Establishment of Rational Points for Location of CHPP in Large Cities

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Abstract. The economic indicators of the development of the economy of the countries of the world and the presence of the ecology of the environment are significantly influenced by the points of location of power plants in large cities. In modern conditions, these points are recommended to be set taking into account the presence of cost factors in each large city. The use of these features allows you to minimize the emission of gases into the city. On the territory of the continent of Eurasia, there is a cargo point located in Kuzbass, in Russia. From this main loading point for coal on the railway network, loaded wagon flows are sent both in the western and eastern directions. The presence of this cargo terminal on the continent will have a significant impact on the rational location of CHP in large cities. The most rational will be the location of CHPPs, which will be located on the territory of large cities and located separately: both for the western and eastern parts of the continent. When energy streams move from the cargo-handling point, CHPs should be located at the entrance to the city. In the western part of the continent of Eurasia, it is more efficient to locate CHP in the eastern part of large cities. For the eastern part of the continent, power plants should be located on the outskirts in the western part of large cities behind the cargo-handling point.

Introduction
In the modern period of scientific and technological progress, the ability to provide the population with electricity at lower costs has become important. This demand for electricity increased to the greatest extent due to the growth in the share of the population living in large cities. Rational locations of power plants in such densely populated areas can have a significant effect from reducing the total transport costs associated with meeting the needs of the population with energy resources.

The procedure for providing the population with electricity, which occurs with technical progress, has gone through several stages and has undergone significant changes in the procedure for transporting fuel and transferring energy resources over long distances. Thus, the provision of the population with fuel for large cities has always been made, from the very beginning of their formation. At the initial stage of urban development, the main energy resources were wood and coal. At that time, the population of the countries of the world did not have electricity. The transportation of energy resources was carried out over long distances: from the points of the location of mineral deposits to the places of residence of a large number of people in large cities [1].

Subsequently, in connection with technical progress, methods of generating electricity were invented and its production on a mass scale was established. The use of electricity has proven to be an effective measure for improving the economic indicators of economic development in the countries of the world as a whole. At the initial stage of technical progress, electricity turned out to be the most effective in lighting dwellings, for use for various equipment. At the next stage, electricity turned out to be very rational in the use of many production processes: in communications, in machine tools, in railway transport. At the present stage, electricity has proved to be an effective measure in heating homes, especially in rural areas far from large cities, as well as in the case of only temporary residence of the population in homes.
Results and Discussion

When evaluating the effectiveness of the options, it should be borne in mind that technical progress in electric power occurred more intensively than in other areas of economic and economic activity of the countries of the world. Thus, at the initial stage, the transmission of electricity, especially over long distances, in increased volumes turned out to be an expensive undertaking. Therefore, at the initial stage of generating electricity, they tried to generate it locally. At the same time, over long distances: from the main coal deposits to the points of its consumption in large cities, energy resources had to be transported first by horse-drawn, and then by rail [2, 3].

Gradually, with the development of energy, it became possible to generate massive flows of electricity, especially for low quality brown coal, and to transmit its increased flows through wires. This measure made it possible to significantly reduce the costs in the throughput of main lines of railway transport associated with a decrease in the level of empty carriage mileage over long distances. In the modern period, due to technical progress, it becomes more expedient to replace the production process, including heating of dwellings: from coal to electricity. This trend will intensify in connection with the invention and implementation in practice of methods for generating electricity from renewable energy sources, for example, using wind power plants [4]. However, the efficiency of the location of CHP plants on the territory of the country and the need for their placement in large cities is influenced by the possibility of using waste heat (CHP) for heating the dwellings of the population in large cities.

The efficiency of this option is additionally influenced by the location of CHP power plants in large cities. From the place of their possible location in large cities, transport costs for the delivery of coal and the costs associated with the transmission of electricity over various distances have a significant influence.

Large cities are the objects in the consumption of the largest volumes of electricity. Here, in addition to a large population, developed industry and other industrial technical facilities, significant energy costs are required. However, at the present stage of scientific and technological progress, mineral fuel sources are usually located far from large cities. This leads to the need for optimal placement of thermal power plants near the population consuming electricity. Therefore, the economic efficiency of providing electricity to the population of large cities with a large territory mainly depends on the location of the CHPP, and the transmission distance for the generated electricity for them is several tens of kilometers. Therefore, at the present stage, the question arose about the choice of rational points for the location and generation of electricity (thermal power plants) that meet the needs of the population of large cities.

Until now, thermal power plants using non-renewable energy sources: coal, oil and gas are the main objects for generating electricity in large cities. At the same time, renewable sources use energy from a large area and are currently most efficiently used to meet the needs of the population living in rural areas and on the outskirts of regions. In addition to generating electricity, waste from thermal power plants is currently widely used for the population of the continent of Eurasia for central heating and, first of all, for providing the population with fuel in large cities.

At the same time, practice has shown that thermal power plants (CHP) have certain disadvantages. So, they use coal, which pollutes the atmosphere and degrades the ecology of the environment. Therefore, in the future, the share of electricity generated from non-renewable energy sources will decline. However, the possibility of heating homes, especially in the harsh conditions of Siberia, forces such countries to use CHPs to provide the population with electricity and fuel in large cities.

In order to ensure a better quality of life, improve the ecology of the environment, it is advisable to use the wind rose. In this case, based on the predominant wind direction, the place for generating electricity for large cities was chosen in such a way that during the entire period of the year the smoke from thermal coal-fired power plants spreads to the least extent throughout the territory of a large city [5].

In Novosibirsk, to provide energy to Akademgorodok, a power plant was built a few tens of kilometers from the city center in order to improve the ecology of life of the population. However, this option has resulted in high capital costs and increased operating costs associated with long-distance heat and power transmission.
To ensure a higher quality of service to the population in practical operating conditions at the present stage, it is necessary to choose an option that causes a better ecology of the environment. In modern conditions, to ensure the achievement of better results, it is necessary to choose the option of taking into account the main direction of movement of fuel cargo (coal), which is required to ensure the generation of electricity especially large power plants located on the outskirts of the large cities under consideration, providing the shortest transmission distance of energy resources through the territory of large cities [6, 7, 8].

In practical terms, conventional power plants were built on the outskirts of large cities. This option generally reduces transport costs associated with coal supply, which ensures better utilization of the city's territory while using electricity by the population.

However, practice has also shown that the best option for providing the population with electricity is achieved when power plants are being built not only on the outskirts of large cities. It is necessary to create such a way that the flows of fuel and electricity as a whole constitute the least amount of costs associated with the distance of fuel transportation, as well as lower costs in the transmission of electricity through the territory of large cities from CHP to the population.

Usually in cities, most of the thermal power plants (3 out of 5) are built on the side of the direction of the main coal flow. This option allows you to achieve the following savings from such a rational location of thermal power plants on the territory of each major city:

- the distance of following coal flows decreases, and first of all over the territory of a large city;
- the transmission distance of electricity generated by urban power plants is reduced, which additionally transmit it to the countryside.

However, this option, which gives a certain effect in small countries with a small territory, cannot be fully used for the territory of the vast continent of Eurasia. For the continent of Eurasia, Russia has the greatest excess of electricity generated by a number of thermal power plants operating on coal, oil or gas [9, 10].

In Russia, for a large territory of the country with increased reserves of mineral fuel, there is a cargo-handling point in the production of fuel, located in Kuzbass. For the continent as a whole, at this point with the largest volume of coal loading by rail along the train movement, both from west to east and from east to west, empty traffic changes to loaded (Fig. 1).

![Figure 1](image-url)

Figure 1. Direction of loaded and empty car traffic across the continent of Eurasia in latitudinal direction: LOADED - loaded direction of car traffic; EMPTY - empty direction of car traffic.

Fig. 1 shows that in the western part of the continent of Eurasia the empty direction changes to the loaded one. So, in the European part of the continent, in places of the highest concentration of
population, unloading of cars is carried out on an increased scale. These wagons, after unloading, usually in an empty direction, are sent back to the geographic center of the Eurasia continent, located in Kuzbass [8].

In the eastern part of the continent, the laden traffic of wagons follows in the Far East of Russia, as well as in the countries of East Asia in the eastern direction, where it is then unloaded on an increased scale, mainly on the terminal part of the continent of Eurasia. After that, the unloaded wagons in the opposite western direction are returned back to the cargo point of the continent of Eurasia in an empty state for loading.

Directly through the cargo-handling point, the flow of loaded wagons follows both the western and the eastern directions. From both the western and eastern parts of the continent of Eurasia, an increased flow of empty wagons arrives at the loading station of the cargo-handling point.

The presence of different directions of the main fuel flows over the vast territory of the continent will have a significant impact on the optimal option for the location of large thermal power plants located on the territory of large cities. When assessing options for the location of power plants, it is necessary to carry out a separation for the two main parts of the continent of Eurasia.

1. For the western part of the continent, the flow of coal-laden wagons follows westward from the cargo area.

2. In the eastern part of the country, the flow of loaded wagons with coal follows in the eastern direction from the cargo point towards the Far East and further to the countries of East Asia.

The presence of a cargo point in car traffic, as well as loaded and empty directions, will have a significant impact on the procedure for placing thermal power plants in large cities for various parts of the continent of Eurasia.

In practical operating conditions, it becomes expedient to build power plants, first of all, depending on the direction of the coal flows. Taking into account this factor, it becomes more profitable to build thermal power plants (CHP) primarily on the outskirts at the entrance to a large city. It should also be taken into account that thermal power plants, which were initially built on the outskirts of cities, turned out to be close to the city center in the central part of a large city. For example, CHPP-2 in Novosibirsk was located near a communal bridge located in the central part of a large city.

Figure 2. Diagram of energy resource flows in case of a power plant located on the outskirts of the entrance to a large city.

Taking this approach into account, it is necessary to take into account the direction of the main flow of coal or fuel that is transported to the CHP plant for electricity generation.

A) At the entrance to the city from the outskirts of a large city.
CHP - the location of the power plant in relation to the territory of a large city;
B) At the exit from the city to its outskirts.

A) If thermal power plants are located at the entrance to a large city, there will be lower transport costs for the railways of the continent. In this case, coal streams follow a short distance only to the outskirts of a large city. In this case, the flows of electric energy follow in a straight direction, practically without increasing the transportation distance as a whole, compared to the shortest direction. Therefore, this option provides low costs associated with the delivery of energy resources to destinations located in large cities. It is the best option for placing a CHP in a large city. In this case, the total travel distance of energy resources to consumers will have the smallest value. This option is the most rational in the case of meeting the needs of the population in electricity in large cities.

B) In the second conditional version, for comparison, the power generation point (or CHP) is located at the exit from a large city (Fig. 3). In this case, the range of coal travel by rail through the territory of a large city increases. The generated electricity flows will follow the direction opposite to the coal flow. In this case, the costs associated with an increase in the range of the coal and electricity flows will increase. Therefore, this option turns out to be less rational in comparison with the order of placing power plants at the entrance to large cities.

Figure 3. Direction of energy resources in the case of a CHPP located at the exit from the territory of a large city.

The considered model of the placement of power plants as a whole can be used to assess the location of large power plants on the territory of large cities: both for a large country, like Russia, and for the states of the entire continent of Eurasia. To select a rational option for the location of power plants, it is advisable to take into account the presence for Russia of a cargo-handling point with the most massive loading of coal, located in Kuzbass.

To ensure the achievement of the greatest effect, it is necessary to take into account the flows of fuel cargo, and primarily coal, across the territory of the entire continent of Eurasia.

Fig. 4 it can be seen that with the rational nature of the location of energy facilities, it becomes expedient in the western part of the continent of Eurasia to place power plants in large cities in the first place in the eastern part of large cities. This option allows you to reduce costs associated with providing the population of large cities with electricity in the western part of the continent. In the eastern part of the continent, it becomes expedient to organize the location of power plants in the western part of the largest cities.
Figure 4. The procedure for placing the power plant on the territory of large cities on the continent of Eurasia: CITY - large cities; CHP - thermal power plants.

The given variant of placing power plants on the territory of large cities of the continent of Eurasia will reduce the total costs associated with both electricity consumption and transport losses when transporting coal through the largest cities of the country.

Conclusion

For a large territory of the continent of Eurasia, when evaluating rational options for placing power plants across the territory of large cities, one should take into account the presence of a cargo dividing point, where, in the direction of travel: both from west to east, and back from east to west, the empty direction changes to laden.

When assessing the option for the location of CHP in large cities, one should take into account not only the ecology of the environment, that is, the presence of wind. When evaluating options, one should take into account the total transport costs associated with the movement of energy resources across the territory of large cities.

Taking into account the presence of a cargo dividing point as a whole, CHP plants in the western part for the continent of Eurasia should be located in the eastern part of large cities. For the western part of the continent of Eurasia, it is more efficient to locate CHP plants in the western part of large cities.

References

[1] Veselov F.V., Solyanik A.I. Financial and economic adaptation of Russia's thermal power industry to investment challenges in a competitive environment. Izvestiya RAN. Energy. 2019. 1. P. 1–10.
[2] Filippov S.P., Dil'man M.D. Chp plants in russia: the necessity for technological renovation. Thermal Engineering. 2018. T. 65. № 11. C. 775-790.
[3] Veselov F.V., Solyanik A. I. Midterm Development Conditions for the Electric Power Industry of Russia under Hard Price Constraints. Studies on Russian Economic Development. 2020. 31. p. 64-70.
[4] Makarov A., Mitrova T., Kulagin V. Scenario forecast of energy development in Russia, Regional energy and energy saving. 4. 2019.
[5] Dmitrenko A V, Lesnykh E.V., Bekher S.A., Dmitrenko I.Y Buryanina N S, Choosing rational locations for placing wind farms in Eurasia with regard. VIII International Scientific Conference Transport of Siberia – 2020 IOP Conf. Series: Materials Science and Engineering
[6] Sanzhapov B. Kh., Stulova NV Decision support model in the problem of analyzing the ecological risk of urban environment pollution by objects of the fuel and energy complex // Internet Bulletin of VolgGASU. Ser. : Building Informatics. 2014. Issue. 11 (32).
[7] F.V. Veselov, I.V. Erokhina, A.S. Makarova, A.A. Khorshev. Comprehensive assessment of the effective scale of renewal of thermal power plants while substantiating the rational structure of generating capacities for the future until 2035 // Thermal Engineering, Volume 64, Issue 3, 1 March 2017, Pages 161-169.
[8] Likhachev V.I. "Energy security and directions of its provision in the EAEU" // "Energy policy", issue 1, 2017.
[9] Grushevenko D.A., Grushevenko E.V., Kapustin N.O. and Kulagin V.A. "Russia's road transport sector: Prospects for alternative energy" // Environmental Progress & Sustainable Energy, 2017.
[10] Lombardi, P., Sokolnikova, T., Suslov, K., Voropai, N., Styczynski, Z.A. Isolated power system in Russia: A chance for renewable energies? // Renewable Energy, 2016 # 90, c. 532-541.