Assessment of the prospects for energy construction under conditions of increasing share of electrified transport

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Abstract. The electrification of personal and public transport is a worldwide trend. The indicators of some countries demonstrate a rapid rejection of fossil fuel use and conversion to electric traction, which in turn exacerbates the problem of a shortage of energy capacities. The Russian Federation is no exception. The current lag of Russia behind the world leaders in matters of electrification of transport simultaneously determines the possible prospects for a rapid increase in the number of electric vehicles in our country, which inevitably should be accompanied by the process of updating old and commissioning new energy capacities. The study aims to assess, within the framework of the Krasnodar agglomeration, the size of the prospective demand for electric energy upon reaching 100% electrification of public transport and 15% electrification of personal vehicles. Simultaneously, the issue of choosing the most priority type of generation from nuclear power plants to alternative energy sources for a given region is considered. Based on the results of assessing the need and choosing the most promising type of generating center, a conclusion is made about the relevance of construction in the city of Krasnodar by 2035 of a thermal generation facility and facilities of alternative generation of low power outside the city.

1. Introduction

The concept of using electrified vehicles, both for personal use and in urban environments, has become increasingly popular in recent decades. In the ranking of countries that have the infrastructure necessary for the comfortable use of vehicles of this type at the end of 2019, the Russian Federation (RF) took 23rd place out of 25. According to a number of experts, electric transport is a promising market segment capable of replacing traditional vehicles with internal combustion engines (ICE) in the near future; however, its use in modern Russia is associated with the need to solve a number of problems and take into account geographical and climatic features. These problems include:

- small power reserve and lack of battery capacity, their considerable weight in conditions of long roads;
- high price of storage batteries, which is comparable to the price of the vehicle itself (an average electric car in the Russian market is about 750 thousand rubles more expensive than a car with an internal combustion engine).
• lack of developed networks of charging stations, the development of which requires large financial investments;
• strong dependence of battery capacity on weather conditions and temperature [1].

According to statistics, just over 1% of cars currently on the world's roads are electric, that is more than 5.3 million electric vehicles (mid-2020). It is predicted that by 2040 there will be about 530 million electric vehicles on the world market, the share of which in the global car sales will be 54% [2]. The main factor driving the implementation of electric vehicles is environmental friendliness. It is especially relevant in countries with high urbanization, because transport accounts for 20-40% of all emissions.

The turnover of electric vehicles around the world is different, since the introduction of electrified transport is influenced by consumer demand, the market economy, the availability of charging infrastructure and government policies.

Speaking about supporting the development of electric transport abroad, it can be noted that in European countries either minimum tax rates are established for electric vehicles, or they are absent at all. Speaking about supporting the development of electric transport abroad, it can be noted that in European countries either minimum tax rates are established for electric vehicles, or they are absent at all. Subsidies for the purchase of an electric car in Europe reach 5,000 euros. In China, the owner of an electric car receives 35% compensation, in the USA 25%, in Japan there are no taxes, including VAT on electric cars, which allows you to save up to 30% only on the purchase. In Canada, the purchase subsidy is $ 4,000 [3]. In addition to key technologies related to the production and operation of electric vehicles, there is a need to indissolubly develop technologies aimed at minimizing the share of carbon-fueled power plants. The most effective conditions for the development of electric transport from the above countries exist in Norway, France and Brazil. Brief statistics on the use of electric vehicles in a number of European countries are presented in table 1.

Table 1. Electrification of transport in Russia and European countries.

| №  | Country    | Percentage of electrified transport from the total amount of vehicles | Number of cars per 1000 inhabitants | Amount of electric vehicles per 1000 inhabitants |
|----|------------|---------------------------------------------------------------|-----------------------------------|-----------------------------------------------|
| 1  | Norway     | 29%                                                          | 506                               | 29.95                                         |
| 2  | Netherlands| 6.5%                                                         | 481                               | 6.99                                          |
| 3  | United Kingdom | 1.41%                                       | 469                               | 2.09                                          |
| 4  | France     | 1.46%                                                        | 479                               | 1.84                                          |
| 5  | Germany    | 0.27%                                                        | 555                               | 1.5                                           |
| 7  | Russia     | 0.014%                                                       | 369                               | 0.05                                          |
| 8  | Brazil     | 0.038%                                                       | 249                               | 0.0001                                        |

China's plans for the electrification of urban passenger transport are the most ambitious. The growth in sales of electric buses is growing by at least 15% every year. The electric vehicle market in India is in its infancy compared to the global situation around the world. South Korea has also begun to stimulate demand for high-performance batteries by introducing a wireless-charging battery.

Analyses show that the top six countries ordering electric buses (including battery-powered) in Europe since 2002 include the Russian Federation, the United Kingdom, the Netherlands, France, Poland and Germany. Considering the example of the transition to electrified transport in some countries, it is possible to highlight the prospective need of these countries for energy resources [4] (table 2).
Table 2. Prospects for the growth of energy consumption and the need for electric power in the context of an increase in the share of electrified transport in some countries.

| №  | Country | Basis for calculation                                                                 | Electricity consumption growth prospects | Capacity demand growth prospects |
|----|---------|--------------------------------------------------------------------------------------|------------------------------------------|--------------------------------|
| 1  | Germany | Bill allowing the sale of electric vehicles only after 2030                          | 31%                                      | 40%                            |
| 2  | Holland | Replacing 8 million cars with electric vehicles                                       | 21%                                      | 24%                            |
| 3  | Norway  | Replacing 2.5 million cars with electric vehicles                                     | 7%                                       | 12%                            |
| 4  | Great Britain | Reaching 30% share of electrification of transport by 2030  | 36%                                      | 49%                            |
| 5  | USA     | Increasing the level of transport electrification up to 25% in 10 years While maintaining the average annual growth rate of electric transport at the current level of 4.4% per year | 29%                                      | 44%                            |
| 6  | China   |                                                                                      | 19%                                      | 27%                            |

The main purpose of the study is to assess the prospects for energy construction in the context of spread of the global growth rates of the share of electrified transport to subjects of the Russian Federation. One of the agglomerations, Krasnodar, with a total population of 1473.3 thousand people, was chosen as a subject of the Russian Federation [5].

2. Materials and methods

At the moment, more than 130 electric power entities operate in Krasnodar Territory, which carry out the production, transmission, dispatch management and sale of electric energy. There are four large power producers operating in the region - Krasnodar TPS, Sochi TPS, Adler TPS, Dzhubginsk TPS, and lower-capacity generation facilities, such as Krasnopolyansk and Belorechensk HEPs, and about 40 low-capacity HPPs. The total installed capacity of operating power plants in the Krasnodar Territory as of January 2020 amounted to 2370.87 MW, including:

- TPS - 2301.27 MW (of which 25 power plants of industrial enterprises with an installed capacity of 473.148 MW);
- HPP - 69.6 MW.

The main fuel for all HPPs in the Krasnodar Territory is gas, and the reserve fuel is fuel oil. Statistical data on the volumes of generation and consumption of electricity in Krasnodar Territory are presented in table 3.

Table 3. Indicators of production and consumption of electricity in the Krasnodar Territory over the past 5 years.

| No | Year | Electricity production, kW * h | Percentage of production in relation to last year | Electricity consumption, kW / h | Percent of consumption compared to last year |
|----|------|-------------------------------|-----------------------------------------------|---------------------------------|-----------------------------------------------|
| 1  | 2015 | 11.545 billion                | -1.5 %                                       | 25.5 billion                     | +3%                                           |
| 2  | 2016 | 11.8 billion                  | +3%                                          | 26.9 billion                     | +5.7%                                         |
| 3  | 2017 | 11.5 billion %                | -2.9%                                        | 26.9 billion                     | +0.1%                                         |
| 4  | 2018 | 12.5 billion                 | +4.4%                                        | 27.7 billion                     | +2.9%                                         |
| 5  | 2019 | 10.3 billion                 | -15.6%                                       | 27.6 billion                     | -0.3%                                         |
The presented shortage of generating capacities in the territory of the Kuban energy system was traditionally covered by the flows of electricity through intersystem power lines from adjacent power systems. About 40% of the consumed electricity is generated on the territory of Krasnodar. The forecast for the amount of electricity consumption in the Krasnodar Territory by 2025 will reach 30.67 billion kWh, an increase over five years will be to 3.4 billion kWh with an average annual growth rate of 2.71%. According to the preliminary scenario of an increase in the load on the power system by 2025, it is expected to increase to 5330 MW, or by 7.7% of the indicators of 2015.

Over the past five years, in the Krasnodar Territory, there has been an excess of demand for electricity over its production in the amount of 12.5–15.8 billion kWh. Electricity was imported from the neighboring energy systems of the Stavropol Territory and the Rostov Region (Rostov NPP) of the United Energy System of the South. In terms of deficit, the region yielded only to the metropolitan regions, which experience an energy shortage of 30.9 billion kWh, while producing 70% of the electricity they need.

The most important problem of energy supply to the territory of the region consists of three aspects:

- volatility;
- depreciation of fixed assets (up to 70% in the electric power industry, 62% in the heat sector; losses in heat networks are 17%);
- lack of reserves of energy capacities for the implementation of promising programs for the development of sectors of the regional economy.

At the same time, it should be taken into that the construction of new generating capacities in preparation for the 2014 Olympics solved the problem of energy specificity only in the local agglomeration zone of Sochi during the Olympic Games. The main factors hindering the effective development of the energy sector in the Krasnodar Territory [6] are presented in table 4.

| Factors preventing the effective development of the energy sector in the Krasnodar Territory | Problems arising from the above factors |
|-----------------------------------------------------------------------------------------------|----------------------------------------|
| High level of physical deterioration of the energy infrastructure                           | The need for the reconstruction of worn-out and in the construction of additional generating capacities |
| The combination of the region's energy dependence on supplies from the external environment and the growing energy capacity of the reproduction process | Restriction for the implementation of the region in various fields of activity |
| The transfer of the most important elements of the energy infrastructure under the control of large vertically integrated structures. | The need to reserve energy sources |
| Inadequate reflection of the needs of modernization and development of energy infrastructure in strategic agreements between vertically integrated corporations operating in the region and territorial authorities. | High requirements for environmental cleanliness of energy sources |

Currently, most of the energy is produced by thermal power plants in the Krasnodar Territory. Hydroelectric power plants produce electricity without emitting carbon dioxide and other harmful substances into the atmosphere, unlike thermal ones, but there are problems associated with the use and construction of hydroelectric power plants: flooding of arable fertile lands, blocking rivers, changing the level of groundwater, erosion of the coastline, changing climate and so on. Hydroelectric power plants cannot be built in the place of any active need for energy resources, since a significant difference in height and sufficient river capacity are required, therefore the location of hydropower facilities is extremely problematic in conditions of flat relief. At present, the small hydropower industry of the Krasnodar Territory is represented by only three hydroelectric power stations, built in the 50s of the last century. The general structure of electricity generation in the Krasnodar Territory is presented in table 5.
Table 5. Power facilities of Krasnodar Territory.

| Power station type | Power stations names       | Electric power | Status       | Total design electric power |
|--------------------|----------------------------|----------------|--------------|-----------------------------|
| TPS                | Adler                      | 351 MW         | in operation |                             |
|                    | Shochi                     | 160.50 MW      | in operation |                             |
|                    | Krasnodar                  | 1120 MW        | in operation |                             |
|                    | Crimea                     | 18 MW          | in operation | 1649.5 MW                   |
| WPS                | Coast                      | 90 MW          | in operation |                             |
|                    | Kanevsk                    | 99 MW          | under construction |                         |
|                    | Shcherbinovsk              | 99 MW          | under construction |                         |
|                    | Yeisk                      | 72 MW          | under construction |                         |
|                    | Anapa -1                   | 48 MW          | under construction |                         |
|                    | Anapa -2                   | 51 MW          | under construction |                         |
|                    | Gelendzhik -1             | 60 MW          | under construction |                         |
|                    | Gelendzhik -2             | 60 MW          | under construction |                         |
|                    | Gelendzhik -South-1       | 30 MW          | under construction | 2180 MW                   |
|                    | Gelendzhik -South -2      | 30 MW          | under construction |                         |
|                    | Primorsk-Akhtarsk         | 150 MW         | under construction |                         |
|                    | Adygea                     | 150 MW         | under construction |                         |
|                    | Blagoveshchensk -1        | 123 MW         | under construction |                         |
|                    | Blagoveshchensk -2        | 126 MW         | under construction |                         |
|                    | Taman                      | 102 MW         | under construction |                         |
|                    | Krasnodar wind farm       | 1000 MW        | under construction |                         |
| TPS                | Udarnaya                   | 500 MW         | projected |                             |
|                    | Dzhubuginsk               | 198 MW         | in operation |                             |
|                    | Tuapse                     | 153 MW         | in operation | 896 MW                      |
|                    | GTPP Krasnodar Territory   | 45 MW          | in operation |                             |
| HEP                | Krasnopolyanskaya         | 28.90 MW       | in operation | 86.3 MW                     |
|                    | Belorechensk              | 48 MW          | in operation |                             |
|                    | Maykop                     | 9.4 MW         | in operation |                             |
| SEP                | Labinsk                    | 44.1 MW        | under construction | 44.1 MW                   |

Today, in the Krasnodar Territory, the total installed capacity of all generating sources in the region is 2,712.4 MW. The power deficit is covered by the connected capacity about 2,700 MW. In the near future, it is planned to commission 2,253.5 MW, which will allow the region to become energy-independent.

To solve the problem of energy shortages in the region, proposals for the use of alternative energy sources are being considered, while there are objective problems for their development, one of which is the overpriced equipment. The geography of the region allows the use of all types of renewable energy sources: wind, solar, geothermal, biomass energy. However, today the share of “green” energy in the total balance does not even reach 2%. Since the "electrical substitution" of vehicles is carried out in order to reduce greenhouse gas emissions, it is assumed that the additional power generation capacity should be mainly "renewable" - i.e. offshore wind turbines and photovoltaics.

The average ICUF of such sources is about 0.3. Wind power plants lag far behind nuclear power plants, thermal power plants and hydroelectric power plants in terms of installed capacity utilization factor. If for nuclear power plants it is 84%, for thermal power plants it is 53%, for hydroelectric power plants it is 42%, then for wind power plants it is only 20%, which is due to the nature of the energy source itself. In other words, wind power plants are 2-4 times less productive than power plants of traditional types, and in order to obtain the same amount of electricity, they need to be built 2-4 times more. These are additional areas and materials, which means greater environmental damage, especially for the resort region, in terms of kW of generated electricity.

Solar energy is used in sanatoriums and resorts, in remote and inaccessible mountain areas; on the coast, such structures are installed quite often. But, solar energy has a significant limitation: no sun - no energy. Although Krasnodar is located in the southernmost part of Russia, one cannot count on the
generation of a constant capacity of such an energy source, which is directly related to weather conditions.

A promising direction is the use of geothermal sources. In terms of power and volume of use, geothermal heat supply ranks second in the world among renewable energy sources after solar heat supply. 18 geothermal deposits with a potential capacity of 258 MW have been explored in the Krasnodar Territory.

The prospects of the Kuban geotherm are in their integrated use with the construction of large-scale combined heat supply systems and thermal resorts, according to European experience [7]. The main disadvantage of geothermal energy lies in the origin of energy: stations are being built in seismically active zones. In the Krasnodar Territory, depending on the location of the geothermal deposits, the seismic activity scale ranges from 6 to 9. The construction of a station in such places is always a risk, and if we take into account the fact that the construction of a geothermal power plant is costly (the cost of drilling these wells alone is more than 3 billion rubles), the question arises about the expediency of using the power of the Earth’s geothermal waters. To circumvent the risks, for the construction of Geothermal power plants, traditionally “quieter” regions are chosen, where the last seismic activity was noticed long ago.

Another type of alternative energy that can be developed in the region is bioenergy. The Krasnodar Territory is an agricultural one, and the use of biogas plants by agricultural enterprises for processing animal waste into heat would be an excellent solution, both for energy supply and for improving the environment [8]. But this process of obtaining energy is not stable, because largely depends on the condition of animals, large financial investments and the alienation of fertile lands.

Krasnodar nuclear power plant was planned to be built in the mid-80s of the last century. The cancellation of the construction of the Krasnodar nuclear power plant, as well as the neighboring Crimean nuclear power plant, is associated with the events at the Chernobyl power plant. Experts consider the idea of building their own nuclear power plant to be irrational, since after the launch of the fourth power unit at the Rostov nuclear power plant, the energy from which almost completely goes to the Krasnodar Territory and Crimea. An additional argument against the construction of a nuclear power plant in the Krasnodar Territory is the significant duration of the construction phase of the nuclear power plant life cycle, high costs for construction, as well as the need to involve a large number of specialized contractors in the project [9].

You should also take into account the seismic hazard of NPP construction. If, in the event of a similar natural disaster at a nuclear power plant, the cooling system fails, as happened in 2011 at the Japanese nuclear power plant "Fukushima" [10], and radionuclides are released into the environment, then the territory of Russia will enter the zone of possible radioactive contamination up to Moscow and Nizhny Novgorod, and the densely populated Krasnodar Territory will suffer the most.

Despite the fact that the Krasnodar Territory has great prospects in the development of renewable energy sources: wind power plants, photovoltaics and geothermal sources, they do not provide such a stable output as power plants operating on fossil fuel.

Turning to the issue of electrification of transport, it should be noted that the Krasnodar Territory, according to the analytical agency "AUTOSTAT", as of January 1, 2020, took 3rd place in Russia in terms of the number of registered cars. There are 1.89 million passenger cars and 144.2 thousand trucks in the region. This is 4.3% of the total number of registered vehicles in the Russian Federation.

Every year there is a tendency to increase the total car park of Krasnodar by 15–20 thousand units. At the same time, it ranks first in Russia in terms of the number of cars per capita (437 cars per 1000 inhabitants, Moscow - 417 cars, Samara - 409 cars). Over the past 5 years, the number of vehicles in Krasnodar has grown by 17%. By the number of cars sold, the Kuban capital took 6th place among Russian cities with a population of over one million.

The network of regular bus routes in the city of Krasnodar is more than 4000 km. Automobile, including bus, passenger transportation occupies a leading position due to the fairly high mobility of this type of transport. The bus fleet accounts for about 40% of the volume of passenger traffic; buses serve both urban and suburban (including summer cottages) directions. The trolleybus-tram
organization's transportations cover about 400,000 passengers, which is 60% of all passenger traffic in the city. Electric transport lines are available in almost all major areas of the city. Trams and trolleybuses carry an average of 150 million people annually.

The operation of trolleybuses, nevertheless, has its drawbacks: large losses of energy in the wires, cluttering of city streets with wires, inability to bypass an obstacle, low speed that does not correspond to the modern rhythm of the city, in case of a break in wires network, all trolleybuses stop [11].

The construction of tram lines is less in demand in the city and more labor intensive than the operation of trackless transport. Since the capacity of roads does not correspond to a city with a population of over one million, the laying of rails that occupy the usable area of roads causes a lot of inconvenience to motorists when crossing tram lines. When freed from the rails, a part of the carriageway area of the road can be used for expansion, and outer lanes can become dedicated ones, for running electric buses that will increase the speed of their traffic [12].

Replacement of trolleybuses with electric buses is implementation of a comprehensive transport infrastructure development program. An electric bus charged at terminal stations can become an alternative to a bus and a trolleybus on those streets where, as a result of low traffic intensity, the device and maintenance of the contact network is not rational. As a rule, such cars are equipped with an electric motor, a powerful battery and a regenerative or dynamic braking system, which, when braking, converts the kinetic energy of the vehicle into electricity [13].

The issue of further modernization of the city's public bus is developing. The most effective solution to the problem of saving fuel, reducing emissions of harmful substances and reducing congestion on the roads is the transition to urban roadless and wireless electric transport.

Evaluating trends in the household sector, it should be noted that the electric car park in the Krasnodar Territory as of January 1, 2020 is 462 cars. At the same time, over the past six months, the number of electric vehicles has increased by 28.3%. In terms of the number of electric vehicles, Kuban ranks 5th in Russia. Brief statistical data on the registered number of electric vehicles in the subjects of the Russian Federation is presented in table 6.

| Region                  | Registered, pcs. |
|-------------------------|------------------|
| Primorsk Territory      | 980              |
| Irkutsk Territory       | 657              |
| Moscow                  | 594              |
| Khabarovsk Territory    | 477              |
| Krasnodar Territory     | 462              |

The main source of air pollution in the Krasnodar agglomeration is motor vehicles. The share of air pollution from vehicle exhaust reaches 80%. Due to the large number of traffic jams, the average speed of cars moving along the city streets is about 15 km/h, the toxicity of exhaust at this speed is close to maximum. More than half of the Kuban vehicle fleet is in the final stages of operation, the Kuban vehicle fleet is being replenished with used cars, which negatively affects the overall environmental situation in the region.

The development of electric transport in the region presupposes the creation of an efficient and modern charging infrastructure. Charging stations should be installed not only on the territory of settlements, but also on regional and federal highways. To assess the prospects for the use of electrified transport, the calculation of electricity consumption by electrified transport was carried out.

At a cost of 3.2 rubles / kW * h, the annual expenses on an electric bus will be 217 thousand rubles, while the cost of diesel fuel consumed by a bus will be 675 thousand rubles. Thus, for municipal organizations there is a real economic feasibility of using electrified vehicles.

For owners of electric vehicles, the total energy consumption for charging (taking into account losses during charging) in urban mode is 14.44 kWh/100 km, on the highway 16.81 kWh/100 km.
Taking into account the cost of kW/h of a home network, with an average battery capacity of 45 kW, the cost of charging will be about 252.9 rubles. in the daytime and 135.9 rubles. at night. This is much more profitable, with an average fuel cost of 450 rubles per 100 km. In this regard, it can be concluded that by purchasing cars with electric motors, city residents will contribute to the preservation of the ecology of the region, and will also experience significant savings in money.

Having presented household and environmental prospects of electrified transport, it is important to note that the evolution of the vehicle fleet of domestic cars should be accompanied by an evolution in the technology of electricity production [14]. Newly commissioned generating capacities should have an extremely high efficiency and capacity factor, if necessary, be focused on the integrated generation of electricity and heat, and have the minimum possible impact on the environmental situation in the region.

3. Results

To predict the impact of the growing share of electrified transport on electricity consumption in the Krasnodar agglomeration, we will accept four report points: 2020, 2025, 2030, 2035 and the projected number of electrified transport units based on uneven growth for each year. For urban passenger transport, this value within the calculation is 100% by 2035, for personal electric transport the value is 15%. The volume of electricity generation in the Krasnodar Territory in accordance with the previously described generation prospects will gradually increase to the declared coverage of 90% of its own needs. The calculation data are presented in table 7.

Table 7. Prospects for the development of generation and consumption of electricity (electrified transport) in the Krasnodar agglomeration.

| Year | Number of electric-mobiles | Number of electro-buses | Electricity generation, kW * h | Electricity consumption by electric vehicles, kW / h | Burrowed your own electricity needs | Percentage of electricity consumption by electric transport from generation |
|------|---------------------------|-------------------------|--------------------------------|-----------------------------------------------|----------------------------------|-----------------------------------------------|
| 2020 | 462                       | 15                      | 11.3 billion                   | 3 mln                                          | 41%                              | 0.026%                                       |
| 2025 | 50 000                    | 80                      | 16.1 billion                   | 225.1 mln                                    | 58%                              | 1.40%                                        |
| 2030 | 150 000                   | 200                     | 19.9 billion                   | 672.74 mln                                   | 72%                              | 3.38%                                        |
| 2035 | 300 000                   | 400                     | 24.8 billion                   | 1 billion 345 mln                            | 90%                              | 5.42%                                        |

As a result of the calculations, it can be concluded that in the context of the implementation of the plan to increase its own generation of electricity in the Krasnodar Territory to 90% of consumed, the achievement of the declared degree of electrification of public transport (100%) and personal (15%) by 2035 will cause a deficit of generated electricity in the amount of 1 billion 345 million kW/h and electric capacity in the agglomeration within 300 MW, which is a relatively small value.

The resulting value of the required electrical power predetermines the criteria for choosing a promising generating facility. Taking into account the concentration of vehicles mainly within the boundaries of the city of Krasnodar, it seems most expedient to build by 2035 one block of a combined-cycle combined heat and power plant using natural gas as fuel. To cover the demand for electricity outside the city of Krasnodar, along the main transport arteries, wind and solar power devices of small capacity, equipped with energy storage systems, can be used to ensure uninterrupted supply of consumers.

These solutions will help avoid the need to form complex organizational structures of investment and construction projects [15,16] and the implementation of technically complex and expensive projects, which can be recognized as nuclear power plants.
4. Conclusions
The power system of the Krasnodar agglomeration is historically in short supply, while the volume of resource consumption is increasing annually. An increase in the share of electric transport will further contribute to an increase in the load on power supply systems, which emphasizes the importance and feasibility of building new generating capacities throughout the entire Krasnodar Territory.

Assessment of the prospective demand for electricity as a result of the active development of electric transport allows us to reasonably assume that in the near future a significant increase in the region's energy consumption is not expected, however, until 2035, it is advisable to build one HPP unit with a combined-cycle plant with a capacity of no more than 420 MW in the city of Krasnodar, which has the highest efficiency rates, and is designed to cover the electricity consumption of electrified transport and the needs of the population of the city of Krasnodar for thermal energy. At the same time, on the territory of the agglomeration outside the city of Krasnodar, it is advisable to consider the construction of environmentally friendly alternative energy sources of low power.

Areas for further research should be the study of seasonal and daily fluctuations in energy consumption in the region associated with the development of the tourist and agricultural direction of the Krasnodar Territory. It should be noted that over the past 10 years, the peak load volume has more than doubled, which leads to significant overloads of the energy infrastructure of cities and towns in the region. It is also necessary to take into account that the Krasnodar Territory is closely connected with other subjects of the country, such as the Republic of Crimea and the Republic of Adygea. The territory of Republic of Adygea is an enclave, and it is inseparable from the Krasnodar Territory in many issues, including energy supply. A part of the energy from the Rostov NPP is transmitted through the energy bridge built between the Crimea and the Krasnodar Territory, which requires the modernization of substations and power lines operated by the region in the future.

References
[1] Asadov D G 2015 International technical and economic journal 5 136-8
[2] Ponomareva Ye 2018 Energy Bulletin 24 12-20
[3] Gorbenko S D and Chernenko E M 2019 Formation of the electric transport system as a promising idea for the development of technologies and economics in the Krasnodar Territory Proceedings of the II International Scientific and Practical Conference 116-9
[4] Demidov D I and Pugachev V 2019 Journal of news of the Orenburg State Agrarian University 5(79) 173-8
[5] Avdeyeva T T and Lavrova T G 2020 Modern economy success 4 240-6
[6] Zakharova Ye N and Avramenko Ye P 2012 Adyghe State University 1 163-70
[7] Petin Yu M et al. 2013 Bulletin of the Buryat Scientific Center of the Siberian Branch of the Russian Academy of Sciences 2(10) 247-54
[8] Zubko D V 2017 Science and Practice Bulletin 12(25) 300-6
[9] Morozenko A A and Voronkov I Ye 2014 Voronkov Industrial and civil construction 10 74-9
[10] Kutkov V A and Tkachenko V V 2016 Proceedings of higher educational institutions Nuclear energy 4 67-77
[11] Korol V M 2011 Transport of the Russian Federation 5 56-9
[12] Kolin A V 2018 Transport of the Russian Federation 3(76) 38-42
[13] Ostrikov I A and Bochko T F 2015 Ways to improve energy efficiency of environmentally friendly public transport in Krasnodar Bulletin of the Volga University named after V.N. Tatishcheva
[14] Ribkin S A et al. 2015 Economics of education 6 106-14
[15] Voronkov I Ye 2018 Bulletin of BSTU 11 137-45
[16] Voronkov I 2018 IOP Conference Series: Materials Science and Engineering 365 062035