Improvement of the organizational and economic mechanism for managing the development of alternative sources of electricity at the territorial level

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Abstract. The article considers the features of the structure and functioning of energy supply facilities for housing and communal services of municipalities with the identification and analysis of problems, substantiates the main directions of improving the organizational and economic mechanism for the development of alternative sources of electricity supply, taking into account modern innovative energy-efficient technologies. The choice of a rational option for electricity supply to settlements and the region is considered on the basis of an analysis of geographical, climatic and socio-economic conditions, as well as engineering and financial opportunities, the availability of trunk, interregional and other networks, the total installed capacity of regional power plants and a set of other technical and economic Characteristics inherent in the region and its municipalities.

1. Introduction

Electricity supply is one of the first areas of the public services sector, which was reformed, and was gradually transferred to market relations. Russia has huge reserves of traditional fuel and energy resources and considerable potential for using alternative sources. At the same time, studies on the problems of Russian energy sector do not fully cover the sphere of housing and communal services and do not always take into account the problems that arise at the municipal level. The need to understand the essence of the processes that occur in the sphere of public services is the main condition for the improvement and innovative and energy-efficient development of its facilities.

The main condition for the provision of utility services for electricity supply is the availability of production facilities, distribution and sale of electricity - generating stations, networks, systems and electricity meters, without which the technological process of "generation-transportation-distribution-sale of electricity" is not possible. Reproduction processes of these facilities make it possible to ensure the quality and reliability of electricity supply to consumers, including citizens who own operational networks and meters, electrical equipment in accordance with the Civil Code of the Russian Federation [1]. Classification of objects of engineering infrastructure of the housing and communal complex, their grouping by types of equipment and systems is defined in the Town Planning Code of the Russian Federation [2] and classifier of economic activities (OKVED). In accordance with these documents, "Engineering infrastructure is a complex of facilities and communications that ensures the sustainable development and functioning of settlements and inter-settlement territories" [3, 4].

In accordance with OKVED, generation, transmission and distribution of electricity as a kind of activity includes a number of successive processes that are technologically impossible to realize without...
operation of the relevant energy supply facilities that are involved in these processes (Table 1).

**Table 1. Objects of electricity supply of housing and communal services**

| Electricity supply facilities | Kind of activity | Content of activities |
|-------------------------------|------------------|----------------------|
| Thermal, nuclear, hydroelectric, block stations and power plants operating on renewable energy sources, including solar, wind, geothermal power plants | Energy generation | Production of electric energy at all types of power plants (thermal, nuclear, hydroelectric, block stations and power plants operating on renewable energy sources), including activities to ensure the operability of power plants. |
| Electric grid facilities (power transmission lines, transformer and other substations, distribution points and other designed to provide electrical connections and for the transmission of electrical energy equipment) | Transmission of electricity and technological connection to distribution networks | - transmission of electricity from generating facilities to distribution systems by ensuring the operability (operation) of electric grid facilities; - technological connection of power receivers (power plants) of legal entities and individuals to the electric networks of the network organization. |
| Power lines, poles, meters and electric wires | Distribution of electricity | Ensuring the operation of the distribution system (i.e., a system consisting of lines, poles, meters and electric wires) that transmits electricity received from the generating structure or the transmission system to the end user. |
| Counters | Electricity trading | - sale of electricity to the user; - control over energy supply and throughput |

It is necessary to stimulate the process of building power plants using renewable energy sources in order to provide affordable and high-quality electricity to consumers, especially those that are outside the centralized energy supply systems. The use of modern energy technologies will also contribute to the needs of innovative development of the country’s energy sector.

**2. Method and algorithm**

The rationale for optimal management decisions for the development of energy supply facilities for housing and communal services should be differentiated according to the municipalities, depending on natural climatic, geographical, institutional, socio-economic and technical conditions.

Power plants and network infrastructure are both objects of power systems and subjects of wholesale and retail markets, therefore it is necessary to consider investment projects in this area from two positions:

- with the system-wide, which involves the analysis and assessment of technological feasibility, compliance with reliability requirements and the expected level of the tariff reduction for electricity;
- with an individual, which involves the analysis of an investment project that operates on a closed market.

In the conditions of limited investment resources, it is necessary to take into account that the implementation of the investment project should, on the one hand, meet the conditions for the development of the wholesale market and the UES of Russia, and on the other hand, help reduce electricity tariffs for consumers in retail markets, including housing and communal services of municipalities. Technological, territorial and commercial features of electricity markets affect the generally accepted methodological principles of calculating the effectiveness of investment projects, including the rules for ranking investment projects, priorities, efficiency of each. [5]
Given the value of the internal return on investment for each proposed investment project, it is first necessary to estimate the total costs, including capital and current costs, then on this basis a tariff that will make it possible to recoup the investment project. Comparison of the received tariff rate with the current tariffs on the market or with the forecast level of electricity prices will allow at this stage to "cut off" the inefficient ones. In the event of a power deficit in some territory, the problem of the choice is to be solved: either new electrical networks connecting the scarce territory with an already functioning source of electricity are built, or a generation facility can be built close to consumers (next to the municipal entity), for example, using renewable energy sources. Such projects will be mutually exclusive and, therefore, it is necessary to calculate the value of the NPV in each case in order to conclude that it is economically viable. However, not always the decision-making should be based only on economic performance indicators.

The innovative development of the objects of the energy supply system of the territory, as noted earlier, depends on many factors, which include:
- socio-economic indicators (indicators of living standards, tariffs (prices) for electricity and fuel);
- territorial features (restrictions on the use of territories, natural, environmental restrictions, climate, etc.);
- level of innovative attractiveness of energy supply system objects;
- investment potential (including budgetary funds of federal, regional and municipal budgets), including budget funds allocated for the development of power plants using renewable energy sources;
- indicators of the state of the basic production assets of electricity supply companies.

The results of the research showed that the energy supply system of a single settlement or city district and the region as a whole depends on the natural and climatic and geographical conditions, the distance from the network infrastructure and the degree of its congestion and wear, as well as the concentration of industry, the level of investment potential and level social and economic development of the territory. The individuality of the territories of Russia is also due to a great variety of sources of electricity generation, differentiation of tariffs and volumes of electricity consumption by consumers, and the uniqueness of structural schemes for electricity supply to cities and rural settlements.

In accordance with the set of rules "Urban planning. Planning and development of urban and rural settlements ", the cities of the Russian Federation are classified as follows:
- largest - with a population of more than 1 million people;
- large - from 250 thousand people to 1 million people;
- major - from 100 to 250 thousand people;
- medium - from 50 to 100 thousand people;
- small - up to 50 thousand people.

And also allocate rural settlements, tariffs for the electricity in which are set lower (usually with a lowering factor 0.7) than in cities. In addition, it is possible to distinguish shift camps, power line builders, pipelines, etc., hunters, nomads, fishermen, geologists, as well as garden and vegetable plots and partnerships, the number of which can vary from units to tens of thousands of units.

3. Discussion and outcomes
The proposed approach to the development of a model for improving existing and developing alternative sources of energy supply in housing and communal services is based on a multivariate solution to the problem of the appropriateness of the reproduction of energy supply system objects while reducing the growth rates of electricity tariffs for consumers. The choice of a rational option for electricity supply to settlements and the region as a whole is advisable to begin with an assessment of possible options based on an analysis of geographical, climatic and socio-economic conditions, as well as engineering and financial opportunities, the availability of trunk, interregional and other networks, the total installed capacity of power plants Region and a set of other technical and economic characteristics inherent in the region and its municipalities. The main options for energy supply systems are three:
- centralized, i.e. the system is connected to the network infrastructure of the region;
- decentralized (autonomous), which assumes a different level of autonomy: starting from an
autonomous system for a municipal entity as a whole, ending with an autonomous system of one household;
- combined, which involves a combination of the first two options.

The decision to choose the best option for the organization of the energy supply system is taken individually for each city district or settlement, taking into account the assessment of the efficiency of the current electricity supply system and the projected needs of the territory for electricity. Each metropolitan area or settlement is characterized by an individual amount of electricity consumption, but the general characteristics of this indicator can be given on the basis of the number of inhabitants, the norms of electricity consumption established for the region, the level of industrial development.

If there is a need for additional electricity, it is decided which energy sources will solve this problem and, accordingly, estimates the amount of necessary investments and sources of financing for the investment construction program. If the city or village is remote from electricity distribution networks or other objective conditions (condition of transmission lines, electricity costs, etc.), it may be expedient to build new power generating capacities in the region near consumers. And if there is a potential for renewable energy sources, it is necessary to evaluate the efficiency of construction of a generating facility using alternative renewable energy sources (RES).

The indicators of reliability, balance and availability of electric power for consumers, which are calculated in accordance with the methodology for monitoring the implementation of production and investment programs of utility companies, were used to assess the status of existing energy supply system facilities [6].

Based on the analysis of the forecasted volume of electricity consumption and indicators of the efficiency assessment of the electricity supply system, it is possible to draw a preliminary conclusion about the need for the development of energy supply facilities.

The further choice of one of the options requires a careful analysis of many factors characterizing the territory, including the potential for using alternative energy sources, available technical and economic and financial resources (Table 2).

Table 2. Conditions for choosing the direction of development of the energy supply system

| Direction of development of energy supply system | Conditions for selection |
|-----------------------------------------------|--------------------------|
| Centralized                                   | -Large and largest cities (population of 250 thousand people) |
|                                               | -Availability of the centralized system |
|                                               | -The high efficiency of a functioning energy supply system |
| Autonomous (using alternative renewable energy sources) | -Small cities (up to 50 thousand people) |
|                                               | -Settlements |
|                                               | -Rotational villages |
|                                               | -Hunters, nomads, fishermen, geologists |
|                                               | -Garden and vegetable plots and partnerships |
|                                               | -Complete or partial limitation of access to a centralized system |
|                                               | -The presence of local energy resources |
| Combined (using alternative renewable energy sources) | - Small, medium and large cities (up to 250 thousand people) |
|                                               | -Russian settlements |
|                                               | -Garden and vegetable plots and partnerships |
|                                               | -Availability of the centralized system |
|                                               | -Low efficiency of the functioning energy supply system |
|                                               | -The presence of local energy resources |
In order to develop alternative energy sources, it is the territory with decentralized energy supply systems that are most favorable in the presence of favorable natural and climatic factors. The development of power plants using renewable energy sources in Russia is just beginning, there is still little experience and statistical data, so it is extremely important that pilot projects be tested for efficiency and promote further development in this direction.

In some territories of Russia, the potential for developing RES is very high for one source of energy, for others it is for others, and somewhere this potential is minimal. The development of alternative energy sources should start from those areas that have the most favorable characteristics.

For example, in areas with favorable wind characteristics of natural and climatic conditions, the average annual volume of electricity produced can be 25-35 percent of its maximum value. The service life of wind generators is usually 15-20 years. Territories with an average annual wind speed of less than 5 m/s are of little use for the deployment of wind turbines, and with a wind speed of more than 7 m/s - favorable.

The data on the magnitude and structure of the cost of a wind power plant (WPP) differ for different capacity installations. So, for example, the average indicators of the structure of the cost of a wind turbine with a capacity of 750 kW are given in Table 3.

| Index                      | Average cost, thous. USD | In % of total cost | In % of the cost of the wind power plant |
|---------------------------|--------------------------|--------------------|-----------------------------------------|
| Factory cost of wind turbines | 554.4                    | 80.15              | 100.0                                   |
| Foundation                | 27.0                     | 3.91               | 4.9                                     |
| Connecting to the network | 52.0                     | 7.53               | 9.4                                     |
| Electrical equipment and materials | 3.5                     | 0.5                | 0.6                                     |
| Means of communication    | 2.7                      | 0.39               | 0.5                                     |
| Earth                     | 18.3                     | 2.64               | 3.3                                     |
| Road                      | 7.0                      | 1.02               | 1.3                                     |
| Consulting                | 6.4                      | 0.91               | 1.1                                     |
| Financing                 | 3.4                      | 0.5                | 0.6                                     |
| Insurance                 | 17.0                     | 2.45               | 3.0                                     |
| Total                     | 691.7                    | 100.0              | 124.7                                   |

It should be noted that in the world practice of building wind turbines, there is a tendency to reduce the amount of capital investments, so over time this structure may change in the direction of reducing the cost of acquiring the wind turbine itself. There are also statistical data on the reduction and cost of the electricity produced on the wind farm: at wind farms in USA the cost of electricity decreased from 0.45 USD per kW*hour to 0.10 USD per kW*hour.

The cost of electricity produced by the wind turbine is significantly dependent on the following factors:
- average annual wind speed;
- power (scale) of the power plant: the more power, lower the cost;
- due to its capital intensity, the construction of the wind turbine is sensitive to the interest rate for the loan, so it depends heavily on the choice of the financing mechanism.

In practice, economic performance indicators for the construction of renewable energy facilities are tightly tied to the construction site, the cost of equipment and resources. A simple payback period is
expedient to estimate through average indicators of construction of similar objects, regardless of whether they are centralized or autonomous.

To assess the simple payback period for the construction of renewable energy sources, the following initial data are required:
- \( x_1 \) - the specific cost of the installed capacity for the RES facility, RUB/kW;
- \( x_2 \) - the number of hours of use of the installed capacity for the RES facility in a year, hours;
- \( x_3 \) - cost of replaced fuel (traditional, organic), rubles/1000kg;
- \( x_4 \) - specific fuel consumption in the network (local or centralized), 1000kg/kW*h;
- \( x_5 \) - the share of the tariff for electricity in its fuel component;
- \( x_6 \) - a share of operational costs in cost of capital investments.

Then a simple payback period can be expressed in terms of specific indicators as follows:

\[
T_{ok} = \left( \frac{x_2 \times x_3 \times x_4 \times x_5}{x_1} - x_6 \right)^{-1}
\] (1)

Wind energy is a universal and with an accessible inexhaustible source of energy that does not have harmful emissions into the atmosphere. However, in contracts for the supply of electricity, one must take into account the fact that wind energy has a random nature and certain amount of electricity can be guaranteed only with a certain percentage of probability. Fluctuations are possible at level of +/-10%.

Thus, it is necessary to provide for reserve energy supply and accumulation of generated energy.

The process of technological connection requires the construction of new grid facilities, for the preliminary assessment of the value of which the specific indicators given in Table 4 can be used [4,5]. Electric grid facilities include various types of power lines - overhead lines (OL), cable lines (CL) and transformer substations (TS).

**Table 4. The average cost of construction of electric grid facilities**

| Voltage, kV | OL, thous. USD / km | CL, thous. USD / km | TS, mln. USD |
|------------|---------------------|---------------------|--------------|
| 110        | 40-60               | 1100-1200           | 1.2-1.5      |
| 220        | 30-80               | 740-1100            | 1.5-1.9      |
| 500        | 80-110              | 1700-2500           | 10.0-17.0    |

Thus, the cost of building a new electricity network \( C(l) \) can be represented as a function that depends on the extent of the necessary electrical networks, their voltage types and the number of transformer substations:

\[
C(l) = \sum_{i=1}^{n} \left( p_{i}^{OL} \times l_{i}^{OL} + p_{i}^{CL} \times l_{i}^{CL} + p_{i}^{OS} \times k_{i}^{OS} + p_{i}^{CS} \times k_{i}^{CS} \right)
\] (2)

where
- \( p_{i}^{OL} \) - the cost of 1 km of OL of the i-th type, thous. USD;
- \( l_{i}^{OL} \) - length of OL of the i-th type, km;
- \( p_{i}^{CL} \) - cost of 1 km of CL of i-th type, thous. USD;
- \( l_{i}^{CL} \) - length of CL of the i-th type, km;
- \( p_{i}^{OS} \) - the cost of 1 open substation for the i-th type of lines, thous. USD;
- \( k_{i}^{OS} \) - the number of open substations for the i-th type of lines, pcs;
- \( p_{i}^{CS} \) - the cost of 1 closed substation for the i-th type of lines, thous. USD;
- \( k_{i}^{CS} \) – the number of 1 closed substation for the i-th type of lines, pcs;
- \( n \) – the number of voltage levels (from 1 to 3).

If the construction of facilities is carried out in mountainous areas and settlements, the specific
indicators of construction costs increase by 1.5-3.5 times.

After choosing a variant of the electricity supply system, it is necessary to determine the sources of investment. In the absence of budgetary sources, private investors should be involved, and in the absence of budget sources, it is necessary to analyze the factors that reduce the investment attractiveness of projects and develop schemes for co-financing the implementation of such projects on the principles of public-private partnership.

The possibility and expediency of innovative development of energy supply facilities should be assessed taking into account the risks (production, technical, price, financial, investment, regulatory, etc.) that must be managed in order to minimize their negative impact, taking into account the uncertainties. Managing aggregate risks is advisable to implement both at the enterprise level and at the state level.

4. Conclusion
Given the lack of statistical data, experience large-scale implementation projects and typing in the construction of alternative energy sources to supply public utility process of making optimal managerial decisions in choosing the direction of the energy supply system of objects should be initiated at the municipal level, and the final decision should be taken at regional or national levels, depending on the construction of facilities in accordance with applicable of legislation.

The proposed recommendations may be used for the development and introduction of modern innovative technologies in the field of electricity, the development of investment and construction programs, including the development of new areas that need to provide electricity in the conditions of remoteness from centralized systems representatives of executive authorities and local self-government.

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