The main directions of solving energy-related environmental problems in the central ecological zone of the Baikal natural territory

Saneev B G\textsuperscript{1}, Ivanova I Yu\textsuperscript{2}, Maysyuk E P\textsuperscript{2} and Izhbuldin A K\textsuperscript{1}

\textsuperscript{1}Melentiev Energy Systems Institute SB RAS, Irkutsk, Russia
\textsuperscript{2}Irkutsk Scientific Center SB RUS, Irkutsk, Russia

E-mail: nord@isem.irk.ru

Abstract. The object of the study is energy facilities located in the coastal areas of Lake Baikal. The impact on the environment in this territory is of particular importance due to the natural uniqueness and special conditions for economic activity. The paper shows that coal-fired boiler houses are the main sources of impact on the environment. The total calculated emission from energy objects is 24.5 thousand t/year. In the composition of pollutants, particulate matter predominates. The total mass of ash and slag waste from energy objects is 79.8 thousand t/year. An analysis of the main environmental problems caused by the operation of the energy objects in the central ecological zone has allowed us to make a list of recommendations for their elimination. For large boilers houses, the main direction is the reconstruction and modernization of equipment, for small ones - the transition to alternative energy sources: natural gas and electricity. Under current conditions, the solution of the environmental problems in the energy sector is to sort the coal and substitute the boilers for highly efficient automated ones, which will improve the fuel combustion conditions and reduce its consumption.

1. Introduction

The energy facilities infrastructure in the coastal areas of Lake Baikal is sufficiently well-developed, including energy generation sources (heat sources) and electrical grid facilities. In general, a major part of the coastline has a centralized electric power supply and possesses spare power grid capacity to increment higher loads. However, there are still troublesome areas located along the western coastline of Lake Baikal, such as Kotelnikovsky cape, the rural localities of Kocherikova, Onguren and Zama, Peschanaya bay, as well as the rural localities of Khakusy and Davsha together with Chivyrkuysky bay settlements – along the eastern coastline.

The energy facilities of the Lake Baikal coastal areas prove to be the primary sources of environmental impacts. These include numerous boiler houses of various capacity that provide heat to social institutions and administrative offices of local settlements. In general, the atmospheric impacts of energy facilities are due to boiler houses that discharge air pollutants, which can precipitate on water surfaces and soils, thus, affecting living organisms and humans.

Based on the results of the studies we have compiled a register of the coastal area energy companies that lists 98 heat sources, including the former CHP of the town of Baikalsk and municipal level boiler houses, among which there are 66 coal-fired boiler houses, 19 electric boiler houses, 9
wood-fired boiler houses, 3 gas-fired boiler houses, and 1 oil-fired boiler house. At present, the Baikalsk CHP (with the capacity of 585 Gcal per hour and the additional load of 70 Gcal per hour) operates as a boiler house and supplies residents of the town with heat.

We have calculated the emission volumes as well as the amount of ash and slag waste that were generated by heat sources, which operate in the coastal areas of Lake Baikal. Particulate matter dominates the composition of pollutants, which is due to the significant amount of coal burned in boiler houses.

2. Overview of the study object
The object of this study is energy companies located in the Lake Baikal coastal areas where the impacts of boiler houses, including the atmospheric ones, are looming large due to the natural uniqueness and special conditions for carrying out economic activities.

To assess the atmospheric impacts of the energy facilities that operate in the coastal areas of Lake Baikal, above all it is crucial to identify the amount and the quality of the fuels used as well as their combustion methods and the efficiency of treatment facilities.

Almost all kinds of energy resources are used for heat supply in the studied coastal areas within the Irkutsk Region: coal, fuel oil, firewood, and electricity. At the same time, in the Republic of Buryatia they are the coal of the Cheremkhovskoye, Tugnuyskoye, and Pereyaslovskoye deposits, liquefied petroleum gas, and fuelwood.

The structures of heat sources in the Irkutsk Region significantly differs from that in the Republic of Buryatia: in the Irkutsk region, electric boilers have a major share of 38% in the total number of heat sources. This is since electricity tariffs in the Irkutsk Region are much lower, which enables using electricity for heat production.

However, the staple fuel is coal (figure 1).

![THE BREAKDOWN OF PUBLIC SERVICES OF HEAT SOURCES BY FUEL TYPE](image)

**Figure 1.** The breakdown and the distribution of heat sources by fuel type and boiler capacity.
Heat sources of various capacity differ in the efficiency of heat generation and fuel use, as well as environmental effects, engineering sophistication and quality of operation. Hence, heat sources were classified by boiler capacity: the overwhelming majority of boiler houses were with boilers having a capacity of up to 1 Gcal per hour, which was 82% in the Irkutsk Region and 57% in the Republic of Buryatia (see figure 1). As a rule, there is no flue gas treatment or it is poorly performed. Despite the actual availability of cyclones at the boiler station, they are in poor condition and cannot be overhauled due to economic inefficiency of such heat sources.

Among all conventional fuel combustion technologies, solid fuel grate firing has a major contribution.

3. Models and methods
To date, various methodological approaches have been developed for assessing the environmental impacts of energy facilities on the natural environment.

To assess the impact of energy facilities on the environment in the coastal areas of Lake Baikal, the methods were used for calculating emissions of pollutants, which are officially approved in Russia, into the atmosphere by power plants and boilers with different capacities [1-3]. The regulatory and technical data, as well as basic standards for the operation of power equipment, were also considered [4]. The amount of emissions depends on a type of fuel, its qualitative composition and consumption, combustion conditions in boiler plants and the operation of a treatment facility.

Based on mass material balance, the mass of ash and slag waste is a sum of slag and ash captured by ash collecting equipment [5].

To assess the competitiveness of replacing coal-fired boilers by alternative ones, methods were used to determine the potential demand for an alternative energy carrier and its competitive price, taking into account the efficiency of fuel energy transformation into thermal energy and the lower calorific value of the fuel. The obtained estimates of the demand for alternative energy carriers and competitive prices allowed us to establish a dependence of demand in an alternative energy carrier on its price.

The level of competitive prices for alternative energy is a threshold value. On the one hand, the use of alternative energy carriers at a price, which is not higher than the competitive one, will not lead to an increase in tariffs. On the other hand, a comparison of competitive prices and current prices (or prospective estimates) allows concluding the expediency of using a certain alternative energy carrier in the current conditions.

4. Results and Discussion
The total estimated emissions from boiler houses were 23.9 thousand tons per year, and the emissions from small boilers, where flue gas purification is not performed, were 60% of the total emissions. At the same time, coal consumption by boilers of this category did not exceed 26% of the total fuel consumption. More than 74% of the total fuel is burnt in nine large boilers, which emit into the atmosphere 40% of all heat sources in the coastal area of Lake Baikal (table 1).

Considering statistical data on emissions by the CHP in the Baikalsk town [6], the emissions from all heat sources in the coastal area are 24.5 thousand tons per year, including 12.4 thousand tons in the southern basin of Lake Baikal, 1.8 thousand tons in the central basin and 10.3 thousand tons in the northern basin. Solids dominate the composition of the emissions, comprising up to 80%.

The total mass of ash and slag waste from heat sources of the central ecological zone is 79.8 thousand tons/year, of which 49.5 thousand tons are in the southern basin of Lake Baikal – 1.9 thousand tons – in the central basin and 28.4 thousand tons – in the northern basin.

An important aspect is the contribution of emissions from large coal-fired CHP plants located outside the coastal areas to atmospheric pollution of the Lake Baikal water. Coal-fired CHP plants are the largest sources of sulphur and nitrogen oxides released into the atmosphere. Under certain meteorological conditions and due to high flue-gas stacks (150 m and more), air masses transport sulphur and nitrogen compounds to the Lake Baikal watershed, with their concentrations reaching tens
and hundreds of μg/m³ (up to the average daily MPC during winters) and covering substantial air spaces above the Southern Baikal [7-8].

Table 1. Systematization of fuel combustion technologies and air emissions from boilers.

| Indicator                           | Boiler capacity per unit, Gcal/h |
|-------------------------------------|---------------------------------|
|                                     | hand-fed                        |
|                                     | with a spreader stoker           |
|                                     | Up to 0.2 | 0.2 – 1 | 1 – 10 | over 10 |
| The number of boiler houses, units  | 5 | 45 | 16 | 7 | 2 |
| Efficiency, %                       | 40 – 50 | 60 – 70 | 65 – 75 |
| Treatment facilities                | none | multi-cyclones |
| Fuel consumption, thousand tons of  | 9.8 | 9.7 | 27.4 | 25.0 | 109.5 |
| fuel equivalent per year            |
| The volume of emissions, thousand   | 2.6 | 3.4 | 8.0 | 2.8 | 7.1 |
| tons per year                       |

The main directions to reduce the anthropogenic impact of heat sources on the atmosphere in the central ecological zone are upgrading of large coal-fired boiler houses; substitution of coal for alternative environmentally friendly fuels (wood fuel and natural gas); using electricity for heating; applying renewable energy sources.

There are all the prerequisites for the implementation of the above policies, but there are also certain restrictions due to either the problems of legislation regulating protected natural areas or prohibitive economic costs.

On the one hand, the construction of coal-fired boiler houses was banned with simultaneous determination of the possible renovation and retrofitting of existing coal-fired boiler houses by the Decree of the Government of the Russian Federation No 643 with amendments dated March 2, 2015 [9]. On the other hand, the renovation of small coal-fired boiler houses proves infeasible since most of them have obsolete and worn-out equipment (approximately 80% of the equipment is used beyond their useful life). So the reconstruction and modernization should be recommended only for large boiler houses.

At present, the main potential for improving the environmental friendliness of small coal-fired boiler houses is associated with:

- sorting coal, which would increase fuel combustion efficiency by 5-12% and reduce fuel consumption by up to 24%.
- using automated boilers, which would improve the quality of combustion modes and reduce the volume of fuel burnt by 40%.
- transition to the combustion of alternative environmentally friendly fuels.

One of the promising directions is the replacement of coal by natural gas. In general, the rational volume of gas consumption in the southern areas of Lake Baikal is 75-80 thousand tons of fuel equivalent, whereas, in the northern areas, it is 100-106 thousand tons of fuel equivalent. The study considers various options for gasification: autonomous gasification (implies the possibility of using propane-butane or liquefied gas for boiler houses) and pipeline-gas gasification. We have concluded that the transition of small boiler-houses in the central ecological to gas zone is economically feasible in the case of gas exports by pipeline along the southern route from Kovykta gas condensate field to Mongolia and China [10].

Another promising and currently most easily implementable policy is using electricity to meet heat supply needs. The potential volume of electricity required for coal replacement in boiler houses is
1.324 million kWh per year, whereas competitive tariffs are 1.0 ruble per kWh for the Irkutsk Region and the Republic of Buryatia.

5. Conclusion
Based on the results of our studies, we have identified the key environmental concerns related to the emission of air pollutants by the energy facilities that operate in the coastal areas of Lake Baikal. The main causes are as follows: the use of coal in the boiler houses with boilers of small capacity; worn-out equipment of heat sources; the substantial emissions of particulate matter, which enters the air without being properly treated.

Thus, we have identified the following main problems of the energy sector in the central ecological zone:

- 70% of heat sources use coal as their fuel.
- 80% of heat sources are morally and physically obsolete, having exhausted their technical lifetime.
- 60% of atmospheric emissions from energy facilities of the central ecological zone come from boiler houses with small and medium capacity boilers, which have no treatment facilities.
- The greatest impact of energy on the environment is observed in the southern basin of Lake Baikal.

Table 2 indicates the recommended measures to reduce or eliminate the impact of heat sources on the atmosphere in the coastal areas of Lake Baikal, indicating areas of possible implementation in the near future.

The central ecological zone of the Baikal natural area has a special status and requires special decisions, which adoption is necessary at the level of the Russian Government.

Table 2. Recommendations to reduce or eliminate the impact of energy facilities on the atmosphere in the coastal areas of Lake Baikal.

| Recommended measures                        | District and /or object                             | Environmental effect                                      |
|---------------------------------------------|----------------------------------------------------|----------------------------------------------------------|
| Renovation and upgrading of large boiler houses | Slyudyanka town, Severobaykalsk town               | Reduction of emission by 30 to 40%                       |
| The transition of small coal-fired boilers to electricity | All small boilers in the central ecological zone | Total elimination of emissions and ash and slag waste     |
| Use of wood waste from sawmilling and wood processing | Kabansky, Barguzinsky, Severobaikalsky districts | Local reduction of emissions and no sulphur oxide emissions as well as reduction of ash and slag waste |
| Use of renewables (solar heating systems and heat pumps) | Camping sites in the coastal areas of the lake | Local reductions of seasonal emissions and ash and slag waste |

Acknowledgements
The study was carried out within the project of the Integration Program of ISC SB RAS No. AAAA-A17-117041250054-8

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