4 Gt CO₂ eq annually [41]. J. Poore and T. Nemecek concluded that almost a quarter – 24% of food emission is caused by losses in the supply chain (because of

poor storage, lack of refrigeration, spoilage during transportation) and food waste generated by retailers/consumers [42].

Energy security. Along with ensuring the above components, it is extremely important to maintain energy security, because the availability of energy resources determines the functioning of the economy. Since energy security is aimed at the efficient use of resources, the circular economy, due to the peculiarities of production and consumption of energy resources, can help achieve this goal. By contrast, the energy sector can make a significant contribution to the circular economy by incorporating its principles into the development and production of energy assets such as wind turbines, photovoltaic panels and electric vehicles. By moving towards a circular economy, it is possible to avoid an energy crisis and thus increase the level of energy security based on environmental sustainability (Fig. 7). In particular, the situation can be improved by: (1) introducing the latest technologies and increasing the efficiency of energy production from biomass; (2) developing the RES (Renewable Energy Source), which will have a positive impact on reducing the energy component in the cost of final products of the metallurgical, chemical and machine-building industries.

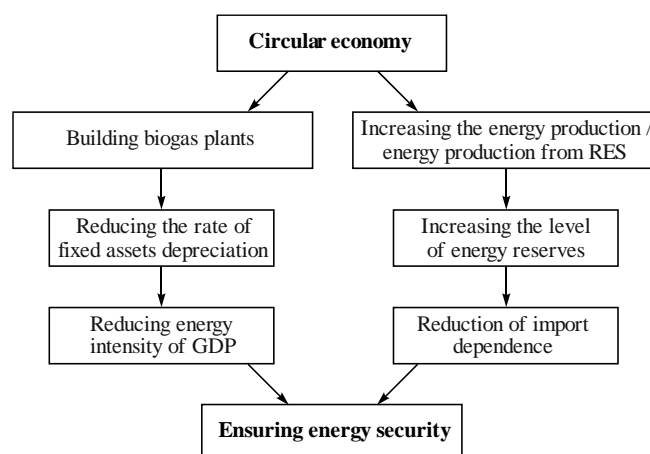


Figure 7. Circular economy influence on energy security

It should be noted that the energy production from RES and green technology depends on individual mineral resources, which are an integral part involved in electricity generation. These materials include indium, which is used as the solar cell electrode. Energy accumulation and storage are carried out using graphite, cobalt, lithium (lithium-ion batteries) and vanadium (vanadium flow batteries). In percentage, the demand for individual minerals used in energy storage technologies (for instance, by 2050 more than three billion tons of minerals such as lithium, graphite and cobalt will be needed) will be 500% of the current volume. Consequently, low-carbon technologies, including RES grids, require more mineral resources than traditional fossil fuel systems.

It should be noted that the attention of the world community has recently been riveted to the cost of renewable energy technologies, and to a lesser extent, on the supply chain that makes these technologies possible. The first link in this chain is the extraction of metals, minerals and inorganic substances. Thus, an increase in the number of offshore wind farms can stimulate the demand for neodymium and dysprosium (used in the production of magnets for turbines). The use of hydrogen for energy transportation (renewable energy storage and transmission) will increase the demand for iridium and platinum due to elec-

trolysis. Lithium, graphite and cobalt are primarily used in energy storage technologies, including batteries for electric vehicles.

The wind/solar energy sector can reduce the need for metals and minerals by introducing “circular” solutions (reuse and recycle) into the production process. In the energy sector, it will be possible to reuse components and materials at the end of one cycle of technical use. For example, first-generation solar cells are nearing the end of their lifespan (approximately 25 years) and these batteries can provide a large amount of valuable materials such as silicon, silver, glass and aluminum. The mobilization of circular methods in the production and consumption of energy resources can contribute to achieving resource efficiency. 40% of organic waste in the process of aerobic and anaerobic decomposition in landfills emits biogas, from which it is possible to produce electricity and heat. This is a very profitable and environmentally friendly way to generate electricity. In carbon energy, direct combustion of solid, liquid and gaseous fuels is associated with a high level of harmful emissions into the atmosphere. This makes the search for and development of technologies, production and combustion of less expensive and safer fuels relevant. One of such energy sources is pellet fuel, which is obtained from hard and brown coal, peat, as well as during beneficiation and processing of coal with high humidity. Coal sludge can become a cheap type of fuel in coal processing plants. For instance, currently, there are 196 sludge pits and accumulators in Ukraine, which contain 116 million tons of sludge products, including 51 million tons of off-balance sludge with an ash content of 45-60%. Most of them can be recycled and efficiently used as bulk fuel.

Mineral resource security. The role of mineral resources in creating an optimal standard of living for the population has increased significantly over the past decades. The increase in the world's population, the scientific and technological revolution cause a sharp increase in the consumption of raw materials with the expansion of the list of minerals and metals. This requires a significant increase in the number of exploited mineral deposits. Ensuring the economic security can be carried out by creating a reliable mineral resource base to meet the current and future needs of the national economy. One of the components of economic security is mineral resource security, which is determined by the availability of mineral resources for domestic consumption and ensures independence from external supplies (Fig. 8). Subsequently, ensuring mineral resource security is a set of measures carried out by the state, including the search and exploration of raw materials, as well as rational use of resources both in the process of mining and transportation and in the process of direct use (deep processing, export earnings, etc.).

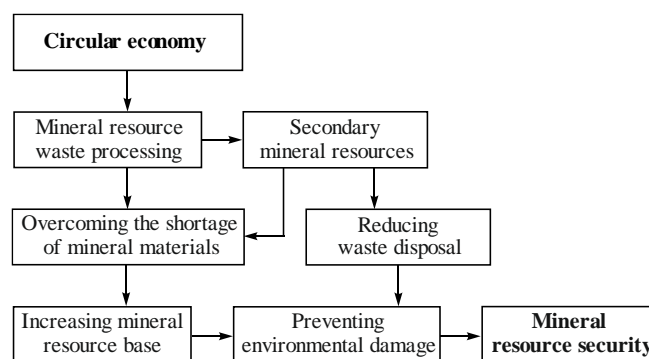


Figure 8. Circular economy influence on mineral resource security

The practical application of the circular model in the context of “resource recovery” can be quite effective in terms of processing waste from the mineral resource complex, which can be considered secondary mineral resources. Their use is favorable both in terms of increasing the economic activity of mining enterprises that consume mineral raw materials and in terms of preserving mineral reserves. Options for moving to a zero-waste system: companies in a number of sectors may try to reduce their consumption of critical mineral resources through alternative clean energy technologies or other products. However, limiting one mineral increases the load on another one.

For example, the use of mining waste can ensure the mineral resource base expansion, overcome the shortage of natural mineral raw materials, save money on waste disposal, reduce investment needs in the development of new deposits, prevent and reduce damage, and also obtain additional social effects. However, not all mining and processing waste can be suitable for industrial development.

Social security. ILO experts [43] equate economic security with the presence of an appropriate level of social security, which “satisfies the minimum human needs for health, security, housing, information and social protection, as well as employment”. Consequently, the long-term inequality of various segments of the population is one of the main factors in the emergence of threats to national security. In order to weaken it, it is necessary to ensure social security, and here the transition to a circular economy will be important (Fig. 9).

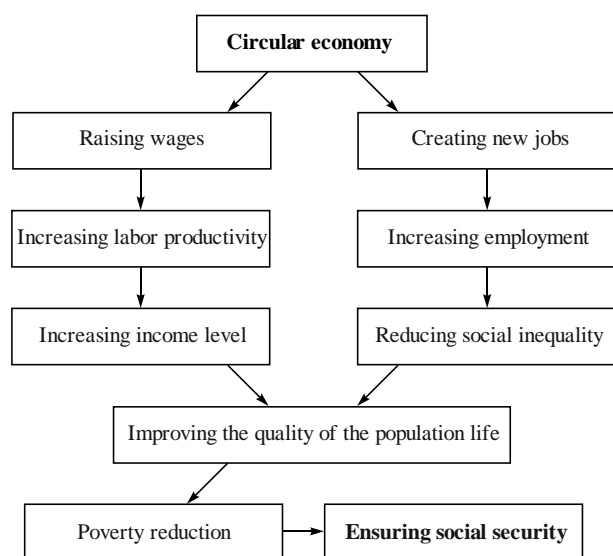


Figure 9. Circular economy influence on social security

The impact can be as follows [44]: (1) through employment in the enterprises; (2) through employment in related industries; (3) through changes in corporate policy regarding social responsibility; (4) through the reduction of unemployment; (5) through growing consumer demand for better and longer-lasting products. It should be noted that enterprises in the circular economy strive for maximum efficiency and improvement of production.

According to ILO estimates, the coronavirus pandemic could lead to more than 24 million jobs losses worldwide. One of the ways out of the situation is to create the same number of new jobs in new industries that will be part of the circular economy and will adhere to “green” principles. It is assumed that the implementation of the Circular Economy

Action Plan could create about 700000 new jobs [45]. At the same time, a reorganization of the company is possible, as a result of which a certain percentage of employees will be reduced. This is a consequence of increasing unemployment. In addition, a negative result in the social dimension in the transition to a circular economy can be the reduction of jobs at enterprises extracting primary raw materials.

Demographic security. Along with social security, the circular economy can somewhat indirectly affect demographic security. It will be accompanied by the further creation of additional production capacity, the transfer of new technologies and managerial skills, and may also affect labor migration. In addition, circular economy enterprises within a city or adjacent areas can lead to increased urbanization, which can deepen the gap in demographic, social and economic development between cities and remote settlements. The positive effect is that problems such as digestion, neurological, respiratory and bone problems can be solved through the implementation of a circular economy [46]. However, this issue requires additional research.

The above-mentioned exposure of the circular economy on economic security indicates interconnectedness: the economic consequences are closely related to innovation, social, environmental and other effects. Effectively implemented principles can help accelerate economic growth, optimize the economic structure and increase product competitiveness. It is proved that circular economy contributes to (1) intensification of innovative economic development; (2) resource and energy savings during production; (3) introduction of progressive quality standards; (4) labor market reform; (5) increase the revenue of the state budget; (6) stimulation of the development of depressed regions; (7) GHG emission reduction; (8) increasing the level of energy production from RES, etc.

5. Implementation of a circular economy in Ukraine. First steps

Ukraine is a state with a large volume of mineral resource consumption and waste generation. The raw material specialization of the Ukrainian economy, together with the outdated technology base, determines the high volumes of waste generation and accumulation. Likewise, the problem of waste generation is acute and significant due to the dominance of resource-intensive and multi-waste technologies in the national economy, as well as the lack of an effective policy for a long time. Such circumstances lead to the deepening of the environmental crisis, the aggravation of the social-economic situation, and necessitate the reform of natural resource use and waste management in general.

Despite the fact that Ukraine is provided with mineral resources, the problem of reserves depletion and their mining remains extremely topical. In this regard, recycling and the transition to the circular economy principles can help to solve this problem in the long term.

For sustainable growth, it is very important to generalize the results achieved in the field of the circular economy, and to formulate directions for increasing the efficiency of using material resources. Figure 10 clearly illustrates the decline in the level of GDP resource intensity, in addition to the increase in waste generation and disposal. Resource intensity indicators reflect the development of higher value-added products, a change in the structure of production towards a decrease in the share of primary sectors, an increase in the share of the service sector, and the intensity of consumption of raw materials.

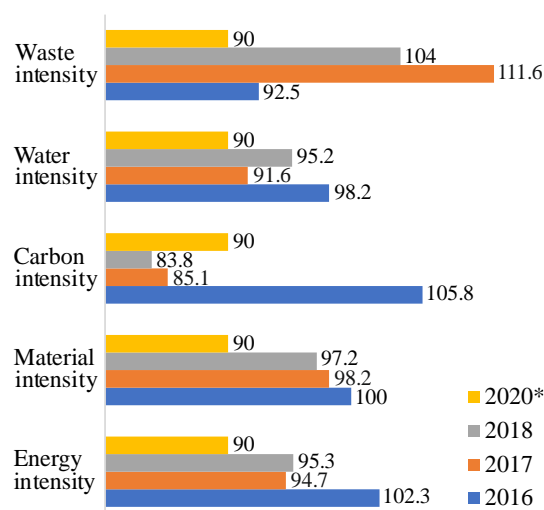


Figure 10. GDP resource intensity, Index, 2015 = 100 [47] (*Target)

Table 1. Waste generation and disposal [47]

Year	2015	2016	2017	2018	2019	2020	2025	2030
Volume of waste generated by all economic activities per unit of GDP, kg per USD 1000 PPP in 2011	977.4	904.2	1089.8	1015	n/a	950	880	800
Share of incinerated and recycled waste in the total waste generated, %	30	29	27.6	29.7	n/a	35	45	55

Achieving a breakthrough is hindered by [48]:

- increase in depreciation of fixed assets (in 2019, the degree of fixed assets depreciation in the processing industry was 51.4%);
- lack of widespread use of energy-efficient technologies and transition to RES;
- the predominance of the primary sector enterprises;
- lack of funding for comprehensive industrial modernization.

More than 10 million tons of household waste was generated in Ukraine in 2019, 94% of which was disposed of in 6000 landfills and dumps [49]. At the same time, as of 2019, separate collection of household waste has been put into operation in 1707 settlements, 35 waste sorting lines, 3 waste incineration plants are in operation. Totally, these plants recycle only 4.1% of household waste, 2% is incinerated. For instance, a biogas production system has been installed at 19 landfills and cogeneration units with a capacity of 26 MWt are in operation.

As in the rest of the world, in Ukraine, the circular economy has become an extremely relevant perspective. In recent years, companies have been gradually adopting business strategies aimed at the most efficient use of resources and “clean” production, implementing the “three R” strategy (Reduce, Recycle, Reuse). In the context of the circular economy, businesses and households actually perform six “actions” [50], [51]:

- 1) regeneration – moving to RES, as well as the return of renewable biological resources to the biosphere;
- 2) sharing – maximization of the product use through reuse (used) or sharing (for example, through a car sharing scheme);
- 3) optimization – increasing productivity and efficiency, reducing waste in the production chain, using automation, remote control, etc.;
- 4) looping – storing raw materials in closed cycles, which minimizes the debris formation;

Resource intensity depends not only on technical efficiency, the physical consumption of material resources, but also on labor cost, living standards and exchange rates.

One of the most acute problems in Ukraine is a large increase in waste generation and consumption, caused by its growth, social and environmental problems. Currently, the volumes of waste generation and consumption in the country are growing rapidly, outstripping the growth rates of production and consumption of natural resources (Table 2).

From the point of view of the circular economy, the tendency of the waste generation intensity at the macro level in relation to GDP seems to be dangerous. Today, the rate of utilization and recycling of waste is low. Consequently, the tendency of “anti-decoupling” at the macro level, when the trends in the consumption of natural resources and the production of pollution outstrip GDP, is questionable.

5) virtualization – providing useful services virtually without generating unnecessary waste;

6) exchange – replacing old non-renewable materials with modern ones and introducing the latest technologies, which should replace less environmentally friendly analogs.

In order to determine the desire of Ukrainian businesses to reorient themselves towards a circular economy, in 2019, a survey of business leaders was conducted within the framework of the Razumkov Center project “Green Investments in Sustainable Development: World Experience and Ukrainian Context”. The survey was conducted from September 12 to October 9 in 2019. According to the survey, investors in Ukraine have a desire to reduce energy consumption in the short and medium term, as well as in the case of modernization, to develop a modern, dynamic and high-tech production sector, which will produce high value-added goods that can be sold on foreign markets. Gradually, Ukrainian business is redirecting cash flows (profits) into “green” investments, maximizing the efficiency of using the raw materials, expanding the use of cleaner materials and modernizing production lines, which will prevent environmental pollution. In addition, 37.5% of respondents indicated the importance of investing in the hazardous waste disposal (including medical waste, plastic products, oil product residues, organic waste, dust and gas emissions, etc.), which are generated and accumulated during production processes [52]. The circular economy encourages private economic agents to innovate. At the same time, it is important to emphasize that in recent years there has been an increase in expenditures for environmental protection (Fig. 11). However, organizational and financial incentives for the use of secondary raw materials remain insufficient.

In accordance with the Association Agreement, Ukraine has assumed obligations to harmonize national legislation, in particular, to implement the provisions of European Directives No. 2008/98/EC “On waste and repealing certain Directives” and 1999/31/EC “On the landfill of waste” into national law.

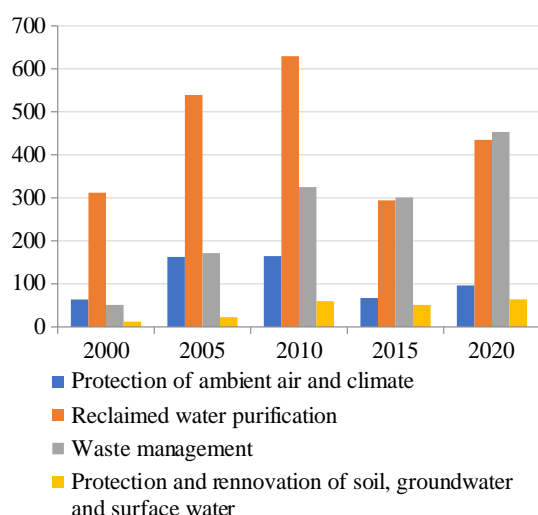


Figure 11. Current expenditures for environmental protection by type of environmental domain protection measures (at current prices), mln USD [53]

Table 2. EU and Ukrainian law on the circular economy

EU Law	Ukraine
Art. 1 of Directive 2008/98/EC contains the concept of a “circular economy”	The legislation of Ukraine does not contain the concept of “circular economy”
Art. 4 of Directive 2008/98/EC establishes the principle of “waste hierarchy”	The legislation of Ukraine does not contain the appropriate category
Art. 9 of Directive 2008/98/EC provides measures to prevent the conversion of food into rubbish	The legislation of Ukraine does not contain measures to prevent the conversion of food into garbage
Directive 2012/19/EU deals with the management of waste batteries and accumulators	The Law of Ukraine “On Waste” does not separate them [batteries and accumulators] into a disparate category of waste
Directive 2012/19/EU provides measures to protect the environment and human health from electrical and electronic equipment waste	Art. 31 of the Law “On Waste” refers to the development and implementation of a system of collection and disposal of electrical and electronic equipment waste, but there are no by-laws on this issue
Directive 2019/904/EC provides the prevention of waste from plastic products	The issue of preventing the generation of waste plastic products is not regulated by special legislation
Directive 2008/98/EC identifies a category of waste such as “bio-waste”	The Law of Ukraine “On Waste” does not contain the concept of “bio-waste”
Directive 2008/98/EC emphasizes the separate collection of both household and construction waste	Law of Ukraine “On Waste” does not contain the question on separate collection of household waste

Its further adoption is extremely important, as the industry will gain new approaches to waste management and will open up considerable economic opportunities. Today, the most adaptable model can be the recovery of raw materials and the recycling of secondary raw materials so that waste is turned into raw materials. Currently, the main problem in Ukraine that halts the transition to the circular economy is the lack of infrastructure for waste management.

The Ecopreneur report as of 2019 offers six main circular economy recommendations, which can be taken into consideration when drafting Ukrainian legislation [55]:

- 1) implementation of green public procurements;
- 2) creation of “circular hubs” for the exchange of information and support on the basis of public-private partnership;
- 3) creation of circular economy strategy, which should set specific goals and indicative deadlines for their achievement;
- 4) improving and expanding the producer responsibility by adding all environmental costs associated with its life cycle to the product market value;
- 5) introduction of VAT differentiation at low tax rates for repair services, resale of goods and some other transactions;
- 6) creating a “green course” for the tax transition from labor to resources.

For a long time, the management of industrial waste was discussed mostly in the context of its disposal, while the reuse of waste was not even mentioned [54]. Although incentives for the circular economy implementation were provided in the Law “On Waste” No. 187/98-VP, they have not been implemented in practice. It is expedient to compare the norms of EU and Ukrainian law in terms of the circular economy regulation (Table 3).

Unfortunately, there is no big breakthrough. In 2017, Ukraine adopted the National Waste Management Strategy, which, in particular, provides for the introduction of the circular economy principles. Currently, the “waste hierarchy” principles are being consolidated in Ukraine. Thus, on July 21, 2020, the Parliament in the first reading adopted the bill “On Waste Management” from June 20, No. 2207-1-d, that offers the appropriate hierarchy. In addition, the draft law provides more than fifty definitions regarding waste, etc.

As of February 2022, it has not yet reached the vote on the second reading.

6. Conclusions

Despite almost 40-year history, the circular economy is an extremely topical issue and an integral part of sustainable development, which remains open to discussion. Its main goal is to preserve the environment and ensure sustainable opportunities for present and future generations. The circular economy is based on rejection of fossil fuels, transition to RES, maximization of resource efficiency in different sectors, getting rid of waste and pollution. The basic definition of the circular economy focuses on the criteria of minimizing the use of raw materials, reducing waste and landfill areas allocated for waste disposal, as well as unorganized landfills. The transformation of waste into a resource is one of the most important directions of the circular economy, and the control of waste generation remains extremely topical.

Many international organizations and countries already have their own circular economy strategies. Its implementation requires transformations in the resource chain used throughout the “product value cycle”, which is possible only with complex changes: technological, economic and organizational. The conducted research has revealed that the economic effect of the circular economy is expressed in a decreased demand for resources. It has been found that, despite

the presence of some negative effects, the benefits from the development of a circular economy are significantly higher.

It has been determined that the reorganization of business processes related to the management of material resources is a prerequisite for the circular economy. This model of the economy allows focusing on the production of durable, maintainable, environmentally friendly products without substances harmful to health and the environment; and for consumers – focusing on the use of goods on a lease basis without the need to buy and, accordingly, dispose of obsolete goods. In addition, eco-design should not be neglected, as it determines the requirements according to which the product should be developed. If initially eco-design meant the energy efficiency of a product, now it includes requirements for maintainability, durability, renewability, and reuse.

Despite the obvious differences, research has determined that economic security and the circular economy are closely related. Meanwhile, economic security acts as an “umbrella”, which includes various components of the economic system development. In turn, the circular economy with its enormous potential to create new and unprecedented opportunities for achieving green growth contributes to sustainable economic growth. At the same time, the circular economy should take into consideration the various components of economic security, its goals, objectives, as well as mechanisms for their achievement.

Ensuring economic security is to meet the needs of individuals, society and the state in the rational use of natural resources, especially mineral resources. Infinite growing needs and limited resources set task of searching for mineral resources to the state. The threat can be the limit of the mineral resources necessary to achieve economic goals and rational use of them. For instance, due to the limited extraction of mineral resources, problems can occur with electricity. It is possible to solve the problem if global and national climates, as well as energy transition strategies go hand in hand with circular economy strategies. It will help to reduce the risks and dependence associated with critical metals and minerals. However, a certain level of new resource extraction will still be required, since the current volume of some recycling resources cannot satisfy future demand.

Based on the study, the authors have substantiated the need to implement the circular economy principles in national legislation in accordance with European standards. The key direction in the European Green Deal is the transformation of the traditional economy in a circular economy with sustainable resource consumption. If Ukraine wants to remain competitive and defend its producers and exporters, the authorities must adopt the necessary legislation and take it into practice. In particular, by improving waste management system, it is possible to determine legal, organizational, economic principles and control protection mechanisms to ensure the environment. This can be achieved by reducing the waste generation and the negative effects of waste management, reuse and recovery of both secondary raw materials and energy resources.

One of the most important measures is to create clear plans with specific goals, as well as providing support for businesses that implement the circular economy principles. Green Public Procurement Policy should also be taken into consideration as it can play a significant role in the transition to a circular economy. The issue of green procurement is relevant to Ukraine, as public authorities can make an important contribution to the

development of sustainable consumption and green production, providing real incentives for the development of environmentally friendly technologies and products.

The priority task for Ukraine for the short- and medium-term is the adoption of the Framework Law “On Waste Management”, which implements Directives 2008/98/EC, 2018/851, and sectoral laws concerning packaging waste, electrical and electronic equipment, batteries and accumulators in household waste. The adoption of this bill is an important step towards the functioning of expanded responsibility for the producer and homeowner. In addition, it is important to determine the interaction of regions and communities in the implementation of joint infrastructure projects for system of household waste management.

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Економіка замкнутого циклу та зв'язки економічної безпеки: приклад України

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Мета. Стаття присвячена теоретико-методологічному рішення наукового завдання обґрунтування зв'язку між сталим видобутком корисних копалин та реалізацією моделі економіки замкнутого циклу в контексті економічної безпеки держави з акцентом на значущість мінерально-сировинних ресурсів, а також розроблення науково-практичних рекомендацій та питання регулювання економіки замкнутого циклу в Україні в контексті забезпечення економічної безпеки.

Методика. У статті зосереджено увагу на позиціях різних експертів та вчених щодо екологічних проблем, економіки замкнутого циклу, управління мінеральними ресурсами та економічної безпеки. За допомогою запропонованого підходу контурного аналізу взаємозв'язку циркулярної економіки із системоутворюючими компонентами економічної безпеки держави визначаються місце та роль циркулярної економіки в системі економічної безпеки.

Результати. У дослідженні наведено результати циркулярної економіки з акцентом на мінерально-сировинні ресурси в контексті економічної безпеки держави. Встановлено, що концепція економіки замкнутого циклу поєднала у собі риси різних системоутворюючих компонентів економічної безпеки (екологічної, промислової, енергетичної, мінерально-сировинної, соціальної, продовольчої). Виявлено, що економіка замкнутого циклу пов'язана із різними науковими напрямками формування еколого-економічних систем.

Наукова новизна. Доведено двоїстість зв'язку впровадження моделі економіки замкнутого циклу із складовими економічної безпеки, що відкриває як можливості зміцнення економічної безпеки за рахунок позитивних ефектів, так і певних короткострокових негативних ефектів.

Практична значимість. Комплексний аналіз використання мінерально-сировинних ресурсів в економіці замкнутого циклу в контексті економічної безпеки держави дозволив сформулювати низку науково-практичних рекомендацій щодо сталого управління економічною безпекою в Україні. Це дозволило створити багаторівневу систему управління циркулярною економікою в Україні з урахуванням мінеральних ресурсів.

Ключові слова: циркулярна економіка, економічна безпека, ефективність використання ресурсів, мінеральні ресурси, видобуток, переробка відходів