

# Efficiency of gasification of remote boiler plants in Kamchatka with liquefied natural gas

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**Abstract.** Extremely high heat tariffs and their permanent growth in the remote regions of the Russian Federation become a considerable barrier to further development of these regions. Therefore, the limitation of the heat tariff increase in the regions is an important goal of energy policy. On the example of two districts of the Kamchatka Territory, the effectiveness of gasification of remote boiler plants with liquefied natural gas is shown as a means of restraining an excessive increase in tariffs for thermal energy. A competitive price for liquefied natural gas has been determined for remote boilers in Kamchatka, and the commercial efficiency of construction of boilers using liquefied natural gas has been evaluated.

## 1 Introduction

The high level of tariffs for heat energy is one of the main problems of heat supply in the Russian Federation. According to the data given in [1], this problem is most acute in the eastern regions of Russia.

The high level of tariffs for heat energy in these regions is due to many factors, such as:

- harsh climatic conditions and long heating period;
- low heat load density;
- high degree of equipment wear;
- high specific fuel consumption and large losses of thermal energy;

- low level of application of energy-saving technologies.

However, the main reason for the high tariffs for heat energy in these regions is the large share of expensive imported fuel - coal and oil products - in the fuel balance.

The extremely high level and permanent growth of tariffs for thermal energy in remote regions are becoming a significant barrier to their further development, and restraining the growth of tariffs for thermal energy in these regions is the most important task of energy policy.

One of the ways to solve this problem is to involve natural gas in the fuel and energy balance of regions, as a more efficient fuel and energy resource.

At the same time, gasification of remote settlements with low volumes of gas consumption, lower density of population and industrial consumers is associated with the need to build extended gas distribution networks, which are often not recouped. In such cases, it is advisable to consider options for alternative gasification - using liquefied natural gas (LNG) or liquefied petroleum gas (LPG) [2].

The limitedness of its own developed natural gas resources in the Kamchatka Territory casts doubt on the possibility of widespread gasification of the region in the foreseeable future, especially in its remote areas. However, PAO NOVATEK's project to build an LNG transshipment terminal in the Bechevinskaya Bay opens up new opportunities for gasification of the region, including gasification of remote boilers.

The paper analyzes the efficiency of gasification of remote boiler plants using LNG using the example of two districts of the Kamchatka Territory.

## 2 Object of study

The heat power industry of the Kamchatka Territory is mainly based on the use of imported fuel (oil products, coal). The share of imported fuel in the fuel balance of the region is more than 95.5%, and only 4.5% is accounted for by local coal, gas and firewood. This predetermines the high cost of heat production in the region.

Petroleum products are supplied to the region mainly from the Angarsk, Omsk and Komsomolsk oil refineries according to complex and extended transportation schemes.

Coal is imported from the seaside, Khakass, Sakhalin and other deposits in the east of the country. Local Koryak coal is used mainly in the Koryak district and its share in the coal consumption of the region is small - about 16.5%.

In recent years, the region has begun to use local natural gas resources.

As part of the gas supply project to the Kamchatka Territory, PJSC Gazprom carried out production drilling and construction of two fields - Kshukskoye and Nizhne-Kvakchikskoye. The design annual productivity of the

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Kshukskoye field is 175 million m<sup>3</sup>, Nizhne-Kvakchikskoye - 575 million m<sup>3</sup> [3].

The conversion of power facilities from fuel oil to gas was started in 2010 from the moment the gas trunkline (MGP) was launched from Sobolevsky District to Petropavlovsk-Kamchatsky with a length of more than 300 km. There were gasified CHP-1 and CHP-2 in Petropavlovsk-Kamchatsky, as well as the city boiler house No. 1, reconstructed and prepared for conversion to gas 6 boiler houses in the Elizovsky district [4]. However, due to a drop in gas production at local fields, CHP-1 and CHP-2 were again switched to burning fuel oil.

Boiler plants in most districts of the region, including boiler plants in the Milkovsky district and some boiler plants in the Ust-Bolsheretsky district, do not fall into the centralized (network) gasification zone and alternative gasification options should be considered for them - using LNG or LPG.

In the Milkovsky district, centralized heat supply is provided by 14 boiler plants, of which 7 work on coal, 7 - on wood. The total productivity of all boiler plants in the region is 48.74 Gcal / h (on firewood - 4.2 Gcal / h), and the maximum total connected heat load is 26.35 Gcal / h.

In the Ust-Bolsheretsky region, centralized heat supply is provided by 7 boiler plants, of which 6 work on coal and 1 on fuel oil. The total productivity of all boiler plants in the region is 31.22 Gcal / h (fuel oil - 9.32 Gcal / h), and the maximum total connected heat load is 17.65 Gcal / h.

The specific fuel consumption of boiler plants operating on fuel oil is 200 kg of standard fuel / Gcal, at an angle - 224-247 kg of standard fuel / Gcal, on wood - 335-487 kg of standard fuel / Gcal.

It is assumed that the transfer of remote boiler plants to LNG can improve their technical and economic indicators and thereby restrain further growth of tariffs for thermal energy.

The possibility of gasification of remote boiler plants in the region arose with the emergence of the PAO NOVATEK project for the construction of an LNG transshipment terminal in Kamchatka in order to reduce the cost of LNG delivery from Yamal to the countries of North-East Asia (NEA) [5]. The idea is to transport LNG on a part of the route (from Kamchatka to the NEA countries) not in ice-class tankers that can pass along the Northern Sea Route, but in conventional ones, the freight cost of which is lower and the speed in open water is higher.

The project provides for the allocation of 5 stages of construction and development of transshipment capacities of the offshore LNG terminal in the Bechevinskaya Bay, 100 km from the city of Petropavlovsk-Kamchatsky. Upon completion of 4 stages, the terminal will provide a cargo turnover of about 11 million tons / year of LNG. At the 5th stage, upon completion of the full construction cycle, the terminal's capacity will more than double and amount to about 22 million tons / year for LNG receiving and shipping. The capacity of the LNG terminal is servicing 328 LNG tankers / year at the intermediate stage and 657

LNG tankers / year - upon completion of construction [6].

Initially, the option of gas supply to the Kamchatka Territory from a floating LNG terminal assumed the use of boil-off gas generated during the storage of LNG in the terminal and the construction of a gas pipeline from Bechevinskaya Bay to Petropavlovsk-Kamchatsky with a length of about 100 km. However, the implementation of this option for gas supply is associated with a number of problems.

First, the use of boil-off gases is a technically difficult and often economically impractical solution. Gasification of heat and power supply facilities requires gas of a certain quality, pressure and in a guaranteed volume. And the formation of boil-off gases depends not only on the chosen storage structure, but also on the intensity of its use for LNG transshipment and on the ambient temperature. Therefore, any decision on gasification using boil-off gases without regasification capacities will not provide the required level of gas supply reliability. In addition, the composition of the boil-off gas can differ greatly in time due to the fact that first of all, the evaporation of nitrogen and methane occurs, later in the composition of the boil-off gas the proportion of heavy hydrocarbons begins to grow, that is, the so-called weathering or aging of the gas occurs [7].

Second, the IHL option turns out to be very expensive. The cost of the construction of the LNGP from Bechevinskaya Bay to Petropavlovsk-Kamchatsky is estimated at 120 billion rubles, which is comparable to the cost of the marine LNG transshipment terminal in Bechevinka [8].

Construction of a regasification terminal in Avachinskaya Bay with a capacity of about 650 million m<sup>3</sup> per year is currently being considered as the main option for gas supply to Kamchatka using LNG, where gas from the LNG transshipment terminal in Bechevinskaya Bay is planned to be delivered by coastal gas tankers [8-10].

From the terminal in Avacha Bay, regasified LNG can be supplied via a gas pipeline to the nearest large consumers, and in liquefied form in cryogenic containers on autogas carriers - to remote small consumers.

### 3 Competitive LNG price

In order to determine a competitive price for LNG, we analyzed the cost items of heat supply companies included in the tariffs for heat energy for the Milkovsky rural settlement of the Milkovsky area and for the Oktyabrsky rural settlement of the Ust-Bolsheretsky area.

The cost of heat energy includes the cost of fuel, water, electricity, wages, depreciation and other costs.

Several boiler plants of various capacities were selected for the study - four coal-fired boiler plants in the Milkovsky rural settlement and one fuel oil boiler plant in the Oktyabrsky rural settlement.

The calculations used the following technical and economic indicators:

- specific fuel (gas) consumption - 155 kg of fuel equivalent / Gcal;
- specific consumption of water and electricity - according to technical certificates of boiler plants;
- number of personnel - according to the staffing table;
- tariff for water - 17.30 rubles / m<sup>3</sup> in the Milkovsky rural settlement and 61.15 rubles / m<sup>3</sup> in the Oktyabrsky rural settlement;
- electricity tariff - 4.0 rubles / kW · h;
- average salary of staff - 40,000 rubles / person. per month;
- deductions for social needs - 30% of the payroll fund;
- depreciation rate - 5% (based on the service life of the installed equipment, equal to 20 years);
- other costs - 1% of the amount of direct costs of the heat source.

The task was to determine the maximum possible (marginal) price of LNG, at which the level of the cost of heat energy in the boiler plant is comparable to the level preceding the transfer of the boiler plant from the design fuel (coal, fuel oil) to LNG. The calculation results are shown in Table 1.

**Table 1.** Determination of a competitive LNG price.

| Name of a boiler plant            | RTPHS* | CK*   | Scharomy* | Melioraciya* | Centralnaya** |
|-----------------------------------|--------|-------|-----------|--------------|---------------|
| Installed capacity, Gcal/h        | 3,45   | 6,00  | 3,45      | 2,60         | 6,90          |
| Annual heat output, Gcal          | 9637   | 8600  | 5966      | 3725         | 8011          |
| Annual fuel consumption (LNG), t  | 951    | 849   | 589       | 368          | 791           |
| Annual costs, thous.rub.          | 38799  | 32765 | 29685     | 16195        | 36196         |
| including fuel costs, thous. rub. | 25959  | 17793 | 18151     | 7973         | 19356         |
| Competitive LNG price, rub/t      | 27296  | 20957 | 30817     | 21666        | 24470         |
| Heat cost price, rub/Gcal         | 4026   | 3810  | 4976      | 4348         | 4518          |

\* Boiler plants of Milkovo rural settlement, Milkovsky area

\*\* Boiler plant of Oktyabrsky rural settlement, Ust-Bolsheretsky area

It follows from the calculations that, taking into account the effect of fuel economy, reduction in the number of personnel and costs of electricity and water, the competitive price of LNG for the considered boiler plants can be about 21-31 thousand rubles / ton.

It is assumed that the cost of Yamal LNG in Kamchatka can be estimated in the range of 15-20 thousand rubles / t. So, for example, the prime cost of LNG in Yamal is 12 thousand rubles / ton, and the selling price is 230 USD / ton (16 thousand rubles / ton), the cost of transporting LNG from Yamal to the port of Busan with transshipment – 1.67 USD / mln BTU [11], which is 70 rubles at a dollar exchange rate. and the conversion factor of 43.62 million BTU to 1 ton of LNG is about 5 thousand rubles / ton. At the same time,

according to [12], the average price of LNG for gasification purposes in the regions of the Russian Federation is estimated at 15-20 thousand rubles / ton.

Based on the LNG price of 15-20 thousand rubles / t, it can be concluded that there are favorable prerequisites for the transfer of boiler plants to LNG in the considered areas of the Kamchatka Territory. First, the difference between the competitive and current price of LNG makes it possible to contain the growth of tariffs for thermal energy. Secondly, the competitive price of LNG seems to be acceptable for investors, which is confirmed by the results of the assessment of the commercial efficiency of the construction of LNG-fueled boiler plants given below.

#### 4 Commercial efficiency of construction of LNG boiler plants

The studies were carried out using the methodology and criteria for evaluating the effectiveness of investment projects in accordance with [13].

The following economic information was used in the calculations:

- the life cycle (economically viable) of new boiler plants is assumed to be 20 years (it is assumed that the manufacture of equipment, site preparation, installation and commissioning with reaching full heat load is completed by the beginning of 3 years);
- depreciation rate - 5%;
- discount rate - 10%;
- income tax rate - 20%;
- value added tax rate - 20%;
- property tax rate - 2.2%;
- the rate of deductions to insurance funds - 30%;
- electricity tariff (excluding VAT) - RUB 4.0 / kWh;
- water tariff (excluding VAT) - 17.30 rubles / m<sup>3</sup> for the Milkovsky rural settlement and 61.15 rubles / m<sup>3</sup> for the Oktyabrsky rural settlement;
- economically feasible tariff for heat energy in the Milkovsky rural settlement - 4695.12 rubles / Gcal, in the Oktyabrsky rural settlement - 4796.53 rubles / Gcal.

The cost of domestic modular gas boiler plants is set on a contractual basis and depends on the configuration, additional commercial services and the size of the order batch. In the performed technical and economic calculations, the price level was adopted at the estimated cost of the installations based on the factory cost estimate, taking into account the conditions of delivery to the Kamchatka Territory. For gas-fired boiler plants, account is taken of the equipment for LNG receiving, storage and regasification.

Capital investments include:

- the cost of transport facilities and communications (1%);
- internal roads (1%);
- vertical planning and landscaping (2.5%);
- temporary buildings and structures (2.5%);
- management content and technical supervision (0.4%);
- design and survey work (4%);
- other expenses (3.5%) and unforeseen expenses (5%).

When calculating operating costs, the costs of fuel, labor costs, capital repairs, depreciation deductions, own needs, and other costs were taken into account.

Specific fuel consumption for gas boiler plants is taken at 155 kg of fuel equivalent / Gcal.

The number of personnel is taken at the standard coefficient for a gas boiler plants, taking into account the use of LNG. Average monthly wages are based on 40,000 rubles / month.

The cost of repairs is taken as 0.1% of the capital investment.

Electricity costs for auxiliary needs are calculated based on the specific consumption of 20-27 kWh per 1 Gcal of heat supplied.

The cost of water consumed for own needs is calculated based on the specific consumption of 0.35 m<sup>3</sup> per 1 Gcal of heat supplied.

Other costs are assumed to be 2% of fuel costs.

The assessment of the commercial efficiency of the construction of gas boiler plants using LNG in the regions under consideration was carried out for 4 variants of the heating capacity of boiler plants (2.5 MW; 3.5 MW; 5 MW and 7 MW) based on boilers of the KV-GM brand (tab. 2).

**Table 2.** Main techno-economic indices of the considered options of gas-fired boiler plants using LNG.

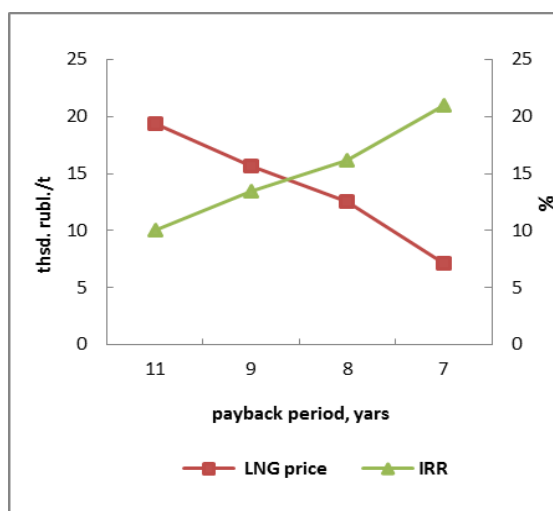
| Indices                              | Options of gas-fired boiler plants |                            |                            |                            |
|--------------------------------------|------------------------------------|----------------------------|----------------------------|----------------------------|
| Installed heat output, MW            | 2,5                                | 3,5                        | 5,0                        | 7,0                        |
| Number and types of boilers          | 2×KV-GM-0,75<br>1×KV-GM-1,0        | 2×KV-GM-1,0<br>1×KV-GM-1,5 | 2×KV-GM-1,5<br>1×KV-GM-2,0 | 2×KV-GM-1,5<br>2×KV-GM-2,0 |
| Rated heat load, Gcal/h              | 1,5-1,6                            | 2,2-2,5                    | 3,4-3,8                    | 4,5-5,1                    |
| Capital investment, million rub      | 62,50                              | 75,61                      | 90,37                      | 125,59                     |
| Number of operation personnel, pers. | 8                                  | 12                         | 13                         | 15                         |

The task was to determine the internal rate of return (IRR) and the payback period of projects for the construction of LNG boilers at different fuel prices and fixed tariffs for electricity and heat.

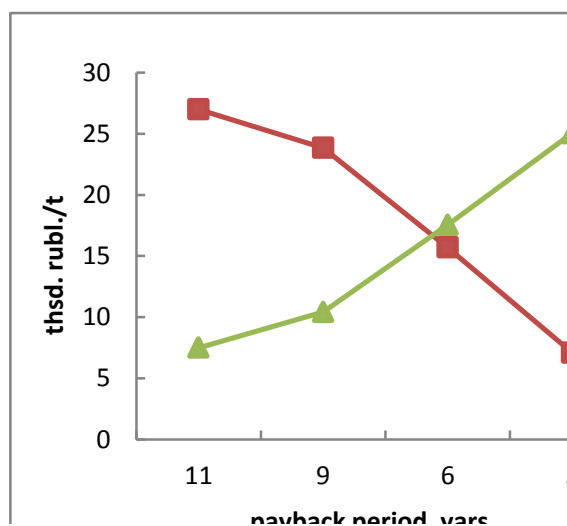
The results of the performed technical and economic calculations are shown in Fig. 1.



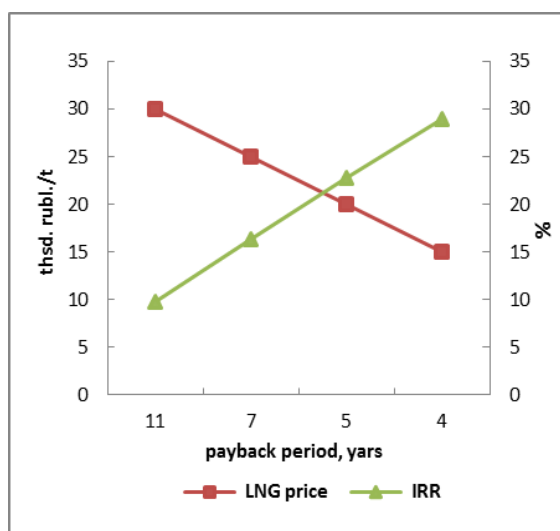
a)



b)



c)



d)

**Fig. 1.** Relationship between the cost-effectiveness of LNG-fired boiler plant construction projects and fuel cost at a boiler plant capacity of: a) 2.5 MW; b) 3.5 MW; c) 5 MW; d) 7 MW.

From the calculations performed, it follows that with the existing tariffs for electricity and heat and with an LNG price of up to 30 thousand rubles / t, the construction of gas boilers plants on LNG in the regions under consideration can be commercially efficient. At the same time, the thermal power of the boiler plants has a significant impact on the payback of the project.

The most effective construction of LNG boiler plants with a thermal capacity of more than 5 MW with the installation of several boiler plants with a unit capacity of 1.5-2 Gcal / h, which allows you to select equipment depending on the heat load and redundancy requirements.

## Conclusion

With the construction of a marine LNG transshipment terminal in the Bechevinsky Bay, new prospects are opening up for gasification of Kamchatka consumers, including boiler plants in remote areas of the region.

For remote boiler plants in the Kamchatka Territory, the competitive price of LNG can be about 21-31 thousand rubles / ton, taking into account the effect of fuel savings, staff reduction and costs for electricity and water.

With an average price of LNG at the level of 15-20 thousand rubles / ton, there are favorable prerequisites for the transfer of remote boiler plants in the Kamchatka Territory to gas due to the positive difference between the competitive and current price of LNG.

With the existing tariffs for electricity and heat, the construction of gas boiler plants in remote areas of Kamchatka can be efficient at an LNG price of up to RUB 30,000 / t. At the same time, the thermal power of the boiler plants has a significant impact on the payback of the project. The most efficient construction of LNG

boiler plants with a thermal capacity of more than 5 MW with the installation of several boilers with a unit capacity of 1.5-2 Gcal / h.

The example considered shows that in remote areas of the Kamchatka Territory, the conversion of coal and fuel oil boiler plants to LNG can significantly improve their technical and economic indicators and thereby restrain the growth of tariffs for thermal energy.

## Acknowledgements

The study was carried out within the framework of the scientific project III.17.6.1of the fundamental research program of SB RAS, registration No. AAAA-A17-117030310445-9.

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