Study of the possibility for reducing of environmental damage when the transition to alternative sources of heat supply systems in housing and communal services

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Abstract. Modern socio-economic conditions dictate increasingly stringent requirements for housing and communal infrastructure. When choosing a source of energy in heat supply systems, variants having maximum environmental efficiency are preferable. For an objective assessment of increasing of environmental safety degree, it is advisable to use a complex indicator that reflects the level of reduced environmental damage to the environment, in particular atmospheric air. In this work, the calculation of the prevented environmental damage for two types of fuel is made: natural gas and wood fuel (pellets). The calculation results showed when using natural gas instead of wood fuel for heat source that environmental and economic damage will be 64% less.

1. Introduction

Environmental issues are becoming increasingly relevant in the system of housing and communal services, as they are an integral part of heat supply systems. The heat supply system includes heat sources (thermal power plants, boiler houses, etc.), which is one of the main sources of negative impact on environmental components. Therefore, among the main criteria when choosing equipment for heat sources of heat supply systems today, not only technical, economic, but also environmental ones are distinguished. It should also be noted that the reconstruction of heat supply systems (in particular, heat sources) is no exception. When choosing a source of heat energy in heating systems of settlements, it is advisable to compare not only the number of emissions of harmful substances, but also the level of damage to the environment.

In the Baikal Natural Territory, technical projects in the field of reconstruction of heat supply systems are subjected to environmental review, during which the degree of environmental efficiency of the accepted technical decisions is identified [1]. However, to compare variants, it is often not enough to compare quantitative indicators for pollutants entering the environment. The most effective should be recognized environmental and economic criteria, in particular the assessment of environmental damage. Environmental damage takes into account not only damage to atmospheric air as a component of the environment, but also as an indicator reflecting the recreational potential of the territory, a decrease in bio-productivity, a possible increase of sickness rate, etc.
2. Statement of the problem
The main priority types of negative impact of equipment of heat supply system are emissions of pollutants into the atmosphere [2]. Assessment of environmental and economic damage is a complex indicator that allows taking into account not only the amount of emitted pollutants, but also the environmental situation, as well as the environmental significance of the state of atmospheric air in the territory under consideration.

The determination of the amount of environmental damage is carried out in accordance with the "Methodology for the determination of prevented environmental damage" [3]. The prevented environmental damage is determined individually on each territory of a separate constituent entity of the Russian Federation in accordance with the amount of negative impact and the value of the indicator of specific environmental damage caused by a unit of the reduced mass of air pollution.

When conducting an integrated assessment of the prevented environmental damage, the following formula is used:

\[ D = D_s \times M_1 \times C_{env} \times C_{env}^{aa} \times J_d, \]

where
- \( D_s \) – specific damage, rubles / standard fuel ton (for the East Siberian region \( D_s = 46.9 \) rubles / standard fuel ton);
- \( M_1 \) – reduced mass of emitted pollutants during operation of the heat supply system, tons / year;
- \( C_{env} \) – coefficient of relative environmental and economic hazard of pollutant interring into the air is taken according to Appendix 2 of the calculation method [3];
- \( C_{env}^{aa} \) – coefficient of the ecological situation and the environmental significance of atmospheric air state, for the Irkutsk region \( C_{env}^{aa} = 1.4 \);
- \( J_d \) – index-deflator by industry, for 2020 the deflator (Electricity, gas and steam supply) will be 104.1 [4].

3. Numerical research
In the framework of this study, for the schema of heat supply system a comparison of the indicators of environmental and economic damage when using natural gas and wood fuel (pellets) as a source of energy was made. Schema of heat supply system is shown in Fig. 1.

![Figure 1. The schema of heat supply system](image)

The article considers the possibility of using boiler using both natural gas and wood fuel (pellets) at a heat source. The characteristics of gas and wood fuels are given in table 1.

| Table 1. The characteristics of gas and wood (pellets) fuel |
|----------------------------------------------------------|

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Parameter               | Gas Fuel | Wood Fuel (Pellets)
-------------------------|----------|---------------------
Ash, %                   | 0.00     | 1.5                 
Sulfur content (total), %| 0.00     | 0.03                
Net calorific value, MJ / kg | 32.500   | 17.322              

At the initial stage, the gross emissions of pollutants into the air were calculated for two variants: when using gas and when using wood fuel in the form of pellets as heat source fuel. The calculation was carried out using the "Methodology for determining of pollutants emissions into the atmosphere when burning fuel in boilers with a capacity of less than 30 tons of steam per hour or less than 20 Gcal per hour" and the "Methodological manual for calculating, standardizing and controlling of pollutants emissions into the atmosphere" [5,6]. The calculation is based on the fuel consumption in accordance with their lower calorific value ($Q_{\text{gas}} = 32500$ kJ / kg; $Q_{\text{pellet}} = 17322$ kJ / kg). At the same time, the calculation of the amount of natural gas burned was 731.375 thousand cubic meters, and 1100 tons of wood fuel (pellets). Table 2 shows a comparison of gross emissions from the use of gas and wood (pellets) fuels. Table 3 shows the calculation results of environmental damage for different types of fuels. The name of the pollutants is given in accordance with the Hygienic Standards of the Russian Federation [7].

Table 2. Results of gross emissions calculation for gas and wood (pellets) fuel

| Code  | Emission name              | Gross emission (t / year) with operation of boiler using natural gas as fuel | Gross emission (t / year) with operation of boiler using wood (pellets) fuel |
|-------|----------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------|
| 0301  | Nitrogen (IV) oxide        | 0.72214486                                                                  | 0.973138459                                                                  |
| 0304  | Nitrogen (II) oxide        | 0.11734854                                                                  | 0.158135                                                                    |
| 0330  | Sulphur dioxide            | -                                                                           | 0.051377                                                                    |
| 0337  | Carbon oxide               | 2.37696875                                                                  | 0.867846                                                                    |
| 0703  | Benz / a / pyrene          | 0.00000125                                                                  | 0.000201881                                                                  |
| 2902  | Suspended matter           | -                                                                           | 0.266893                                                                    |

Table 3. Results of environmental damage for gas and wood (pellets) fuel

| Code  | Emission name              | Environmental damage with operation of boiler using natural gas as fuel (thousand rubles) | Environmental damage with operation of boiler using wood (pellets) fuel (thousand rubles) |
|-------|----------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| 0301  | Nitrogen (IV) oxide        | 81.44415                                                                                   | 109.7514                                                                                   |
| 0304  | Nitrogen (II) oxide        | 13.23467                                                                                  | 17.83461                                                                                  |
| 0330  | Sulphur dioxide            | 0                                                                                        | 7.023448                                                                                  |
| 0337  | Carbon oxide               | 6.498828                                                                                  | 2.372762                                                                                  |
| 0703  | Benz / a / pyrene          | 0.1068                                                                                    | 17.24873                                                                                  |
Thus, despite the «environmental friendliness» of wood fuel [8], a lower value of environmental
damage corresponds to the variants with boiler using natural gas.

The calculation results showed that when using natural gas as boiler fuel, the amount of
environmental damage will amount to 101.28 thousand rubles, and when using wood fuel (pellets) – 159.16 thousand rubles (in prices for 2020). Therefore, a more «environmental friendliness» variant is
heat supply system with a natural gas-based heat source.

A graphical representation of calculation results is shown in Fig. 2.

As can be seen from fig. 1, the main contribution to the environmental and economic damage (in the
case of using natural gas as a fuel) to the atmosphere is carbon monoxide, and when using wood fuel (pellets) – nitrogen dioxide. It should also be noted that when using natural gas, such pollutants as sulfur
dioxide and suspended solids are absent in the emissions.

4. The practical relevance of numerical research and conclusions

Environmental and economic damage is a comprehensive indicator that assesses the damage to
atmospheric air not only as an object of the national economy, but also takes into account possible
consequences for public health. The results of environmental and economic damage can be used when
choosing alternative variants for the reconstruction of heat supply systems in housing and communal
services [8].

Tightening of requirements in the field of environmental safety of the Russian Federation [9,10,11]
leads to the need to search for new renewable energy sources [12], and accept of increasingly energy-
efficient and environmentally friendly solutions. While the sphere of housing and communal services
are no exception.

In this paper, we assessed the environmental damage when using alternative variants of heat energy
source of in heating systems of settlements. The calculation method proved that environmental and
economic damage when using natural gas instead of wood fuel (pellets) will decrease by 64%. It was
revealed that during the operation of equipment using natural gas, there are no such pollutants as sulfur
dioxide and suspended solids in the emissions.
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References

[1] Khan V.V., Dekanova N.P., Khan P.V. 2017 IOP Conference Series: Materials Science and Engineering 262(1) 012081
[2] Lavygina OL, Grebneva OA. 2019 University News. Investments. Construction 9(4) p 726 [In Russian]
[3] Methodology for determining prevented environmental damage (Approved Chairman of the State Committee for Environmental Protection of the Russian Federation on November 30, 1999, Moscow) [In Russian]
[4] Letter of the Ministry of Economic Development of the Russian Federation of October 1, 2019 N 33198-PB / D03i “On the Application of Forecast Indicators for the Socio-Economic Development of the Russian Federation for the Pricing of Products Delivered by State Defense Order” [In Russian]
[5] Method of Determining Atmospheric Emissions of Pollutants Produced by Burning Fuel in Boilers Having Capacity of 30 t/h of Steam or Less Than 20 GCal/h 1999 (Moscow: State Committee for Ecology of Russia) [In Russian]
[6] Method for calculating, standardizing and controlling emissions of pollutants into the atmosphere (supplemented and processed) 2012 (St. Petersburg: Research Institute Atmosphere) [In Russian]
[7] GN 2.1.6.3492-17 2017 [In Russian]
[8] Olga Lavygina, Oksana Grebneva, and Irina Maizel 2019 IOP Conf. Series: Materials Science and Engineering 667 012056
[9] Federal Law of July 21, 2014 N 219-FZ (as amended since January 1, 2020) [In Russian]
[10] Federal Law of January 10, 2002 N 7-FZ (as amended from January 1, 2020) [In Russian]
[11] Federal Law of May 4, 1999 N 96-FZ (edition as of November 1, 2019) [In Russian]
[12] Shelekhov I. Yu., Shishelova T.I., Smirnov E.I. Bulletin of the Mordovian University = Bulletin of the Mordovian University 2018 28(1) p 48 [In Russian]
[13] Pupyrev E I and Chupin V R 2019 Features of regional development of water disposal systems in the central ecological zone of the Baikal natural territory Proceedings of Universities. Investment. Construction. Real estate 9 pp 354–363
[14] Chupin V R and Dushin A S 2019 Assessment of the reliability of water supply to consumers: water supply reliability indicators Proceedings of Universities. Investment. Construction. Real estate 9(3) pp 578–593