Assessment of the cogeneration biogas plant possibilities in the autonomous power supply system

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Abstract. The use of biomass and wood waste for heat and power production is increasing from year to year. Waste wood is low carbon footprint, has low sulfur content and relates to renewable energy sources. The paper demonstrates the possibility of increasing the energy efficiency of power supply system of the Stepanovka settlement (Tomsk region) by means of replacing diesel power plant (DPP) by the biofuel gas piston CHP. The assessment was based on the possibility of the technical and economic comparison of power supply options in the settlement.

1 Introduction

Currently the energy efficiency of decentralized power supply systems is one of the urgent tasks required to accelerate social and economic development of the country. In Tomsk region the decentralized power plants (DPP) are the main sources of electrical energy for autonomous power supply systems. Low technical and economic indicators of most diesel power stations, high prices for diesel fuel and higher transportation rates lead to excessive cost of DPP-based electricity generation. According to experts [1, 2], the fuel component in the electricity tariff for diesel power plants is by more than 7 times higher than the cost of 1 kWh of electricity from the centralized system of power supply.

Reduction of the energy resources consumption and increase in the efficiency of their use can be implemented on the basis of high-performance poly-generation systems [3, 4, 5] In these systems, the energy of various kinds (heat, cold, and electricity) is produced in a combined way using only one primary energy source. The excess heat generated by the engine can be used to produce heat or cold for household consumers and technological needs of production. This is possible when the thermal circuit contains the compressor or absorption air conditioners, consequently it will increase the working efficiency of the installation in summer period [6, 7, 8].

Studies performed on the possibility to use different types of fossil fuels [9] have shown that the best kind of energy resource for the specified type of generation is wood fuel – wood chips. Its reserves, accessibility and technological transformation process allow efficient use of this resource for the gasification. Depending on the method of obtaining the raw materials (sawmill waste, waste in the cutting area, unmerchantable timber), the cost of

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transportation and processing into chips - the raw material cost can vary from 2000 rubles/t. ref.fuel (waste on the upper timber landing, wood waste) to more than 7000 rub./t.ref.fuel (waste in the cutting area). The potential of wood biomass available within a radius of 30-50 km from the object completely covers the needs for this type of fuel. When planning the reconstruction of the electricity and heat supply system of Stepanovka settlement it is recommended to consider the project where the electrical energy is produced by the diesel power plant and electric and thermal energy – from biomass gas piston installation.

The article demonstrates the review of the following results in the specified topic:

- Analysis of the settlement power supply system and assessment of the heat and electricity consumption volumes.
- Technical and economic comparison of power supply system's options.

2 Analysis of the settlement power supply system and assessment of the heat and electricity consumption volumes

The current state of Stepanovka (Tomsk region) settlement utilities is characterized by a high degree of wear and tear, for most objects the depreciation rate ranges from 48 % to 82 %. On average, 68 % of utilities have served their rated resource.

The main technical and economic characteristics of DPP operation for 2015 are summarized in Tables 1 and 2. DPP analysis revealed the following:

- The working efficiency of DPP installed capacity is equal to 8-13% in real terms for 2010-2015;
- The high rate depreciation of DPP equipment which outlived its service life by more than 100%;
- The excess of the actual fuel costs over standard values.

Table 1. Diesel generators specifications.

Type of diesel generators	Kilowatt nominal	Year of commissioning	Action time for the operating period eng. hr. for 2013
DG72M №1	800	DG72M №1	43618
DG72M№2	800	DG72M №2	39235
11D-100	1000	11D-100	32746

The electricity consumption volumes were assessed according to [10]. The main technical and economic performance indicators of the DPP for 2015, and data on the volume of electricity consumption are summarized in Table 2.

Table 2. DPP technical and economic performance indicators for Stepanovka settlement in 2015 [10].

The electricity tariff for consumers, RUB / kWh	16.65
Electricity generation, thous, kWh	2768.29
DPP auxiliaries, thous. kWh	110.73
Busbar output, thous. kWh	2657.55
Process losses, thous. kWh	478.62
Net electricity supply, thous. kWh.ч.	2178.93
Specific consumption of diesel fuel, thous. kWh.	0.29
The average price of diesel fuel, RUB/ton	33286

Evaluation of heat consumption was performed based on [10] There are three boiler houses operating on wood, which supply heat to socially significant facilities – school, hospital and community centre. Actual total heat production for 2015 was amounted to 1290 Gcal. Design load is 0.46 Gcal./hour.

3 Technical and economic comparison of power supply system's options

To select the optimal power supply system we carried out technical and economic calculations of the following options:

Option 1: the production of electricity using gas generating plants, excluding by-products (heat), taking into account the capital costs in the tariff and based on budgetary funds.

Option 2: the operation of mini CHP in the cogeneration mode, taking into account the by-products and the distribution of costs in proportion to the electricity and thermal energy generation, taking into account the capital costs in the tariff and based on budgetary funds.

The indicators were calculated by the method described in the paper [9]

All the major technical and economic calculations of the options are summarized in Table 3.

Table 3. Technical and economic calculations of power supply system's options.

Rated capacity, kW	960
Specific capital expenditures, rub/kW	18412.5
Depreciation charges, rub/year	1767000
Generated electric energy, MWh /year	3 087.187
Generated heat energy, MWh /year	1 867.6
Annual electrical energy production costs, rub/year	930600
Annual heat production costs, rub/year	756000
Payback period, years	9.6
Electrical energy prime cost, rub./kW	8.69
Heat energy prime cost, rub./Gcal	5762

According to a feasibility studies for **the option 1** the average tariffs (including VAT) for electricity generated using gas generator installation excluding by-products (heat) in 2015 values are determined by the following:

1.1 with the capital costs included in the tariff – 17.65 RUB/kWh which is higher than the average tariff for the existing DPP's by 6%.

1.2 if the construction is financed from budgetary funds – 13,25 RUB/kWh which is lower than the average tariff for the existing DPP's by 20,4 %.

Given the significant reduction in the efficiency of the production of electricity only in the absence of co-generation, this **option is not feasible**.

According to the **option 2,** gas generator works as a mini-CHP with the production of electricity and heat (concomitant) energy for consumers. Option requires the allocation of costs in proportion to the generation of electricity and heat in cogeneration.

Average tariffs (including VAT) for electricity and thermal energy for 2015 amounted to:

2.1 with CAPEX included in the tariff:

- electricity – **8.69** RUB/kWh, which is lower than the average tariff for the existing DPP's by 56.4 %;

- heat - 9839.13 RUB/Gcal, which is higher than the current average tariff for boilers located in the same localities as the DPP (5762.52) by 41.4 %.

2.2 if the construction is financed from budgetary funds:

- electricity – 6.73 RUB/kWh, which is lower than the average tariff for the existing DPP's by 66.2 %;
- heat – 7 607.55 RUB/Gcal, which is lower than the average tariff for boilers (5762.52) by 24.3 %.

In the **second option** there is a significant reduction in electricity tariffs, compared with actual prices of 24.3-41.4 %. Factor increasing/reducing the tariffs for electricity and heat makes this option interesting for further planning**.**

4 Conclusion

One of the most promising ways of increasing the efficiency of local energy supply systems is the use of the renewable energy as a part of the regional energy mix and operating modes optimization of the main power equipment. Involvement of wood fuel in the energy mix of electricity generation will significantly reduce the need for imported liquid fuels and solve environmental and social problems.

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