

The problem of modeling the heating sector at the city level

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Abstract. The article proposes a model for the functioning of the district heating sector. However, at the city level, a number of problems arise: problems of modeling the heat supply of cities associated with the inconsistency of statistics on the production and supply of thermal energy - unequal estimates of heat supply, losses and specific fuel consumption; the problem of forecasting heat consumption in cities; the problem of modeling the financial balance of the DH sector in cities. These problems can lead to an erroneous description of urban heating systems and the possible adoption of incorrect decisions on the development of the city's district heating, which has an impact on the development of the country's industry.

1 Introduction

District heating in Russia is a large industry that performs the most important function of life support for the economy and the population. District heating in Russia is from 2/3 to 3/4 of heat consumption [1] or 1 208 million Gcal in 2021 [2]. Russia accounts for 40-45% of the world centralized heat production [3, 4].

Modeling district heating sector is a key task for ensuring the reliability and efficiency of the industry, assessing its state and determining options for the development of the industry.

Modeling district heating sector at the city level allows you to create tools to improve the efficiency of the industry at the city level. At this stage, the municipalities are actively moving into heat supply price zones. Modeling the heat supply sector for the city allows assessing the risks and consequences of the transition of the city to the price zone of heat supply, to systematize the process of transition of cities to the price zones of heat supply.

2 Description of the district heating sector operation model

To describe the heat supply industry, an industry model was proposed (Fig.1), which includes three combined balances: the balance of production and consumption of heat energy, the balance of fuel consumption in heat supply, and the financial balance of the industry. The concept of the model is described in the article [5].

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The physical balance consists of blocks of production and consumption of heat; the heat balance is related to the fuel balance through the specific fuel consumption per heat produced, the volumes of which are used to calculate the total fuel consumption and its costs.

The financial balance is built on the basis of revenue - the total supply is multiplied by the weighted average price of one Gcal. In the expenditure, fuel costs are calculated, and all other items are balanced through a specified loss/profit and cost structure. Thus, the fuel balance is linked to the financial balance through fuel consumption, which is taken into account in the sector's costs. The financial balance completes all balances.

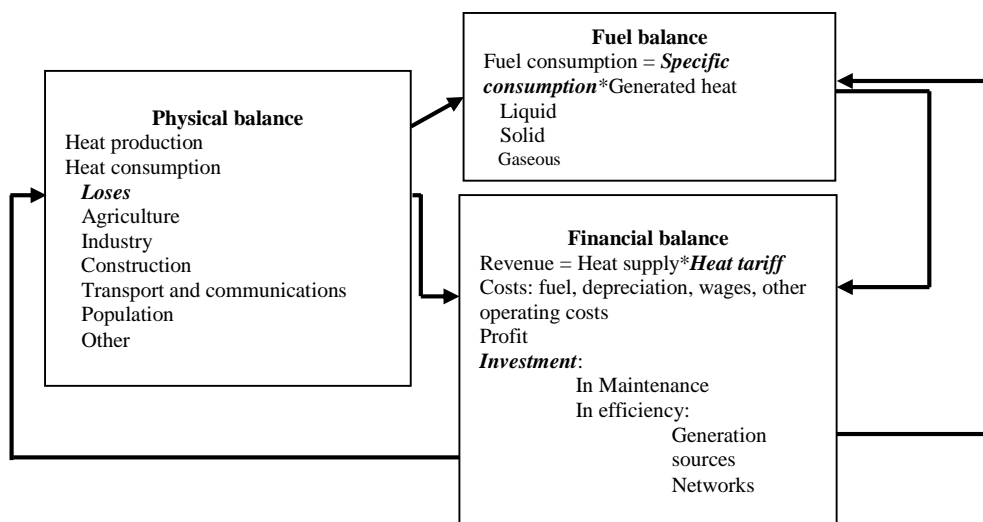


Fig. 1. Diagram of the functional model of district heating sector.

The heat supply model is built for two segments: the segment of alternative heat plants (price zones of heat supply) and the other segment of district heating. Their sum is the district heating sector of the country.

The input parameters of the model for segments of alternative heat plants and concessions are investments and tariffs, which affect the volumes of heat energy consumption, specific fuel consumption, and losses in heating systems, and hence the costs of these items. The traditional segment reflects the inertial development of the industry. The model presents mutually reconciled heat consumption, heat production structure, fuel consumption, cost structure, and sector revenue.

The logic of the model is that in the segment of alternative heat plants an investment process is taking place, which changes the parameters of the functioning of district heating systems (DHS), while in the segment of other heat supply, development proceeds by inertia. Such a top-level model makes it possible to evaluate the effects of the introduction of alternative heat plants or other mechanisms for the development of DHS and industry operation models.

In the model in the segment of alternative heat plants, for each price zone of heat supply, a model of the operation of DHS in this locality is built by analogy with the model of the entire industry - that is, the same three balances that were mentioned above.

To build a heat supply model for individual municipalities, data from heat supply schemes, as well as various statistical forms of Rosstat (6-TP, 1-TEP, 4-TER, P-2, 1-enterprise) are used. We have built such urban models for 18 large price zones: Novosibirsk, Krasnoyarsk, Samara, Perm, Tolyatti, Barnaul and others. Small towns and villages that have moved into price zones are combined into one point and a model is also built for them.

3 Features of functioning of alt boiler plants

Heat supply price zones were created in order to attract investment in the heat supply industry [6]. The mechanism allows DHS to function on more liberal, compared to the current, conditions when pricing according to the alt-boiler method - the price for heat is set freely within the price of an alt boiler plants (the estimated price of the cost of heat from a new heat source for the district), which includes the investment component.

In most cities, the heat tariff is calculated using the cost plus method. At the same time, tariffs are directly related to costs, so heat supply organizations have no motivation to optimize costs and increase efficiency.

In addition, after the introduction of the price zone, the Unified Heat Supply Organization (UTO) is selected, which becomes responsible for the entire heat supply chain in the municipality. This is how the tariff is equalized within the limits of the UTO activity. If the costs are higher than the heat tariff, the company will have to increase efficiency or leave the market.

UTO activity is regularly checked according to several criteria – heat losses, number of emergencies, the share of CHP electricity generation in the combined cycle, specific fuel consumption in heat production, and others.

Thus, a more transparent system of organizing heat supply and a system of responsibility in the municipality appears, which, among other things, can attract investors.

Heat supply price zones are already a significant segment of the heat market. As of February 2023, price zones include 37 municipalities in 18 regions of Russia, where 12.9 million people (8% of the population of the Russian Federation) live. About 15 municipalities are considering the possibility of being included in the price zone.

The planned volume of investments in price zones for 10-15 years is 283 billion rubles, which is 2.6 times higher than the volume of investments that would be directed to these municipalities without moving to price zones and 1.5-2.4 times higher than the annual volume of investments in the country's heat supply systems. More than 50% of the funds are directed to the modernization and construction of new heating networks in price zones.

Investors in the projects of the alt boiler plants are 7 companies, the most active are PJSC T Plus (18 heat supply price zones) and Siberian Generating Company LLC (12 heat supply price zones), which account for 96% of investments.

In practice, the growth of the tariff in the future period occurs according to the $CPI + 1.5-4\%$ formula, depending on the municipality, which, according to the authorities of the region, is not critical. The authorities of the regions also say that the introduction of heating price zones allows partially reducing the burden on the budgets of municipalities by reducing subsidies.

Thus, a new segment of the heat market is being formed, which operates on conditions different from those of the entire district heating system.

4 Features of heat supply schemes

The main source of data on the state of heat supply at the city level is the heat supply scheme.

According to the law [7] the heat supply scheme serves as a justification for the efficient and safe functioning of the city's heat supply systems and its development. The heat supply scheme is an element of energy planning; it must be based on the city's territorial planning documents (city master plan). The heat supply scheme describes the development vector of district heating systems (DHS) as well as the current and prospective position of the DHS. The heat supply scheme serves as the basis for the further construction of various facilities in the city and the allocation of budget investments for these purposes.

Heat supply schemes are developed for an estimated period of 10-15 years. The actualization of heat supply schemes takes place annually, during which the planned and actual values of indicators are compared and the necessary adjustments are introduced [8, 9].

The mass development and distribution of urban heat supply schemes began in the 1950s, when life support systems were actively developing [10]. Heat supply schemes make it possible to develop the city's engineering infrastructure, housing and communal services systems and capital construction optimally and comprehensively. In Soviet times, the development of heat supply schemes for cities and settlements was carried out by large design institutes, since the development of territories took place systematically [11].

In 1990-2010 heat supply schemes were rarely developed and practically not used, which is a consequence of the fall in demand for heat and the departure from the Soviet planning system [12]. The system of design institutes that were involved in the development of heat supply schemes was abolished.

Now local governments of municipalities and cities are responsible for the development and updating of heat supply schemes [13, 14]. Drawing up heat supply schemes for settlements, including small ones (up to 10 thousand people), using district heating, is mandatory. Heat supply schemes for cities with a population of 500 thousand people. and more must be approved by the Ministry of Energy. The development of heat supply schemes can be carried out independently by the administration of the settlement in the presence of the necessary competencies (which does not happen often), as well as specialized design organizations - the largest of them are NP "Energy Efficient City", OJSC "VTI" [15, 16, 17, 18].

Heat supply schemes are a tool for monitoring the state of DHS in a city, as well as a tool for strategic planning of territorial development and improving the energy efficiency of cities. A well-designed heat supply scheme allows taking into account the interests of consumers and producers of thermal energy, and is also the basis for making managerial decisions on the development of the city's communal infrastructure and optimal spending of budget funds.

5 Problems of modeling the heating sector in cities

A number of problems were identified in the construction of the city-level heat supply models described above.

5.1 Problems of modeling the heating sector in cities related to the inconsistency of heat production and supply statistics

Data from different sources give different estimates of heat supply. Thus, according to the heat supply scheme in Perm, heat supply is about 10 million Gcal, and the estimate of heat supply according to Rosstat forms 6-TP and 1-TEP is 14 million Gcal. One of the reasons for the difference in estimates of heat supply is that heat supply schemes often do not take into account the supply of heat by small boilers.

Often, incorrect heat losses are reflected in heat supply schemes [19]. Thus, according to I. A. Bashmakov, in reality heat losses in individual district heating systems can reach more than 50% [20], which will not be reflected in official statistics. According to other estimates, only 20–30% of the supplied/produced heat can reach the consumer (Gornozavodsky district of the Sverdlovsk region) [21].

Sometimes, in heat supply schemes, the indicators of specific fuel consumption (SFC) turn out to be lower than theoretically possible values (142.8 kg of fuel equivalent/Gcal). So, in the scheme of heat supply of the city of Cheboksary, the SFC of power plants is 133 kg of c.u. tons / Gcal, in Novosibirsk - 142 kg. tons/Gcal.

In the form 1-TEP (data on boilers) SFC are also underestimated relative to real indicators.

5.2 The problem of forecasting heat consumption in cities

As is known, throughout the country and in most regions, heat consumption in DHS is falling. And in most heat supply schemes, an increase in heat consumption in the DHS is incorporated. This is due to the intersection of the interests of the two parties. Firstly, customers or heat supply companies are interested in increasing capacities in order to more easily reconcile investments and costs, and hence tariffs and revenues. Secondly, city administrations and new potential consumers of heat from DHS (mainly residential buildings) want to make sure that there is no capacity shortage. This is also facilitated by the procedure for the development of master plans, where areas are allocated for residential development, but the terms of construction and the principles of organizing heat supply in new microdistricts are not prescribed. Then the administration of cities and the main heat supply companies consider these zones as generating additional demand.

The experience of studying heat supply schemes has shown that the forecast values are mainly obtained by calculation and standard methods. In this case, the specific consumption of fuel and heat do not correlate with the main influencing factors - industrial heat consumption, climate and population density [22]. If the modernization of heating networks and the reduction of losses are envisaged, this is not taken into account. The potential for improving the efficiency of the entire system is also not taken into account (improving the regulation of the supply of coolant, increasing the energy efficiency of buildings (including due to the overhaul of the fund), putting things in order in accounting and reducing nominal (estimated) losses, where it is used, the possibility of using secondary energy resources of the city). In addition, the growth trends of the decentralized segment of heat supply are not noticeable in heat supply schemes, reflecting important changes in the industry [22].

As a result, the predicted values of consumption and production of heat in the DH are overestimated [23], which justifies unnecessary investments and, as a result, even a deterioration in the efficiency of the DH operation.

This problem is similar to how the inputs/forecast demand for electricity in the Scheme and development program and inputs of transformer capacity in the power grid sector were overestimated before they began to deal with this.

Nevertheless, to reduce the balances of production and consumption of heat and consumed fuel is a problem to be solved.

5.3 The problem of analyzing and modeling the financial balance of the DH sector at the city level

The third group of problems is related to the modeling of the financial balance.

To analyze the financial condition of the DHS at the city level, a financial balance is built, where the revenue part is formed as heat supply volumes multiplied by tariffs by consumer groups, and the expenditure part is formed as an estimate of fuel costs (linked to the estimate of fuel consumed in the city's DHS) and other items costs. If such a methodical approach is applied to the formation of the financial balance at the city level, then implausible results and complete incompatibility for different cities are obtained.

For example, according to the basic model, it turned out that the profitability of DHS in some cities can reach abnormally high values - above 60-80% in terms of revenue (Prokopyevsk, Kemerovo). Whereas in reality, the management of organizations complains about low tariffs that do not cover costs.

In our opinion, this reflects two problems.

First, in this calculation there are all inconsistencies in the statistics, which were mentioned earlier. Secondly, the lack of direct reporting data on costs and profitability. It is possible to proceed from the model cost structure and link it to the volume of heat supply, the power of sources, the depreciation of fixed assets and their age, losses in heat networks, and the types of fuel used. But for each cost item there is a specificity. Thus, the cost of coal fuel can vary greatly depending on the terms of supply, the timing of the signing of a supply contract, the affiliation or lack of affiliation of the heat supply company with the coal producer. Or, for example, depreciation in two physically identical companies can be calculated according to different estimates of the value of fixed assets. The real costs of wages or repairs are also difficult to estimate. In addition, the specifics of accounting and management reporting for each organization are superimposed here. What is attributed to current or major repairs, and what to investments is decided by specific managers and cannot be verified from outside the organization. At the country level as a whole, this problem is leveled by the generalization of data, and already at the city level, problems arise in reflecting this specificity.

To solve the first problem, it is necessary to coordinate statistics and build coordinated balances of production and consumption of heat and fuel consumed for these purposes at the city level.

To solve the second problem in terms of industry management, it is necessary to develop a system for monitoring / benchmarking costs - not to influence specific companies, but to create a tool to improve the efficiency of the entire industry. Such a system would help to create price zone agreements with better quality, protecting the interests of both consumers (so that tariffs are not too high) and investors (so that tariffs are sufficient to cover current costs and return on investment). The presence of such a system will allow companies to exchange experience, and regulators, in case of problems, will quickly understand them.

From the point of view of research in this area, in our opinion, the problem of a disparate financial balance can be solved by a modified model that takes into account the specifics of 20-30 cities. If for such a population a model is developed and calibrated that works according to a number of standard rules, then it can be extended to any number of cities.

6 Conclusions

A number of these problems reflect the peculiarities of the functioning of heat supply and the specifics of accounting for statistics in certain price zones. However, other problems lead to an erroneous description of the city's heat supply systems and the possible adoption of incorrect decisions on the development of the city's DHS, which has an impact on the development of the country's industry.

If there are no problems to build one single model of the city, and even without coordinating three balances, as suggested in [5], then for a large model it is necessary to use the same construction technique, which, with the available data, leads to incompatibility of the results. The problem of such systemic (of the same type) modeling of DHS in cities is important and difficult to solve with the available data set.

At the same time, the development of a modified model that takes into account the specifics of 20-30 cities and works according to a number of standard rules will allow expanding the model to any number of cities. And this will improve the efficiency of district heating systems at the city level - it will help to draw up agreements on the transition to the price zone with better quality, protecting the interests of both consumers (so that tariffs are not too high) and investors (so that tariffs are sufficient to cover current costs and return on investment).

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