On the Issue of Sustainable Energy Development: The Economic Aspect of Transferring Regional Heat Supply to Local Renewable Fuels

Karolina Ketova [a] and Denis Nefedov [b]
Kalashnikov Izhevsk State Technical University, Studencheskaya street, Izhevsk, Russia

Keywords: The Sustainable Energy Development, Regional Economic System, Heat Supply, Energy Security, Renewable Fuels, Economic Efficiency.

Abstract: The paper considers the heat supply system of the regional socio-economic system as an important element that ensures the stability of its existence in modern conditions. To ensure the stability and safety of its functioning, the use of local renewable energy resources in the heat supply system of the region is considered, for which it is necessary to transfer the heat supply system available in the region to other types of energy resources. For this, a methodology for assessing the compliance of the planned and actual progress in the implementation of measures to transfer the regional heat supply system to local types of fuel, based on a system of indicators, is proposed. The methodology contains quantitative indicators of the effectiveness of the implementation of measures. Various financial sources for the implementation of the planned activities were considered: funds from budgets of all levels; consolidated funds based on public-private partnership; budgetary and extrabudgetary grants for research and development work; borrowed funds of credit institutions; own funds of enterprises. Numerical calculations were carried out for one of the regions of Russia - the Udmurt Republic. For this region, the use of local energy resources, primarily wood waste and animal waste, is one of the possible options for solving the problem of energy supply to remote areas in the face of a shortage of fuel and energy resources and a steady rise in prices for traditional fuels and transport costs for the delivery of raw materials to the region.

1 INTRODUCTION

In modern conditions of development of world economies and increasing competition in this regard, the risks associated with the functioning of all elements of socio-economic systems are growing. An important element of the sustainable existence of any socio-economic system is its heat supply system.

The demand for energy resources in the modern world is constantly present, while the reserves of traditional fuels are being depleted, and new deposits are being developed slowly. Identification of emerging social trends that will affect future energy demand are presented in (Brugger, Eichhammer, Mikova and Dönitz, 2021) and (Zihao et al., 2021).

The depletion of traditional fuels leads to higher prices for traditional fuels and, in parallel, to an increase in tariffs for rail and road transport. In this regard, the task of transferring regional heat supply systems to local types of fuel becomes urgent. Modern scientific research in the field of transition of heat supply systems to new types of fuel is given in (Ketova and Trushkova, 2012) and (Bogdanov et al, 2021).

The need to reconstruct the regional heat supply system to increase the sustainability of its existence is also due to a number of other reasons. Firstly, it is the need to develop production capacities and new industries based on innovations and the creation of new technologies for processing fuel and energy resources. These points are highlighted, in particular, in the works (Weinberger and Moshfegh, 2018) and (Rusyak et al, 2010). Secondly, it is ensuring the energy security of the region, which is detailed in the articles (Karatayev and Hallc, 2020) and (Pei et al.,

[a] https://orcid.org/0000-0001-7143-1930
[b] https://orcid.org/0000-0003-4569-3376

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2021). Also, this problem is relevant from the point of view of ensuring environmental safety. The problem of environmental safety from the point of view of the use of various types of fuel in the modern world was studied in (Fang et al., 2021) and (Proskuryakova, 2018).

The conceptual framework for the modern definition and development of the regional energy balance is formulated in the work (Mc Gookin et al., 2021). The influence of energy factors on the development of the socio-economic system is given in (Ketova et al., 2020).

To carry out the reconstruction of the regional heat supply system, it is necessary to assess the economic feasibility of carrying out the necessary technical measures. We will develop a methodology for assessing the economic feasibility of transferring the regional heat supply system to local types of fuel, which will also be aimed at solving the problem of efficient distribution of investments in the heat supply system of the region.

The purpose of this work is to analyze sources of funding, develop a business plan and a network schedule for the reconstruction of the heat supply system in the region. For example, consider the regional system of one of the Russian regions - the Udmurt Republic (UR).

2 RESEARCH METHOD

The main types of fuel consumed in the UR are gas, oil products and coal supplied from other regions. Local fuels are peat, firewood, logging and wood processing waste. They make up a small part of the region's fuel balance. The republic is dependent on traditional fuel and energy resources imported from other regions of Russia. The demand for fuel in boiler houses that do not use gas as fuel is 81.4 thousand tons of fuel equivalent (t f.e.).

According to estimates given in (Rusyak et al., 2010), in most districts of the UR, the energy potential of local energy carriers (wood waste, animal waste) exceeds the total demand for energy resources. However, this potential is not fully exploited. To solve this problem, the concept “Supply of the population, social facilities in remote settlements of the UR with local fuels, alternative to natural gas” was developed (Rusyak et al., 2010). Within the framework of the concept, a cluster analysis was carried out to solve the problem of optimal distribution of fuel and energy resources (Rusyak, et al., 2017) and the logistic problem of fuel supply to a distributed regional heat supply system was solved (Ketova and Trushkova, 2012). As a result, the following list of activities necessary for the implementation of the task was obtained, namely:

- construction of points for processing wood waste into chips;
- creation of points for the accumulation of wood waste;
- construction of pellet plants;
- creation of points for processing animal waste;
- construction of a gas pipeline;
- reconstruction of boiler houses converted to wood chips;
- reconstruction of boiler houses converted to pellets;
- reconstruction of boiler houses converted to biogas.

In this regard, it is necessary to analyze the economic feasibility of transferring the regional heat supply system to local types of fuel and determine possible financial sources for the implementation of technical measures.

Sources of funds for the implementation of the transfer are:

- funds from budgets of all levels and consolidated budget funds;
- private capital based on public-private partnership;
- borrowed funds from credit institutions;
- own funds of enterprises.

The funds of the consolidated fund should be directed to the development of technical measures and further monitoring of their implementation. The diagram (figure 1) shows the financing of activities at the expense of the consolidated budget funds. The relevant ministries of the region (the Ministry of Construction, Housing and Utilities and Energy of the Udmurt Republic, the Ministry of Industry and Trade of the Udmurt Republic), in cooperation with the Republican Energy Commission, submit proposals on the use of consolidated funds to the Government of the Udmurt Republic, which forms the direction for using the consolidated funds and approves the list of measures to be implemented. Further, the consolidating organization finances the list of approved activities, concludes contracts with contractors.

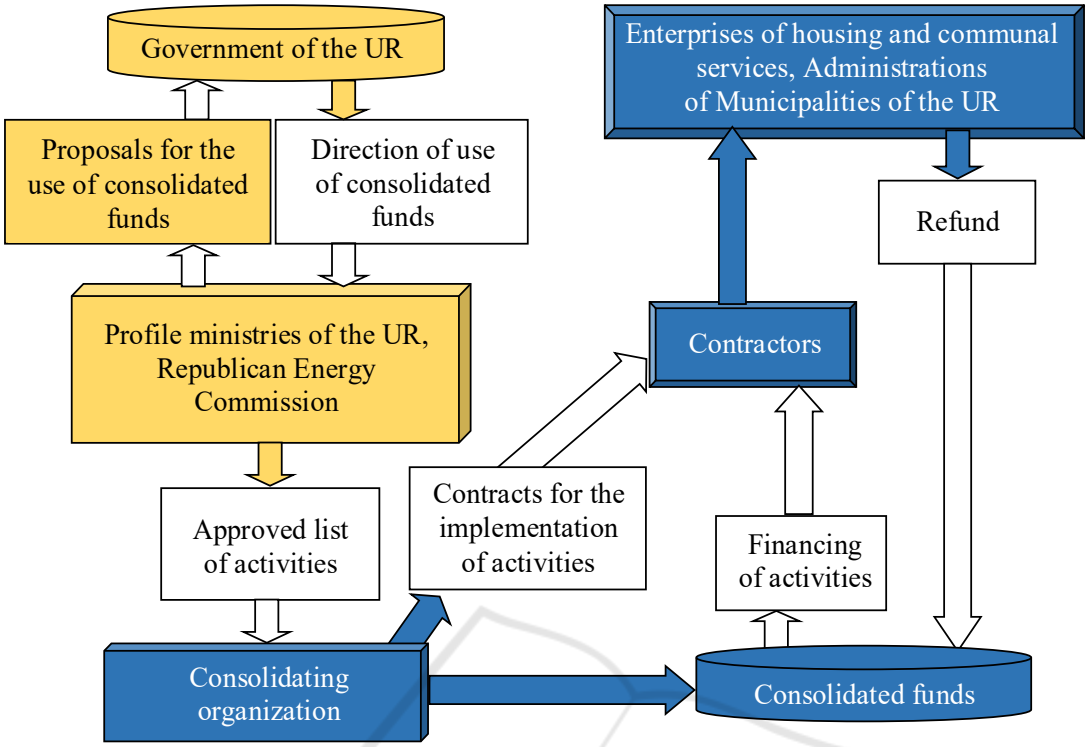

Figure 1: Scheme for financing events from consolidated budget funds.

At the expense of consolidated funds, it is also possible to provide subsidies to reimburse part of the interest rate on loans and part of the cost of paying lease payments. During the implementation of the transfer of the regional heat supply system to local types of fuel, it is possible to finance part of the costs from consolidated funds (for example, design work), as well as the provision of subsidies to reimburse part of the interest rate on loans and part of the cost of paying lease payments (for the purchase of equipment).

It is possible to attract funds from budgets of all levels, the use of which is regulated by documents. In the regional budget, it is necessary to provide funds for the provision of state guarantees in the direction of credit institutions, as well as the provision of tax incentives and subsidies to enterprises that finance measures for the reconstruction of the regional heat supply system. The scheme of financing events at the expense of credit funds is shown in figure 2.

Evaluation of the effectiveness of the measures implementation to transfer the regional heat supply system to local types of fuel will be carried out on the basis of the use of a system of indicators, which are measurable quantitative indicators characterizing the current change in the situation and the achievement of the goal as a result of the measures implementation.

The developed system of indicators reflects three groups of indicators: energy group, economic and environmental. These groups allow an objective assessment of the effectiveness of the measures taken at all stages of their implementation (table 1).

Consider the indicators shown in table 1. Energy efficiency E shows how efficiently the generated energy is consumed, what losses occur at the same time at the heat source, in the utility networks when delivering energy from the producer to the consumer. The value of energy efficiency is determined by the expression:

$$E = \left(V_{FER} / V_{TEP}\right) \cdot 100\% \quad (1)$$

where V_{FER} is the total consumption of fuel and energy resources (FER), t f.e.; V_{TEP} is volume of energy production for all boiler houses, t f.e.

The indicator “Percentage of local types of energy carriers (wood chips, pellets, biogas) in the structure of FER consumption” shows the energy independence of the UR from external fuel and energy resources.

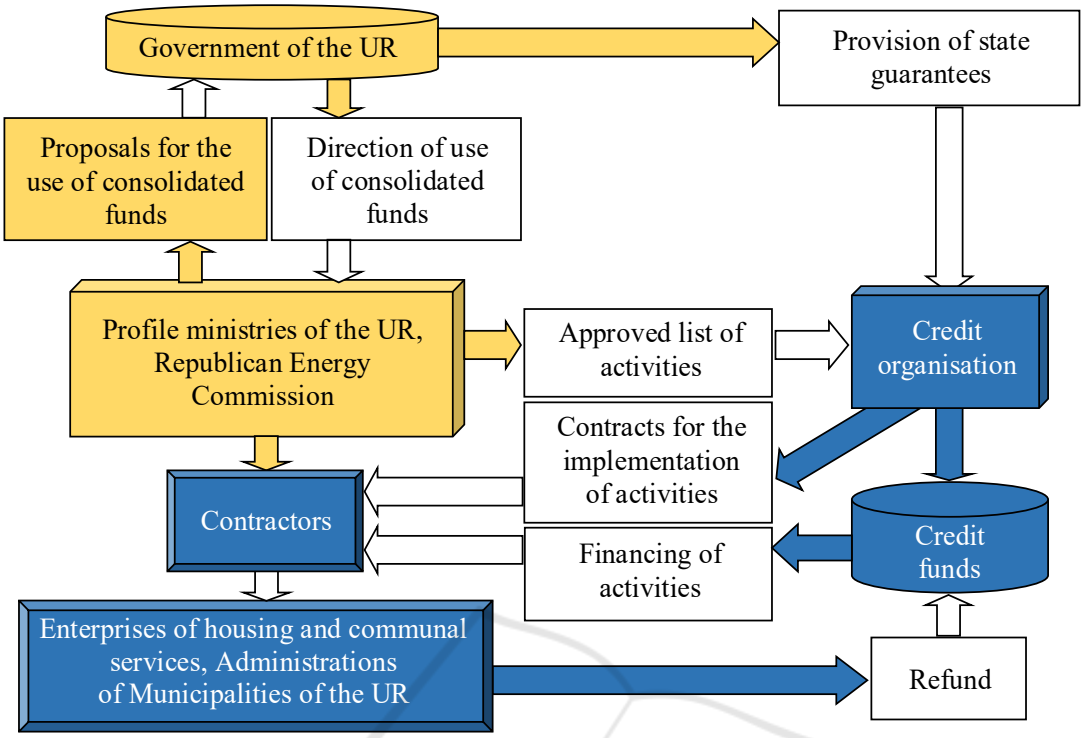

Figure 2: Scheme for financing events using credit funds.

Table 1: Indicators of the quality of the implementation of measures to transfer the regional heat supply system to local types of fuel, divided by groups.

№	Names of indicators	Unit of measurement
1	Energy	
1.1	Energy efficiency	%
1.2	Percentage of local types of FER (wood chips, pellets, biogas) in the total structure of their consumption	%
1.3	Percentage of converted heat sources from the planned	%
2	Economic	
2.1	Specific heat consumption of budgetary organizations relative to 2020	%
2.2	Saving budget funds	
2.3	Percentage of expenses for FER in the cost of heat energy	%
3	Environmental	
3.1	Percentage of recycled wood waste	%
3.2	Percentage of recyclable animal waste	%
4	Percentage of actual completion of activities	%
5	Effectiveness of program implementation	%

The main types of fuel and energy resources consumed in the UR are gas, coal, oil products, electricity, which are delivered from other regions. Local fuels are peat and wood, and wood chips, pellets and biogas produced on their basis. The percentage of local types of energy ε is calculated using the formula:

$$\varepsilon = \left(V_{FERL} / V_{FERT}\right) \cdot 100\% \quad (2)$$

where V_{FERL} is the volume of consumption of local FER, t f.e.; V_{FERT} is total consumption of FER, t f.e.

In the republic, much attention is paid to improving the energy security of heat supply to the population of the UR. The problem of energy security arises due to the aging of heat source equipment. Therefore, as one of the indicators for assessing the implementation of measures to transfer the regional heat supply system to local types of fuel, we will consider the percentage of converted heat sources κ :

$$\kappa = \left(N_{CT} / N_T\right) \cdot 100\% \quad (3)$$

where N_{CT} is the number of converted heat sources, pcs; N_T is the total number of heat sources planned for re-equipment, pcs.

There are about 1.5 thousand heat sources in the region that generate heat for municipal and industrial

needs. Moreover, more than one thousand heat sources are on the balance sheet of budgets of various levels. A significant part of these heat sources is equipped with equipment that currently has a service life exceeding its useful life. Equipment failure leads to a failure in heat supply.

Specific heat consumption of budgetary organizations relative to the base year is calculated by the formula:

$$V^{u}_{FER\,BO} = \left(V^{u}_{FER\,B} \middle/ V^{u}_{b}\right) \cdot 100\,\% \qquad (4)$$

where $V^{u}_{FER\,B}$ is the specific heat consumption by budgetary organizations, t f.e./ thousand m^2; V^{u}_{b} is specific heat consumption by budgetary organizations in the base year, t f.e./ thousand m^2.

Local renewable fuels (wood chips, pellets, biogas) are more cost-effective compared to currently used energy sources. The production of own types of fuel will lead to a decrease in the unit costs for the delivery of energy resources from other regions and can be reflected in the indicator "Percentage of expenses for FER in the cost of heat energy". This indicator is defined as the ratio of the cost of fuel and energy resources to the total cost of heat production.

The budget savings resulting from the use of economically more profitable types of fuel are calculated using the following formulas:

$$E_i = \sum_{j=1}^{N} \left(T^{TE}_{ij} - C^{TE}_{ij}\right) \cdot V_{il}\,,\ \Theta = \sum_{i=1}^{T} \Theta_i \qquad (5)$$

where E_i is the saving of budgetary funds in the ith year; T^{TE}_{ij} is the tariff of heat energy in the ith year at the jth heat source, rubles/t f.e.; C^{TE}_{ij} is cost of heat energy in the ith year at the jth heat source when it is transferred to a local type of fuel, rubles/t f.e.; V_{il} is volume of heat production in the ith year at the jth heat source, t f.e.; N is the number of heat sources, pcs; T is the number of years during which the re-equipment of heat sources takes place.

The use of wood waste and animal waste as local fuels has a positive effect on the environmental situation in the region. The indicators "Percentage of recycled wood waste" and "Percentage of recycled animal waste" are calculated, respectively, according to the following formulas:

$$\beta_w = \frac{V^{pr}_{w}}{V_w} \cdot 100\,\%,\ \beta_a = \frac{V^{pr}_{a}}{V_a} \cdot 100\,\% \qquad (6)$$

where β_w, β_a is the percentage of processed wood waste and animal waste, respectively, of the total amount of the corresponding waste, %; V^{pr}_{w}, V^{pr}_{a} is the volume of processed wood waste and animal waste, respectively, t; V_w, V_a is the total volume of wood waste and animal waste, respectively, t.

The indicator "Percentage of actual implementation of the program" is calculated as the ratio of the cost of actually performed work to the total planned volume of necessary investments for the implementation of the full list of activities:

$$\alpha = \left(S_{WP} / I\right) \cdot 100\,\% \qquad (7)$$

where α is the share of actual program execution,%; S_{WP} is the cost of the work performed, reduced to the considered year, in prices of the current years, thousand rubles; I is the total amount of investment required for the implementation of activities, thousand rubles.

An integral assessment of the effectiveness of the implementation of the republican target program is determined by the formula:

$$J = \sum_{i=1}^{m} \lambda_i J_i\,,\ J_i = \frac{T_{fi}}{T_{ni}} 100\,\%\,,\ \sum_{i=1}^{m} \lambda_i = 1 \qquad (8)$$

where J is the effectiveness of the implementation of measures, %; λ_i is weighting coefficient of the ith indicator; m is the number of indicators on the basis of which the effectiveness of the implementation of measures is assessed; J_i is the effectiveness of the measures implementation progress, characterized by the ith indicator, %; T_{fi} is the actual value of the indicator characterizing the implementation of measures; T_{ni} is the planned value of the ith indicator.

3 RESEARCH RESULTS

Some calculated planned values of indicators for assessing the effectiveness of program activities implemented over 10 years are shown in figures 3-7. For example, budget funds are considered as a source of funding. The shorter the investment period of the program, the faster the required values of target indicators are achieved (the share of local types of energy carriers in the structure of FER consumption should be 30%).

Figure 3 shows a diagram of changes in the "Energy efficiency" indicator for different periods of budget investment. The fastest achievement of the target value is achieved with a 5-year period of budgetary investment in measures to transfer the regional heat supply system to local types of FER.

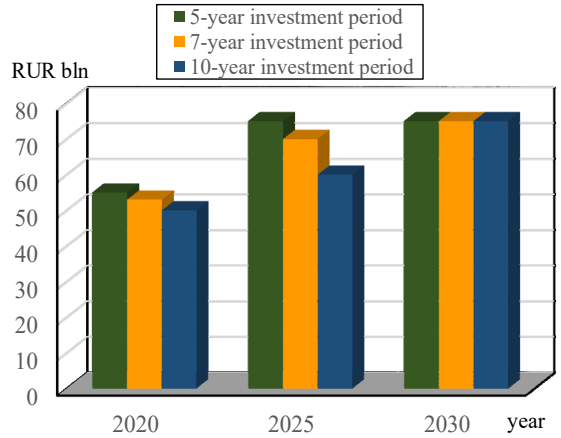

Figure 3: Dynamics of the "Energy efficiency" indicator at different investment periods.

The diagrams in figure 4 and figure 5 demonstrate the change in the indicators "Percentage of local types of FER" and "Percentage of converted heat sources" at different periods of budget investment. The transition to local types of energy resources and, accordingly, the re-equipment of heat sources for these purposes is likely to be carried out within a 5-year period.

Thus, the fastest achievement of the target value is achieved with a 5-year period of budgetary investment in measures to transfer the regional heat supply system to local types of FER. Targets are slowest to take on target values over a 10-year investment period.

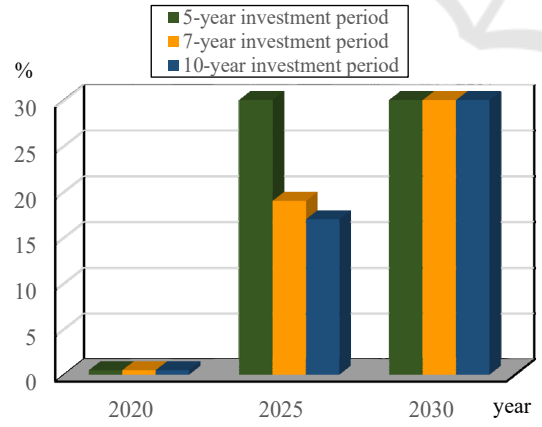

Figure 4: Dynamics of the indicator "Percentage of local types of FER" for different periods of investment.

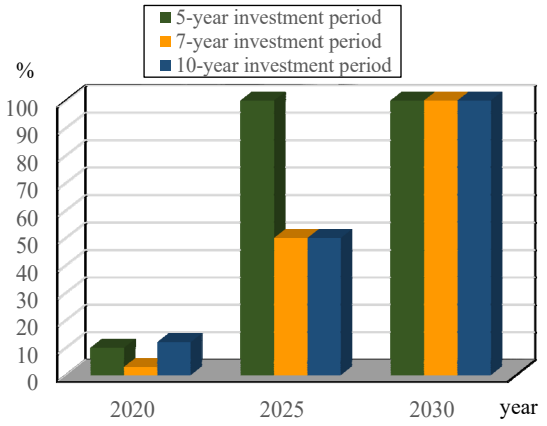

Figure 5: Dynamics of the indicator "Percentage of converted heat sources" at different investment periods.

Figures 6 and 7 show the dynamics of the planned values of indicators reflecting the contribution of measures to the economic sphere: "Specific heat consumption of budgetary organizations relative to the base year" and "Percentage of expenses for FER in the cost of heat energy". The first year of the planning period is the basic one in the calculations, therefore the considered indicators take the highest value (100%). Then, for a 5-year period of investment in measures to transfer the heat supply system of the region to local types of FER, for subsequent years the values of the indicators are set at 45% and 20%, respectively.

For a 7-year investment period, the value of 65% is taken by the indicator "Specific heat consumption of budgetary organizations relative to the base year" in 2025 and the value of 45% in 2030. Also, for a 7-year investment period, the value of 25% is taken by the indicator "Specific heat consumption of budgetary organizations relative to the base year" in 2025 and the value of 20% in 2030.

For a 10-year investment period, the indicator "Specific heat consumption of budgetary organizations relative to the base year" takes a value of 78% in 2025 and a value of 45% in 2030. Also, for a 10-year investment period, the value of 35% is taken by the indicator "Specific heat consumption of budgetary organizations relative to the base year" in 2025 and the value of 20% in 2030.

Thus, in 2030, the values of indicators reflecting the contribution of measures to the economic sphere are set at the same level.

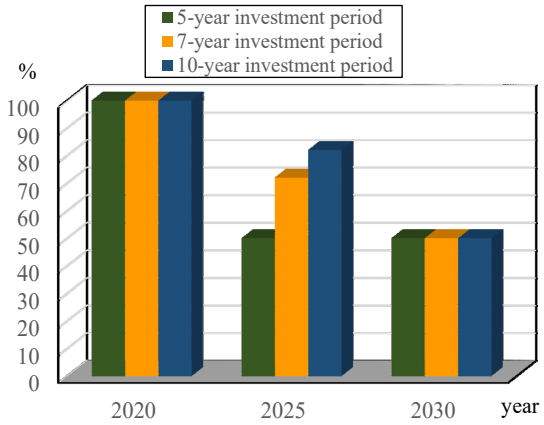

Figure 6: Dynamics of the indicator “Specific heat consumption of budgetary organizations” for different periods of investment.

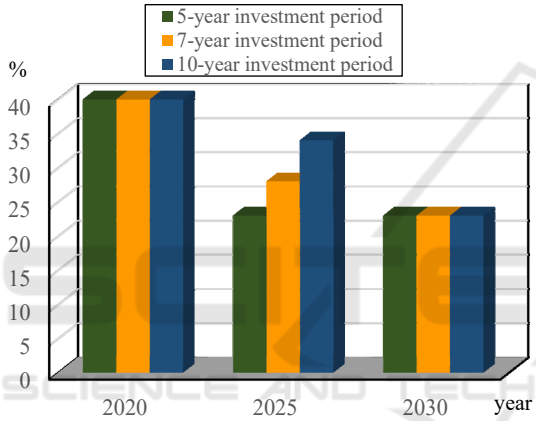

Figure 7: Dynamics of the indicator “Percentage of expenses for FER in the cost of energy” for different periods of investment.

Figure 8 shows the dynamics of the planned value of the target indicator “Saving budget funds”, reflecting the contribution of activities to the budgetary sphere. It can be seen that the shorter the investment period (the time of implementation of measures to transfer the regional heat supply system to local types of fuel), the greater the value of the indicator.

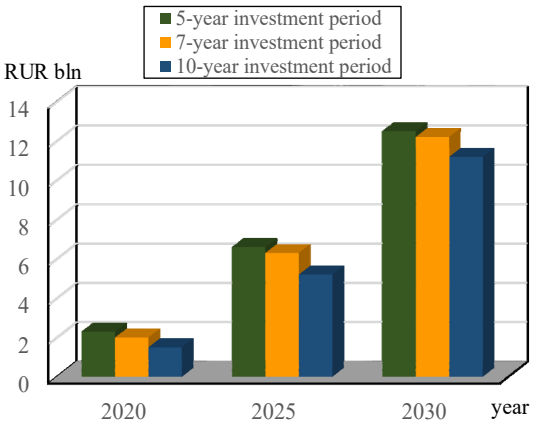

Figure 8: Dynamics of the indicator “Saving budget funds” for different periods of investment.

An additional product obtained in the production of biogas is biofertilizer. Figures 9 and 10 show the dynamics of the planned values of indicators reflecting the contribution of measures to transfer the regional heat supply system to local fuels into the environmental sphere: “Percentage of recycled animal waste” and “Percentage of recycled logging waste”, respectively.

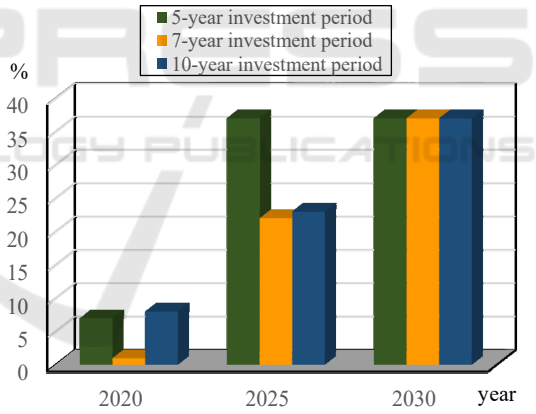

Figure 9: Dynamics of the indicator “Percentage of recycled wood waste” at different investment periods.

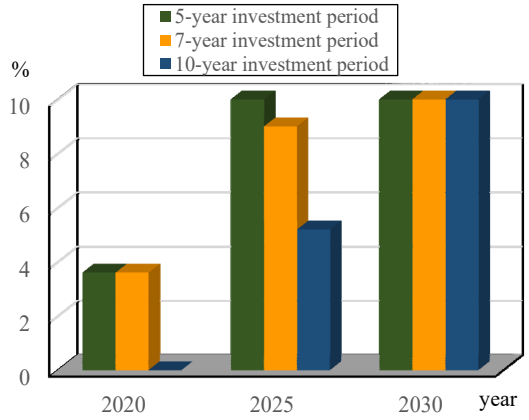

Figure 10: Dynamics of the indicator "Percentage of recyclable animal waste" at different investment periods.

Evaluation of the effectiveness of achieving the target indicators of the program lies in the analysis of the quality of the result of each individual project, the compliance of the actually achieved values with the planned ones.

The indicators "The percentage of actual program implementation" and "Program implementation efficiency" can be calculated as needed at any stage of its implementation to monitor the current state of the degree of program implementation.

4 CONCLUSIONS

Thus, a methodology has been developed for assessing the compliance of the planned and actual progress in the implementation of measures to transfer the regional heat supply system to local types of fuel, based on a system of indicators. The methodology contains quantitative indicators of the effectiveness of the measures implementation.

Various sources of financing for the transfer of the regional heat supply system to local types of fuel are considered: funds from budgets of all levels; consolidated funds based on public-private partnership; budgetary and extrabudgetary grants for research and development work; borrowed funds of credit institutions; own funds of enterprises.

Numerical calculations were carried out for one of the regions of Russia - the Udmurt Republic. For this region, the use of local energy resources, primarily wood waste and animal waste, is one of the possible options for solving the problem of energy supply in remote areas in the face of a shortage of fuel and energy resources and a steady rise in prices for traditional fuels and transport costs for the delivery of raw materials to the region..

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