Concession as a tool for improving energy efficiency in case of tariff regulation

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Abstract. In this paper, we study the state of heat networks in Russian Federation. Modern technologies used to reduce losses in the pipeline and increase energy savings in the boiler house are considered. The article analyzes the experience of using pipelines in foamed polyurethane insulation as the most effective way to combat heat losses. The current problem of financing investment projects in the energy sector and the difficulties of attracting private capital in this area are studied. One of the ways to solve this situation is to conclude concession agreements. The paper presents the results of tariff calculations with the participation of the boiler house in the concession, which prove the effectiveness of modernization under the concession agreement.

1. Introduction
The issue of the state of heating distribution networks in Russian Federation is quite important. As of 2019, the country has 342 thousand km of heat networks. Approximately 34 percent (99 thousand km) of networks need to be replaced due to an increase in the number of accidents and the end of their service life. At present, the specific damage rate for the regions of Russian Federation is on average 1.8–2.2 per 1 km per year, with an acceptable 0.3. This indicator is equal to 0.1 in Western Europe. The volume of re-laying of worn-out heat networks does not exceed 1.2% of their total length and only in some regions is 1.8%, with the need for 4-5 or more per year [1]. Most heating networks in the Russian Federation are in poor condition, which leads to a crisis in the housing and communal services system.

2. State of heating networks in Russian Federation
Active build of cheap heat-wasting housing in the 50s and subsequent decades of the twentieth century was accompanied by dispersed urban development. This reduced the cost of construction and stimulated the rapid development of centralized heat supply systems – local natural monopolies. As a result, the length of heating lines and the cost of their construction have increased dramatically, heat losses have increased many times, and operation has become more expensive. Currently, about 72% of all thermal energy is produced by centralized sources (with a capacity of more than 20 Gcal / h), the remaining 28% is produced by decentralized sources, including 18% by autonomous and individual sources. In addition, a small part of the demand for thermal energy (4.5%) is met by recycling waste heat from technological installations, and the share of heat generated from renewable energy sources is very small.[2]

District heating systems generate about 1.4 billion Gcal of heat per year. About 600 million Gcal of thermal energy is produced annually by 68 thousand municipal boilers. In most major cities (more than 100 thousand people), 70-95% of the housing stock is provided with district heating.
The key problem of housing and communal services is to increase the reliability and efficiency of heat supply, since 20% of all heat sources are located in this sector of the economy and 20-30% of the expenditure part of municipal budgets is used for heat supply.

About 50% of municipal heating and utility networks require replacement, and at least 15% are in an emergency condition. For every 100 kilometers of heat networks, an average of 70 damages are registered annually. Losses in heat networks reach 30%, and with leaks of the heat carrier more than 0.25 cubic kilometers of water are lost annually, 82% of the total length of heat networks require capital repairs or complete replacement.

The main reasons for the deplorable state of municipal heating systems include the lack of financial resources, wear and tear of equipment and heating networks, weak management and unresolved issues of the division of powers and responsibilities in the municipal energy sector, and the lack of promising schemes for the development of heat supply systems. [3]

The development of decentralized heat supply sources will continue at a rapid pace, both due to the growth in the number of residential buildings and public buildings in rural areas, suburbs, small towns and urban village, and due to the transition to individual heat supply in urban areas with persistent critical conditions for the functioning of district heating system. The use of technically and energetically advanced designs and schemes will allow you to constantly reduce fuel consumption, increase the reliability of heat supply and ensure the cost of heat at a level adequate to the income of the population.

The planned levels of heat supply development, radical modernization and technical re-equipment of the industry will require a significant increase in investment. The main source of capital investment will be the industry's own funds, regional and municipal budgets, tariff sources, and borrowed funds, including those raised under project financing conditions.

3. Experience of application of pipelines in polyurethane foam insulation

Most homes in the Russian Federation use Central heating. Hot water is also provided centrally in almost all regions of the country. However, it is not enough to heat the water — it still needs to be delivered to the consumer with minimal heat loss.

In Soviet times thermal insulation of the pipeline consisted of the following:

- The pipe was wrapped in a layer of thermal insulation.
- Glass wool was fixed with ordinary annealed steel wire.
- The top of the pipe was covered with a sheet of galvanized iron.

During the epidemic of theft of non-ferrous metals in the 90s, galvanizing had to be abandoned. The surface was often coated with a simple cement solution. It was not stolen, of course; however, the heat loss was greater in this case: the galvanizing also reduced the radiation loss, which is not true of the solution.

Finally, about 15 years ago, using pipes in PUF (in polyurethane foam) started. In parallel, another product release was established: the shell of polyurethane foam for the pipes is could serve as heat insulation to existing heating mains.

The material against the background of its predecessors has a number of advantages:

- extremely easy installation;
- when the outer shell is violated, if the glass wool, getting wet in the rain, sharply deteriorates the heat-insulating qualities, then the pipe in the PUF has equally low heat loss at any humidity;
- the pipe with a polyethylene coating on top of polyurethane foam can be laid in the ground without any additional insulation and protective box;
- vandalism and theft of thermal insulation have become almost impossible;
- corrosion of the pipe under the water-tight shell slows down by tens of percent.

PUF steel pipe is an ordinary steel pipe for heating or water supply, which is covered with a heat-insulating layer of polyurethane foam at the manufacturing stage. Depending on whether the pipe is
intended for laying in the ground or for laying in the air, an external protective coating is selected over a layer of polyurethane foam.

For the soil, the ideal choice is a polyethylene protective layer (the pipe is called PUF PE), for the air - good old galvanizing. The same one that was used before.

The production of PUF pipes does not involve any technical difficulties: an ordinary steel pipe is surrounded by a shell of polyurethane foam (known, by the way, to builders as an ordinary mounting foam) and then protected by an external layer of polyethylene or zinc.

The technology by which PE pipes are produced, in general, is as follows:

- By extrusion (squeezing the heated polyethylene from the tank through a mold), an outer shell is made, in which a steel pipe is placed.
- The space between them is filled with a foamed polymer that quickly hardens when it comes in contact with air.

Installation of PUF pipes includes the following main stages:

- The pipe is stripped of insulation at a distance of up to 300 mm from each edge.
- A welded joint is performed, which is checked for strength by a portable flaw detector.
- A heat shrinkable coupling is put on the pipe.
- The cavity under it is filled with a foamed polymer (mounting foam), after which the coupling is heated and seated in place, ensuring the tightness of the outer shell.

The construction of reliable and economical heating networks is the basis for ensuring efficient heat supply in any country. On average, heat losses in heating networks in Russia are more than 40%, and about 30% of networks are in an emergency or close to an emergency state, which suggests that the state of heating networks in the Russian Federation is unsatisfactory. The cost-effectiveness of heating networks is assumed to be low expenditure on construction, installation and operation, as well as minimal heat loss in pipelines. Experience in using pipelines mounted from pipes in polyurethane foam insulation (PUF), and their technical characteristics have revealed many of their advantages.

Thus, calculations and practical experience show that the construction of networks by the method of channel-free laying (this is how the installation of PUF pipes occurs) is carried out 3-4 times faster than the construction by the method of channel laying at almost equal costs.

In addition, pipes insulated with polyurethane foam have a much longer service life. Pipelines with channel laying serve about 12-13 years, while their service life with channel-free laying exceeds 30 years.

During the entire period of operation, high-quality pipes in PUF insulation practically do not need capital repairs, except for the occurrence of system and external damage. The causes of system damage may be insufficient quality of system components, as well as unprofessional installation work (for example, poor joint insulation). Extraneous damage may be caused by mechanical damage to pipes and elements of the operational remote control system.

For comparison, during the operation of PUF pipes, channel laying pipes in mineral wool insulation will necessarily require capital repairs, which will take about 60% of the cost of initial construction, and given the costs of operation and maintenance of such pipes, their use becomes irrational and adds another plus to pipes in PUF insulation.

Pipes insulated with polyurethane foam (PUF) have been used in our country for more than 15 years. Unfortunately, the use of pipes in PUF insulation affects not all regions of Russia. Active use of PUF pipes was found in Moscow and the Moscow region, St. Petersburg and other administrative centers and major cities of the country. Thus, pipelines from pipes in PUF insulation make up less than 5% of the entire heat pipeline system in Russia, which clearly does not contribute to improving the energy efficiency of the country as a whole. To achieve the goals that correspond to the energy development strategy of the Russian Federation, it is necessary to introduce PUF pipes everywhere, throughout the country.
Heat loss in pipes of this design is minimal. The pipes in foam insulation are virtually not affected by stray currents, means, and external corrosion. The "pipe-in-pipe" design allows us to completely eliminate external corrosion of the pipeline.

There are specialists who oppose the widespread implementation of this technology in practice. The main reason for this is often the low quality of specific heat-insulated pipe products produced by small enterprises that violate production requirements (which was quite common in the first years of development of this technology), as well as the frankly low quality of steel pipes for the needs of the housing and communal services, that is, the usage of used pipes.

Among the obvious problems in the first years of implementation of this technology are the following:

- the operational remote control system was not installed often enough;
- the joints were insulated with shells and thermal tape instead of filling polyurethane foam and using shrinkable couplings;
- components of low-quality PUF or in the wrong dosage were used, which affected the low heat resistance of the polymer PUF heat insulator, which could not withstand the operating temperature of 130 °C and a number of other problems.

However, despite the existing problems, it should be emphasized that in general, the quality of PUF insulated pipe products is growing every year. Existing production facilities are equipped with new and more efficient equipment. The domestic market is developing.

4. **Investments in heat supply projects and their efficiency**

The energy sector is one of the main elements of the Russian economy. At all times, it is the development of energy that has been of paramount importance. This approach allowed the industry to survive and work with minimal financial losses in times of crisis for the country. It should be noted that any economic sector can’t just stand still, it must develop, to improve results and further work constantly requires an influx of capital.

The previously planned system of the economy allowed for large financial investments in the energy sector. This made it possible to modernize the industry in a timely manner and constantly increase production capacity.

At present, when a significant part of the energy complex of our country can’t rely on subsidies from the state budget, investments in energy become especially relevant, because:

- In almost all countries, especially in countries with unstable economic conditions, the energy complex exists thanks to investment.
- Priority in investment is given to the energy sector because for any country it is the basis that provides a stable state of the economy and life, industry (all without exception located in the country) and production.
- Failure, lack of financing, or an unstable situation in the energy sector can throw the country into chaos in a short time (this applies to any state in General). [4]

Heat supply in Russia is one of the most underfinancing industries. The heat supply system is in poor condition and requires urgent and large-scale investments, but at the moment the legislation and tariff policy do not allow to guarantee the return of invested funds.

Investment — "long-term contributions" of public or private capital in your own country or abroad in order to generate income in enterprises of various industries, business projects, socio-economic programs, innovative projects.[5]

To solve the problems of attracting investment in order to create energy-efficient systems in the presence of a solid legislative base, we can use public-private partnership (PPP) mechanisms.
5. Concession agreements as a means of implementing state energy saving and energy efficiency programs

One of the options for attracting additional funds to energy development is public-private partnership. As a result of analysis common in Russia, forms of public-private partnership (PPP), by which it is possible to carry out measures on energy saving and energy efficiency, it was found that the output of the current industry's adverse situation can serve as a concession agreement, which is the most complex form of PPP that can improve the efficiency of state property management, to attract private investment in the energy sector due to the possibility of risk sharing, state payment of the grantor, guarantees and benefits, as well as through long-term relationship, allows you to conduct strategic planning of activities.

A concession or concession agreement (CA) is usually understood as a system of public-private relations, in which the private sector is involved in the management of state or municipal property in order to improve the efficiency of management, improve the quality of goods and services provided on mutually beneficial terms. The concession agreement is a contract for the transfer of a set of exclusive rights that are the property of the rightholder for a certain period of time (or without specifying the term). A concession is temporary, usually created to solve a specific task over a certain period of time. On CA, the concessionaire undertakes to create and (or) to reconstruct, at its own expense provided by him for temporary use for a certain period, the property owned by the grantor, and use the object of the CA [6, 7, 8].

Concession agreement were used in various historical periods, the practice of its application is counted for tens of centuries. Russian Federation is one of the countries with a rich historical experience in applying concessions in various spheres and sectors of the economy. In the period from 1921 to 1929, the USSR was the absolute leader in the number of concession agreements concluded, but in 1937, for political reasons, the large-scale concession program was discontinued. Only 68 years later, based on the successful experience of implementing concession agreements abroad, the law "On concession agreements" was adopted in Russia in 2005 [6, 9, 10]. It acts as a regulator of relations arising during the development, conclusion, modification, execution and termination of concession agreements, as well as determines the objects, parties, terms of the agreement, fees, conditions, guarantees of rights, features of the transfer of certain types of property to the concession, defines the basic rights and obligations that must be included in the concluded concession agreement, the procedure for concluding a concession agreement [7, 11, 12].

Every year, as the legislative framework in the field of concession agreements improves, the number of concluded concessions is gradually increasing. According to the Ministry of economic development, at the beginning of 2020, there were about 3,100 CA. It is also reported that the majority of CA is concluded in the utility and energy sector (90%). [13]

6. Effect of the concession agreement on the tariff amount

A number of advantages have been identified based on the experience of using PUF insulation. The use of heat networks with PUF insulation allows:

- to increase the service life of heating pipelines to 30-40 years;
- to reduce heat losses during transportation up to 2%;
- significantly to reduce fuel and electrical energy consumption: with a pipe diameter of 1020 mm-0.106% for 1 km of networks; with a pipe diameter of 530 mm-0.217% for 1 km of networks; with a pipe diameter of 219 mm-0.08 % for 1 km of networks;
- to ensure that the temperature drops accordingly: at 1020 mm-0.05°C / km; at 530 mm-0.12°C / km; at 219 mm-0.46°C/ km;
- to reduce capital expenditures by 15-20%;
- to reduce operating costs by 9 times;
- to reduce repair costs by 3 times;
- to reduce the time of laying heating lines by 3-4 times;
- to eliminate accidents of heating lines, due to the mandatory installation of operational remote control system of the humidification of thermal insulation. [14]
Therefore, as an example of calculating the effect of the concession agreement on the tariff amount, we consider the option of modernization heating networks, which consists in replacing the pipeline along its entire length with a pipeline with PUF insulation.

The considered boiler house and its pipeline have the following parameters necessary for calculation:

- the length of the pipeline 5,168 km;
- produced heat energy 31044.25 Gcal/year;
- heat supply to consumers is 28,285.14 Gcal / year;
- heat losses in the pipeline reach 7.6%;
- the consumption of heat energy for the boiler house's own needs is 439.61 Gcal / year.

With the parameters described above, the amount of the required gross revenue of the boiler house at the moment is 50,197.04 thousand rubles and the current tariff is 1,774.68 rubles/Gcal.

Implementation of the proposed pipeline replacement will reduce heat losses in the network by up to 2%, as well as reduce operating costs and repair costs by 9 and 3 times, respectively.

The required volume of production, taking into account the new amount of losses, will be 29,302 Gcal/year.

According to the company’s price list, replacing one meter of pipe with a PUF insulation pipe costs 4,423 rubles [15]. This means that the capital cost of modernization is equal 22,858,064 rubles.

The service life of pipes with PUF insulation is 30 years, which means that with the linear method of depreciation, depreciation charges per year is equal 761,935.4667 rubles.

Thus, the following change in the structure of the cost of heat energy is obtained:

- fuel costs are reduced by decreasing heat losses in the pipeline, which means that the volume of heat production is reduced while the volume of consumption is constant;
- depreciation charges are increased due to the introduction of new equipment;
- operating and repair costs are reduced due to new technology aimed at decreasing these cost items.

Since there is a cost estimate for the entire boiler house as a whole and the amount of costs in the structure of the expenditure of heat energy related to the pipeline in these costs is unknown, several calculations are made for different shares of costs related to the operation of the pipeline, changing the share from 0 to 50% in increments of 5%.

Table 1 shows the results of the calculation of the required gross revenue and the tariff amount after the implementation of the concession agreement in order to replace the pipeline with pipes with PUF insulation, depending on the share of operating and repair costs incurred by the pipeline in the total cost estimate for the production and transmission of heat energy.

Figure 1 shows the potential difference in tariff amounts between the current value and the value after the implementation of the concession agreement.

From the calculation and graph it is seen that modernization is effective, reduces the amount of the tariff for thermal energy by increasing reliability of heat supply of consumers, increasing the efficiency of the boiler operation.
Table 1. The amount of required gross revenue and tariff after the concession agreement.

| The share of expenditure on the pipeline (%) | Required gross revenue (thousand rubles) | The tariff amount (rubles/Gcal) |
|---------------------------------------------|-----------------------------------------|-------------------------------|
| 0                                           | 49,543.5                                | 1,751.57                      |
| 5                                           | 49,436.11                               | 1,747.78                      |
| 10                                          | 49,328.72                               | 1,743.98                      |
| 15                                          | 49,221.33                               | 1,740.18                      |
| 20                                          | 49,113.94                               | 1,736.39                      |
| 25                                          | 49,006.55                               | 1,732.59                      |
| 30                                          | 48,899.16                               | 1,728.79                      |
| 35                                          | 48,791.77                               | 1,725                          |
| 40                                          | 48,684.38                               | 1,721.2                       |
| 45                                          | 48,576.99                               | 1,717.4                       |
| 50                                          | 48,469.6                                | 1,713.61                      |

Figure 1. Effect of the concession agreement on the tariff amount.

7. Conclusion

In contrast to outdated methods of laying heating lines, the technology of using pipelines in in foamed polyurethane insulation foam allows us to significantly reduce costs, improve the quality and service life of communal pipeline systems. This technology would help to partially overcome the crisis of water supply and sanitation facilities. Of course, the poor condition of the pipeline is not the only reason for high heat energy costs, but losses in the heat networks range from 30 to 40%, when new technologies will allow us to reduce this figure to 2% and increase the life of the accident-free heat networks to 30 or more years.

Since there is an acute problem of financing projects in the energy sector, public-private partnerships, including concession agreements, as the most common mechanism of interaction between the state and business, will help attract investment in the industry.

The implementation of the heat network replacement project within the framework of the concession agreement will not only help to improve the technical characteristics of the boiler house and pipeline, as well as the energy efficiency of its use, but will also reduce the tariff amount for heat energy, which is the advantage of this project.

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