Problematic aspects and potentialities of applying the principles of a circular economy in the mining industry

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Abstract. The concept of a circular economy (CE) gradually penetrates into various spheres of production and consumption as part of the “Green Course” ideology, ensuring sustainable development in the long term. The mining sector cannot be called interested in transforming the linear economy into a more resource-efficient circular economy using regeneration systems. The idea of cyclical recovery of values from waste and used products in closed supply chains is aimed at minimizing the use of scarce primary resources. The mining sector actors perceive this idea as a threat rather than an opportunity to improve their market position. Along with the drivers there are barriers and bottlenecks that impede the implementation of CE principles in the mining industry. There are very few studies related to development or adaptation of circular business models for mining companies. The aim of the work is to analyze the possibilities of applying the principles of CE in the Russian mining industry, taking into account European experience. Mineral extraction waste considerably affects the environment and can be a potential source of raw materials. Environmental problems associated with mining are acute in Arctic mining regions such as the Kola Peninsula. For struggling against wastes and harmful emissions the state began applying environmental regulations based on the best available technologies. In the metal ores mining segment, there are certain prerequisites for forming circular business models based on revealing the relationship between separate elements of the CE concept and introduction of BAT. The presence of such opportunities allows a consistent review of production waste within the CE framework, as well as linking the principles of circularity with the strategies for innovative development of mining enterprises to adapt them to new external challenges.

1. Introduction
The dynamically developing in the last decade concept of a circular economy (CE) has become one of the theoretical bases of the “Green Course” economic policy [1], [2]. The European Union became an integrator and global leader in promoting the concept of CE at the micro-, meso-, macro-, and mega levels. The basis of the CE Action Plan (COM (2015) 614), adopted by the EU in 2016 was the idea of disclosing the potential for growth and employment by transition from the linear economy model to the CE model. It was recognized that waste management plays a central role in CEs by transforming waste into resources at all stages of the value chain, regardless of the activity or product type. Any waste, not excluding mining waste, should become a “secondary raw material” for further use in production. This increases the security of supply of potentially critical materials and makes the economy more “green”.

In the period when the EU implemented the first CE Action Plan as part of the EU CE Package, Russia introduced a system of environmental regulation based on BAT, similar to the mechanism previously worked out in the EU. 51 BAT handbooks were developed, of which five handbooks cover the mining sector. In contrast to the EU, where the BREF (Best available Techniques Reference Documents) system has a long history, the environmental reform in Russia coincided with current research in the field of sustainable development in the framework of the “Green Course”. Therefore, there is a noticeable connection between the study of the possibilities of introducing CE elements in various activities, the concept of a “green economy” and environmental regulation based on BAT. Important for Russia extraction and processing of solid minerals has a harmful effect on the environment and generates a huge amount of waste as resources. In the Murmansk Region alone, about 8 billion tons of industrial waste containing useful components have accumulated. The increase in the amount of production waste and emissions continues. Debatable opinions are expressed on the possibility of applying the ideas of CE in the field of extraction of solid minerals. It is unclear how enterprises of the sector can use the principles and business models of CE in their strategies to increase competitiveness, given that return flows of waste and secondary raw materials in the manufacturing industry pose a challenge to the mining industry. The use of CE elements in the solid minerals extraction sector is constrained by insufficient motivation of mining companies and the lack of reliable theoretical prerequisites for this in CE models. The latter may be due to the fact that the concept of CE has not yet been fully formed.

2. European regulatory experience

In 2019, the European Commission approved a report on implementation of the CE Action Plan (COM (2019) 190), which included a report on the implementation of 54 activities and outlined the challenges to building a climate-neutral economy, in which pressure on natural resources and ecosystems would be minimal. As part of the report, the “Guidelines for Promoting Best Practices in Mineral Waste Management Plans. The action of the circular economy were adopted [3]. It supplemented the existed MTWR BREF guide for the extractive industry waste management.

In March 2020, a new CE Action Plan (COM (2020) 98) was adopted - one of the main building blocks of the European “Green Course” (COM (2019) 640 final). The new Plan launched a transition to an industrial strategy based on a regenerative growth model that will make it the norm to create sustainable products, services and business models that minimize waste flows. To reach this goal, it is planned to create in the EU a balanced market for secondary raw materials and a smooth expansion of the waste processing sector. It is estimated that the introduction of circular principles and business models by 2030 will add 0.5% to EU GDP and create about 700,000 new jobs. Although the mining sector is not named among the priority ones for CE in the new Plan, it follows the general logic of transition to CE taking into account the specifics of the activities and in accordance with Directive 206/21 / EC on management of the extractive industry waste. However, research on this issue is in its very beginning. The EU CE Action Plan (COM (2019) 190) describes circular economy as an economy in which valuable products and resources are maintained for as long as possible. Mineral resources are not excluded from CE, but there is a goal to reduce the share of primary resources in production at the expense of increasing share of secondary raw materials. This goal is recognized as strategic at the global level due to growing demand and the increasing trends in global demand for natural resources. In the framework of the EU flagship initiative “Horizon 2020”, aimed at the development of CE, the ERA-MIN 2 program has been implemented since 2017, supporting research and innovation in the field of metal, industrial and building minerals [4].

3. Theoretical aspects

In the Ellen MacArthur Foundation’s basic theoretical model of (CE) [5], materials and energy give rise to closed supply chains in the production of technical products. Mining, as well as energy, is not covered by the flows of return logistics of waste. The transformation of the linear model of the economy into a circular model in the production and use of technical goods mainly concerns the
manufacturing industry. The mining sector in the base model remains outside the CE. This is consistent with the fact that storage at landfills and incineration of waste is fundamentally not related to CE processes. The basic model of CE also does not show short industry loops for waste as secondary raw materials that can be generated at each stage of production. The CE model focuses on what happens to the product when it is in the final stages of use and after use. The life cycle of any technical product in the CE after the exhaustion of the possibilities for the regeneration of its functions ends with recycling in the form of processing residual items into secondary raw materials. The flow of secondary raw materials partially replaces the need for primary raw materials. If the source of primary raw materials is exhaustible natural resources, for example, metal ores, then the intensive circulation of secondary resources in closed supply chains will allow more economical use of limited mineral resources.

In the context of CE, the positive externalities from the decreasing volume of mining are the reduction of production waste and harmful emissions, increasing resilience of natural ecosystems, and preserving mineral resources for future generations. However, mining companies are the losers, which, as a rule, seek to maximize profitable mining in the framework of “linear” thinking. This conflicts with the CE objectives of the CE.

The CE model from ERA-MIN 2, unlike the basic CE model of Ellen MacArthur Foundation includes the entire value chain of primary materials: exploration, mining, mineral processing, and waste recycling. At the same time, it remains unclear whether the principles of CE can be efficiently applied in the segment of production of primary materials, such as metals, and if so, what business models should be used for this. Satisfactory answers have not yet been received yet. The basic principles of CE in relation to flows of technical products come down to three simple requirements: 1) design without waste and pollution; 2) use products, materials and resources as long as possible; 3) restore natural systems [5]. The practical implementation of the principles of CE is carried out using circular production methods, which are associated with certain sets of R-components. For example, the 1st principle of CE can be associated with such R-components as “Redesign” and “Reduce”, the 2nd – “Recycle”, “Reuse”, “Refurbish”, etc. In turn, R-components can be considered as strategic tools of circular business models that represent key activities during the transition to the CE. It is customary to single out five main business models [2]: 1) circular deliveries; 2) restoration of resources; 3) extending the life of the product; 4) sharing; 5) product as a service. To include the production sector in the CE circuit, it is necessary to determine its R-components and develop appropriate business models.

4. Research overview

Are there opportunities for adaptation of the mining industry to CE, and if so, which ones? The few publications by Russian authors on this subject are scattered. Nevertheless, a generally positive view is being formed on the role and prospects of applying the concept of CE in the Russian mining sector. There is an understanding (O. Kudryavtseva et al., 2019 [6]) that in Russia the principles of CE are not fully recognized by either the state or the business community, but taking into account the country's natural resource potential, the economic and environmental benefits of applying and scaling of cyclic business models are huge. T. Tambovtseva and M. Tereshina (2019 [7]) believe that the transition to a cyclical economy will be a key factor in the country's competitiveness and long-term sustainability, and waste management should play a major role in this transition. L. Mochalova (2019 [8]) notes that at mining enterprises BAT should facilitate organizing circular business models. In her opinion, the business models of “circular deliveries” and “increasing the product life cycle” in the field of mining are not directly applicable. An efficient is the business model for implementation of waste processing technologies and use of secondary resources. The organization of production closed in flows of substance and energy can reduce the environmental impact of the mineral resource complex.

E. Klyuchnikova, D. Makarov, V. Masloboev (2018 [9,10]) assume the use of CE principles as a conceptual approach in developing a strategy to minimize the impact of mining waste on the environment in the Arctic climate. The authors of the study note that as early as the beginning of the 1980s, the Soviet Union developed an approach to integrated use of mineral raw materials, which
could become the basis for the transition to a closed-loop economy, but it was never implemented. For successful implementation of circular models in the mining complex of the Murmansk region, the authors propose using all available approaches, as well as the experience of Finland in organizing interactions of companies in the region. G. Kharitonova (2019 [11]) believes that the gradual transition to CE in the Arctic territories is predetermined by accumulated environmental damage of the tailings. At the same time, the main barriers to the use of circular business models are technologies and the lack of solvent demand for resource recovery products.

More specific and advanced are the results of studies of applicability of the concept of CE in the mining sector by authors based on EU initiatives and previously developed approaches to “circularity” for the mineral resources sector in China. E. Lebre et al. (2017 [12]) investigated the role of the mining industry in the transition to CE and substantiated the applicability of the CE concept in mining practice in Australia. Mount Morgan mine is an example of how mining companies can make significant progress if they apply the principles of CE. J. Woźniak and K. Pactwa (2018 [13]) examined the problems associated with mining waste in Poland and concluded that they have potential for recycling in accordance with the concept of CE. M. Tayebi-Khorami et al. (2019 [14]) believe that it is necessary to “rethink” the management of mining waste in the form of waste and tailings from the perspective of integrative “circular thinking”, which will enable mining enterprises to reduce security risks, increase development sustainability and the economic value of mining waste. Five key areas are identified that are covered by an integrative approach within the framework of the concept of CE: the social sphere, geoenvironmental and geomechanical aspects, the economic factor and legal consequences.

M. Schmidt et al. (2019 [15]) basing on a large-scale study, revealed that, some of the clients of mining companies in various industries have already made CE their strategic priority by buying restored or processed raw materials. Miners will be forced to adapt their operating and business models and create new types of partnerships with customers. The business model with “feedback” may become promising for mining companies when it is not the ownership of the product that is sold, but access to it. ACCENTURE’s research report (R. Bartels et al. 2019 [16]) indicates that mining and metals companies are increasingly facing growing pressure from “circular thinking” of traditional customers, which requires an adequate response. Therefore, G. Mishra (2019 [17]) notes that miners and metallurgists need to quickly adapt and adopt changes to protect their market share, while taking advantage of the potential of such a new source of value as the secondary market. The transition of mining and metallurgical companies from a traditional linear to a more sustainable cyclical economic model provides a chance to turn the challenges of circularity into new opportunities to keep up with innovative industry leaders such as Rio Tinto, ArcelorMittal, Codelco and Novelis.

In the applied aspect, the work of P. Kinnunen and A. Kaksonen (2019 [18]) are noteworthy. Based on seminars and thematic interviews, the authors investigated the problem of valorization (increase in value) of enrichment waste in tailings in the context of the transition to CE. Technological, environmental, institutional and economic drivers were identified as opportunities for using tailings as a source of raw materials. It also revealed the needs, barriers and bottlenecks that are important for tail valorization and can serve as important guidelines when considering other waste streams in the mine. A review of publications shows that the problem of responding to CE challenges for mining companies is relevant. Its solution is at the stage of selecting response ways and searching for adequate business models that allow companies to “fit” into the CE.

5. Results and proposals
The CE model from ERA-MIN 2 schematically included mining in the CE circuit, including the recycling of accumulated production waste. However, this is not enough to extend the concept of CE to the mining industry. One of the approaches to adapting the basic elements of CE in the ore mining sector may be their consideration together with elements of the BAT concept. Although the concept of CE is broader than the concept of BAT, both of them have at least one common goal - to reduce the harmful effects of production on the environment. An analysis of the BAT reference manual
“Extraction and beneficiation of non-ferrous metal ores” showed that of the 46 BAT, the majority corresponds to circular R-components. A significant part of BAT corresponds to the concept of “3R” (Recycle, Reuse, Reduce), but it is not limited only to the management of production waste. Another part of BAT that meets the principles of CE is beyond the scope of the “3R” concept, such as BAT “restoration of the terrain”. This creates the prerequisites for taking into account the principles of CE in the development strategies of mining enterprises when introducing BAT, as well as for the adapted use of circular business models in the mining sector. For example, the problem of the integrated use of mineral raw materials can be approached from the standpoint of industry-specific innovation cycles determined by periods of renewal of BAT. The principle of CE “design without waste and pollution” is applicable for designing waste disposal facilities simultaneously with the development of the project of the deposit. The business model “mining waste as work” may turn out to be productive — the circular business model “product as service” adapted to the specifics of the mining industry, when access to waste processing is provided, for example, to a small mining business without transferring the ownership rights.

6. Conclusion
The development of the concept of a circular economy in the EU countries is of the nature of a steady trend due to the desire to reduce the level of consumption of primary resources along the entire value added chain. For the mining sector, expanding the use of CE principles in production is a challenge and at the same time a new opportunity that requires adjusting approaches to doing business with traditional customers. Although mining is formally part of the CE framework, the search for adequate approaches and business models for mining enterprises is at its initial stage. In Russia, the possibilities of CE are discussed at the level of scientific publications. The idea of promoting the state of the CE concept together with the BAT concept may prove to be productive. Separate studies are required to identify feasible forms and methods of applying the principles of CE for mining enterprises in the Arctic zone.

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