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Analysis of the Structure of Power and Electricity Balances of the Sverdlovsk Region Power System

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ABSTRACT
The regional power system of the Sverdlovsk region with an annual electricity consumption of over 40 billion kWh per year is one of the largest in Russia. There are powerful mining, metallurgical and machine-building enterprises on the territory of the region which require large volumes of cheap thermal and electric energy. One of the options for reducing the cost of electricity is to change the structure of the installed capacity of power plants. The key facility of the power system is Reftinskaya SDPP with an installed capacity of 3800 MW, which operates on coal and provides up to 40 % of electricity generation. Reducing the cost of electricity in the future can be achieved by reconstruction of power units at Reftinskaya SDPP, as well as its transition to Kuzbass coal. In addition, by 2030 the commissioning of new generation facilities in the region may take up to 2000 MW due to the construction of a new power unit at the Beloyarsk NPP (1200 MW), small gas generation facilities (up to 500 MW) and due to the construction of small hydro power plants (up to 300 MW). The possible potential for reducing the cost of electricity when changing the structure of electricity generation in the region can be no more than 30 %. Taking into account the long construction time of power plants, the structure of their installed capacity and the structure of electricity generation will not change in the region in the future until 2030, and in order to curb the growth of electricity tariffs in the region, innovative market management mechanisms or other methods of electricity production are required.

Keywords: *Regional power system, Structure of installed capacity, Structure of electricity generation, Installed capacity utilization factor, Electricity tariffs.*

1. INTRODUCTION

The Sverdlovsk region is located in the Middle Urals, occupies an area of 194,3 km^2, in which more than 4.33 million people live. The administrative center of the region is the city of Ekaterinburg with a population of 1.53 million people. The region is one of the largest industrial centers in Russia and traditionally belongs to the donor regions of the Russian economy. The gross regional product (GRP) of the region at the end of 2020 amounted to more than 2 330 billion rubles (₽). The basis of the economy of the Sverdlovsk region are the enterprises of ferrous and non-ferrous metallurgy, which are the most energy-intensive consumers of energy resources, as well as mining and machine-building industrial enterprises [1, 2].

The foundation of the region's steadily growing economy is trade, a powerful ore raw material base, and powerful engineering and energy sectors. The regional power system of the Sverdlovsk region is one of the largest in Russia and it needs considerable volumes of cheap energy resources capable of generating cheap thermal and electric energy.

2. PRICE ZONES OF THE WHOLESALE ELECTRICITY MARKET

One of the peculiarities of the region's economy and energy is relatively high electricity tariffs, which increased significantly from 1990 to 2010 and became the reason for the closure and / or dismantling of a large number of energy-intensive industrial facilities and their further relocation to new sites in Siberia.

Today, the purchase of electricity for all large electricity consumers is carried out on the wholesale

Russian electricity and capacity market (WECM), which operates in 2 price zones, Figure 1:

Figure 1 Price zones of the electricity market in Russia.

The Sverdlovsk region is located on the territory of the 1st price zone of the WECM, while Siberia is the 2nd price zone of the WECM. In 2021, the difference in the price of the purchase of electricity for consumers on the WECM is 50 % in summer and up to 80 % in winter. The prices for capacity and electricity in Siberia are always lower due to the presence of huge hydropower resources that ensure the low cost of electricity generation at the Angara-Enisei cascade of hydropower plants (HPPs).

According to the trading data on the WECM on June 22, 2021 (summer), the price for the purchase of electricity was 1 693 ₽ / MWh and 938 ₽ / MWh in the 1st and 2nd price zones respectively. As of November 25, 2021 (winter), the price for the purchase of electricity was 1 706 ₽ / MWh and 1 083 ₽ / MWh in the 1st and 2nd price zones, respectively [3].

For end consumers who purchase electricity not on the WECM, but at fixed tariffs from the networks of guaranteed suppliers, the difference in the cost of electricity can be even greater and differ by 2-3 times. So, in the first half of the year, the cost of electricity for consumers at the CH-II tariff level (10 and 6 kV) at a single-rate tariff, in the Krasnoyarsk and Irkutsk region amounted to 2,35 and 1,1 ₽ / kWh, respectively (Siberia), and in the Sverdlovsk region (Urals) – 2,76 ₽ / kWh [3–5].

For many industrial enterprises, this difference in the cost of electricity is critical. Therefore, ensuring low tariffs for electricity, in order to ensure further opportunities for sustainable development of industry and the economy of the region, is one of the most important tasks.

3. REPORTING INDICATORS OF THE FUNCTIONING OF THE ENERGY SECTOR AND ECONOMY OF THE REGION

The volume of annual electricity consumption in the Unified Power System of Russia (UPS of Russia) is over than 1 trillion kWh. The regional power system of the Sverdlovsk region is part of the largest in the UPS of Russia, the Interregional Power System of the Urals (IPS of the Urals) with an annual consumption of over than 250 billion kWh of electricity.

According to System Operator of the Unified Power System, JSC ("SO UPS", JSC, www.so-ups.ru), at the end of the 2020 calendar year, the volume of electricity consumption in the Sverdlovsk region amounted to 41 347 billion kWh, according to this indicator, the region is in 6th place among the largest (TOP-10) regional power systems of Russia [6, 7], Figure 2:

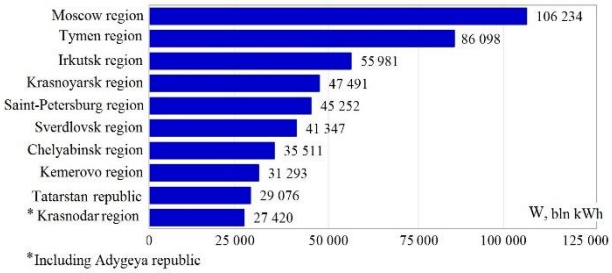

Figure 2 Electricity consumption in the largest regional power systems of Russia at the end of 2020

Another feature of the Sverdlovsk region power system is the absence of significant hydropower resources and reserves of thermal coal and gas, in connection with which all large power plants generate electricity at thermal power plants (TPPs) by burning imported coal or by burning natural gas supplied from the Yamal-Nenets Autonomous districts. Thus, the transportation of energy resources inevitably leads to an increase in the cost of electricity in the region.

At the same time, in the Sverdlovsk region power system for the period from 2010 to 2020, there is a steady trend towards a decrease (drop) in the electrical load from 6 960 to 6 013 MW (-14%) against the background of relatively stable electricity consumption at the level of 40-43 billion kWh per year. At the same time, the GRP of the region from 2010 to 2019 increased annually and grew from 1 046 to 2 409 billion ₽, which indicates a relatively high efficiency of energy use at the enterprises of the region [8, 9].

4. POWER PLANTS OF THE REGIONAL POWER SYSTEM

The Sverdlovsk region power system is based on TPPs operating on coal and gas. According to the Scheme and Program for the Development of the Electric Power Industry of the Sverdlovsk region for the period 2021-2025 [10], as of March 1, 2020, 32 power plants with an installed capacity of 2.4 MW and above are operating in the Sverdlovsk region, on the sites of which 118 power generation units are installed (turbine + generator), their total installed capacity is 10 540,85 MW. At the same time, 32 power plants include 1 nuclear (Beloyarsk NPP, 1485 MW, 4 power units) and 1 HPP (Verkhoturskaya HPP, 7.0 MW, 3 power units). The other 30 power plants

with a total installed capacity of 9048.85 MW are TPPs operating on gas and coal. As part of gas-fired TPPs, there are 6 new combined cycle gas turbine units (CCGT) with a total installed capacity of 2029.2 MW, which are new and were commissioned at the sites of 5 TPPs in the period from 2011 to 2017.

According to [11], based on the results of operation in 2020 (as of 01.01.2021), the installed capacity of power plants of the Sverdlovsk region regional power system amounted to 10 557.7 MW, and electricity generation – 56.417 billion kWh. Those with electricity consumption in the region in the amount of 41.35 billion kWh in 2020, 73 % of the generated electricity is consumed within the region, the remaining 27 % of electricity is exported to neighboring energy systems.

The total structure of the installed capacity of power plants and the structure of electricity generation at power plants of the Sverdlovsk region power system as of 01.01.2021 according to [11] is shown in Figure 3, 4 and in Table 1:

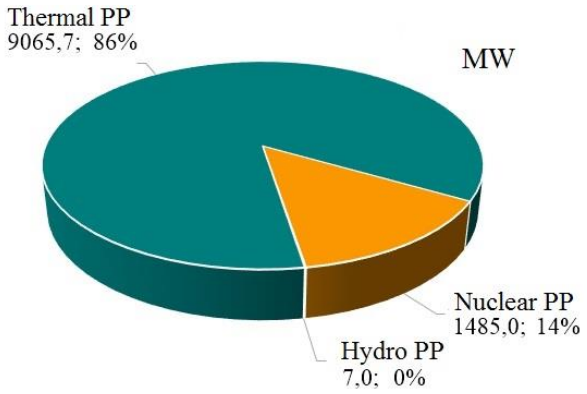

Figure 3 The structure of the installed capacity of power plants of the Sverdlovsk region power system as of 01.01.2021.

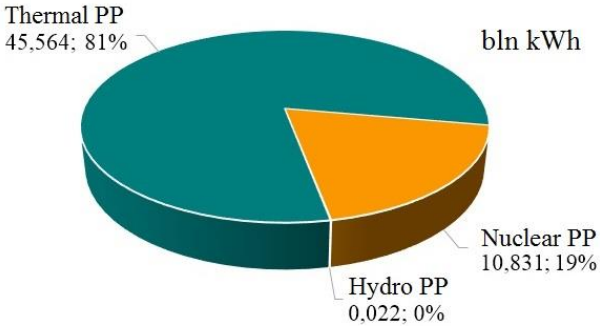

Figure 4 Structure of electricity generation at power plants of the Sverdlovsk region power system in 2020.

Table 1. The structure of the installed capacity and the structure of power generation at the power plants of the Sverdlovsk region's power system in 2020

№	PP type	N_{PP}, units	Installed Capacity, MW	Weight, %	W_{year}, bln kWh	Weight, %
	Sverdl. region	**32**	**10 557,7**	**100,0%**	**56,417**	**100,0%**
1.	Nuclear PPs	1	1 485,0	14,1%	10,831	19,2%
2.	Hydro PPs	1	7,0	0,1%	0,022	0,0%
3.	Thermal PPs	30	9 065,7	85,9%	45,564	80,7%

The reported data of «SO UPS», JSC [6, 7] and the data of the Government of the Sverdlovsk region [10, 11] are objective. However, their significant drawback is the lack of a structure of the installed capacity of power plants and power generation by fuel type. Therefore, in order for such data to be used to analyze possible ways to reduce the cost of electricity in the region, it is necessary to further refine them.

5. INSTALLED CAPACITY AND POWER GENERATION STRUCTURE

In order to determine possible areas of probable reduction in the cost of electricity in the region, it is necessary to establish how much electricity is produced on what type of fuel and at what power plants is generated annually. As regards power units operating on gas, modern energy-efficient combined cycle gas turbine units of TPPs (CCGT) are of particular interest.

To solve this problem, first, according to [10], the types of fuel on which the power plant operates were determined, then, using satellite images of technological sites of power plants, the data were confirmed, and for individual stations they were refined. In addition, to determine the volume of electricity generation, data from the annual reports of the owners of power plants were used. The results of research and identification of the structure of power and electricity balances by fuel type are shown in Figure 5, 6 and in Table 2:

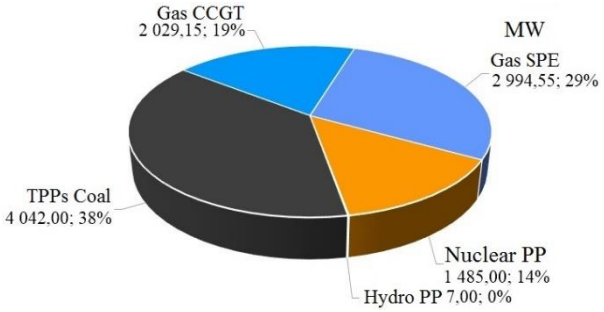

Figure 5 The structure of the installed capacity of power plants of the Sverdlovsk region power system as of 01.01.2021 with identification of fuel types.

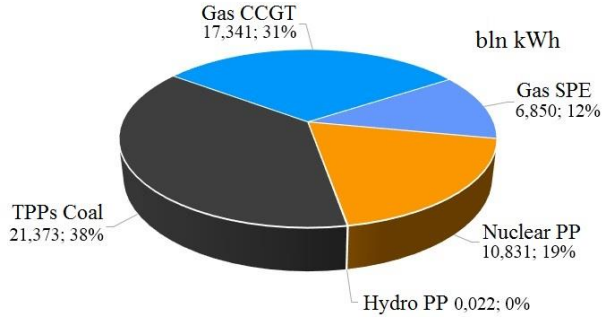

Figure 6 The structure of electricity generation at power plants of the Sverdlovsk region power system in 2020 with identification of fuel types.

Table 2. Installed capacity and power generation at power plants by fuel type in the Sverdlovsk region as of 01.01.2021

№	Fuel	N_{PP}, units	Installed Capacity, MW	Weight, %	W_{year}, bln kWh	Weight, %
	Sverdl. region.	**32**	**10 557,7**	**100**	**56,417**	**100**
1.	Nuclear PPs	1	1 485,0	14,7%	10,831	19,2%
2.	Hydro PPs	1	7,0	0,1%	0,022	0,0%
3.	Thermal PPs	30	9 065,7	85,9%	45,564	80,7%
3.1.	TPPs Coal	3	4 042,0	38,3%	21,373	37,9%
3.2.	TPPs Gas CCGT	5	2 029,2	19,2%	17,341	30,7%
3.3.	TPPs Gas SPE	23	2 994,6	28,4%	6,850	12,1%

In total, in the Sverdlovsk region power system, as of 01.01.2021, there are 32 power plants with a total installed capacity of 10557.7 MW, in 2020 they generated 56.417 billion kWh of electricity. It is not difficult to establish the production volumes for NPPs and HPPs, since stations of these types operate in the amount of 1 unit. It is much more important to highlight the structure of the TPP.

Thus, the largest TPP in the Sverdlovsk region - Reftinskaya SRPP with an installed capacity of 3800 MW (10 power generation units), operates on coal and is the largest coal-fired TPP in Russia. The Bogoslovskaya CHPP (7 power units, 141 MW) and 6 power units of the Krasnogorsk CHPP (6 of 7 units, and 101 of 121 MW) also operate on coal. In total, 23 power units operate on coal at 3 thermal power plants with a total installed capacity of 4042,0 MW. The number and installed capacity of the CCGT unit were established in Section IV. The rest of the installed capacities and production volumes fall on TPPs operating according to the block scheme (including distributed generation facilities), they have been assigned the symbol "SPE Gas" (steam power equipment).

Thus, out of 80,7 % of the electricity generated by TPPs, 37,9% are coal and 42,9 % are gas. Among them – 30,7 % falls on TPPs with CCGT and 12,1% falls on TPPs operating in a block scheme.

6. GENERATING EQUIPMENT LOAD ANALYSIS

All power units for admission to the WECM undergo a mandatory procedure for selecting composition of included generating equipment (SCIGE), which is regularly carried out on the basis of a competitive capacity outtake (CCO) of "SO UPS", JSC [12-14]. The implementation of the SCIGE procedure ensures the generation of electricity using energy-efficient generating equipment, which makes it possible to ensure the minimum cost of electricity on the WECM for consumers.

An indicator of duration of loading power plants during a calendar year and an indicator of the efficiency of their technological operation is the installed capacity utilization factor (ICUF). Calculation of ICUF by types of power plants and by types of fuel for the Sverdlovsk region power system of the for 2020 based on the data in Table 2 is shown in Figure 7:

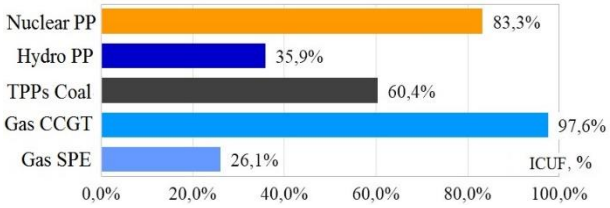

Figure 7 The ICUF of the types of power plants by fuel types of the Sverdlovsk region power system in 2020.

From the calculations of the ICUF in Figure 7, it can be seen that the most efficient modern generating equipment of TPP CCGT during the entire 2020 calendar year was in operation for 8546 hours (ICUM 97,6 %) with short breaks for repairs. Also, a high ICUF was recorded at the Beloyarsk NPP, which operated in 2020 for 7294 hours (ICUF 83,3 %) and was taken out of work during the fuel reload. The only Verkhoturskaya HPP with a normal ICUF of 35,9 % does not play a significant role in the power system, therefore it is not considered hereinafter. Gas TPPs operating according to the block scheme operated with ICUF below average – 2287 hours (26,1 %), while according to [6], the ICUF of all TPPs in Russia in 2020 amounted to 41,3 %.

The situation shown in Figure 7 shows that the power plants in the Sverdlovsk regional power system are loaded rationally. However, special attention should be paid to coal-fired generation, which worked for 5288 hours and has a high ICUF – 60,4 %.

The key object of coal generation and the entire power system of the Sverdlovsk region is Reftinskaya SRPP with an installed capacity of 3800 MW. According to [15], Reftinskaya SRPP generated a total of 20.324 bln kWh of electricity in 2020. Those, Reftinskaya SRPP has a 36 % share in the structure of the installed capacity of the power system, generated more

than 36 % of all electricity in 2020 with an ICUF of 61 %, which indicates a high load of the coal station throughout the 2020 calendar year.

The high load of Reftinskaya SRPP is due to the fact that the station is a backbone object and forms the electrical regime in the 500 and 220 kV network of the IPS of the Urals. Also, Reftinskaya SRPP is a key facility providing power supply to large industrial consumers in the Sverdlovsk, Chelyabinsk and Tyumen regions. Therefore, a decrease in the power plant load will inevitably affect the stability of the production processes of industrial enterprises.

7. THE LARGEST POWER PLANTS IN THE POWER SYSTEM

The Sverdlovsk region power system includes the largest power plants with installed capacity of over 1000 MW, which, like Reftinskaya GRES, are systemically important and are key both for the region and for the IPS of the Urals [10]. Such power plants are Reftinskaya SRPP (3800 MW), Sredneuralskaya SRPP (1578.5 MW), Beloyarsk NPP (1485 MW) and Verkhnetagilskaya SRPP (1062.15 MW). These 4 power plants account for 7925.65 MW – more than 75 % of the total installed capacity and more than 75 % of the total electricity generation in the power system. At the end of 2020, these 4 power plants generated 42.727 billion kWh, provided 103% of the demand for electric energy in the Sverdlovsk region and 75 % of the total volume of generated electricity.

Also, in the regional power system there are 5 large combined heat and power plants (CHPPs), which provide heat and power supply to large cities and block stations of industrial enterprises that provide heat and power supply to industrial sites of mining, metallurgical and machine-building industries. Data on the operation in 2020 of such largest power plants with an installed capacity of over 100 MW are shown in Figure 8 and 9:

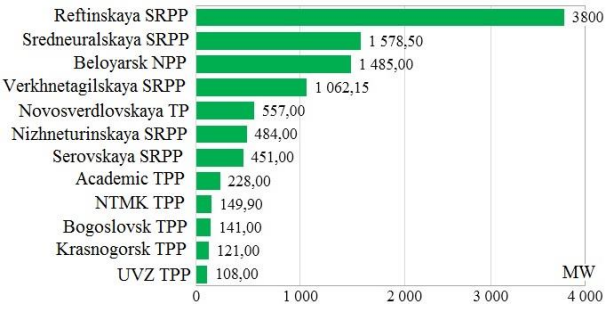

Figure 8 Installed capacity of the largest power plants of the Sverdlovsk region power system as of 01.01.2021.

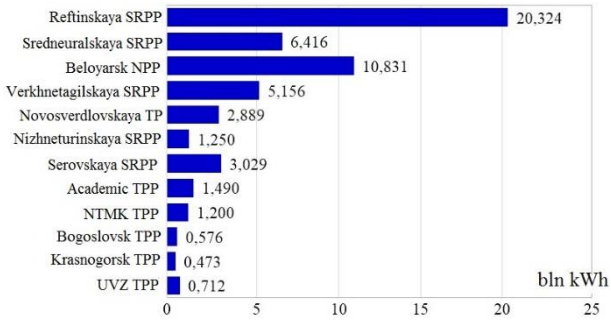

Figure 9 Power generation at the largest power plants of the Sverdlovsk region power system in 20201.

Indicated in Figure 8 and 9 largest power plants in 2020 with an installed capacity of 10165.55 MW (96.3 %) generated 54.346 billion kWh (96,3 %) of electricity. Among them, the key object is Reftinskaya SRPP, which generated 20.324 billion kWh (36 %) of electricity by burning coal.

The rest of the power plants of the region's power system with an installed capacity of less than 100 MW are local and provide mainly heat and power supply for small power districts and small industrial enterprises. The total number of such plants in the power system is 20, their installed capacity is 392.15 MW, during 2020 they generated 2.07 billion kWh (3.7 %) of electricity with a high ICUF of 60.3 %.

Taking into account the provisions of the Forecast for the development of energy in the world and Russia for the period up to 2040 [16] and taking into account the fact that most of the generating equipment in the Sverdlovsk region power system is gas, new and efficient, and Reftinskaya SRPP participates in the formation of the cost of electricity in the region by up to 36 %, it is in relation to it that it is necessary to consider measures for a possible reduction in the cost of electricity.

8. ANALYSIS OF POSSIBLE WAYS TO REDUCE THE COST OF ELECTRICITY IN THE REGION

Analysis of possible ways to reduce the cost of electricity in the Sverdlovsk region can be considered both in the direction of the transition of Reftinskaya SRPP to other thermal coals, or in relation to the commissioning of new replacement capacities.

In 2020, as a result of a commercial transaction, Reftinskaya SRPP was transferred from “Enel Russia”, PJSC to “Siberian Generating Company”, LLC (SGK, LLC). Since 2021, SGK, LLC is considering the transfer of the Reftinskaya SRPP operating on Ekibastuz coal (Kazakhstan) to the coal of the Kuznetsk coal basin (Kemerovo region, Russia). Scientific studies [17] have confirmed the effectiveness of this transition. Additionally, individual power units of

Reftinskaya SRPP are included in the comprehensive modernization program scheduled for 2026.

New generating (replacement) capacities can be put into operation at the Beloyarsk NPP. The operator of the Beloyarsk NPP is "Rosenergoatom Concern", JSC, according to the program of which it is planned to build unit № 5 with a capacity of 1200 MW at the Beloyarsk NPP site by 2030 [18]. Those by 2030, the installed capacity of the Beloyarsk NPP may grow to 2685 MW, but this is clearly not enough to replace the capacity of the Reftinskaya SRPP.

Another way of developing generating capacities in the Sverdlovsk region is the construction of distributed generation facilities. Thus, for the period from 2008 to 2020, 12 small generation facilities with a total installed capacity of 165.9 MW were put into operation in the Sverdlovsk region [10]. Also, in the region there is the possibility of developing small HPPs, the potential of which is estimated at 300 MW [19]. However, such volumes of generating capacities are clearly insufficient to supply power to large metallurgical and mining enterprises.

In this regard, the structure of the balance of power and electricity in the Sverdlovsk region power system will remain unchanged in the long term (up to 2030), and restraining the growth of electricity tariffs largely depends on the mechanisms of state regulation and the introduction of modern demand management and market technologies [20].

9. CONCLUSION

1. The Sverdlovsk region is one of the largest industrial centers in Russia; the regional power system of the Sverdlovsk region with an annual electricity consumption of more than 40 billion kWh per year is ranked 6th among all regional power systems in Russia.

2. The installed capacity of 32 power plants of the regional power system of the Sverdlovsk region is 10557.7 MW. There are 1 NPP (1485.0 MW), 1 HPP (7.0 MW) and 30 TPPs (9065.7 MW) in the region. The main volume of electricity generation in the region is carried out at 12 TPPs with a capacity of over 100 MW – 54.346 billion kWh.

3. In the structure of the installed capacity of the regional power system, 38 % are coal-fired TPPs, 19 % are gas-fired CCGT TPP units, 29 % are gas-fired TPPs operating on the block scheme and 14% are NPPs.

4. As part of the structure of power generation in the region, 38 % of all electricity is generated on coal, 31 % – on gas blocks of CCGT TPPs, 12 % – on block TPPs and 19 % on nuclear fuel at NPPs. CCGTs have a high load of generating equipment and a high ICUF – 97,6 % and NPP – 83,3 %, which confirms the optimal load of the generating equipment of the power system to ensure minimum prices for electricity.

5. The key objects of the Sverdlovsk region power system is Reftinskaya SRPP with an installed capacity of 3800 MW, operating on coal. Reftinskaya SRPP has a 38% share in the structure of the installed capacity and generates more than 21 billion kWh (38 %) of electricity per calendar year.

6. Possible potential for reducing the cost of electricity in the region can be no more than 30% and can be realized through the transition of Reftinskaya SRPP to Kuzbass coal, and / or through the construction of new or replacement capacities in the amount of ~ 2000 MW: construction of a new power unit of the Beloyarsk NPP with an installed capacity of 1200 MW, construction of small generation facilities with a total installed capacity of up to 500 MW running on gas and due to the construction of small HPPs with a total installed capacity of up to 300 MW.

7. Taking into account the long construction time of power plants, as well as taking into account the strict dependence of electricity prices on the cost of primary energy carriers, the structure of the installed capacity of power plants and the structure of electricity generation in the Sverdlovsk region will not change until 2030. A slight decrease in electricity tariffs or containment of tariff growth in the future in the region can be implemented through management and market-based governance mechanisms in the energy sector.

REFERENCES

[1] Strategy of social and economic development of the Sverdlovsk region for 2016-2030. Law of the Sverdlovsk region №151-OZ. Adopted by the Legislative Assembly of the Sverdlovsk region on December 15, 2015, Ekaterinburg.

[2] Spatial development strategy for Ekaterinburg. Concept. Ekaterinburg: Tatlin Publ., 2017. 312 p.

[3] Order of the Ministry of Tariff Policy of the Krasnoyarsk region of December 29, 2020 №64-e "On the establishment (revision) of uniform (boiler) tariffs for services for the transmission of electrical energy on the territory of the Krasnoyarsk region, with the exception of the tariff group of consumers" Population and equivalent categories of consumers. "The official Internet portal of legal information of the Krasnoyarsk Territory" (www.zakon.krskstate.ru).

[4] Order of the Tariff Service of the Irkutsk region dated December 25, 2020 № 488-spr "On the establishment of uniform (boiler) tariffs for services for the transmission of electrical energy in the Irkutsk

region for 2021", "Official Internet portal of legal information" (www.publication .pravo.gov.ru).

[5] Resolution of the Sverdlovsk region of 12/30/2020 № 276-PK "On the establishment of uniform (boiler) tariffs for services for the transmission of electrical energy through the networks of the Sverdlovsk region". "Official Internet portal of legal information of the Sverdlovsk Region" (www.pravo.gov66.ru).

[6] Annual reports of «SO UPS», JSC on the functioning of the UPS https://www.so-ups.ru/functioning/tech-disc/tech-disc-ups/

[7] Monthly releases of "SO UPS", JSC on the functioning of the UPS https://www.so-ups.ru/news/press-release/nyear/2020/

[8] Analytical review of the socio-economic situation of the constituent entities of the Russian Federation (with indicators affecting energy consumption). Ural federal district. Sverdlovsk region. Non-profit partnership "Market Council". November 2013 18 p.

[9] Gross regional product for the constituent entities of the Russian Federation. Federal State Statistics Service. (Rosstat). Reports for the period from 208 to 2019. Rosstat. https://rosstat.gov.ru

[10] Scheme and program for the development of the Sverdlovsk region for the period 2021-2025 http://www.pravo.gov66.ru/media/pravo/224-UG_qM5B2gN.pdf

[11] Schemes and programs for the development of the UPS of Russia https://so-ups.ru/index.php?id=dev_sch

[12] Chernykh F.Yu. Improving the efficiency of the power plant in the conditions of the electricity and capacity market: Abstract, Ural Federal University named after The first President of Russia B.N. Yeltsin. Ekaterinburg, 2011. 24 p.

[13] Decree of the Government of Russia of January 25, 2019 №43 "On the selection of projects for the modernization of generating facilities of thermal power plants," "Official Internet portal of legal information" (www publication.pravo.gov.ru)

[14] Modernization of thermal power plants: raising the retirement age. Vygon Consulting. Analytical report for July 2021. Moscow. 32 p.

[15] Siberian Generating Company LLC Public Report for 2020

[16] Forecast of energy development in the world and in Russia until 2040. Analytical Center for the Government of the Russian Federation. Moscow. ERI RAS. AC-2013. 110 p.

[17] "Reftinskaya SRPP confirmed the possibility of using Kuzbass grade D coal". The newspaper "Energy and Industry of Russia. Issue № 21-22 (425-426) November 2021. https://www.eprussia.ru

[18] Innovative development and technological modernization of ROSATOM for the period up to 2030 (in the civilian part). Passport of the program. Moscow. 2016.

[19] Shcheklein S.E. Mini and micro hydroelectric power plants: Textbook. Allowance. 2nd ed. Yekaterinburg: Ural State Technical University. 2003.102 p.

[20] Ghoziev Bakhtiyor, Vladislav O. Samoylenko, Andrew V. Pazderin. "Demand Response Programs Influence On a Load Pattern". Proceedings of the 2020 Ural Smart Energy Conference, USEC 2020, Ekaterinburg, 13-15 November, pages 114-117, DOI: 10.1109 / USEC50097.2020.9281259.