Public-private partnership as a mechanism for the development of heat supply

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Abstract. The relevance of the research topic is caused by the need to form new innovative approaches in the field of heat supply, aimed at modernizing thermal power plants that provide heat to urban areas. In recent years, the Russian government has adopted several state programs related to environmental protection, directed towards reducing the emission of harmful substances into the atmosphere. Thermal power plants are objects whose emissions significantly pollute the environment. Considering the wear of equipment, according to various estimates, reaches 60-80% in different regions, such equipment is extremely necessary to be modernized. Using the mechanism of public-private partnership in the field of heat supply is examined in this study. An algorithm for constructing a model in the field of creating mini thermal power plants is considered. They provide heat supply to individual urban areas, as well as to ensure a significant reduction in the level of environmental pollution. The main financial indicators are estimated based on the above algorithm. This project's performance is assessed on the basis of financing both from the state and private companies. Conclusions about using the proposed model for the development of heat supply are drawn.

Keywords: natural resource management, energy, sustainable development, public-private partnership mechanism, financial analysis, heat supply, mini thermal power plants, investments

1   Introduction

In the field of heat supply, there are some problems that can be solved by using the mechanism of public-private partnership. The following problems can be distinguished: the wear and tear of fixed assets of public utilities approach to 60%, it reaches 80% in some regions; the share of losses and unaccounted consumption in the total volume of produced heat energy is about 30%; investment demand (reducing the share of networks that need

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replacement, providing centralized heat supply services) - 2 trillion rubles; annual investments in the sector do not exceed 100 billion rubles; external sources of financing (loans, equity) account for only 10-15%. [1] The problems of attracting investments are the inability of private operators to predict future revenues, which is caused by regulatory risks. [2] The mechanism of public-private partnership ensures the formation of innovative approaches in the field of creating new heat supply facilities reducing the negative impact on the environment, while ensuring sustainable financing in their creation.

2   Materials and methods

In this study, the method of investment analysis was applied, representing a set of tools and actions that determine the attractiveness and forecast the amount of profitability of investment in the selected project. [3] Based on the proposed method, an investment project was assessed to create mini thermal power plants within a public-private partnership mechanism.

3   Results and discussion

When a mini-thermal power plant facility is put into power supply systems, there is no need to build distribution networks to connect new consumers, and, accordingly, the amount of required investments in the development of networks is reduced. [4] Capital investments in the construction of distribution networks are determined on the basis of design and estimate documentation in each specific case. The aggregated cost indicators of the construction of overhead and cable lines and transformer substations can be used to assess this systemic effect. Saving capital investments in distribution networks during the construction of small distributed power supply (MDPS) facilities is determined by the formula (1):

$$\Delta K_t^{nw} = k_o \times l_o + k_c \times l_c + k_s \times \text{m}, \qquad (1)$$

where

ΔK_t^{nw} - saving capital investments in the development of distribution networks when entering objects MDPS into the regional energy system;

k_o, l_o - specific capital investments in the construction of 1 km of overhead and cable lines, respectively, ₽/km;

k_c, l_c – the length of overhead and cable lines (respectively) from a centralized power source to consumers, km;

k_s - specific capital investments in the construction of one substation, ₽/un.;

m – the number of substations in the distribution network, un.

The volume of reducing the necessary investments in the development of distribution networks of the regional energy system depends on many factors:

— the structure in terms of thermal capacity and geographic location of boiler plants in the municipalities in the region;

— the structure by size and territorial distribution of electric loads of consumers;

— the structure by voltage and length of electrical distribution networks. [5-6]

In this case, for assessing the economic effect associated with reducing the cost of developing electrical distribution networks, a mathematical model is necessary to create and optimize that would provide the best result when building the required network configuration. [7] In the mathematical model under consideration, under the existing growth rates of electrical loads caused by the connection of new consumers in the region and possible options for modernizing existing thermal power plants with and without their transition to cogeneration facilities, optimization of both the circuit and the main values of

the network connection parameters can be carried out. The parameters of transformer substations should also be optimized according to the main criterion aimed at obtaining a minimum of the total value of investments in electrical networks, with a planning period of 10-15 years. This would ensure optimal financing of heat supply. [8-10]

When mini-TPPs are launched, the undersupply of electricity to consumers will decrease by 15.34 million kW·h/ year or 12% due to increased reliability of the power supply. According to the methodological recommendations for the design of the development of power systems, developed by JSC "Institute" Energosetproekt ", the specific damage will be 50-150 r/ kW·h. Then the introduction of mini-TPP into the regional energy system would reduce the damage from undersupply of energy by 767-2301 million rubles/year. Losses during transmission of electricity in the network will decrease by 39.08 MW or 14%, taking into account the number of hours of maximum losses in the amount of 2500 hours and the weighted average price of the wholesale market of 2.5 r/kW·h. The cost of compensation for losses during transmission when commissioning MDPS facilities will decrease by 244.3 million rubles/year (prices of 2019). On the basis of the obtained results of systemic effects during the commissioning of mini-TPPs, the indicators of specific effects from the commissioning of MDPS facilities in the networks and at consumers were evaluated (Table 1). [11-12]

Table 1. Specific effects of entering MDPS objects

Name	Reduction load limits, MW	Reduction undersupply of electricity, million kW·h/MW	Decrease power losses in the network, MW
Specific indicators of small TPPs with cogeneration	0,0006	0,0239	0,0609

An integral estimate of the systemic effect of reducing investment in distribution networks was carried out on the basis of the 6-10-35 kV distribution network model. It ranged from 2 to 5 thousand rubles per 1 kW of installed capacity of MDPS facilities. When the estimated cost is 1 kW of the MDPS facility of about $ 1000 or 76 thousand rubles/kW, the indicated values from this type of systemic effect are 4-8% of the specific investment per 1 kW of the MDPS facility. The model was used to create a mini-TPP by the mechanism of public-private partnership.

The construction of mini-TPP is carried out by attracting funds from a leasing company with their further return on the basis of a leaseback scheme. In this study, the payment under the main lease agreement is suggested in equal installments. The number of lease payments and the schedule of payments is determined according to the lease agreement:

— project cost – 424 270 000 rubles;

— leasing term – 48 months;

— the contractual payment is made in equal monthly installments;

— The amount of the leasing company's annual cost premium is assumed to be 10% of the project cost.

For analyzing the mini-TPP construction performance, the project's economic efficiency was evaluated based on the enlarged financial model using the forecast prices necessary for the correct calculation of the main parameters of the project: the level of costs, the level of tariffs, cash flows for the project, etc. The payback period of the project and the amount of profit that can be obtained by the investor from this investment project was defined based on the assessment of the net present value, which is as follows (2):

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{\prod_{i=0}^{t}(1+r_i)} - \sum_{t=0}^{t} \frac{I_t}{\prod_{i=0}^{t}(1+r_i)} \tag{2}$$

where

T- the number of planned time intervals for the implementation of the information project,

CF_t – cash flow during a time period t,

I_t – investment in the project during a time period t,

r – discount rate.

Estimations are shown in tables 2 and 3.

Table 2. Cash flow of mini-thermal power plants from 2021 to 2026

Indicator, thousand rubles	2021	2022	2023	2024	2025	2026
1. Revenue from the sale of thermal energy	130 945	137 492	144 367	151 585	159 164	167 123
2. Production costs, including	212 836	215 884	219 085	222 445	109 299	113 004
2.1. Fuel	60 122	63 128	66 285	69 599	73 079	76 733
2.2 Repairs and service	194	204	214	225	236	248
2.3 Amortization	21 214	21 214	21 214	21 214	21 214	21 214
2.4. Main personnel	13 987	13 987	13 987	13 987	13 987	13 987
2.5.Unexpected expenses	645	677	711	747	784	823
2.6. Lease payments	116 675	116 675	116 675	116 675	-	-
3. Gross profit	-81 891	-78 392	-74 718	-70 860	49 865	54 119
Income tax	0	0	0	0	7 230	7 847
Net profit/loss	-81 891	-78 392	-74 718	-70 860	42 635	46 272
Cash flow	-60 678	-57 179	-53 504	-49 647	63 848	67 485
Cumulative CF	-60 678	-117856	-171361	-221007	-157159	-89 674

Table 3. Cash flow of mini-thermal power plants from 2027 to 2032

Indicator, thousand rubles	2027	2028	2029	2030	2031	2032
1. Revenue from the sale of thermal energy	175 479	184 253	193 465	203 139	213 296	223 960
2. Production costs, including	116 894	120 979	125 268	129 771	134 500	139 464
2.1. Fuel	80 569	84 598	88 828	93 269	97 932	102 829
2.2 Repairs and service	260	273	287	301	316	332
2.3 Amortization	21 214	21 214	21 214	21 214	21 214	21 214
2.4. Central personnel	13 987	13 987	13 987	13 987	13 987	13 987
2.5. Unexpected expenses	864	908	953	1 001	1 051	1 103
2.6. Lease payments	-	-	-	-	-	-
3. Gross profit	58 585	63 274	68 198	73 368	78 796	84 496
Income tax	8 495	9 175	9 889	10 638	11 425	12 252
Net profit/loss	50 090	54 099	58 309	62 729	67 371	72 244
Cash flow	71 303	75 313	79 523	83 943	88 584	93 457
Cumulative CF	-18 370	56 942	136 465	220 408	308 992	402 449

Net present value during the first 12 years of the project is presented below in Table 4.

Table 4. Net present value of mini-thermal power plants from 2021 to 2032

Period number (year)	NPV value, thousand rubles
1	-55 161,64
2	-102 416,68
3	-142 615,36
4	-176 524,63

5	-136 879,74
6	-98 786,18
7	-62 196,23
8	-27 062,26
9	6 663,07
10	39 026,67
11	70 074,87
12	99 853,30

Besides, let us consider the indicators that identify the investment attractiveness of this project (Table 5).

Table 5. Investment attractiveness indicators

Indicator	Value
Average rate of profit	2,64 %
Payback period	7,2 years
Return on investment index	1,62
Net present value for 12 years	99 853,3 thousand rubles
Discounted return on investment	8,8 years
Discounted return index	1,34

The results obtained through the analysis of economic efficiency showed that the cost of the heat production process would exceed the amount of revenue within four years from the start of the project. Due to the connection with the fulfillment of its obligations under the main lease agreement, the situation changes after the transfer of objects into the ownership of the investor and the completion of lease payments by the leasing company. Starting in 2025, the cost of heat production would be significantly lower than revenue. As a result, the discounted payback period would be 8.8 years (at a discount rate of 10%).

4   Conclusion

Having analyzed data, the following conclusions can be drawn:

1. Because of the poor technical condition of the objects that are part of the heat supply facilities, there is an acute issue of low productivity, low efficiency of capacities, and a fixed large loss of energy carriers.

2. It should be noted that public-private partnership is the optimal solution to the modernization problem of utility and energy facilities that is important for the country.

3. The following main results of the made changes must be noted:

― reduction of heat energy loss;

― replacement of old equipment with more economical ones.

The main economic effect from the modernization of the existing heat supply system is achieved due to:

― reduction of heat energy losses in heating networks;

― replacement of old equipment with more cost-effective ones.

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