UPGRADE OF VALUE CHAINS AND THE EFFECT ON RESILIENCE OF RUSSIA'S COAL INDUSTRY AND RECEIVING REGIONS ON THE PATH OF ENERGY TRANSITION[1]

Keywords: resilience, resilience concept, resilience indicator, resilience in the Russian coal industry, value chains.

1. Introduction: Problems of resilience in the coal industry

Coal is a conventional energy source which is sufficiently popular in many countries and takes a considerable part in the global energy balance. Transition to renewable energy sources (solar, wind, bioenergy, etc.) and launching of alternative energy generation has weakened the role of coal as a source of energy. This fact induced reorganization in the coal sector in the form of large-scale closure of coal mines, reduction in coal production and consumption in advanced economies and growth in coal demand in less developed countries. The Paris Agreement and assumption of obligations by many nations to orderly reduce CO_2 emissions by means of technological modernization and climate change adaptation has abridged coal demand yet more.

At the same time, the coal sector faced such problems as instability of market economies, extreme volatility of coal prices and seller's market oriented at coal with strictly defined qualities. This affected incomings in the coal mining industry and made it exceptionally unstable. These problem are particularly acute in the coal-producing regions and countries (Table 1).

Table 1 - Coal production in TOP 10 countries (2009-2020).

		Coal production (million tonnes)			Growth rate per annum 2020/2019	Growth rate per annum 2020/2009	Share (2020)
		2009	2019	2020			
1	China	2903,4	3846,3	3902,0	1,2%	2,1%	50,4%
2	India	515,8	753,9	756,5	0,1%	3,1%	9,8%
3	Indonesia	240,2	616,2	562,5	-9,0%	9,2%	7,3%
4	US	1063,0	640,8	484,7	-24,6%	-4,1%	6,3%
5	Australia	408,0	504,1	476,7	-5,7%	1,8%	6,2%
6	Russian Federation	330,2	440,9	399,8	-9,6%	3,8%	5,2%
7	South Africa	252,2	258,4	248,3	-4,1%	0,4%	3,2%
8	Kazakhstan	111,1	115,0	113,2	-1,9%	1,3%	1,5%
9	Germany	192,5	131,3	107,4	-18,4%	-3,3%	1,4%
10	Poland	144,0	112,4	100,7	-10,7%	-1,8%	1,3%
Total World		7050,1	8133,4	7741,6	-5,1%	-1,4%	8133,7

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Source: BP Energy Outlook 2021

Russia is the world's sixth producer of coal. Transition of the global economy and energy engineering to the low-carbon development path decreases sharply resilience in the coal sector, i.e., capability to respond and adapt quickly to external impacts (in the short term), as well as to find and implement promising lines of development (in the long term) (The art and science of enterprise resilience, PWC, 2020). This both affects Russia's coal mining industry and leads to considerable social, economic and ecological risks in the country and in individual regions engaged in coal production.

The social and economic risks include: drop in the rate of economic growth, reduction in the personal income, budget cut and increase in the social inequality and tension. New ecological risks, which were unidentified during operation of coal mines, now can nullify advantage of the reduced environmental stress owing to coal mine closure. Such risks involve: pollution of groundwater and drinking water supplies; flooding, including populated areas; inflow of mine water from flooded mines to operating mines; uncontrolled gas release (methane, carbon dioxide) (Agapov, 2008; Rudakova, 2013).

Inoperative mines continue emit methane for many years after their closure. These emissions remain yet uncontrolled and unknown in many coal-producing regions in the world. Gas, accumulated in mined-out spaces, can, given certain geological conditions, come out to ground surface and pollute air in basements and premises, which is a repeated cause of explosions and injuries. Uncontrolled gas releases from closed mines were and are taking place in all coal-producing countries. For instance, in Kuzbass in the Kemerovo Region in Russia, methane explosion took place in a private house in 2019 as a result of methane liberation from underground openings of a mine which was closed 70 years ago. Provisional forecasts tell that the volume of methane collected in underground manmade voids can two–three times exceed the volume of methane released during coal mining over the whole period of mine operation, which is confirmed by the international practice. The forecasts of methane liberation from mines which are closed or in the process of being closed show that its volume has made 17 % of total methane release in mines in 2010 and can grow up to 24 % by 2050, which may greatly contribute to global warming.

In this respect, the future of the coal sector is connected with optimization of mining and with transition from coal export to eco-friendly production at high added value.

This paper aims to assess current resilience of the coal industry to stress and to define prospects for coal production optimization using high technologies pursuant to global challenges and requirements of energy transition.

2. Literature review

The notion of resilience was brought to the economic research from psychology in the early 1970s by Holling (Holling C.S., 1973). The science always exhibits a growing interest in resilience in the times of recession, i.e. the economic and political crises (Simmie, J.; Martin, R., 2010; Eraydin, A. 2016; Ezcurra R, Rios V. 2019). The economic research mainly addresses spatial resilience (Martin, R. and Sunley, P., 2015; Martin, R., Sunley, P., Gardiner, B. and Tyler, P., 2016). The studies into the resilience of companies and industries, including mining, are few in number (Mine 2021: Great expectations, seizing tomorrow, PWC 2021). Some recent researches attempt to relate industrial resilience with the prevailing chains of added value (Meller & Parodi, 2017, Pietrobelli et al., 2018; Kondratiev, 2018, 2019; Goosen E.V., Nikitenko S.M., 2019; 2020)

3. Data and methods

Our research is based on the resilience concept adapted to the coal industry. It is proposed to divide the coal sector into segments depending on the prevailing value chains (VC). Using the analysis of sequence of stages involved in creation of value and the intra- and inter-company interaction within the framework of the prevailing value creation chains, this approach allows revealing and comparing competitive advantages of companies which differ in structure, sources of profit and management methods, juxtaposing the ‘past’ and the ‘future’, detecting the most pervasive changes (VC upgrade) in the companies and predicting their ‘future’ situation (Park, Nayya et al, 2013; Dementiev, E.V., Ustyuzhanina, S.G. et al, 2018)

The empirical measurement of the resilience of coal companies uses the index of stability applied in the resilience assessment of a regional economy. Quite understanding the difference between the resilience of companies and regions, we think this index fits our purpose if based on the variation in the rate of growth in output of run-of-mine coal (Lagravinese, 2015; Faggian et al., 2018; Doran & Fingleton, 2016). The scope of the analysis embraced 92 companies operated over the period from 2011 to 2020. The reference sources are the databases of IAE, BP and Central Supervision Office of the Fuel and Industry Sector, as well as official corporate paperwork.

4. Results. Resilience of Russian coal companies and prospects for their VC upgrade

The accomplished research has shown that the coal sector of Russia is composed of four segments (groups of companies) clearly distinguishable by the criterion of resilience (response to external stress). The lowest level of resilience is 1, the highest level is 4 (Table 2).

Table 2 - Groups of coal companies by level of resilience

Level of resilience	The resistance and recovery indicators of groups	Number of companies	Share of companies (%)
1	Low resistance and slow recovery	29	32,58
2	Low resistance and fast recovery	15	16,85
3	High resistance and slow recovery	26	29,22
4	High resistance and fast recovery	19	21,35

Source: authors' calculations

Furthermore, four representative models of VC are identified in the coal sector. Their characteristics and resilience levels are compiled in Table 3.

Table 3 - Typical models of value chains in the Russian coal industry

Model of VC	Resilience Method	Example / Share in national coal production	Level of resilience
1. Open short market-type value chain	Work for the local market, narrow specialization, cost savings, often at the expense of security	Small independent mines and cuts (insignificant share)	1
2. Closed branched value chain	Consolidation of several small mines and cuts, around a trading company (trade center)	Raspadskaya coal Company (1 %);	1-2
3. Closed hierarchical value chain	Derived character of demand for coal. Distribution of income in favor of higher levels.	EVRAZ plc (4%); Mechel plc (4%)	3-4
4. Closed hierarchical value chain	Control of all main links from production to final consumption, redistribution of income	SUEK plc (20%); «Kuzbassrazrezugol'» plc (9%)	4

Source: authors' calculations

The tabulated data show that the least resistant are VC of the first and second types as they are the most susceptible to the risk of volatility of demand and prices, and have no capacities to control VC and to redistribute profit inside the chain. They extremely need modernization (upgrade). Upgrade of VC in the coal sector aims to lighten uncertainty of demand and prices, and to ensure a company's resilience by promoting flexibility of supply and expanding production scale owing to inclusion of products of allied industries in VC. Such effects are mostly intrinsic to the companies of groups 3 and 4. On the other hand, the companies of groups 1 and 2 are capable to remain on the market given certain governmental support. It is important that upgrade takes into account the present-day challenges of the companies.

The most promising lines of upgrading VC in the coal industry include:

- Elongation of VC owing to introduction of clean technologies of coal conversion and utilization;
- Creation of parallel VC by means of waste management;
- Branching of VC (conversion of a company's VC into a production network).

The upgrade effectiveness is governed in many ways by applicability of advanced coal processing technologies, usability of waste, expandability of production, entrance to non-rival markets and localization of new segments of VC in receiving regions.

The illustration of the first variant is introduction of low-profitable, flexible and clean technologies of dry coal preparation. This variant of VC elongation may also include introduction of supercritical steam generators in power generation. These generators both reduce CO_2 emissions and enhance efficiency of power plants—quantity of output energy of combustion–cost per one tonne. There is some case-history of such generators in the world. In the Arab Emirates, this technology was used to start-up the first block of Hassyan coal-fired power plant valued at USD 3,4 billion. The capacity of the plant is expected to grow up to 2400 MW by 2023. Furthermore, this approach enables preservation of the coal industry under conditions of energy transition and ensures energy security of a region (resilience) owing to differentiation of energy sources.

The second and third variants of VC upgrade may be illustrated by the low-temperature pyrolysis technologies. They make it possible to separate coal into gas fuel and carbonic residue, and reduce CO_2 emissions owing to transition to eco-friendly energy source (gas fuel) and production of carbonated coal, which allows producing clean smokeless high-calorific fuel instead of ash and slag. In case of such VC, alongside with the environmental effects, production scales up (trigeneration—simultaneous production of three useful outputs from coal). VC gets both elongated (deeper conversion of coal) and more flexible owing to the option of different combination of productions of these three outputs, and, also, it becomes better adaptable to shift in demand and price. Such type of VC is the most profitable when allocated directly in receiving areas, which enables overcoming of mono specialization in the regions and improves their resilience.

It is also important that upgrade of VC by means of formation of new high-tech inter-industry production networks within the framework of operating surface and underground mines can reduce social, economic and ecological risks associated with closure of coal mines.

Such promising route of VC upgrade is application of methanotrophic bacteria to produce protein to be used as feed-stuff in fish, poultry and cattle breeding, or in production of ferments, lipoids, sterols, antioxidants, pigments and polysaccharides.

Closed mines can use recovered methane as a clean energy source. Such approach allows improving safety, energy supply and ecology in a region. There exist methods of methane utilization from uncontrollable sources, including preliminary treatment and recovery of methane from air-and-methane mixture, or decomposition of methane to hydrogen and acetylene. Separated hydrogen is used in hydrogen fuel cells to generate power to feed the process of methane utilization and to supply external consumers. Experience of using such technologies is gained in Australia, Germany, Belgium, Poland, France and in some other countries.

One more promising area in formation of production networks can be carbon farming on ground surface above closed mines—green belts for increased absorption of carbon dioxide using special technologies, and to produce carbon units for enterprises, which manufacture not carbon-neutral products, to balance their greenhouse gas emissions. The studies implemented in carbon farming test grounds with different terrain show that one hectare of area can absorb up to 7 tonnes of carbon. And the 1 tonne carbon absorption cost is less than USD 3 in this case.

Conclusions

Despite the recent paradigm of carbon-free energy generation, it is possible to preserve the coal mining industry using the differentiated approach to upgrade of value chains based on novel flexible technologies with regard to specificity of mining companies. The value chains can be formed in operating coal mines. Later on, it will be possible to create different industries to produce ecological products based on the operating VC.