# Modeling the Development Prospects of the Coal Industry of Russia and its Regions

A.D. Sokolov, L.N. Takaishvili*

Melentiev Energy Systems Institute of Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia

***Abstract* — The paper is concerned with the approach to modeling the development prospects of the Russian coal industry. A brief overview of the simulation modeling experience is given. A profile of the Russian coal industry and its specific features are given as an object of research. A research workflow is provided. The hierarchy of levels of studying the Russian coal industry and the system of models corresponding to these levels are shown. The system of models is represented by optimization and simulation models corresponding to various hierarchical levels (Russia as a whole, federal districts, federal subjects, and companies). Separate optimization models have been developed to make projections of the development of production, consumption, and supply of steam and coking coal. Consumer costs of coal purchase and transportation are minimized provided that a given demand for coal and other constraints are met. The simulation models are of four types, corresponding to different levels of hierarchy and aspects of consideration. An aggregated diagram of the relationships between the models is studied. We detail the most frequently used types of models that either represent the last option for certain studies or are typical of a given category. To fit each study, either previously developed models were adjusted or new ones were developed. References to the studies carried out using the tools covered in this paper are provided.**

***Index Terms* — Russia, coal industry, modeling, hierarchy, a system of models, research workflow, optimization model, a simulation model.**

* Corresponding author.
E-mail: luci@isem.irk.ru

http://dx.doi.org/10.25729/esr.2019.02.0008
Received August 18, 2019. Revised September 11, 2019.
Accepted November 5, 2019. Available online January 25, 2020.



## I. Introduction

Modeling the development and operation of the coal industry is presented in the research published in Russia and other countries [1-2 2]. Models were developed to study the prospects for the entire industry, coal-mining regions, and companies. A significant number of publications are concerned with modeling of various aspects and conditions affecting the development of coal mining, i.e. hazardous seismic conditions [ 5 ], hydrological conditions [ 18, 19 ], coal consumption and coal prices [ 22 ], and others.

In their studies of the development prospects for the coal industry, the scholars in Russia and elsewhere most frequently use optimization and simulation models [1, 3, 15, 17], and also logistic, static, and dynamic models [2].

The experience accumulated in Russia in the field of modeling the development of the coal industry spans 70 years [11-17]. The Energy Research Institute (ERI) of the Russian Academy of Sciences has developed a system of simulation models that enables one to identify the most efficient directions of the industry development based on the projected scenarios of the development of the Russian economy [12]. The Melentiev Energy Systems Institute of the Siberian Branch of the Russian Academy of Sciences has investigated and projected the development of the national and regional coal industries as part of the energy sector for over 50 years [ 2 1]. These studies rely on optimization and simulation models. A research workflow that takes into account the specific features of the Russian coal industry has been developed, and a system of models, software and information support [16,17,23] have been implemented.

The hierarchical approach, also known as the integrated approach, allows considering the coal industry in interaction with other industries of the economy, at the level of individual regions and companies within the model. It is widely used in modeling the development of the coal industry in various countries [1,3,6,7,21]. Multiple links between the coal industry and other industries of the economy and the internal structure of the industry are most comprehensively taken into account in the coal market module of the U.S. National Energy Modeling System (NEMS) [1]. The Russian government, unfortunately, does not have a tool of this kind.

The conditions for the development of the coal industry vary significantly from country to country. These are social and economic situation; the development of transportation system; the tariff policy for coal transportation; competition with other energy resources (gas, hydropower, etc.); mining and geological, hydrological, and other conditions of coal production. The difference in quality characteristics of coal leads to their use in a variety of fields, the main of which are energy, by-product coke production and, in the long run, the coal chemistry sector. One of the essential features of the Russian coal industry is a large share of the exported coal. In 2018, it accounted for more than 50% of total coal supplies [2 4].

This paper presents an approach to modeling the development of Russia's coal industry and a system of models that take into account the specific features of the coal industry. Both of the above have been developed with the participation of the authors at the Melentiev Energy Systems Institute, SB RAS.

## II. Russia's coal industry as an object of study

Modern science views the national coal industry as one of the energy systems that possess certain properties [14, 25]. Such properties of the coal industry as its structural complexity, scale, inertia, dynamism, pro-active nature and limitedness (balance reserves, resources, demand, interchangeability of the product, etc.) predefine the complexity of building the models of the coal industry operation and arranging a computational experiment.

The Russian coal industry, as an object of modeling, is characterized by the following:

- a large number of components, the numerous relationships between which are rather difficult or impossible to define by an analytical function;
- constraints on the resource base, transportation, and other resources, including those related to regional features of coal production and consumption;
- a large number of technical and economic indicators to be factored in;
- a high degree of uncertainty inherent in the projection of economic development scenarios, based on which the demand for coal is calculated, the constraints on the development of the industry are set, and other indicators necessary for research;
- the effect of various factors on the development of the coal industry, which are difficult to consider analytically.

Coal is the marginal fuel, the consumption of which increases or decreases depending on climatic conditions. Coal consumption also depends on whether or not the transportation infrastructure operates or it is constructed

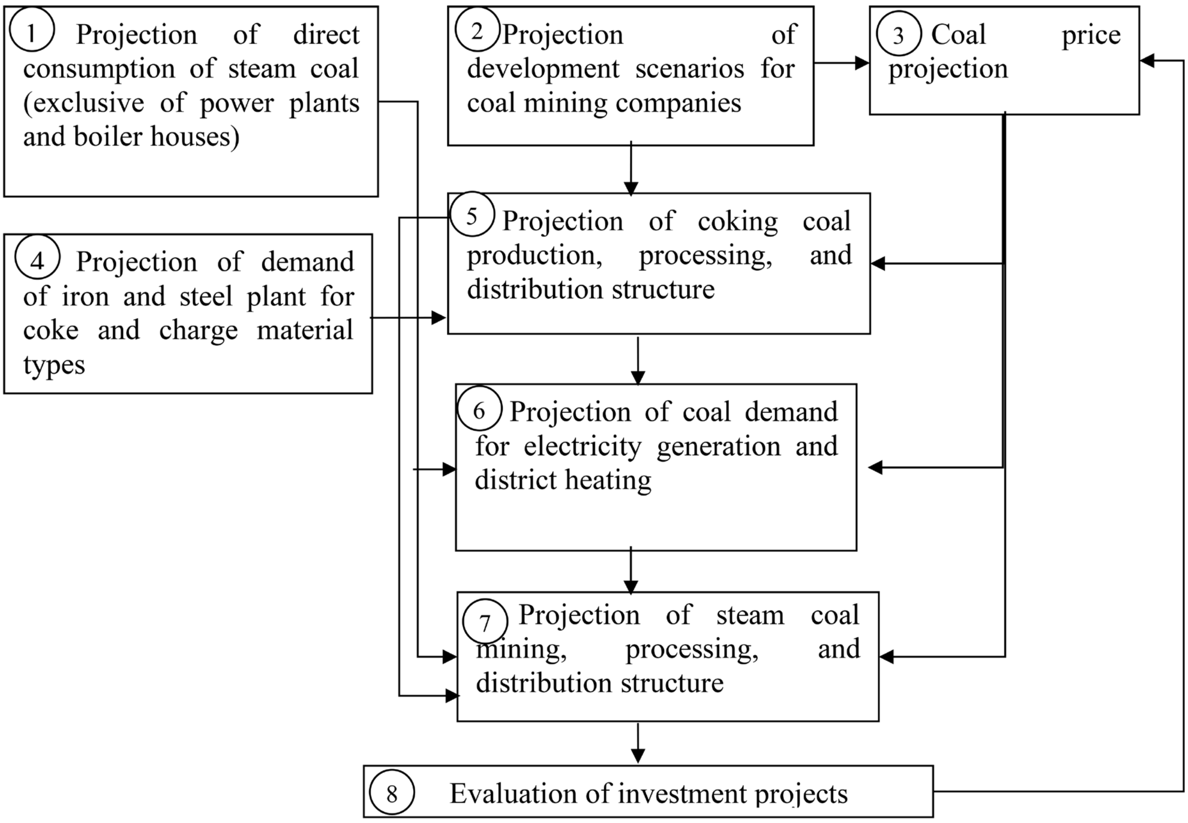


*Fig. 1. The workflow of the coal industry development study*

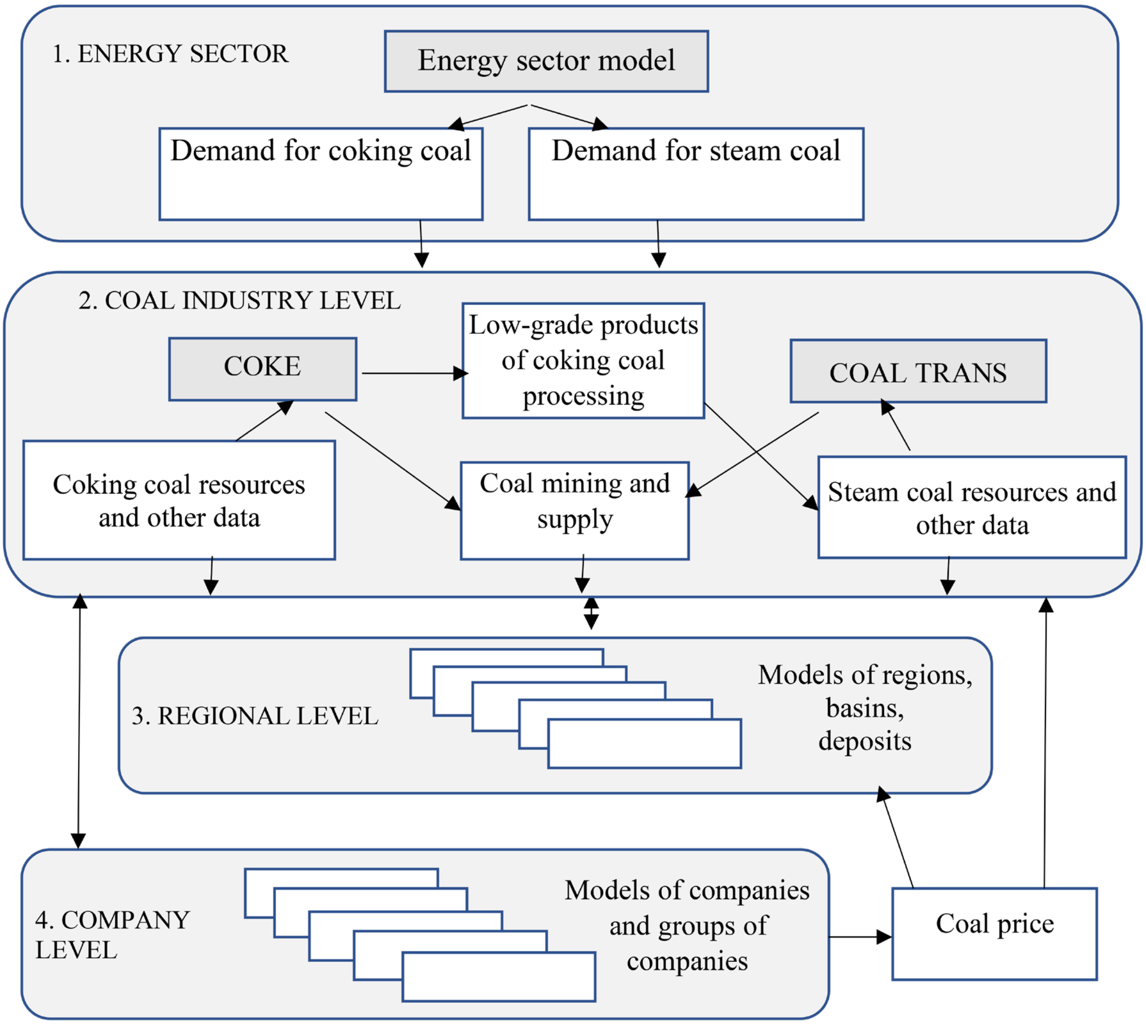


*Fig. 2. An aggregated diagram of hierarchical levels and relationships between models in the system of models.*

for the implementation of new coal-mining projects. Among the climatic conditions, the most significant effect is due to cold/warm winters and water content of rivers that determine the hydroelectric power plant output in the regions where the hydropower industry is developed.

One of the options to overcome the complexity of the structure, including the existence of multiple links and poorly structured problems in large energy systems, is to construct them using the principle of hierarchy. Hierarchical (multi-stage, multi-step) modeling implies using a hierarchy of mutually complementary models to make a projection of the development and operation of the coal industry.

## III. A Workflow of the Research into the Coal Industry Development in Russia and Its Regions

Making projections of the coal industry development involves solving the following range of problems:

- assessment of resources and possible volumes of coal production;
- projection of coal demand;
- projection of coal price;
- projection of coal production volumes;
- projections of volumes of inter-regional coal supplies;
- an economic evaluation of investment projects for the development of coal-mining companies.

The above problems are interrelated. The sequence of solving them forms a workflow for studying the development of the coal industry (Fig. 1).

The problems of studying the industry can be described as poorly structured and multi-criteria problems. Poorly structured problems are the problems whose solving process apart from the well- known formalizable procedures also contains components characterized by uncertainty and heterogeneity inherent in them. Formalization of such problems is challenging and they are similar to unstructured ones in terms of the effort to be made by experts. They require human participation to arrive at the most preferable solution. Four levels of the hierarchy have been identified to study the development of the Russian coal industry:

1. the energy sector of Russia;
2. the coal industry of Russia;
3. regions (federal districts and federal subjects);
4. companies (coal-mining and coal-processing companies).

## IV. A system of models for researching the coal industry development in Russia and its regions

The system of economic and mathematical models has been developed and used to solve the problems corresponding to different hierarchical levels (Fig. 2):

1. A model of the energy sector development (optimization of the territorial and production structure of the regional energy sector);
2. Models of the development of the coal industry of the country and its regions (optimization of production, inter-regional supplies, and the use of steam coal [COAL TRANS] and coking coal [COKE] by consumers);
3. Simulation models of regions and coal basins;
4. A model of financial and economic analysis of investment projects of coal mining companies and groups of companies.

Mutual alignment of solutions to the above problems can provide an optimal solution to the entire initial problem. Depending on the problem statement, the models can be used jointly or independently. Several problems can be solved using one model.

At the levels of the energy sector and the coal industry, the computational experiment is carried out with the models stated in the form of linear programming problems. The objective function, as a rule, contains financial and economic indicators.

The models used at the levels of individual regions and companies are simulation models.

The energy sector development model is designed to study the dependence of the main parameters of the Russian energy sector development on the level of energy consumption, the extent to which the territories are provided with primary energy resources, etc. for the time horizon of 10-25 years. The energy sector model is used to determine the demand for coal for electric power generation and district heating.

The coal industry development model COAL TRANS is designed to make projections of the structure and volumes of inter-regional supplies of steam coal for the case of changes in prices, transportation tariffs, coal demand and possible constraints on supply volumes. This model quite comprehensively considers the geographical administrative division by distinguishing between over 80 coal consumers in the corresponding federal subjects (territories, regions, and republics) and over 30 suppliers of brown coal and hard coal, and the established supply chain.

The model is built as a linear programming problem. Consumer costs for the purchase and transportation of coal are minimized for a given coal demand by individual federal subjects and available coal resources. The quality of coal is factored in through the heating value and the demand for mandatory supplies. The coal-fired power plants in Russia were designed for a certain quality of fuel or coal from certain deposits, which affects the supply chain. The consumer price is calculated given the current tariff policy for coal transportation, the distance from the site of production to the consumer, and other parameters.

To analyze the development prospects of the coal industry, the results of calculations obtained for the federal subjects and individual companies are aggregated by federal districts, areas of use, mining methods, etc.

The COKE model of the development of coking coal production and consumption is similar to the COAL TRANS model.

The COKE and COAL TRANS models are designed to project the structure and volumes of inter-regional coal supplies for the case of price changes. These models have a similar structure but differ in some parameters. The need to develop individual models is primarily due to significant differences in the calculation of the demand for coking and steam coal, the units of measurement, and the supply chain. In the COKE model, coal is delivered to by-product coke plants, while in the COAL TRANS model the destination is federal subjects. The demand for coking coal at by-product coke plants depends on the composition of coal charge as per coal grades. The coal charge at the Russian by-product coke plants can contain both domestic and imported coking coal grades. The model takes into account the specific features of coking coal mining and processing. For process reasons, mines and open-pit mines can produce several grades of coking coal and run-of-mine steam coal. In the process of coking coal preparation, coke concentrate and low-grade processed products are produced, which are suitable for use only as an energy fuel (Fig. 2). Steam coal resources are formed from steam coal resources proper and coal resources derived from coking coal processing at coal-preparation plants and accompanying steam coal production during coking coal mining. A significant amount of coal mined in Russia is exported [23]. The models allow determining coal resources available for export. The most exported product is coal concentrate. The constraint on resources for coal export is a lack of demand for low-grade products of coal processing in the energy industry.

When modeling the development of the coal industry, it is difficult to take into account the entire set of factors affecting the development of the properties of facilities and links to consumers, including transportation. Optimization models provide projections that need further refinements. Simulation models are the most suitable for refining the solutions. The final solution is obtained with the direct participation of an expert, which allows considering most features of the operation and development of coal production, processing, and consumption.

The specifics of scientific research are such that practically for each of the above processes respective simulation models had to be developed based on the previously developed ones. Lack of opportunity to create tools for simulation models with fixed input and output is due to significant differences (uniqueness) in coal industry facilities; uncertainty inherent in the available source data; the unpredictability of the volume and algorithm of provisional calculations of performance indicators.

Table 1. Characteristics of simulation models.

| Model | Level of detail | Coal market participants | Result |
|---|---|---|---|
| INVEST COAL<br>1) Direct problem<br>2) Inverse problem | Enterprise or company | Technical and economic performance indicators of the project | 1) Efficiency indicators<br>2) Coal price or other indicators |
| BALANCES | **Coals**, FD | Groups of companies* | Projection of demanded coal production and delivery in the country and FD |
| REGIONAL BALANCES | **Coals**, FSs, coal-mining companies, deliveries, exports | Consumers: FDs, export | Projection of demanded coal production, schemes and volumes of coal supply, and coal balances for FSs and FDs |
| FEDERAL SUBJECT | Companies, coal-preparation plants, marketable products, FD areas | Coal-mining companies | Projection of demanded coal production and processing in FSs, coal deliveries to RF regions, and coal balances in FSs |

Four types of simulation models have been implemented, each corresponding to different hierarchical levels and aspects of consideration (Table 1).

The INVEST COAL model is designed to evaluate the economic performance of the operation and development of a company or a group of companies. This model can also be used to solve the inverse problem, i.e. the determination of the coal price or other indicators for a given performance indicator. The model calculates the pre-tax profit; net profit; product profitability and cash flow; and proceeds from the sale of products. Coal production costs include electricity, heat, materials, and labor costs; depreciation; taxes; industrial services; loan interest, and other costs. The indicators that serve as criteria include current account status; discounted current account; net present value; profitability index; product profitability; internal rate of return, and payback period. To improve the reliability of the estimates obtained, a stability analysis is performed, which is a calculation of the dependence of the summarizing financial and economic indicators on certain changes in the initial parameters of the project.

The simulation models “BALANCES”, “REGIONAL BALANCES” and “FEDERAL SUBJECT” differ in their level of detail and some other aspects, without significant differences in their structure. They contain three functional modules: "Production", "Consumption", and "Coal Balances"(Fig.3). Models of the same type created for specific studies differ depending on the composition of the information available and the objectives of the study. Depending on the level of detail, the market participants are types of coal, coal mining and coal processing companies, and regions. Supply volumes and transportation costs represent links between market participants. Coal supply and consumption are projected given the established trends

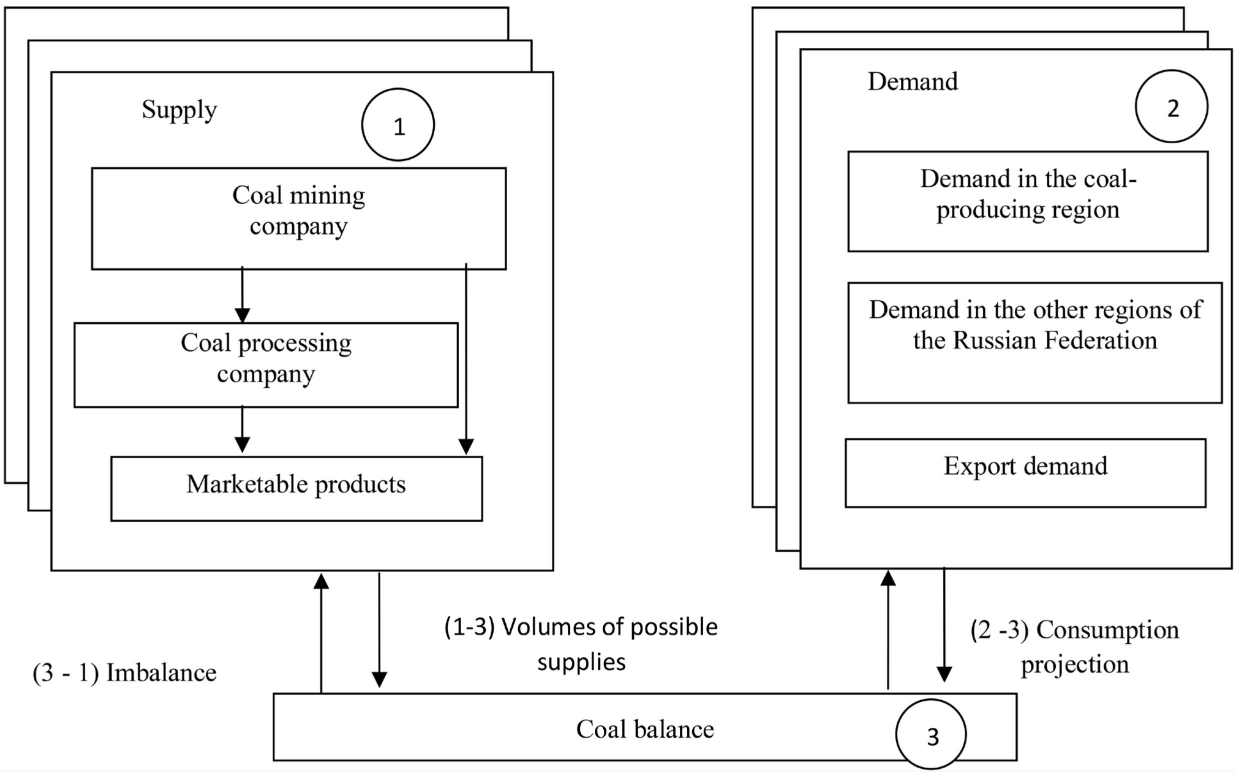


*Fig. 3. Structure of the “balances”, “regional balances”, and “federal subject” models.*

in coal supply and consumption.

The "BALANCES" model allows projecting the demand for and supply of coal outside the region based on the potential coal mining opportunities and coal demand.

The "REGIONAL BALANCES" model supplements the COAL TRANS optimization production and transportation model of the Russian coal industry, and the "BALANCES" model.

The FEDERAL SUBJECT model is intended for the study of the coal industry development at the level of a federal subject. It provides most completely the details of the indicators for coal-mining companies, coal-preparation plants, consumption of certain coals in the context of the federal subject given its division by any features it has (administrative, transport accessibility, etc.), and so on.

To research the development prospects of the coal industry, an information and model system has been developed, which includes an information system [ 2 3], a system of models [ 16, 1 7], projections of constraints and conditions of prospective development, and programs for building models and processing calculation results. The composition and structure of the system take into account the hierarchy of models for the study of the development prospects for the coal industry, corresponding to the second, third, and fourth levels of the hierarchy.

Dual estimates in the LP problem determine the marginal coal prices.

The models make use of the indicators, the main of which are:

- projections based on individual economic development scenarios: demand for coal; constraints on steam coal resources; constraints on the production of steam and coking coal;
- estimates of the opportunities for the development of coal mining companies;
- quality characteristics of coal;
- technical and economic performance indicators of companies;
- data for calculating resource requirements, such as capital expenditures, electricity, heat and labor, and corresponding specific indicators;
- the existing coal supply chain;
- historical data on coal supply and consumption.

The results of the calculations are consistent with the historical data. They contain projected indicators in the form of tables (with varying degrees of detail for different models) in the context of the administrative division of the country and its regions:

- potential opportunities for the development of coal mining and possible volumes of export quality coal production;
- volumes of coal supplies, including those for export;
- volumes of demanded coal production, including those by individual company;
- potential coal resources for the energy industry;
- new capacity additions in the coal industry;
- coal processing volumes;
- output of marketable coal products;
- balances of coal in general and steam coal in particular;
- the demand for resources to maintain and develop coal production: capital expenditures; labor power; electricity and heat;
- directions of the coal industry development (new construction projects, capacity expansion);
- the structure of production (surface mining vs. underground mining; brown coal vs. hard coal; steam coal vs. coking coal) and processing;
- tables and charts to be used in printed matter.

## V. Conclusion

The hierarchical approach to the studies of the coal industry development in the country and its regions using the presented system of models allows considering different aspects of the coal industry development, solving many interrelated and stand-alone problems with different development criteria, which would otherwise be difficult to reduce to a single model. The use of simulation models, in addition to optimization models, enables experts to consider the variables that are difficult to factor in analytically. In different years, the presented models were used to make projections of the development of the coal industry of the country, Eastern Siberia, the Far East, and individual federal subjects (Republic of Sakha; Amur, Sakhalin and Irkutsk regions; Chukotka Autonomous Okrug; etc.) [26-3 3].

## Acknowledgements

The research was carried out as part of the scientific project XI.174.2. of the program for basic re-search of the Siberian Branch of the Russian Academy of Sciences, reg. No. AAAA-A17-117030310435-0.

## References

[1] Coal Market Module of the National Energy Modeling System: Model Documentation 2018/ U.S. Energy Information Administration June 2018. 41 p. [Online]. Available: https://www.eia.gov/outlooks/aeo/nems/documentation/coal/pdf/m060(2018).pdf.

[2] Steve Mohr, Mikael Höök, Gavin Mudd, Geoffrey Evans Projection of Australian coal production - Comparisons of four models/ Paper presented at International Pittsburgh Coal Conference 2011/ [Online]. Available: https://www.researchgate.net/publication/286295507_Projection_of_Australian_coal_production_-_Comparisons_of_four_models.

[3] Wojciech Suwala. Modeling Adaptation of the Coal Industry to Sustainability Conditions. Energy, Volume 33, Issue 7, July 2008, Pages 1015-1026 [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0360544208000662.

[4] M.D. Budeba, J.W. Joubert, R.C.W. Webber-Youngman. A Proposed Approach for Modeling Competitiveness of New Surface Coal Mines /

November 2015, Journal of the Southern African Institute of Mining and Metallurgy 115(11):1057-1064, DOI: 10.17159/2411-9717/2015/v115n11a10.

[5] Bogucki, R., Lasek, J., Milczek, J.K., Tadeusiak, M.: Early Warning System for Seismic Events in Coal Mines Using Machine Learning. IEEE Federated Conference on Computer Science and Information Systems (FedCSIS), pp. 213–220 (2016) [Online]. Available: https://arxiv.org/pdf/1609.06957.pdf.

[6] Syed Aziz Ur Rehman, Yanpeng Cai, Rizwan Fazal, Gordhan Das Walasai and Nayyar Hussain Mirjat. An Integrated Modeling Approach for Forecasting Long-Term Energy Demand in Pakistan. November 2017. 23 p. [Online]. Available: https://www.researchgate.net/publication/321089708_An_Integrated_Modeling_Approach_for_Forecasting_Long-Term_Energy_Demand_in_Pakistan.

[7] Energy Forecasting and Modeling [Online]. Available: https://www.enerdata.net/brochure/energy-forecast-models-consulting-brochure-enerdata.pdf.

[8] Strager M.P., Strager J.M., Evans J.S., Dunscomb J.K., Kreps B.J., Maxwell A.E. (2015) Combining a Spatial Model and Demand Forecasts to Map Future Surface Coal Mining in Appalachia. PLoSONE 10(6): e0128813. DOI: 10.1371/journal. 26 p. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4474888/pdf/pone.0128813.pdf.

[9] Yanbin Li and Zhen Li. Forecasting of Coal Demand in China Based on Support Vector Machine Optimized by the Improved Gravitational Search Algorithm. Energies 2019, 12(12), 2249; https://doi.org/10.3390/en12122249 [Online]. Available: https://www.mdpi.com/1996-1073/12/12/2249/htm.

[10] M.R. Betz, M.D. Partridge, M. Farren, L. Lobao. Coal Mining, Economic Development, and the Natural Resources Curse. Energy Economics 50, Coal Mining, Economic Development, and the Natural Resource Curse, August 2014, pp. 105-116 [Online]. Available: https://mpra.ub.uni-muenchen.de/58016/3/MPRA_paper_58016.pdf.

[11] Tsvetkov N.I. Using the Mathematical Modeling Method at the Complex Design of a CoalField. - Ugol' (Coal), 1967, No. 2, pp. 10-15. (in Russian).

[12] Plakitkina L.S. Simulation Models to Predict the Coal Industry//Proceedings of the Russian Academy of Sciences. Power Engineering, No. 3, 2010. pp. 162-175. (in Russian).

[13] Churashev V.N, V.M. Markova. Development and Transformation of Modeling Industrial Subsystems of FEC: Evolution, Hierarchy, Trends, Scenario Conditions, System modeling and analysis of meso- and microeconomic objects / Ed. by Kuleshov V.V., N.I. Suslov; Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences. - Novosibirsk, 2014. - Ch. 3.1. pp. 112-115. (in Russian).

[14] System Research in Power Engineering under New Social and Economic Conditions / V.P. Bulatov, N.I. Voropai, A.Z. Gamm, et al. Novosibirsk: Nauka, RAS, Siberian Publishers, 1995. 189 p. (in Russian).

[15] N. Pavlov, N. Petrov. Coal Industry of the Republic of Sakha (Yakutia): Tools and Forecast. Paper 03002. January 25, 2019. DOI: https://doi.org/10.1051/e3sconf/20197703002.

[16] L.N.Takaishvili. Simulation Models to Study the Development of the Coal Industry as Energy Sector Component. Research paper 02004. January 25, 2019. DOI: https://doi.org/10.1051/e3sconf/20197702004.

[17] Agafonov G.V., Sokolov A.D, Takaishvili L.N. Modeling of Coal Industry Development/ Proceedings of RAS. Power Engineering. 2011.No.6, pp. 159-165. (in Russian).

[18] Zégre N, Miller A, Maxwell A, Lamont S. Multi-scale Analysis of Hydrology in a Mountaintop Mine-impacted Watershed. Journal of the American Water Resources Association. 2014. DOI: 101111/jawr12184.

[19] Bonta J.V., Amerman C.R., Dick W.A., Hall G..F, Harlukowicz T.J., Razem A.C., et al. Impact of Surface Coal Mining on the Three Ohio Watersheds–Physical Conditions and Ground-water Hydrology. Journal of the American Water Resources Association. 1992; 28 P. 577–596.

[20] Merriam E.R., Petty J.T., Strager M.P., Maxwell A.E., Ziemkiewicz P.F. Scenario Analysis Predicts Context-dependent Stream Response to Landuse Change in a Heavily Mined Central Appalachian Watershed. Forest Science. 2013; 32(4):1246–1259.

[21] Makarov A.A., Melentiev L.A. Methods of Research and Optimization of the Energy Sector. - Moscow: Nauka, 1973.

[22] Shumin Jiang, Chen Yang, Jingtao Guo, Zhanwen Ding. ARIMA Forecasting of China's Coal Consumption, Price and Investment by 2030// Energy Sources, Part B: Economics, Planning, and Policy, Volume 13, 2018. Issue 3. https://doi.org/10.1080/15567249.2017.1423413.

[23] Sokolov A.D., Takaishvili L.N. Implementation of the Software to Forecast Coal Industry Development in Russia's Regions. State-of-the-art Technologies. Systems analysis. Modeling. No. 1(41). pp. 126-133. (2014). (in Russian).

[24] Tarzanov I.G. Results of the Coal Industry Operation in Russia for 2018, Coal, 2019. No. 3, p. 36-51. DOI: http://dx.doi.org/10.18796/0041-5790-2019-3-64-79.

[25] Takaishvili L.N. Factoring in the Properties of the Coal Industry as an Energy Sector System when Modeling its Development, Proceedings of Irkutsk State Technical University, Vol. 21, No. 10 2017 P. 138-149. DOI: 10.21285/1814-3520-2017-10-138-149. (in Russian).

[26] L.N. Takaishvili, A.D. Sokolov. Coal Industry of East Siberia - Prospects for Development. Paper 03001, January 25, 2019. DOI: https://doi.org/10.1051/e3sconf/20197703001.

[27] Sokolov A.D., Takaishvili L.N., Muzychuk S.Yu. Coal in the Fuel and Energy Balance of the Irkutsk Region, Proceedings of Irkutsk State Technical University. 2017. Vol.21. No. 12 P. 185-194. http://dx.doi.org/10.21285/1814-3520-2017-12-185-194. (in Russian).
[28] Sokolov A.D., Takaishvili L.N., Petrov N.A., Pavlov N.V. Coal Industry of the Republic of Sakha (Yakutia): its Current State and Development Prospects, Proceedings of Irkutsk State Technical University. 2010. No. 4 (44). P. 64–69. (in Russian).
[29] Sokolov A.D., Takaishvili L.N. Coal Industry of the Baikal Region: its Current State and Development Prospects, Proceedings of Irkutsk State Technical University. 2012. No. 12 (71). P. 112–118. (in Russian).
[30] Sokolov A.D., Takaishvili L.N. Development Trends in the Coal Industry of the Eastern Regions of Russia as a Component of the Energy Sector for the Future, Proceedings of Irkutsk State Technical University. 2016. Vol. 20. No. 11. P. 157 - 169. DOI: 10.21285/1814-3520-2016-11-157-169. (in Russian).
[31] The Energy Sector of the Baikal Region: its Current State and Development Prospects / Ed. by B.G. Saneev; Russian Academy of Sciences, Siberian Branch, Melentiev Energy Systems Institute. Novosibirsk: Academic publishing house "Geo", 2015. 176 p. (in Russian).
[32] The Eastern Vector of the Energy Strategy of Russia: its Current State and Future Outlook / Ed. by N.I. Voropai, B.G. Saneev; Melentiev Energy Systems Institute. 2010. 25 printer's sheets. (by the publishing house "Nauka" of the Siberian Branch of the RAS)]
[33] The Energy sector of the Irkutsk Region: its Current State and Development Prospects/ed. by B.G. Saneev, P.A. Voronin. Moscow: Publishing House "Energiya", 2013. - 304 p.

**Alexander Sokolov** received D. Sc. degree in engineering from the Melentiev Energy Systems Institute of the Siberian Branch of the Russian Academy of Sciences in 2006. Currently, he is a chief researcher and the head of the Laboratory of the Energy Sector of Siberia and the Far East at the Melentiev Energy Systems Institute SB RAS. His research interests include the studies and modeling of the development prospects of the energy sector industries.

**Liudmila Takaishvili** received a Ph.D. in engineering from the Melentiev Energy Systems Institute of the Siberian Branch of the Russian Academy of Sciences in 1991. Currently, she is a senior researcher at the Melentiev Energy Systems Institute SB RAS. Her research areas include the studies of the coal industry development prospects and the development of software and information support for these studies.