Heat Supply of Villages and Towns of Eastern Siberia. Problems and Ways of Development

V V Khan¹, N P Dekanova², P V Khan³

¹Department of Urban Construction and Management, Irkutsk National Research Technical University, 83, St. Lermontov, Irkutsk 664074, Russia
²Department of Information systems and protection of information, Irkutsk State Transport University, 15, St. Chernyshevsky, Irkutsk 664074, Russia
³Laboratory of Dynamics of Steam Generating Systems, Melentiev Energy Systems Institute, Siberian Branch of Russian Academy of Sciences, 130, St. Lermontov, Irkutsk 664033, Russia,

E-mail: khan@istu.edu

Abstract. The ways for improving heat supply energy efficiency in small and medium settlements of Eastern Siberia are considered by the example of Irkutsk oblast. When choosing the energy saving measures, one must take into account a complex system of factors. The dynamics of particular settlements development can also be considered which makes the choice significantly differ from the traditional one.

1. Introduction
One of the most serious problems facing the national economy of Russia is the low efficiency of heat supply systems. According to official data, 31% of thermal energy sources and 68% of heating networks are operated with an excess of the standard service life [1,2]. In some heating networks losses reach 80% [3,4]. This situation leads to serious social and environmental consequences. Social problems arise from the growth of tariffs. In Eastern Siberia, the main fuel is coal. It is traditionally assumed that using the coal heat sources gives low tariffs for thermal energy. However, when such system factors as the structure of fuel price, logistics, economically justified wage level, payments for pollutant emission and required investments are taken into account, it turns out that the existing tariffs are marked down. Such underestimated prices, first of all, result in false estimates of the energy saving measures effectiveness, and also lead to the degradation of settlement heat supply systems [5-7].

At present, the conditions and cost parameters of heat supply are significantly different for facilities supplied from high-efficiency CHP plants in large cities and one supplied from small and medium-sized boiler houses. With centralized heat supply, the tariffs for thermal energy are about 238 rubles per GJ. Such tariffs are economically justified and one can expect that their growth in the near future will follow the average consumer price index.

The situation for facilities supplied from small and medium-sized boiler houses is more complicated, especially in smaller settlements. The tariffs level ranges from 346 rubles per GJ for the southern regions of the Irkutsk oblast to 835 rubles per GJ and higher for northern and remote areas. Tariff growth is controlled by regulators, but there are many objective factors affecting the level...
of economically justified prices, that cannot be ignored too long. It is necessary to radically change the approaches to the formation of the market of thermal energy. [4,7].

2. Objects and methods
The structure of the thermal energy tariff for small and medium-sized settlements in the southern part of Eastern Siberia is analyzed. The economically justified tariffs are calculated according to the decree of the Government of the Russian Federation on pricing in heat supply[7]. A significant part of tariffs is formed by the wage fund of the main production personnel and administrative and management personnel. Labor costs are estimated on the basis of the industry tariff agreement in the housing and communal services of the Russian Federation for 2014-2016[8]. In assessing the costs of fuel and materials, the influence of system factors, such as climate, environmental constraints, logistics, etc., is considered [7,9-15]. Also, the state of the equipment is taken into account.

3. Results and discussion
Consider the influence of system factors on the dynamics of thermal energy tariffs on the example of the Mishelevka village in the Usoisky region. This settlement is typical for the south of the Irkutsk oblast. The average distance between settlements from the fuel supply centers is about 100-120 km. The equipment of boiler houses and networks is worn out. The efficiency of the boilers is 61%. The loss of thermal energy in heating networks is 18.7%. Own consumption of the boiler house equals 2.4%. These factors lead to an increased specific fuel consumption high tariff. In present, the regulators manage to keep the average thermal energy tariff in the settlements of the southern part of the Irkutsk oblast at the level of 346-468 rubles per GJ. It is achieved by keeping the average monthly salary of the staff at the level of 18.0 - 21.0 thousand rubles per person, and fixing the prices for coal at the level of 1500 rubles per ton. [4].

The by-effects of such regulation include low reliability and further degradation of heat supply systems. Low level of wages does not allow attracting qualified personnel. Cheap coal has a low quality: low calorie, high content of sulfur, moisture and inert substances [4,7].

The average monthly salary of the main production personnel, calculated according to the industry tariff agreement equals 37.63 thousand rubles per person in 2016. The average monthly salary of administrative and managerial personnel is 70.87 thousand rubles per person. Therefore, the economically justified thermal energy tariff for the Mishelevka village, defined as the ratio of the required gross proceeds to the volume of the net thermal energy production, will be 581 rubles per GJ.

Until recently, it was believed that the main share in tariffs for thermal energy is provided by the fuel component. Operational costs were less than 40%. Now, their share in the required gross has already reached 56.6%, and soon exceeds 60%, because, due to the use of obsolete equipment, heat losses in the networks and expenses for own needs increase. In general, the level of remuneration of labor is also growing. In addition, the structure of the necessary gross proceeds does not provide for capital repair and / or reconstruction costs, as well as investment component. However, the moral and physical wear and tear of equipment necessitates including these components.

For the present, the payments for emissions and ash dumps are relatively low. However, with the tightening of environmental constraints, these expenses will also increase.

In figure 1, the forecast of the thermal energy tariff growth for the heat generated by small and medium-sized coal boiler houses is presented. It includes the indexation of labor costs, which must correspond to the consumer price index amounting about 5% a year, investment and environmental components. With all non-certainty of the forecast, it is necessary to recognize that the following factors that cause tariff growth exist objectively:

- the cost structure changes, because the operating expenses are significantly increasing due to the increase in labor cost and payments for emissions;
- the depreciation and investment components of costs are increasing;
- the fuel transport expenses must be higher for settlements that are remote from the coal mines and logistic centers.
Considering all these factors, the economically justified thermal energy tariff shall now amount about 597 rubles per GJ. Taking into account the growth rate of the main tariff components, it can be expected to achieve 835 rubles per GJ in 2022 and 955 rubles per GJ in 2027.

Containment of tariffs at a level much lower than one based on the economically justified necessary gross proceeds leads to the degradation of heat supply systems and, as a result, to emergency situations with severe economic, social and environmental consequences. One of the key directions in reforming the market of thermal energy is the transition to a pricing system based on concept of “an alternative boiler room” [5-7, 9]. Other possible measures includes the following:

- transition to cogeneration;
- using more economically efficient fuels;
- using local heat generation at a part of facilities, considering there characteristics and operating conditions [11-18].

One of such alternative solutions may be the use of pellets as fuel [10]. It is advisable to use them as an autonomous source of thermal energy, or for a compact group of buildings. Taking into account the high level of losses in heat networks, as well as the high level of the operating expenses, the use of local heat generation in some cases may be more preferable than connection to centralized heat supply systems.

Taking into account other components of the tariff, the economically justified costs of heat generated by using an autonomous heat source on pellets turns out to be lower than from existing coal-fired boiler houses. This becomes possible due to a higher efficiency of the heat source, eliminating losses in the heat networks, reducing the environmental pollution and associated payments, reducing labor costs by using the automatic control and saving on the maintenance of a cumbersome administrative and managerial apparatus, typical for centralized heat supply organizations. Production of pellets in the same settlement from local raw materials can reduce the cost even more.

At the same time, the cost of fuel transportation is an important factor for facilities located in remote settlements. Irkutsk region is a leader among the Russian regions in terms of timber harvesting (about 20 million m³ of timber per year). Therefore, the introduction of technologies of utilization of timber processing waste is actual. In regions with significant volumes of logging and timber processing the cost of using pellets is also decreased by elimination of the warehouse for their storage [10, 19].

Another important advantage of pellet boilers is the effective heat power adjustment in a wide range [19]. This makes it possible to significantly reduce the thermal energy cost for such facilities as educational institutions, cultural institutions, office buildings and other facilities with highly variable mode of heat load: the absence of staff at night, on weekends and holidays; for educational institutions also during long vacations. Heating costs in such public buildings can be significantly reduced by using standby heating modes during off hours. Low-power coal boilers in small settlements do not provide...
such effective adjustment. The application of on-duty heating modes on pellet boilers can reduce heating costs by 20% and more. The total reduction of the thermal energy cost for such facilities is approximately 35-40% compared to the base variant.

For facilities with a high level of hot water consumption in summer, it is expedient to use solar systems for hot water supply.

Another example is the town heating system in Baikalsk. The source of thermal energy is the thermal power plant of the Baikal Pulp and Paper Mill (BPPM). The plant is currently stopped and is subject to dismantling. Installed at the thermal power station, steam boilers BKZ-75 were designed to provide steam for the technological processes of the plant and for the town's heat supply. With the stoppage of the plant, the capacity of the boilers became excessive. The hot water and heat demands of the town are below the threshold of effective regulation of boilers. This leads to over-consumption of fuel. Equipment of the CHP is physically worn out. Taking into account today's environmental restrictions regarding development of the Lake Baikal Region, the replacement of existing boilers with similar modern coal-fired boilers is not allowed. Therefore, installation of environmentally friendly sources of thermal energy is required.

In the existing heat supply system of Baikalsk town there are four main zones: the BPPM industrial zone and the microdistricts Yuzhny, Gagarina and Stroitel. In the future, the special tourist economic zones Podgornaja and Pribrezhnaja are planned. In each of the microdistricts a pumping station is installed. The equipment of heat networks is worn out. The loss of thermal energy through thermal insulation is more than 16%.

Part of the heat transfer agent losses caused by the consumers, which are located in the peripheral zones of heat networks and drain the water into the sewage system. They do so because of insufficient pressure drop between the supply and return pipelines. The pressure profile of the network is distorted because in the most of the town building the inputs are not equipped with elevators, mixing pumps, and other devices for converting heat transfer agent parameters. Also, at the input nodes there are no control and measuring devices provided for by the rules of technical operation of thermal power plants. The absence of devices for converting the parameters of the heat transfer agent does not allow the use of high-temperature regimes of constant flow/variable temperature control in the heat consumption systems.

Currently, the district pumping stations partly serve as central heat supply stations.

Without solving the problem of adjusting the hydraulic regimes of buildings heat consumption systems, any solutions at the level of heat networks will be ineffective. As mentioned above, some of the consumers at the peripheral zones of the heating networks drain the heat transfer agent into the sewage system in order to provide water circulation. Other consumers install circulation pumps, which distort the hydraulic regime of the heat supply networks even more. Avicious circle.

A significant part of the dwellings in Baikalsk town consist of one- and two-story old wooden houses. The enclosing structures of most buildings do not meet modern requirements and cause a high level of heat losses. A very high level of heat losses in networks and buildings makes any measures to develop or upgrade sources of thermal energy ineffective without normalizing thermal and hydraulic regimes of heat supply networks and reducing losses.

A detailed analysis of the problems of heat supply in Baikalsk shows that these problems cannot be solved by any single measure. The following tasks are necessary to perform:

1. Replace the existing heat supply CHP plant to another one, meeting modern requirements. It is helpful to consider decentralization of heat supply system.

2. To carry out reconstruction of heat networks. It is necessary to eliminate the leakage of heat transfer agent from the heat networks; to minimize the heat loss through the insulation; to provide the normative parameters of the heat transfer agent at the entrances to the system of heat consumption of all consumers of heat networks (the available differential pressure shall not be less than 0.05 MPa; constant flow/variable temperature control in the heat consumption systems with temperature range 368/343 K); to carry out the adjustment of the hydraulic regimes of the district heat supply networks in conjunction with other measures to normalize regimes and reduce losses in consumers’ networks.
In this way, the heat supply networks in Baikalsk can be put in order only if the consumers heat networks are adjusted too. The heat supply organization alone cannot solve this problem, since the consumers heating systems are the property of various physical and legal entities. Therefore, along with technical measures, it is necessary to carry out organizational measures that will stimulate the adjustment of the consumers’ heating systems, and impose a fine of consumers’ who allow excessive loss of heat transfer agent.

The choice of heat sources for the Baikalsk town is also an issue. Taking into account environmental constraints, the following options exist: electric heat supply systems, gas boilers, pellet boilers, heat pump systems. None of them is optimal.

If the tariffs for electricity is above 0.56 rubles per MJ, then, taking into account the operating expenses and losses in heat supply networks, the thermal energy will cost at least 840 rubles per GJ. A significant reduction in price can be achieved with a more diversified use of electrical energy.

For example, instead of one district boiler one can consider the options for installing electric boilers at each building. This will allow avoid the expensive reconstruction of heat supply networks and eliminate losses in the networks. The climatic conditions of Baikalsk (relatively warm winters) make the option of using the air heat pumps efficient with an average conversion factor of 2.5-3.

Recently, the option of installing boilers on liquefied natural gas (LNG) is being widely discussed. The disadvantage of this option is the high cost of LNG and the high cost of its transportation. Calculations show that the cost of LNG in Baikalsk will be at least 28 thousand rubles per ton. Taking into account the operating expenses and losses in the networks, the cost of thermal energy for consumers will be at least 840 rubles per GJ. In this case, thermal energy cost reduction can be achieved by using cogeneration on a centralized heat source.

For individual zones of the Baikalsk town, using of stand-alone pellet boilers in each building may be optimal. To this end, it is advisable to consider the production of pellets in the Baikalsk town.

Before introduction of a new heat source, it is advisable to consider the possibility of transferring the existing steam boilers BKZ-75 to the water-heating mode with the installation of muffle burners, which will enable deeper adjustment of power and reduce the fuel consumption.

4. Conclusions.

Given the full complex of system factors, in the nearest future the coal boiler plants will cease to be the cheapest heat sources for many small and medium-sized settlements in Eastern Siberia. It is advisable to optimize the heat supply schemes. In many cases, the introduction of boilers operating on such ecologically clean fuel as pellets is promising.

In the future, it is advisable to consider the prospects of using liquefied natural and liquefied hydrocarbon-containing gas in mini-thermal power plants as a source of electric power supply for such settlements. Taking into account the dynamics of tariffs for thermal energy received from traditional energy sources, the use of renewable and unconventional energy sources is effective in many cases.

For the recreational zones of the Southern Baikal region, the use of heat pumps and solar energy is effective [19,20]. In most cases, non-traditional and renewable sources of energy cannot completely cover the heat demand of the settlements, but they provide the opportunity to optimize and reduce costs.

These measures can provide a significant improvement in the economic, social and environmental situation in Eastern Siberia.

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