Specific features of the energy sector in Russia's eastern regions and their influence on shaping the Eastern direction in the new geopolitical landscape

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Abstract. The paper presents an analysis of regional features of energy systems in the eastern regions of Russia. The analysis aims to identify their effect on the development of the territorial and production structure of the energy sector, energy consumption, the transportation infrastructure, the export of energy resources to the countries of the Asia-Pacific region, and the efficiency of energy supply to consumers in the off-grid and hard-to-reach territories. Several categories of features are distinguished for the regional energy systems in the eastern regions of Russia. These are socio-economic, infrastructural, sectoral, environmental, and climatic. All these features are interrelated and require consideration when building the energy development scenarios, in particular those with a focus on the transition to low-carbon technologies.

1 Introduction

The studies on the development of the energy sector in the eastern regions of Russia, considering the trends in the technological advancements in the country's fuel and energy industry, are complex and comprehensive. In the face of new challenges related to the geopolitical situation and sanctions pressure on Russia, the role of the eastern regions gains particular importance. At present, the conditions of energy and fuel supply to consumers in the eastern regions of Russia have their specific features, which are due to the harsh climatic conditions of the territories, the increased need for heat and electricity, as well as the presence of rich reserves of fuel and energy resources. The energy industry of the eastern regions has a significant resource potential, which enabled the establishment of a large fuel and energy base of Russia here.

One of the global modern challenges is the transition to a low-carbon economy both in Russia and in many countries of the world. In this regard, Russia has developed a Strategy for the socio-economic development of the Russian Federation (RF) with a low level of greenhouse gas emissions until 2050 [1]. According to this strategy, Russia has assumed obligations to reduce greenhouse gas emissions by 2030 to 70% of the 1990 level, taking

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into account their absorption by the ecosystems. In order to fulfill these obligations, it is crucial to swiftly implement measures that will restructure the production framework in the national economy with a focus on the energy sector, since it is the primary source of greenhouse gases into the atmosphere. According to the National Report on the Inventory of Anthropogenic Greenhouse Gas Emissions [2], up to 80% of total greenhouse gas emissions enter the atmosphere from the energy sector. In order to formulate proposals and strategies for decarbonizing Russia's energy sector, it is essential to analyze the distinct regional features of the energy systems in the eastern regions of Russia and evaluate their influence on the formation of the Eastern direction of the country. A thorough analysis of the unique regional features of the country's energy sector makes it possible to identify problem areas and limitations in its development. Moreover, it helps outline the primary strategies and actions required to transition towards low-carbon energy development.

2 Socio-economic and structural features

The socio-economic features of the eastern regions include a low density of settlement over the territory, when 17.2% of the total population of Russia lives on an area of 11.3 million km2, which is 66.1% of the country's area.

A rich mineral resource base contributes to the growth of production of all types of energy resources. These regions produce 96% of the country's coal, 15.6% of oil, 8.5% of natural gas; generate 25.2% of electricity and 21.7% of thermal energy; and refine 19.7% of oil.

Severe climatic conditions, as one of the features of the region, contribute to the high consumption of primary energy resources - 142.3 million tce or 18.4% of the country's total primary energy consumption. The eastern regions account for about a quarter of the country's electricity consumption, a fifth of thermal energy consumption, 68.5% of the total Russian coal consumption, and only 7.9% of natural gas [3]. The presence of large oil and natural gas deposits in the eastern regions creates the prerequisites for the organization of large oil and gas complexes here that can satisfy not only the internal needs of the regions, but also supply excess hydrocarbons for export to Japan, China, Korea, and other countries of the Asia-Pacific region.

Despite the rich mineral resource base, tax revenues per capita are significantly lower than GRP per capita, and the budgets of the eastern regions are highly subsidized.

The role of the eastern direction in the export of fuel and energy resources in the current geopolitical context is very significant, particularly from the standpoint of energy security of the world and its main regional markets, as well as from the perspective of the country's export earnings. The capacity and condition of transportation routes, ports, and terminals, along with the vast distances involved, are the primary limiting factors. In general, 3.4 billion kWh of electricity, 11.6 million tons of liquefied natural gas, 3.8 billion m^3 of pipeline natural gas, and 48.2 million tons of oil were exported from the eastern regions in 2020.

3 Specific features of electric power systems

The unique features of electric power systems in the eastern regions include a significant share of hydro generation, in contrast to the western regions of the country, it accounts for more than 50% (Fig.1).

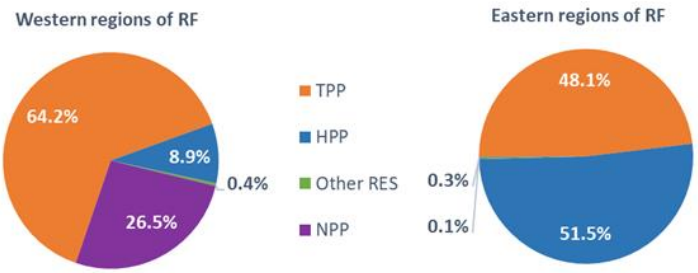

Fig. 1. Electricity generation mix (as of 2020).

Annual electricity generated by power plants in 2020 amounted to 251 billion kWh. Of this volume, 46% was produced at thermal power plants, 54% at hydroelectric power plants (mainly in Siberian regions), and 0.1% at solar power plants.

Another important feature is the predominant share of coal in the fuel burnt at thermal power plants, which is 76% of the total fuel consumed.

At the same time, the specific fuel consumption at TPPs is elevated and averages 350-390 g of tce/kWh.

Annual electricity consumption in 2020 was 250 billion kWh [4]. The extensive power supply service area in the eastern regions causes increased electricity losses in the networks, for example, according to PJSC Rosseti Siberia, at the end of 2020, they are estimated at 7.3% of the power supplied to the network. At the same time, the electric power systems in the eastern regions have export electric tie lines with neighboring states: a double-circuit 220 kV transmission line runs from Siberia to Mongolia, and the electric power system of the East is connected to the electric power system of China via 220kV and 500 kV transmission lines.

The large spatial extent of the electric power systems in the eastern regions and harsh natural and climatic conditions in the territories they cover cause increased capital intensity and operating costs, as well as long construction periods for power plants and power grid facilities.

Off-grid energy systems are predominant in the eastern regions of Russia. These systems typically consist of multiple energy generation centers, where power plants exhibit lower technical and economic efficiency than the national average. Renewable energy facilities operate as part of the energy systems in the eastern regions, but their share in total electricity generation does not exceed 0.5%. Solar power plants are the only renewable generators in the energy systems, there are no wind power plants, which is also a characteristic feature of the eastern regions.

In the area serviced by local generation systems, renewable generation, with the exception of large hydroelectric power plants, is represented by wind power plants in the Chukotka Autonomous Region and in the Kamchatka Territory. There are also geothermal power plants in the northeast of the Kamchatka Territory. Even though the renewable generation in the eastern regions is quite small, it is larger than that in the western part of the Russian Federation, especially in the off-grid areas where it is used to save on long-distance fuel delivery.

In view of the large territorial extent in the eastern regions, there is a significant number of power generation centers isolated from the electric power systems, where consumers are supplied with electricity by autonomous power plants, mostly diesel ones.

4 Specific features of heating systems

The share of the eastern regions in the structure of the installed thermal capacity of TPPs in Russia is 25%. The thermal energy production by all heat sources in 2020 reached 269 million Gcal, or 31.7% of the total heat production in the country [5]. The structure of heat production in the eastern regions is characterized by the predominant share of thermal power plants, in contrast to the western part of the Russian Federation (Figure 2).

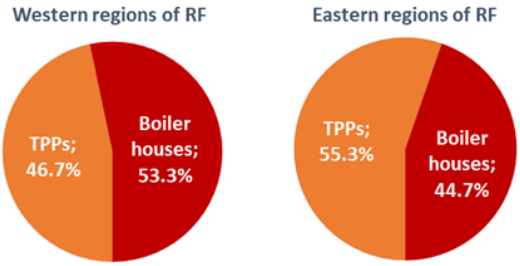

Fig. 2. Heat generation mix (as of 2020).

The main fuel in the eastern regions is coal. The share of coal in the production of thermal energy from thermal power plants is 76%, the share of gas is 21.6%. The share of coal burnt in boiler houses is 58%, and that of gas is 23.8%. Meanwhile in the European regions gas fuel prevails both in thermal power plants (88%) and in boiler houses (90%).

The specific consumption of reference fuel (coal equivalent) for production of thermal energy by boiler houses is characterized by relatively high values compared to the average Russian indicators (170.4 kg of coal equivalent/Gcal) and varies from 187 to 208 kg of coal equivalent/Gcal [5], which is because coal-fired boilers with low efficiency predominate in the eastern regions. The total length of heat networks in the eastern regions in 2020 was 41.7 thousand km, or 24.8% of the total length of heat networks in Russia. At the same time, the share of dilapidated heat networks is estimated at 18-31%.

5 Features of coal mining and supply

There are both positive and negative aspects associated with the specific features of coal mining and supply in the eastern regions of the country. Over the last two to three years, there has been a growth in coal production (386 million tons/year), processing, and exports (192 million tons).

The stable and reliable operation of the coal industry requires reducing import dependence related to the production of mining equipment, especially for open pit mining [6, 7].

To achieve environmentally-friendly coal production and processing, it is crucial to promptly tackle the development of an effective legislative framework and to encourage the optimal operation of coal enterprises.

In order to effectively meet the increasing demand for coal both within the country and for export, it is essential to focus on developing port terminals and improving rail transport. This is especially important considering the large distances involved in transporting coal products.

The low-carbon development of the economy set by the world community and the Russian government may also have a significant impact on the development of the coal industry, as demand for coal may go down significantly.

6 Specific features of gas supply and conversion to gas

Despite the presence of huge reserves of natural and associated gas, the eastern regions of Russia have virtually no gas supply infrastructure or it is poorly developed. Against the background of Russian indicators of conversion to gas (70.9%), their values for the eastern regions of the country are the lowest, which is associated with high capital intensity and low payback of conversion-to-gas projects (Figure 3).

Fig.3. Zoning of the Russian Federation territory by the level of conversion to gas (as of 2020).
Note: NWFD - North-Western Federal District; CFD - Central Federal District; VFD - Volga Federal District; SFD - Southern Federal District; NCFD - North Caucasus Federal District; UFD - Ural Federal District; JAR - Jewish Autonomous Region.

The shift to gas on such a small scale is driven by a variety of factors. These are low population density and spatial dispersion of settlements, relatively low prices for coal and electricity, as well as low consumer solvency, and harsh natural and climatic conditions.

7 Environmental features

The environmental features linked to the operation of energy facilities in the eastern regions of Russia depend on the quantity and quality of the fuel utilized. Despite the high share of hydro generation in electricity production, eastern regions account for 63% of the total pollutant emissions from thermal power plants and boiler houses in Russia.

The boiler houses are the major air polluters emitting 68.6% of the total emissions from boiler houses in Russia. Calculations of emissions for four main pollutants by emission source (thermal power plants and boiler houses) are presented in Figure 4.

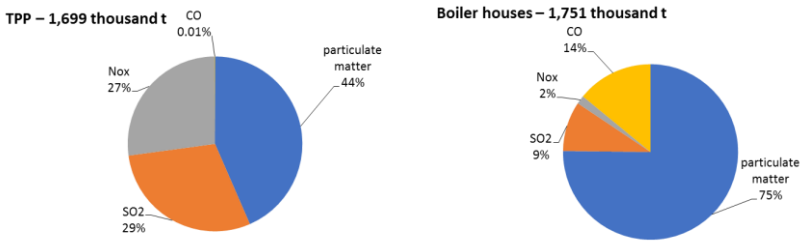

Fig.4. Calculated emissions of pollutants into the atmosphere from energy facilities in the eastern regions.

In contrast to the western regions of the country, in the eastern regions, the predominant impurity emitted from boiler houses is particulate matter, while the prevailing pollutants from thermal power plants are sulfur and nitrogen oxides.

Up to 11 million tons of ash and slag waste is produced annually from energy facilities in the eastern regions, which is almost 2 times higher than from thermal power plants and 3-3.5 times higher than from boiler houses in the western part of the Russian Federation.

Calculated carbon dioxide emissions from thermal power plants and boiler houses in the eastern regions are estimated at almost 200 million tons, which is 31% of all emissions from the energy facilities in Russia, Table 1.

Table 1. Calculated carbon dioxide emissions from energy facilities in Russia (as of 2020).

Region, country	Total	Energy facility	
		Thermal power plants	Boiler houses
Russia, including:	642	489	153
- Eastern regions	197	157	41
- European regions	445	332	112

In the western regions of the Russian Federation, most of the calculated CO_2 emissions from generating facilities are produced by thermal power plants, which is explained by the significant volumes of fuel consumed. However, this contribution is due to the consumption of natural gas (94% of the total gas of the Russian Federation). In the eastern regions, the main factor behind the high contribution of thermal power plants to carbon dioxide emissions is coal generation. The specific emission of carbon dioxide in the eastern regions is 2.5 tCO_2/tce, which is 1.5 times higher than in the western regions, i.e., 1.7 tCO_2/tce of fuel burned.

8 Conclusion

An analysis of the current state of the energy sector in the eastern regions of Russia made it possible to identify the main categories of features of regional energy systems: socio-economic, infrastructural, sectoral, and environmental. All these features are interrelated and often contradictory, but they need to be taken into account when building the scenarios of decarbonization and transition to low-carbon energy development in the eastern regions.

Following the identified features and considering the fact that it may not be possible to completely exclude coal from the fuel balance of the eastern regions in the near future, the energy development scenarios for the eastern regions of Russia should factor in the following main directions of decarbonization:

- applying more efficient coal combustion technologies;
- preparing coal before burning (coal gasification technologies, etc.);
- adopting innovative technologies at coal-fired thermal power plants (combined cycle turbine units, ultra-supercritical plants, and others);
- using CO_2 capture technologies;
- increasing the number of gas consumers in the regions by supplying them with piped and liquefied natural gas;
- promoting the expansion of renewable energy sources.

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References

1. Decree of the Government of the Russian Federation dated September 2, 2022 No. 2515-r. Available at: http://publication.pravo.gov.ru/Document/View/0001202209020048 (accessed 22.12. 2022)
2. National report of the Russian Federation on the inventory of anthropogenic emissions from sources and absorption by greenhouse gas sinks not controlled by the Montreal Protocol for 1990-2021. Moscow, Yu.A. Israel Institute of Global Climate and Ecology, 479, (2023).
3. Regions of Russia. Socio-economic indicators. Stat. Book, Rosstat, Moscow, 1242, (2020)
4. Report on the operation of the UES of Russia in 2020. System operator of the Unified Energy System. 36, (2021).
5. Use of fuel and energy resources for certain types of products, work (services) in 2017-2020. Form 4 FER. Rosstat.
6. A.A. Rozhkov, S.M. Karpenko. Assessment of the import dependence level for the coal industry in Russia and training of engineering personnel for import substitution of mining equipment. J. Mining Industry. 4, 24-36 (2020)
7. Rozhkov A.A. Structural analysis of import substitution in the Russian coal industry: Reality and forecast, J.Mining Industry. 6. 4-13 (2017)