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TECHNOLOGIES OF ALTERNATIVE COAL CONVERSION AND WASTE MANAGEMENT: GENERAL ASPECTS OF ECONOMIC EXPEDIENCY

In the global fuel and energy balance, the share of coal generation is about 40%. This is the cheapest source of energy for consumers: it is 3-10 times cheaper than other sources, for example, renewable energy sources in Russia now there are more than 600 licenses for the right to use subsoil for coal facilities, mainly in the Siberian and Far Eastern federal districts. The coal industry is the only one in the structure of the fuel and energy complex of Russia fully represented by private capital. In recent years, the Russian coal industry has been developing and increasing its volumes, primarily through the use of export potential (coal production in Russia for 15 years – from 2000 to 2017 – has increased by 58%, from 258.3 to 408.9 million tons, and exports – 3 times, from 60.7 to 186 million tons.

The study examines the current problems of creating conditions in the field of waste management of coal production in order to ensure their minimum release into the environment and to ensure as much as possible re-involvement in the material production of many types of waste from the coal industry.

The authors propose to use modern technologies for the processing of coal into products of higher quality and utilization of coal waste, which positively affect the quality of coal products and the resulting products from coal, contributing to the reduction of environmental pollution. Large coal companies consider environmental protection to be an integral part of their business approach. The key mechanism for the implementation of this policy is the program for the protection of the environment and the rational use of natural resources, as well as the program to reduce the risks of environmental impact.

Extensive development of the coal industry has almost exhausted itself, so it is necessary to bring coal as a basic component to new markets: chemical products, carbon materials. Coal is the beginning of a chain of high value-added products.

Keywords: *modern technologies, coal processing, coal production, coal waste utilization.*
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Introduction

The turn of the 21st century features the coal boom in the world. As forecasted by the International Energy Agency, the share of coal in the global energy balance will jump from 17 to 29% by 2030. Consumption of coal will grower faster as against other prime sources of energy. Despite the slack in domestic demand for coal and irrespective of coal displacement by gas, Russian coal will remain popular in the world as many developing countries suffering from energy deficit yet place stakes on coal as the most available energy source, even in the face of severe ecological constrains imposed on coal.

The coal industry is Russia possesses huge resources (3.8 trillion tons) sufficient for a long period of time (470 years), on the one hand. On the other hand, these resources are of low quality, which constricts their application range. At the same time, material constitution allows using this coal as process feed stock to be converted into products of any state of aggregation and purpose [1].

The critical factor for innovations in the coal industry is toughening of environmental standards placed on coal conversion technologies and coal products.

The best part of prime resources is irreproducible. This fact barely means that economic resources are limited in quantity. A jump in extraction of natural reserves unavoidably ends in production output commensurable with the volume of proved and even potential reserves. In such conditions, it is inevitable to decelerate and, perhaps, to reduce production, and to standardize use of the proved reserves in order to sufficiently support economics in the future. Moreover, an increase in extraction of crude reserves is associated with transition to lower grade reserve and, thus, to more capital-intensive mining. Accordingly, at a certain stage of economic development, the resource and investment constraints have decisive effect on production dynamics [2].

Increase in coal production output and waste

As seen in **Fig. 1**, coal output tends to growing as per the Central Dispatching of the fuel and energy sector. For instance, the output increased by 11.7 Mt or by 3% in 2016 as against 2015, and the shape of open pit mining made 79.9% in the overall production. In 2017, coal output reached 22.2 Mt or and an increase of 6% as compared with the previous year, while the open pit mining share in the overall production was 74.2%, which was 1.3% higher than in 2016 [3]. One of the major challenges for the coal industry in Russia is the absence of the domestic demand for coal and its displacement by gas. Coal takes around 15% in the overall fuel balance in Russia. Cheap and available gas is a strong rival.

The international markets places stringent requirements on coal quality (ash content 8–12%, sulfur content less than 0.5%, moisture content under 8–9%, heat value over 6000 kcal). In the structure of coal resources of categories A, B and C in Russia, commercial reserves off the international quality standards make about 30% [4].

Currently produced coal is mostly burnt by heat power plants. It is known that coal combustion at power generation plants is associated with considerable emission of carbon dioxide and with the greenhouse effect. Among fossil

fuels, coal is the most problematic in terms of the change of climate as coal has the highest content of carbon.

Russia uses coal to generate more than 20% of electric energy, to produce 100% of metallurgical coke and to satisfy 50% of needs of public utility industries and population [5]. More than 88.6 Mt of coking coal was produced in 2017, which was lower than in 2016 by 4 Mt or 4%. The share of coking coal in the total output was merely 22%.

The global intervention of man and technology in the nature in order to take mineral reserves has resulted in the colossal waste accumulation on ground surface. Mineral mining and processing produces tens million cubic meters of tailings and dumps. Coal dressing and conversion technologies are suitable for low-grade coal, which may considerably enlarge commercial reserves.

Construction and operation of coal mines and preparation plants exert multilateral attack on the natural environment.

Dynamics restrictions of facilities are to a great extent connected with constraints on resources and labor. For example, deceleration in manufacture of constructional materials immediately affects production output of assets-creating industries that define expendability of productive capacities in economy. Extensive build-up of productive capacities runs into restrictions governed by the conformity between the number of new jobs and the dynamics of human resources. Among other things, productive capacities require replacement when worn out or become obsolete.

Modern technologies of coal conversion

Specific environmental threat is produced by the overall impact of coal mining waste. The ecological challenges call for profound efforts to be undertaken; it is necessary to develop low-waste production based on the integrated use of mineral and energy by-products in surface and underground coal mines.

In 2017 production of concentrate reached 108.6 Mt (by 4.2 Mt or 4% higher than in 2016), including 58.4 Mt of coking concentrate (by 1.1 Mt or 2% less than in 2016). Production of coarse and medium size coal made 16.8 Mt in 2017 (by 1.7 Mt or 11% higher than in 2016), including 1.55 Mt of anthracite (by 400 thou t or 35% higher than in 2016). Furthermore, in 2017 machine-assisted picking devices processed 5.3 Mt of coal (by 1.03 Mt or 24% higher than in 2016). Coking coal is totally subjected to dressing, while only 30% of energy-generating coal goes to beneficiation (**Table 1**).

Proliferation of industrial solid waste processing plants and their capacity expansion will increase the state budget revenue (in the form of various taxes), i.e. its income and surplus (narrowing of budgetary gap), as well as will add to local budget receipts. Manufacture of construction materials from local industrial solid waste can contribute to solution of housing problem in sparsely populated areas lacking man power in the country [6–8].

The introduction of technologies of coal conversion to higher quality products and refuse coal treatment will level down environmental pollution.

The list of advance technologies improving quality of coal products should be added with washing, thermal briquetting and gasification.

Washing as a method of coal quality upgrading in terms of ash content is widely used in countries with the

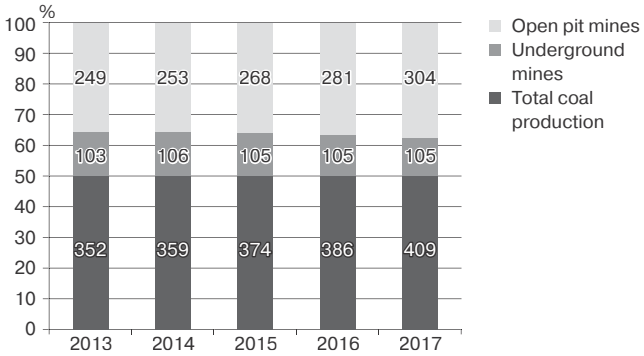

Fig. 1. Coal production dynamics in 2013–2017, million tons

Table 1. Coal conversion in Russia

Description	2017	As against 2016	
		%	+/–
Total coal conversion	191.2	+2.0	+4.6
including for coking	91.8	–2.0	–1.8

developed coal industry. The preparation plants in Russia recently convert 83 Mt of coal, which is 30% of total coal mining. As a result of washing, ash content is reduced to 8–10% in coking coal concentrate and to 20% in power-generating coal concentrate. Before washing, ash content is 27%. It should be emphasized that washing partly removes sulphide compounds (15–20%) with ash. Reduction in ash content of coal used by power plants has beneficial effect on ecology and economy [9, 10].

Regarding ecology, coal dust emission in the air is completely eliminated as dust it totally removed from furnace gas by electric filters.

Another effect of not less importance is contraction of charges for violation of ecological standards. Economically, production performance of users of fuel made of coal washed fro ash is improved. Regarding power plants, efficiency of primary equipment is enhanced, and fuel consumption per unit energy output is decreased while the hours of installed power utilization are increased.

Gasification of coal as the method of clean fuel production for power-generating plants has a long history with periods of jumps and decays. This is mostly governed by application ranges of the basic product of coal conversion—gas: from the source of lighting in urban stress to feedstock for various types of production. Technically, gasification is considered as either the method of production of process and high-heating gases to be used as feed and domestic fuel, respectively, or as the method of preparation (beneficiation) of multi-impurity coal (with high content of ash and sulfur) by converting such coal into gas cleaned from dust and sulphides [11, 12].

The second development trend in coal gasification is of practical significance for the most countries with high share of bituminous coal and lignite in the fuel reserve balance. This application range of coal should be developed in Russia as fuel reserves of power generation are dominated by multi-impurity coal. Combustion of such coal without preparation entails technological difficulties and ecological implications. Performance potential of gas production from coal is backed up with many technologies (Lurgi,

Koppers-Totzek, Winkler, Texaco processes). In Russia the technology of low-pressure fluidized-bed coal gasification has been developed. With this technology, at a pilot plat at the Moscow Coke and Gas Plant (Vidnoe) , experimental production of power generation gases was undertaken using Kans-Achinsk coal featuring high moisture content (35%), Moscow Basin coal with high content of sulfur (3.5%) and Ekibastuz coal with ash content to 50%. Gasification process of these coal types produced gas with combustion heat of 1200–1300 kcal/m^3, completely clean from dust and free from sulphides to 95%. Economics of clean gas utilization in power generation is also of concern, and determines preference of gas over other types of fuel.

Briquetting of coal improves ecological properties of furnace gases as against coal by sulfur fixation in ash residue. One of the methods to cheapen feedstock is production of mixed briquettes made of expensive coal grade added with cheaper coal, ore vice versa [13–16].

Major advantages of the products are: ecological leanness, high useful quality, solid competitiveness as compared with with other domestic fuel time, ample reserves for briquetting production as well as much lower cost as against foreign analogs.

Benefits of environmental management and sound use of natural resources is expressed in terms of annual economic effect. This index is obtained from comparison of the reduced cost of environmental procedures with their economical impact.

The economic effect evaluation should use current economic appraisals of land, water, forest and mineral resources. In case that such economic appraisals are undeveloped, the economic effect is determined based on the cost and expenditures of clean products; given such indices are absent, partial economic effect is allowed to be estimated based on the figures of prices, value added, profit return and cost. As fuel briquettes are made from coal waste (slime), the economic effect will include the decrease of pay for waste disposal. Arrangement of fuel briquetting from coal waste at low cost (200–300 Rub/t) will provide coal mining companies with extra profit and additional jobs. In this manner, reduction in cost of briquetted products should be connected with measures toward cheapening of coal feedstock.

Alongside with the economic efficiency of the introduce technologies, there is a social effect, namely, health effect. As of today, pollution charges are such low that companies prefer to pay penalties rather than invest in the nature-conservative measures. In connection with this, it is of the current concern to expand small- and medium-size business in coal slack and slime conversion into secondary feedstock in the form of briquettes meeting the modern standards of energy generation processes.

Of special ecological attractiveness is production of smokeless fuel Extracite manufactured from dressed anthracite with addition of inorganic binder. Extracite briquettes have high combustion effect and low ash content, produce no smoke and soot in burning, and offer comfort. These are carbonated brown coal briquettes. Thermal briquetting of batch mixture composed of coal with fly ash content not less than 15%, coke fines, oil coke and recycling solid waste allows solution to the problem connected with waste and mitigates ecological impact.

Conclusion

Currently coal production and coal-fired power generation waste is used insufficiently and out of accordance with composition of waste. As a result, much fuel is lost (methane, coal residue) alongside with valuable components (clay, limestone, alumina and iron oxide). In the meanwhile, modern technology and available experience allow using this type waste as extra source of fuel and feedstock for manufacturing of such products as bricks, fly ash aggregates, alumina, etc.

It is important to treat and utilize coal mining and processing waste both as an alternative source of raw produces to enlarge resources and reserves of the country, as well as from the view point of the environmental protection.

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