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# MANAGEMENT OF METAL SCRAP AND METAL WASTE FOR THE TRANSITION TO CIRCULAR ECONOMY AND THE RECOVERY OF UKRAINE

*In the modern world, the production of metal products requires significant energy and raw materials, which leads to serious economic losses and environmental damage. The article considers the problem of recycling in the metallurgical industry to reduce the negative impact on the environment and improve economic indicators. Nowadays the problem of scrap metal disposal is an urgent issue for Ukraine especially due to the military actions on its territory. This is an additional challenge for the domestic economy, which is prompting a shift from a linear economic structure to a circular one. The European countries are already actively moving towards the 10R principles for the circular "green" economy by introducing up-to-date legislation and implementing proper organizational, scientific and technological measures. Ukraine has already adopted some documents regarding sustainable development and circular economy such as the National Waste Management Strategy, the Strategy of the State Environmental Policy of Ukraine, the Concept for the Implementation of the State Policy in the Field of Climate Change, the Strategy for Low-Carbon Development of Ukraine, etc. Nevertheless there is no proper legislative framework for specific circular economy measures and recycling of metal scrap and waste in our country.*

***Keywords:*** *circular economy, recycling, metal waste, industry, environment, sustainability.*

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# ПОВОДЖЕННЯ З МЕТАЛОБРУХТОМ ТА МЕТАЛЕВИМИ ВІДХОДАМИ ДЛЯ ПЕРЕХОДУ ДО ЦИРКУЛЯРНОЇ ЕКОНОМІКИ ТА ВІДНОВЛЕННЯ УКРАЇНИ

*У сучасному світі виробництво металопродукції потребує значних енергетичних та сировинних ресурсів, що супроводжується вичерпуванням природних ресурсів та викидами забруднювальних речовин в навколишнє середовище. Стаття розглядає проблему рециклінгу в металургійній галузі для зменшення негативного впливу на довкілля та покращення економічних показників. Сьогодні проблема утилізації металобрухту є актуальною для України, особливо у зв'язку з воєнними діями на її території. Це додатковий виклик для вітчизняної економіки, який спонукає до переходу від лінійної її структури до циркулярної. Концепція циркулярної економіки, яка передбачає використання вторинної сировини та мінімізацію відходів, має важливе значення у вирішенні проблем вітчизняного ринку вторинної сировини, зокрема тих, які виникають через війну та окупацію територій. Країни Європи вже активно рухаються до 10R-принципів циркулярної «зеленої» економіки (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover). В Україні прийнято ряд документів в сфері сталого розвитку та циркулярної економіки, таких як Національну стратегію управління відходами в Україні до 2030 року, Стратегія державної екологічної політики України, Концепція реалізації державної політики у сфері зміни клімату на період до 2030 року, Стратегія низьковуглецевого розвитку України до 2050 року тощо. Тим не менш, належна законодавча база для впровадження конкретних, визначених нормативними та програмними документами заходів циклічної економіки та переробки металобрухту та відходів металургійного виробництва, відсутня. Регулювання процесів управління відходами на засадах циркулярності вимагає комплексного підходу, включаючи законодавчу підтримку, технологічні інновації та інвестиції. Незважаючи на практично безмежний потенціал циркулярної економіки, її практична реалізація залишається повільною, витратною та надзвичайно складною. Стаття важлива для розуміння актуальності циркулярної економіки для економічного та екологічного відновлення країни в повоєнний період, можливостей та перешкод у впровадженні циркулярної економіки в Україні, а також її основних принципів та підходів.*

***Ключові слова:*** *циркулярна економіка, рециклінг, металобрухт, виробництво, навколишнє середовище, сталість.*

**Statement of the problem.** In the modern world, there are plenty of metal products that require a huge amount of energy to produce as well as raw materials which cause sufficient economic losses and degradation of the environment. For instance, the entire mining process requires burning of the significant amounts of fossil fuels, including gasoline, diesel, and coal, which leads to emissions that lead to chronic diseases, reduction the duration and the quality of life [1]. Additionally jobs created by the metal industry as a rule have harmful occupational and health conditions. The world's leading countries are concentrated at implementing green technologies and circular economy approaches [2–4]. It is known that recycling can require only 5…7 % of the electricity used for primary production [5] depending on the technology and the metal processed. There is also no need to make landfills that occupy a huge

amount of territories and contain waste that might has been decomposed for 100, 200, or even 500 years. The use of scrap metals plays a special role in reducing greenhouse gas emissions [6].

Ukraine annually generates approximately 500 million tons of industrial waste [7], including 100 million tons of metallurgical waste. In the pre-war period 1/7 of the country's territory was covered with garbage, the amount of which is equal to the area of Switzerland, and 3.8 % and 0 % of it was recycled and composted, respectively [8]. Additionally, with the beginning of military actions Ukraine faced a problem with the military equipment utilization.

In the paper [9] the assessment of current situation of the scrap metal market in Ukraine is carried out. Thus, in 2022 about 1050 companies of various forms of ownership specializing in scrap metal operations were officially registered. Around 20 % of these companies and their fixed assets are located in temporarily occupied territories or areas of active hostilities, so they cannot operate. It is informed that another 50 % of the companies in the register have stopped operations due to economic or social problems. Most metallurgical enterprises were affected in Donetsk, Mykolaiv, Kherson, and Sumy regions. The full-scale war has affected Ukraine's main consumer of scrap metal: the seized steel and foundries were forced to stop or reduce production. In 2022, about 841.9 thousand tons of scrap metal were supplied to steelmaking enterprises, compared to 3,055.9 thousand tons in the same period of the previous year [9]. In connection with military actions and the use of weapons and ammunition, vehicles, there is a large amount of scrap metal that needs processing – and in the context of de-occupation and post-war reconstruction of Ukraine, this number will increase.

**Analysis of recent research and publications.** The circular economy is an economic system established with a life-cycled view around the waste hierarchy from reducing, reusing, and recycling to recovering materials and operating at the micro (products, companies, consumers), meso (eco-industrial), and macro scale (city, region, nation and beyond) [10] to achieve economic prosperity and social equity while protecting the climate system, atmosphere, hydrosphere and biosphere.

The theoretical aspects of the circular economy as a new paradigm of sustainable development are attracting the attention of many scientists and practitioners. Among them are: Carrez D., Van Leeuwen P., Geisdorfer M., Bocken N., Gultink E., Haas W., Krausman F., Wiedenhoefer D., Hynes M., Millar N., Berger T., Yuan Z., Moriguichi J.B.Y., Babak A., Tarantzova A., Sergienko D., Zvarych I., and others.

The transition from the old linear model of the economy which can be described as the chains "Extraction-Production-Consumption-Disposal" or "Take-Make-Use-Dispose", to a circular one involves the creation of new business models and market niches (industrial design, engineering, remanufacturing, processing, services and so on) [11; 12].

The initial circular approach was based on the 3-R principle: reduce, reuse, and recycle [13; 14]. In 2018, the World Economic Forum significantly expanded the principles of the circular economy to ten items (10R) [15; 16]:

1. Refuse (refusal to produce a product using certain technology and materials, offering an alternative).

2. Rethink (rethinking the use of the product, exchanging or sharing the product).

3. Reduce (reduction of natural resource use with increased production or consumption efficiency).

4. Reuse (reuse of a used product by another consumer for its intended purpose).

5. Repair (repair and maintenance of a defective product with its subsequent use for its intended purpose).

6. Refurbish (restoration of an old product for further consumption).

7. Remanufacture (re-processing and use of a part of an old product in a new product for its primary purpose).

8. Repurpose (reorientation of a part of an old product in a new product to a different functional purpose).

9. Recycle (processing of materials to produce products of the same or worse quality).

10. Recover (combustion with the recovery of the energy spent on their production).

In a closed-loop economy, resources are constantly recycled back into production on the one hand and the resources embedded in products must be used for the longest possible period on the other. Transforming waste into secondary material for use as new inputs is the oldest and most widely used circular resource recovery strategy (e.g., recycling). Recycling or secondary production is an alternative to primary metal production with high proven potential for the energy saving and reducing the emissions.

The circular economy has the potential to dampen rising demand for raw materials and reduce the volatility of global resource prices. By reducing the environmental impacts of products and production, external costs such as waste disposal and health care can be reduced. Closed-loop economics offers new areas of activity and transforms waste management into a reverse logistics and recycling economy. New technical and organizational requirements arise from the circular economy. In order to assess the environmental implications of a closed-loop economy, it is useful to consider the entire life cycle of a product from the extraction of raw materials, production, transportation, and final use, to completion by recycling. The assessment of circularity metrics, in partircularity the measurement indices and circularity evaluation tools was made by Corona B. et al [17]. The life cycle assessment approach is described in [13].

In addition to the environmental benefits of circular business models – such as a significant reduction in the use of non-renewable materials, a reduction in production waste, and the use of manufacturing by-products and surplus materials previously considered waste – a growing body of research points to the undeniable role of manufacturing companies in redesigning the entire economy [16]. In 2014, The Ellen MacArthur Foundation and the World Economic Forum released a report [18] stating that if governments, corporations, and large and medium-sized businesses focus on building circular chains to increase the rate of recycling, reuse, and remanufacturing, more than $1 trillion a year could be generated by 2025 and 100,000 new jobs could be created for the global economy over the next five years. Circular economy is linked to digitalization, data driven solutions, artificial intelligence and so on [19].

According to some estimates, the processing industries have already provided about one million jobs in Europe. The scrap metal industry provides jobs for more than 50,000 people worldwide [20]. The impact of the circular industrial model on the structure and viability of labor markets remains to be seen. However, there are clear signs that the circular economy, under the right circumstances, will

increase local employment, especially in entry-level and semi-skilled jobs, thereby addressing a serious challenge that Ukraine is facing in the current situation.

**Formation of the objectives of the article (task statement).** The purpose of the work is to analyse the main principles, foundations and opportunities of the circular economy for the metal industry in the context of the post-war recovery of Ukraine.

**Summary of the main research material.** At the end of 2015, the European Commission proposed a project for the development of the circular economy until 2030, which contributes to the harmonization of supporting laws [21]. The European Union (EU) has adopted a Circular Economy Action Plan [22]. Even within the framework of the EU-Ukraine Association Agreement and the European integration course, our country has committed to harmonizing national legislation with the European one. The EU Circular Economy Action Plan describes activities from the design and manufacture of a product to its consumption, repairing, recycling, reusing, and return to the economic cycle. The plan envisages a series of interconnected initiatives to create a strong and coherent strategy to make products more sustainable and change services, business models, and consumption patterns to generate less waste.

A Circular Economy Action Plan includes such stages to carry out in Ukraine [23; 24]:

1. Ensure the organization of the work of the EU Circular Economy Mission in Ukraine in order to:

– improve cooperation on circular economy issues;

– gain a better understanding of Ukraine's environmental challenges;

– facilitate business partnerships between European and Ukrainian entrepreneurs.

2. Ensure accession to the Global Alliance for the Circular Economy (GAERCE) for international coordination on issues related to the convergence of the Ukrainian economy towards circular economy principles, with the Ministry of Environment as the responsible implementer and the Minister of Environment as the representative.

3. Support the transition of businesses to circular economy models through cooperation with international initiatives such as "switch to green".

Following the adoption of Directive 2008/98/EC on waste management [24], the European Union steel industry has faced difficulties in utilizing scrap metal as raw material in its daily activities [16; 17]. This situation led to the adoption of Council Regulation (EU) No 333/2011 [25] on the criteria by which certain types of scrap are no longer considered waste and therefore outside the scope of the Directive. The Circular Economy Action Plan was adopted as well.

In Ukraine, the main policy documents on the circular economy are the following: National Waste Management Strategy until 2030; National Waste Management Plan until 2030; Strategy of the State Environmental Policy of Ukraine until 2030; Concept for the Implementation of the State Policy in the Field of Climate Change for the Period up to 2030 and its implementation plan; Strategy for Low-Carbon Development of Ukraine until 2050 and others [16].

The National Waste Management Strategy to 2030, adopted in 2017 [26], provides the implementation of European best practices in Ukraine for the management of different types of waste (industrial waste, household solid waste, agricultural waste, construction waste, hazardous waste, and other waste). The strategy aims to identify and solve the main problems of waste management in Ukraine; identify priority areas of action to create an innovative waste management model in Ukraine; identify ways to improve the existing waste management infrastructure; ensure sustainable development of Ukraine; improve the quality of services provided and reduce the administrative burden.

The National Waste Management Strategy envisages, among other things, the implementation of circular economy principles. In the circular model, used materials and waste again become raw materials for the economy. This solves the problems of scarcity of natural resources and high raw material prices and reduces dependence on imported materials. Circular economy strategies can help to avoid the negative effects of isolation, as distribution chains and supply channels are geographically closer to the point of production. The circular economy also prevents the use of toxic chemicals that prevent product reuse or negatively impact the environment and human health.

The Low Carbon Development Strategy of Ukraine until 2050 (LCDS), adopted at the meeting of the Cabinet of Ministers of Ukraine on 18 July 2018, provides the transition of the Ukrainian economy to a low-carbon development model, including a shift to renewable energy sources and, most importantly, a reduction in greenhouse gas emissions [27]. The strategy was developed to fulfill Ukraine's obligations under the Paris Agreement and decisions of the Conference of the Parties to the UN Framework Convention and to implement the orders of the Cabinet of Ministers of Ukraine. The objectives of the strategy are to create a new energy system, increase carbon capture and sequestration, reduce greenhouse gas emissions, and introduce the concept of green production in Ukraine through the use of green technologies.

In early December 2022, the Cabinet of Ministers adopted The Resolution "Some Issues of Using Samples of Weapons, Military and Special Equipment of the Enemy Destroyed in the Course of Repulsing and Deterring the Armed Aggression of the Russian Federation" [28; 29]. It recommends that the Defense Ministry take measures to effectively manage destroyed military equipment. In order to effectively manage scrap metal resulting from the decommissioning of destroyed military equipment, the following requirements should be met:

– involvement of private and foreign companies in the processing process;

– removal of restrictions on the export of scrap metal;

– full disclosure and transparency of the organization and operation of the recycling process. Today the life cycle of many goods is very short. And the use of a linear production model does not contribute to the production of sustainable products.

The slow integration of circular technologies is connected with the lack of clear quantitative and qualitative indicators of the effectiveness of circular infrastructure implementation; insufficient development of the market for circular technologies in Ukraine; lack of adequate infrastructure for waste disposal and recycling as well [30; 31].

The other causes are institutional and legal. They are the lack of a general policy for the implementation of the circular economy at the national level; lack of uniform standards for the application of circular technologies (at the legislative level); lack of investment measures to promote the development of circular technologies; government measures can create incentives for waste generation,

etc. [32; 33]. Insufficient financial resources (limited state budget); insufficient investment funds (also from abroad); expensive and long investment cycles; long payback period; limited sources of long-term credit; high transaction costs for consumers also slow down the implementation of the circular economy [8, 34]. The other problem is psychological unpreparedness for new management and social interaction methods. It requires the support of governmental organizations as well as organizations that help promote, regulate, and monitor the implementation of the circular economy. It requires a new set of tools and a better understanding of how the latest technologies can help the industry change its approach to sustainability [32; 33].

To support larger-scale solutions the following actions and measures are needed: development and implementation of a long-term, holistic vision for circular economy objectives; establishment of cross-sectoral coordination and fostering a culture of cooperation and knowledge sharing in local initiatives; involvement of non-state actors in the transformation process; development a circular economy strategy; analysis of urban metabolism as a basis for developing a strategic transformation plan for specific priority sectors; educating consumers (and other stakeholders) on the benefits of circular economy initiatives and projects.

Support for better financing is possible by using public procurement for the circular economy to create demand for circular innovation; using external sources of financing for circular economy initiatives and projects at the EU or national level to complement the public sector's budgets. Regulatory support includes the facilitation of space and funding for experiments, innovations, knowledge transfer, and harmonization for businesses, support for research institutions, and interested citizens; creating forums with like-minded cities at the national (and possibly EU) level to lobby for changes in EU and national legislation that hinder the transition to a circular economy; monitoring and evaluation of the implementation of circular projects and initiatives to build solid knowledge-based tools; promotion of obtaining relevant skills and knowledge, both among organizations supporting the circular economy and among target groups of people and businesses.

Developing a circular economy requires specific skills in monitoring and implementing innovative production processes or in inter-organizational cooperation and communication, and gaps in these skills need to be identified and addressed at appropriate levels; communication needs to be adapted to the local context (local level) and all stakeholders need to be adequately informed. Strategies and pilot projects often face a lack of public awareness. Given the overarching goal of an inclusive circular economy to 'close the loop' and create a paradigm shift, establishing links and relationships between different strategic initiatives will enable: cycles in most areas to be lengthened, made more efficient and even new cycles can be closed; efforts to be coordinated at different levels of government; and knowledge sharing to ensure that existing circular economy approaches are disseminated [16; 35].

Transition to the circular economy can be carried out in the following steps [36; 37]:

– Develop and implement a long-term, holistic circular thinking vision.

– Ensure cross-sectoral coordination and promote a culture of cooperation and knowledge sharing in local initiatives.

– Develop a circular economy strategy; analyze the urban metabolism as a basis for developing a strategic transformation plan for specific priority sectors.

– Educate consumers and other stakeholders in society on inclusive and participatory approaches to circular city design, especially in specific cities, as the position of citizens is crucial.

In order to create an effective process for the disposal of damaged military equipment and minimize these risks, several measures should be taken [36; 37]:

– Organize a system for assessing the quantity and quality of scrap metal that may be generated during the disposal of military equipment.

– Develop an effective and modern mechanism of state control over operations with scrap metal generated during the disposal of military equipment.

– Develop mechanisms for applying modern technologies of military equipment processing and utilization.

– Create conditions for the revival of the Ukrainian scrap metal market and promote export opportunities for companies that process destroyed military equipment.

Sustainable development experts [38; 39] provide recommendations that should be included to regulate scrap activities and accelerate the transition to a circular economy. Firstly, these are establishing criteria and prerequisites for the termination of the waste status of scrap metal and metallurgical by-products, making appropriate changes to the State Waste Classifier, encouraging maximum substitution of virgin raw materials by waste, and simplifying licensing procedures for companies involved in the purchase and exploitation of scrap metal.

Secondly, the state should take concrete steps to rectify Ukraine's chosen path to a circular economy and reflect international best practices. That is, it is necessary to enshrine in legislation financial and economic instruments to be implemented through state incentives to reduce the consumption of primary raw materials by gradually replacing them with secondary raw materials. In particular, it is the principle of maximum substitution of primary raw materials by waste, subject to technical possibilities and when developing new technical standards or revising old technical standards, creation of state aid for projects on waste recovery operations, provision of special state guarantees to protect investments during business activities related to waste disposal in Ukraine, etc.

**Conclusions.** The topic of circular economy is gaining more and more attention, but countries and Ukraine are no exception, facing several barriers that need to be overcome in order to promote the circular economy industry. These barriers can be found in different areas: organizational, institutional and legal, financial, technical, infrastructural, and psychological.

Expanding the scale of the circular economy and introducing new circular business models in Ukraine is impossible without a systemic and comprehensive restructuring, starting with legislative regulation, the introduction of technologies and innovations, financing and the introduction of new standards, and building the readiness of society as a whole to change its habits towards the widespread use of circular products, creating new platforms and schemes for the interaction of producers and consumers of circular goods.

Therefore, the introduction of a circular economy is not only beneficial for the company or business but also for society and consumers. Long-term benefits also arise from

the optimization of material flows, the possibility of opening up new markets, expanding services, and achieving additional profits in the service sector. Circular economy is of great concern for the post-war recovery of Ukraine [40]. However, reaching such a qualitatively new level of resource efficiency will require technological innovations and changes in behavioral patterns, large-scale investments, and governmental regulation. The potential of the circular economy is limitless, but its practical implementation is still slow, expensive, and extremely complex.

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