Low-carbon development of Kuzbass: coal mining and land reclamation

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Abstract. The purpose of the study is to examine the adaptation of coal mining enterprises to the requirements of the Climate Agenda and the prospects for a low-carbon future of the Kuzbass region. The subject of the research is the impact of coal mining on the conservation of the region's biocapacity and the future "green" development of Kuzbass on the basis of mine reclamation. The following tasks are tackled: 1. to show the role of mining enterprises in the movement of the region's economy towards a low-carbon future, 2. to determine the relationship between the coal production and the area of mined lands for the period 2013-2019, 3. to reveal the need to increase the mine reclamation rate and conserve the biodiversity of the region's ecosystem, 4. to forecast the growth of the area of mined land with an increase in coal production of more than 300 million tons, provided that the current socio-economic situation in the region remains unchanged. Research methods are elements of a systems approach, regression analysis, building a one-factor linear regression model using the IBM SPSS Statistics software.

1 Introduction

Modern industrial development should be focused on a responsible and respectful attitude to nature, not to violate the carbon balance in accordance with the Paris Agreement on Climate 2015 [1]. Scenario forecasts of the ratio of the ecological (carbon) footprint and biocapacity of territories by 2050, monitoring and accounting of pollutant emissions into the atmosphere, carbon capture by various natural systems, creation of carbon farms and test sites [2], inventory of greenhouse gas emissions in managed forests are becoming the subject of scientific research. While society moves towards zero carbon by 2030 and 2050, the role of the use of the world's best environmental practices for mine reclamation [3-5] and biodiversity conservation is growing. The authors consider the possibilities of sustainable development of Kuzbass, taking into account the previously identified decoupling effect in the field of coal mining in terms of pollutant emissions into the atmosphere [6], and detail the analysis of the relationship between the increase in coal production and the area of mined land. A forecast of the growth of the area of mined land is

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presented, provided that the sustainable coal production limit is exceeded in the amount of up to 300 million tons per year. The negative impact of coal mining on the ecosystem and landscapes in the absence of systematic mine reclamation is shown.

2 Results and discussion

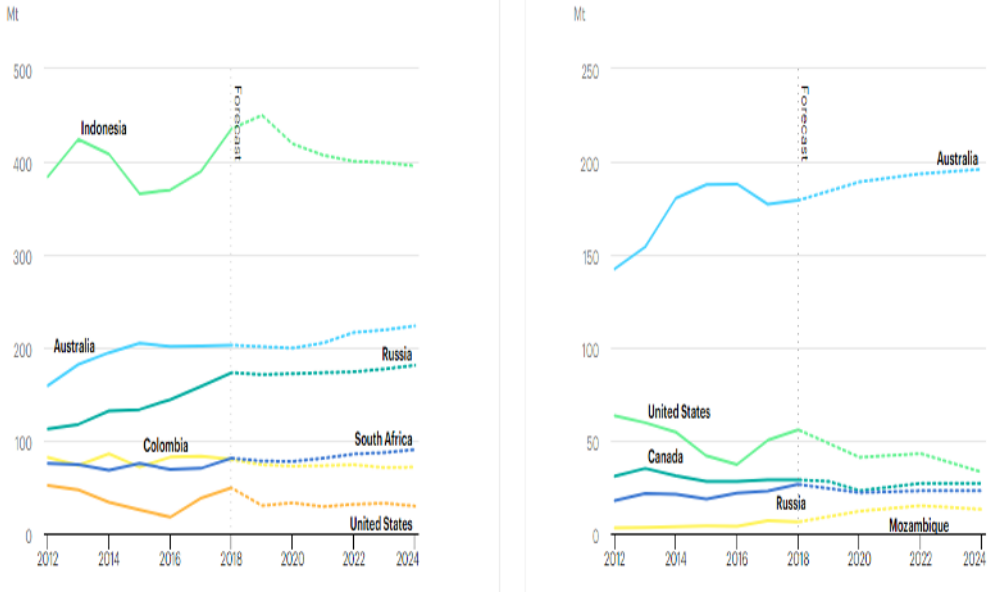
The sustainable future development of the Russian economy requires a compromise to ensure a balance between industrial growth and environmental conservation, moving towards a low-carbon economy. The formation of two worlds: the one with coal energy and the one without it leads to a mismatch between the interests of the world leaders' countries and the rest of the world, which is due to the different degrees of their readiness to stop coal mining and consumption by 2030 [7]. Within the framework of systems theory, the sustainability of biosphere is understood as its ability to self-reproduction and reproduction of the environment within the limits of its natural fluctuations as a result of the influence of external factors, which implies the action of Le Chatelier's principle. The essence of the principle is that changes in the system occurring under the influence of external factors enhance the processes that counteract these changes. Thus, the system-wide regularity, in case of violation of the ecosystem equilibrium, consists in the action of compensation processes that eliminate the emerging changes in its organization. From the point of view of the theory of biotic regulation of the environment, human economic activity should not destroy the natural basis for the development of society.

In the context of the transition of world economies to carbon-free energy [8, 9], the introduction of cross-border carbon taxes when importing products by countries consuming carbon-intensive products, coal mining companies are concerned with the problem of reducing their ecological (carbon) footprint [8]. The carbon footprint indicator interconnects the marginal values of economic development of the industrial region Kuzbass with the “biocapacity of territories” indicator, i.e. the ability of the ecosystem to generate O_2 and absorb CO_2, maintaining a stable equilibrium of the ecosystem. Industrial carbon footprint, including that of coal mining enterprises, is considered in close connection with biocapacity of the territories of the regions where they operate. The average per capita biocapacity index in Russia is 6.5 ha − 7.0 ha [10].

The environmental limits to the mining growth, including coal, depends on the biological productivity of land, forest and water resources, the degree of development of the infrastructure for absorption and processing of waste, emissions of pollutants into the atmosphere, water and land, including carbon dioxide (CO_2) generated by the combustion of fossil fuels” [6]. In Russia, for the period 2012-2018, with an increase in coal production by 30%, emissions of harmful substances increased by 12%, the amount of trapped and neutralized harmful substances decreased by 55.4%, the area of mined land increased by 154%, and the area of reclaimed land decreased by 42%, the volume of accumulated waste increased by 30%. In Kuzbass, as in other of coal mining areas of Russia, there is a long-term accumulation of environmental damage: undisturbed natural areas are decreasing, biodiversity is decreasing, emissions of pollutants into the atmosphere are growing, and the state of the environment is deteriorating.

Most of the coal exported from Russia to world markets is mined in Kuzbass. Kuzbass coal mining companies are among the world's major exporters of thermal and coking coal. However, Russia's positions in the global thermal coal market are more favorable - it ranks 3rd after Indonesia and Australia, in terms of coking coal Russia ranks 4th after Canada. Despite the reduction in coal consumption in the European Union countries (Germany has stopped coal mining, but is still importing coal for thermal power plants), the USA and Canada, the demand for coal as a conventional energy resource remains in Asian markets.

Dynamics of exports of thermal and coking coal from the six main world exporters in 2012-2024 is shown in Fig. 1, where: a) thermal coal exports; b) coking coal exports.



а) Thermal coal exports from selected countries

б) Coking coal exports from selected countries

Fig. 1. Evolution of coal exports from six major exporters, 2012-2024 [11]

The long-term development strategy of Kuzbass is focused on the growth of coal production and the export from the region. Coal mining is the main source of the gross regional product, so the coal production will continue to increase. By 2035, it is planned to produce 427 million tons of coal annually in Kuzbass. Dynamics of coal production for the period 2013-2020 is shown in Fig. 2.

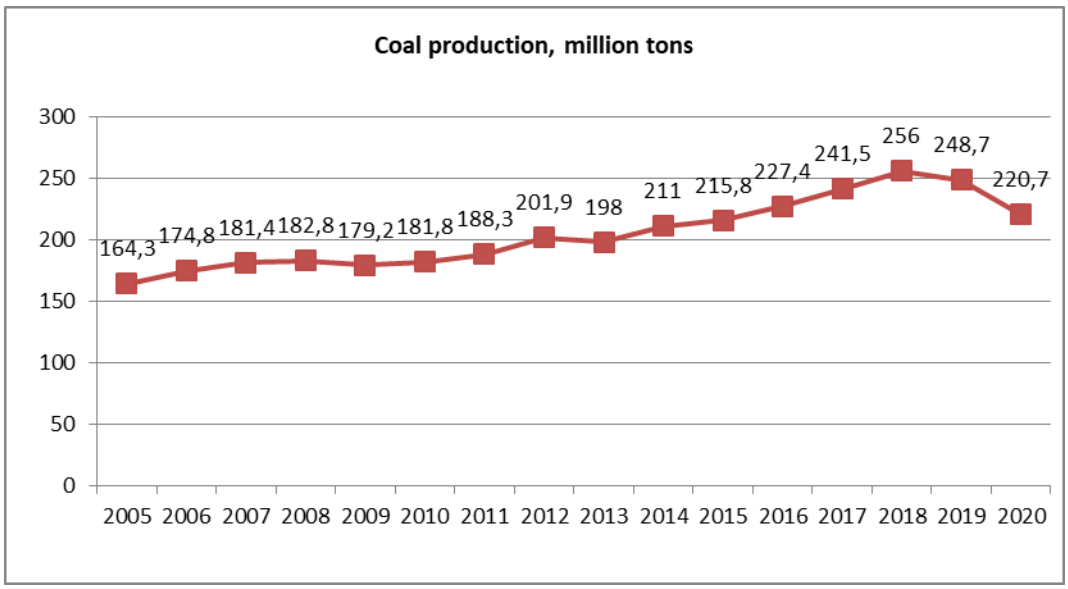


Fig. 2. Coal production for the period 2013-2019, Kuzbass

Coal mining, consumption and transportation is a highly carbon-intensive process, therefore, the requirements of the global Climate Agenda affect the socio-economic development of the region as a whole. In 2021, at the regional level, climatic tasks for the development of the coal industry of Kuzbass were determined, the solution of which is possible by strengthening the interaction of state environmental structures, scientific organizations of the region and coal miners. These include:

– assessing the carbon intensity of the Kuzbass economy (calculating the forecast of probable sectoral losses from the introduction of a cross-border carbon tax by the EU);

– creation of a system of greenhouse gases emission inventory at the regional level;

– organization of work on the assessment of the absorptive capacity of forests and other ecosystems of Kuzbass;

– implementation of pilot projects for the creation of carbon farms and test sites, as well as for the methane capture and utilization.

The solution of new (climatic) problems facing the region should be accompanied by the intensification of mine reclamation by coal mining enterprises, and in general is aimed at increasing the greening of coal mining in the region, reducing the carbon footprint of coal, increasing biocapacity of the Kuzbass territories. It is advisable to use the accumulated world experience in mine reclamation by mining companies in Australia, Indonesia, China, including monitoring of the state of mined lands under reclamation in Bulgaria [12], reclamation of land of abandoned mines in South Africa, Namibia [13-14], reforestation of coal dumps in the United States [15]. Mine reclamation in Kuzbass is not only a part of the necessary activities of license holders, but also a factor in the socio-economic development of the region. Land reclamation as a process of economic activity in coal mining has three main components: environmental, economic and social. Their content is shown in Figure 3.

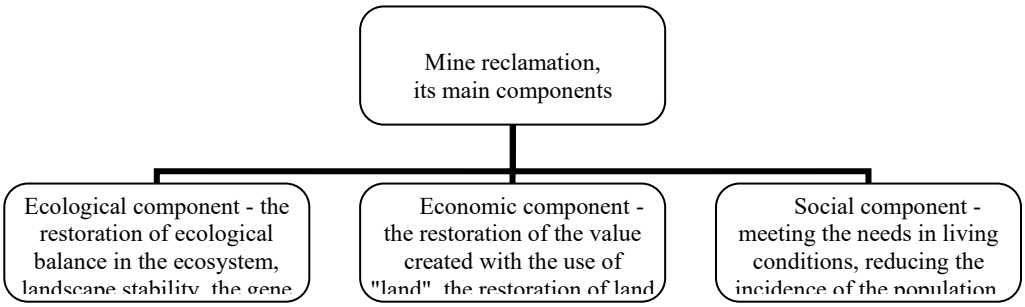


Fig. 3. Three components of land reclamation in coal mining

Mine reclamation management plays an important role in reducing the negative consequences of coal mining, conserving the natural base for the development of the region. The dynamics and areas of annually reclaimed land in Kuzbass are shown in Figure 4.

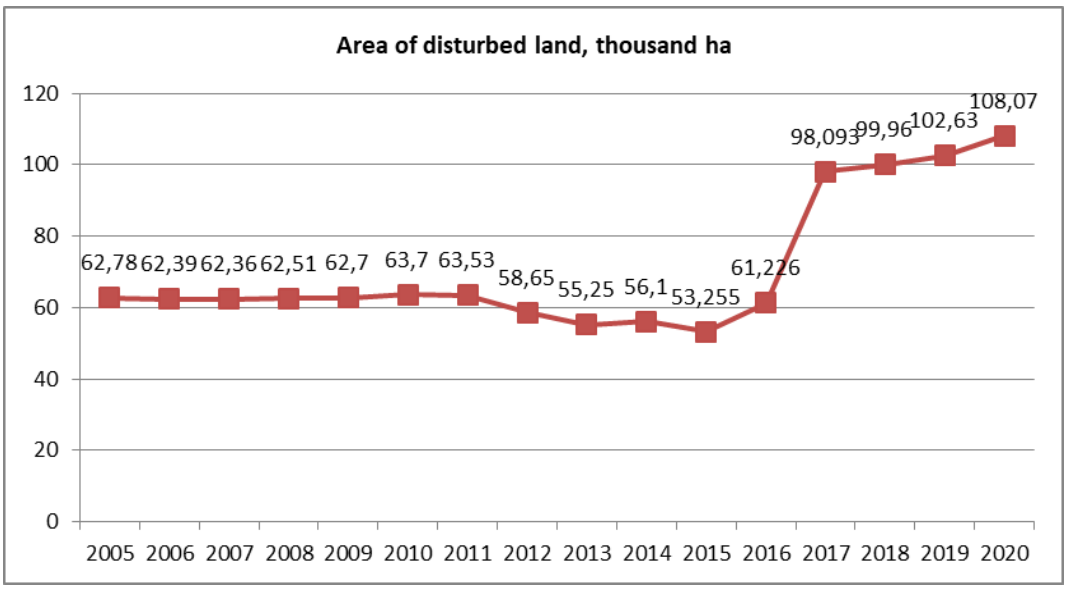


Fig. 4. Area of mined land for the period 2013-2019, Kuzbass

Mine reclamation in Kuzbass by coal miners can be assessed as a poorly managed process. The low rates of land reclamation in Kuzbass are explained by the specifics of the mining and geological conditions of the Kuzbass coal basin, including the multi-layer structure of coal deposits, their great depth of occurrence, mainly external dumping, high land consumption of coal mining and the cost of reclamation. The damage from coal mining to agricultural land is often not compensated by license holders in any way. It is cheaper for mining companies to pay fines than to take the necessary measures to restore soil fertility. The amount of fines for mines and open pits-violators ranges on average from 100 thousand rubles to 400 thousand rubles, and the approximate cost of reclamation, including technical and biological stages, per hectare of land in Kuzbass is 200 thousand rubles. Thus, license holders are not incentivized to reclaim mined land. The market for

reclamation services in coal mining is not developed and is almost not supported by the state. The ratio of the annual growth of the area of mined and reclaimed land in 2013-2019 is presented in Table 1.

Table 1. The ratio of the areas of mined and reclaimed land in Kuzbass for the period 2013-2019

Indicator	2013	2014	2015	2016	2017	2018	2019
Area of mined land per year, thousand hectares	2.60	2.028	2.976	3.171	5.01	1.076	5.443
Area of reclaimed land per year, thousand hectares, (as a percentage of the area of mined land for the reporting year)	0.88 33.8	1.264 62.3	0.730 24.5	0.152 4.7	0.97 19.4	0.028 11.6	0.711 13.1

The Table 1data reveal two opposite trends. On the one hand, as coal production grows, the area of mined land grows, and on the other, the percentage of reclaimed land decreases. So, if in 2013 0.88 thousand hectares were reclaimed, which amounted to 33.8% of the area of mined land for the reporting year (2.60 thousand hectares), then in 2019 0.711 thousand hectares were reclaimed, which amounted to 13.1% of the area of mined land for this year (5.443 thousand hectares). The significance of land reclamation consists not only in restoring the vegetation and soil cover of the land, but also in increasing the region's biocapacity, which makes it possible to make up for the emissions of pollutants into the atmosphere. As a result of open-pit coal mining, the ecosystem of the steppe biome was almost destroyed (only fragments survived). In 2014, in order to reclaim mined land and restore the steppe ecosystem, PJSC Kuzbass Fuel Company started a test site on an area of 3 hectares on the dumps of the Vinogradovskiy open-pit mine in 2014. In 2020, at the Kedrovsky coal mine of JSC MC Kuzbassrazrezugol, work began on the creation of a test site for testing innovative technologies for bio-reclamation of mined lands.

Significant damage is caused to forest ecosystems. Thus, about 44 thousand hectares of forested land were transferred to coal mining companies, the area of agricultural land has decreased due to coal mining by 45.3 thousand hectares. Coal mining companies are forced to intensify their land reclamation works, to develop a system for accounting and calculating the capacity of CO_2 absorption by forests. In general, "Russia is the territory of the absolute carbon sink": carbon dioxide is absorbed by forests in the amount of at least 200 million tons of carbon per year [9]. Despite the fact that Kuzbass forests of accounts for 59.8% of the total land, agricultural land - 27.7%, and specially protected areas - 4%, for several decades, as coal production increases, the area of mined land (reaching 100 thousand hectares) and the proportion of non-reclaimed land in the region grow. Agricultural land is transferred to coal mining companies every year. As of January 1, 2021, coal miners owned (or leased) 2,480 hectares of land.

The ecological footprint in Kuzbass is greater than biocapacity of the territory. The area of forests to be restored increases annually, but only 75% of the lost trees are compensated. It is important to take into account the factor of forest degradation as a result of natural processes and anthropogenic impact. So, if trees are damaged but not cut down, then the carbon release is three times greater than when they are cut down. The Kuzbass Development Strategy 2035 sets the task to achieve a 100% level of compensation for damage caused to the forest by coal mining in the region by 2024, including through

afforestation. According to experts, 1 ha of pine forest absorbs 1-1.5 tons of CO_2 per year, 1 ha of poplar forest - 5-7 tons per year.

JSC Suek-Kuzbass began work on the creation of carbon farms and test sites. Together with biologists, work is underway to find tree species that absorb more carbon dioxide than pine trees. In addition, it is planned to monitor CO_2 absorption in a specially protected natural area "Kokuy swamp". Over the past five years, the company has reduced greenhouse gas emissions - from 1.620 million tons to 1.491 million tons. Work is underway to create "green belts" around the Kuzbass cities. Figure 5 shows a map of the parkland of Kemerovo (the space of the parkland is marked in green, the red line is the city boundaries).

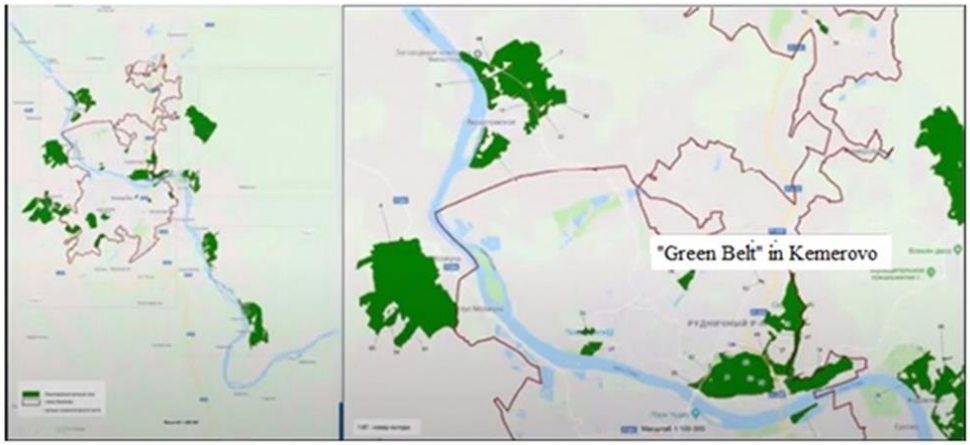


Fig. 5. Map of the "Green Belt of Kemerovo»

The impact of the growth in coal production on the growth of the areas of mined land in Kuzbass for the period 2013-2020 is presented in Table 2. The data are taken from official documents - Reports on the state and protection of the environment of the Kemerovo region - Kuzbass for 2013-2020.

Table 2. Impact of coal mining on the growth of areas of mined lands in Kuzbass for the period 2013-2019

Indicator	2013	2014	2015	2016	2017	2018	2019
Coal production per year, million tons	203.0	211.0	215.8	227.4	241.5	256	248.7
Area of mined lands per year, thousand hectares (*ML*)	2.60	2.028	2.976	3.171	5.01	1.076	5.443

As a result of comparing the indicators of the table, a direct linear relationship was found between the growth of coal production and the growth of mined lands, described by the regression equation Y_t^{ML} = 0,02 x -1,393. It follows from the regression equation that each additional million tons of coal mined leads to an increase in the area of mined land in the amount of approximately 0.02 thousand hectares = 20 hectares.

Considering that by 2035 Kuzbass plans to produce 427 million tons of coal annually, the area of mined lands in the region will only grow and will amount to 7.147

thousand hectares per year, with the state of things in the field of reclamation unchanged.

3 Conclusion

The coal industry is a key branch of the Kuzbass economy. The export orientation of coal mining in the region determines the growth of coal production. The transition of the world market towards a gradual decrease in the specific share of coal in the structure of consumed energy resources on European markets, in the USA and China, will be made up for by an increase in demand in India and other Asian countries. Today, coal mining in Kuzbass is extremely carbon intensive, which leads to disruption of ecosystems and landscapes, does not meet the challenges of the Climate Agenda 2030 and 2050. Maintaining the carbon balance in Kuzbass and reducing the carbon intensity of the region is possible through the use of the best available technologies in coal mining that do not harm the environment, reducing emissions of pollutants into the atmosphere by industrial enterprises, and carbon-dioxide absorption by carbon sinks.

Nowadays, mine reclamation management is not efficient and does not ensure biotic regulation of the environment. On the part of the state, conditions have not been created for the generation of demand from coal miners for reclamation services. However, there is a positive experience in the application of the technology of restoration of steppe and forest vegetation on dumps by coal mining enterprises in Kuzbass, the creation of carbon farms and test sites.

The interaction of regional authorities and coal miners with the involvement of the scientific community and environmental organizations contributes to solving new climatic problems of the development of the coal industry in Kuzbass by conserving and restoring forests, creating "green belts" around urban areas, restoring biodiversity and reclaiming mined land. The growth of coal production requires an increase in the level of environmental responsibility of license holders in the field of mine reclamation. With the global economy moving towards zero carbon, the socio-economic importance of mine reclamation for the development of the region is increasing. Reclamation is necessary to conserve, firstly, biodiversity and biocapacity of the region, secondly, provide the competitiveness of coal mining enterprises in the global coal and energy markets, and thirdly, contribute to the economic growth of the region in a low-carbon economy of the future.

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