ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

Экономика замкнутого цикла в металлургической отрасли

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Аннотация: Статья посвящена вопросам перехода к экономике замкнутого цикла, которую также называют «циклической», или «циркулярной», базирующейся на принципе повторного использования ресурсов. В основу циклической экономики положена схема замкнутой цепочки производства и потребления, когда отходы становятся сырьем для производства. Постоянно растущие потребности человечества при ограниченности ресурсов ставят новые задачи перед государством и бизнесом. Возможным вариантом решения проблемы исследователи считают переход к «зеленой» экономике. Однако текущая модель потребления ресурсов, материально-техническая база, логистические цепочки не отвечают критериям «зеленой» экономики. Промежуточным решением является замкнутая (или циклическая) ее версия. Качественный переход базируется на технологических решениях, многие из которых все еще разрабатываются. В Российской Федерации также сформировалась экономическая политика в данном направлении, в частности, разработан и утвержден федеральный проект «Экономика замкнутого цикла». Наиболее точечно разобрать текущие реалии, инструменты реализации и будущие эффекты авторы статьи предлагают на конкретной отрасли, сфокусировав внимание на специфике металлургической промышленности России, так как металлургическая отрасль входит в число крупнейших по сгенерированным отходам за последние годы. Решив проблему, возможно получить рабочий отраслевой механизм перехода к циклической экономике, а затем и к «зеленой» экономике.

Ключевые слова: «зеленая» экономика, циклическая экономика, экономика замкнутого цикла, металлургия, промышленные отходы, утилизация, переработка
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Closed-loop economy in the metallurgical industry

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RESEARCH ARTICLE

Abstract: The article discusses the transition to a closed-loop economy, also known as cyclical or circular, based on the principle of reusing resources. In a cyclical economy, wastes become raw materials for new production through a closed chain of production and consumption. The ever-increasing needs of humanity, along with limited resources, pose new challenges for government and business. Researchers believe that transition to «green» economy is a possible solution to the problem. Nevertheless, current supply chains, logistics, and resource consumption patterns do not meet the requirements of «green» economy. An intermediate solution is a closed-loop (or cyclic) version. The qualitative transition relies on technological solutions, many of which are still in development. The Russian Federation has also developed and approved an economic policy in this direction, specifically the «Closed-Loop Economy» federal project. Since the metallurgical industry in Russia produces a significant amount of waste compared to other industries, the authors propose to analyze the implementation instruments, future effects, and current realities with particular attention to this industry. After addressing the issue, we can create a structured approach to transitioning to circular economy and eventually to «green» economy.

Keywords: «green» economy, cyclical economy, closed-loop economy, metallurgy, industrial waste, utilization, recycling
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Introduction

The current stage of human development emphasizes the need to revise the existing economic model. According to the UN estimates, there will be 8.5 billion people on Earth by 2030, 9.7 billion by 2050, and 10.4 billion by 2080[1]. 2011 saw the crossing of the 7 billion mark, indicating ongoing overall growth. The use of resources will rise concurrently, some of which are non-renewable (oil, ore, etc.). High volatility and consistent price increases indicate that resource scarcity has been an issue for many years. At the same time, the generation and accumulation of production and consumption waste increase significantly. The combination of these factors makes it necessary to reorganize the current economic model to increase the useful life of material goods and enable the rational use and consumption of resources.

It is challenging to keep up with consumption growth, even though mankind is using natural resources far more efficiently than it did in the past. The annual consumption of natural resources surpasses their regeneration by 75 %. However, the demand for finite resources is expected to rise over the next few decades, according to the researchers. For instance, by 2030, increased demand will cause metal mining to increase by 250 % [Lacey, Long, Spindler, 2023].

The closed-loop economy model in present realities

Since the Industrial Revolution, the linear economic model of «extract – produce – use – waste (bury)» has proven to be ineffective in the current economic realities. Experts agree to define the shift to «green» economy as an additional development vector [Semertzidis, 2022]. The circular economy is a new model for producing and consuming goods that has gained widespread political attention as a long-term development strategy. However, the theoretical framework remains poorly structured and insufficiently explored. The model is based on multiple schools of thought, with its roots primarily in ecological economics and industrial ecology [Bruel, Kronenberg, Troussier, Guillaume, 2023].

The United Nations Environment Programme (UNEP) defines the «green» economy as «economic activities that enhance human well-being and social justice while substantially reducing environmental risks and the impoverishment of nature»[2]. The qualitative transition relies on technological solutions, many of which are still being developed. The model's cornerstones are waste management and the utilization of renewable energy. A linear economy cannot be quickly transformed into a fully green one. The circular economy, or cyclical economy, will be the interim solution. Rather than abandoning dirty fuels and non-environmental consumer products, the main distinction between a circular economy and a «green» economy will be the recycling of materials made from non-environmental raw materials and their subsequent reuse in production processes. Furthermore, the circular economy will include renting, reusing, repairing, and refurbishing items, extending their useful life without prematurely discarding them.

Table 1. Extended framework for closed-loop economy

Element	Description
Utilization	Waste and unutilized product recycling
Disposal	Material combustion with energy recovery
Reduction	Reducing the amount of natural resources and primary materials used
Refusal	Transfer of a product to the category of surplus. Further rejection of a product or substitution of its functions with another product
Reusability	Reuse of a product to fulfill a new or original function
Restoration	Product repair and maintenance
Recycling	Utilizing parts of an obsolete original product in a new product or changing the parameters of the original product
Reprofiling	Change of use of the original product to fulfill new functions
Revision	Increased efficiency of the initial product utilization
Modernization	Improving, restoring and updating the original product

Determining the resource and material intensity of different industries and their weight in the GDP is essential for the circular economy because it allows for the evaluation of the possible effects of structural changes on waste generation and the comparison of national indicators with those of other countries [Bobylev, Solovyova, 2020].

Most studies related to the concept of cyclical economy follow the 3R principles of reduce, reuse, and recycle [Sanguino, Barroso, 2020]. However, some scholars supplement the 3R principle with other principles, analyzing over 100 definitions of circular economy and presenting an expanded framework of the 10R [Kirchherr, Reike, Hekkert, 2017. P. 223].

According to researchers, the regulatory framework must be modernized consistently and on time to support adopting the circular economy's principles, the integration of innovative technologies into the manufacturing process, and the development of related alternative business models [Ilyina, 2022].

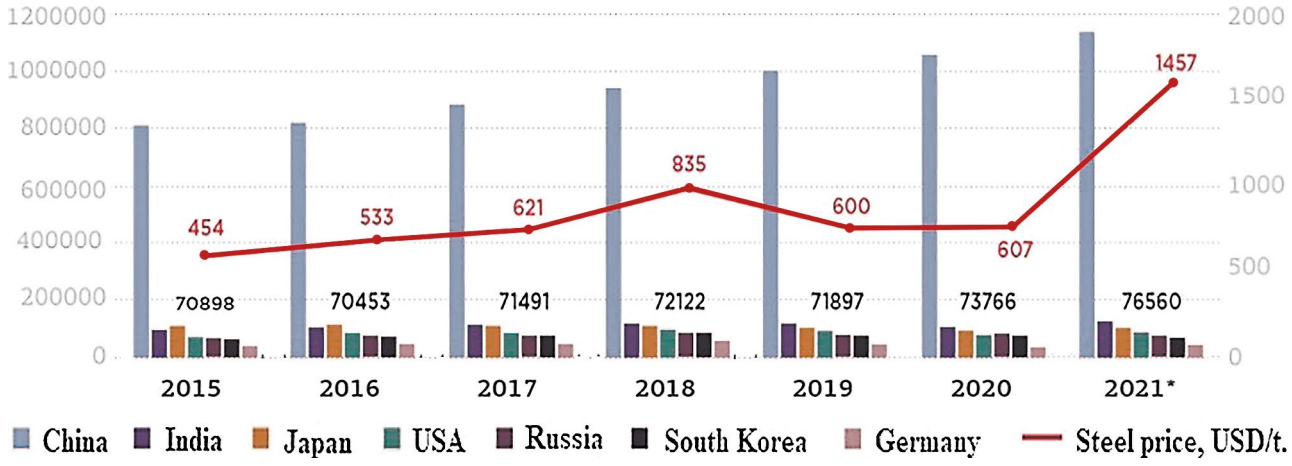
Regulatory and legal aspects

In December 2015, the European Commission adopted the Circular Economy Action Plan, which consolidated the formal reflection of the EU's transition to a circular economy and aimed to create a competitive, resource-efficient,

1 https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf

2 https://wedocs.unep.org/bitstream/handle/20.500.11822/25918/GE_Briefing_RU.pdf

Figure 1. Steel production dynamics in TOP-7 countries, thousand tons (left axis) and average annual steel price in 2015–2021, USD/t (right axis)



Source: LME, WorldSteel, Analytical research. Metallurgical industry in Russia: largest steel producers (2021) (https://delprof.ru/upload/iblock/4ef/DelProf_Analitika_Metallurgicheskaya-otrasl.pdf)

and carbon-neutral economy by stimulating investment, growth, and jobs. The Commission approved over 10 billion euros in funding for the Action Plan from 2016 to 2020 [Pechenina, 2021. P. 38]. The Plan's main goals were to integrate the principles of the cyclical economy into the plastics industry, water management, FMCG (fast-moving consumer goods), and waste management.

The new Circular Economy Action Plan (CEAP)[3], adopted by the European Commission in March 2020, includes initiatives aimed at developing green products in the EU, focusing on resource-intensive sectors, reducing unrecycled waste, and other initiatives.

Within the framework of the federal project "Circular Economy" 2022, the Russian Federation has also formalized the shift to a circular economy[4]. The supervising organization is the public law company "Russian Environmental Operator" (REO). The project's key indicators include "the index of the utilization of secondary resources and raw materials from waste in the sectors of the economy" and "the share of packaging types recycled in the Russian Federation". By 2030, the index of utilization of secondary material resources (SMR) from waste is expected to rise from 6 to 32 %, with recycled packaging accounting for 40 to 85 %. The Russian Environmental Operator's Unified Digital Platform for the Circular Economy[5] describes the structure and management system of this strategic project, as well as the main areas of work, which include:

1) minimization of waste generation;
2) creating waste management infrastructure;
3) ensuring demand for SMR;
4) limiting the circulation of "non-ecological" packaging;
5) creation of waste and secondary resource tracking system;
6) environmental education.

This list also includes the most significant effects on the population, government, and business. To examine the circular economy transition process in detail and evaluate its development prospects, a specific industry must be chosen.

Specifics of waste generation in the metallurgical industry

Given its unique geographical and historical features, the Russian Federation's main industry is the raw materials sector. In particular, the metallurgical industry is a core industry. Ferrous metallurgy works with cast iron, steel, ferroalloys, manganese, and chromium. Non-ferrous metallurgy includes copper, lead, zinc, tin, nickel (heavy metals), aluminum, titanium, and magnesium (light metals).

For further analysis, consider the fundamental branch of heavy industry: ferrous metallurgy, the products of which serve as the foundation for the development of machine building and construction. Russia's three primary centers of metallurgy are the Ural, Siberian, and Central regions. Let us examine the primary statistical data to better understand the scale and state of the metallurgical industry in the Russian Federation.

Over the last five years, the Russian Federation has consistently ranked among the world's top five iron and steel producers (**Figure 1**). Due to widespread lockdowns and the worldwide industry's general shutdown, the metal production index figure for 2020 showed a decline. However, in 2021, there is growth and a return to previous indicators. The first quarter of 2022 saw a worsening

3 https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

4 https://news.solidwaste.ru/wp-content/uploads/2022/07/EZTs_pasport.pdf

5 https://reo.ru/ezc

of the Russian steel industry's situation due to Western sanctions. However, the reorientation of Russian exports to Asia and India prevented a significant decline in the Russian ferrous metallurgy sector.

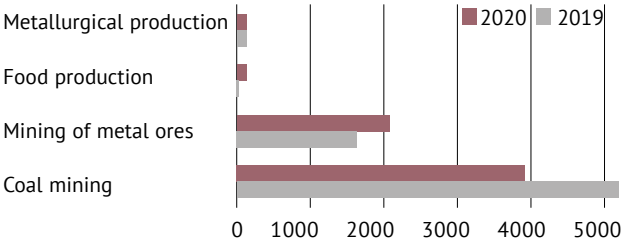
Due to the peculiarities of production, each of the companies generates waste. Production waste is the residue of various materials, including original raw materials and semi-finished products, that are obtained during the manufacturing process and have lost their useful properties (fully or partially) and do not meet quality standards. Article 4.1. of the Federal Law of the Russian Federation No. 89-FZ of June 24, 1998, "On Production and Consumption Waste", defines five hazard classes of waste:
Class I – extremely hazardous waste;
Class II – highly hazardous waste;
Class III – moderately hazardous waste;
Class IV – low-hazardous waste;
Class V – practically non-hazardous waste.

Metallurgical solid waste is divided into several types:
1) slag – residues of raw materials obtained from processing in production; this material is a by-product, often formed from imperfect production technology;
2) oxide – material formed during the oxidation of iron;
3) sludge – waste materials generated after gas cleaning of blast furnaces, open-hearth furnaces, and converters which are used in the production of steel and cast iron;
4) waste metals – this category includes scrap, rejects and under-castings, cuttings, amortization scrap, and other metal waste.

According to statistics, metallurgy is one of the top waste-generating industries (**Figure 2**). At the same time, FinExpertiza estimates that each metallurgical enterprise generates an average of 230,000 tons of waste annually[6]. In this regard, the Russian Federation's metallurgical waste recycling issue is relevant. The necessity and expediency of recycling have been recognized in the last five years as a result of the trend toward ESG transformation (environment, social policy, corporate governance) associated with the crisis phenomena – rising mining and production costs in the industry, as well as the gradual impoverishment of existing mines.

The Russian Federation Government Order No. 84-r of January 25, 2018, approved the "Strategy for the development of the industry for the treatment, disposal, and neutralization of production and consumption waste for the period until 2030", which "is the basis for the formation of the implementation of the state industrial and scientific and technological policy at the federal, regional, municipal, and sectoral levels in the field of waste treatment, disposal, and neutralization, resource-saving, and waste involvement in economic turnover".

Figure 2. TOP-4 industries by volume of generated waste in 2019–2020, million tons



Source: According to FinExpertiza data

Conclusion

Using the metallurgical industry as an example, the following ideas can be emphasized within the framework of the cyclical economy model:
1) recycling of metallurgical slag dumps;
2) recycling of annual products in the form of raw materials (scrap) for smelting;
3) revision of the useful life of metals;
4) reducing the use of concentrates and ores (natural resources) in production.

This will not only improve the steel industry's economic model but also move it closer to a fully developed closed-cycle model, which will benefit the environment. In the most developed countries with high mining costs and limited natural resource reserves, the share of scrap metal used in steel production is greater than 50 % (EU – 55 %, USA – 72 %, Turkey – 78 %), whereas in Russia, the indicator is 25 % [Verzhansky, 2020. P. 81]. The use of scrap in steel production reduces pollutant emissions by 5–10 times, and the cost of smelting is reduced by 2–4 times. Utilizing scrap and other waste materials will reduce production waste by repurposing them into another cycle of production. This will benefit businesses by lowering the cost of raw materials, the general public by providing cheaper finished goods, and the government by creating new jobs and preventing production waste.

6 https://finexpertiza.ru/press-service/researches/2020/rekord-proizvodstv-otkhod/

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