

# Integrated efficiency evaluation of the heat-supplying enterprises activity

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**Abstract.** Heat supply is the industry which forms the comfortable living environment in many respects. It is especially felt in those regions, where climatic conditions demand maintenance of the comfortable thermal mode during the cold winter period. On the one hand, the efficiency of the heat-supplying enterprises activity determines the level of the population comfort, including temperature condition in rooms, uninterrupted heat supply, on the other hand, it influences the tariff level for heat supply services. The article presents the results of the research, which purpose was to reveal the indicators of the heat-supplying enterprises activity, allowing to estimate their efficiency in the most complete way from the position of various stakeholders. The system of indicators, created as a result of the conducted research, can be used by both management of the enterprise, and external stakeholders for the efficiency evaluation of the heat-supplying enterprise in statics and in dynamics.

## 1 Introduction

Nowadays it is absolutely impossible to imagine a modern city and the whole country without the use of different types of energy resources, transformed to energy, which is necessary both for providing comfortable living conditions, and for work of all the branches of economy as well as for the implementation of practically all types of activity. Reliable and uninterrupted heat supply for consumers is the most important problem of the heat supply system. It creates the basis for forming of comfortable living environment at low values of temperature of the external air [1]. Heating during a certain period (from 2...3 to 9...12 months) is required on the most part of the planet.

At the same time, it is possible to consider the efficiency of heat supply functioning from various points of view. So, the comfort of living conditions during the heating period is determined by the reliability and service quality of heat supply. These characteristics can be estimated through the determination of compliance of temperature condition and pressure of the heat carrier in the heating systems to standard indicators, the quantity of accidents and interruptions in supply of the heat carrier, etc. The comfort of living conditions forms the level of population living in many respects.

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Tariff for services of heat supply is the second indicator. At the same time, it is obvious that high quality of services of heat supply can be hardly provided at a low tariff. Low indicators of accident rate and interruption in heat supply during the heating period demand timely updating of the pipelines and its high-quality and timely maintenance as well. Moreover, the technologies of "clever heat supply", which implementation assumes the installation of sensors, data collection and processing by the means of the specialized software can be used for ensuring permanent monitoring of the heating systems condition. That means that high quality of heat supply demands considerable investment and operating costs which, in turn, lead to the growth of tariff for services. The increase in the share of utilities costs in the total amount of the household expenses leads to the decrease in the level of the population living, as well as to the increase in the utilities costs in the expenses of industrial enterprises results in the growth of prime cost and price for products.

In spite of the trend to transition to the decentralized heat supply, consumers of the centralized heat supply make up the considerable share of those in many countries. Russia is, perhaps, the leader of the centralized heat supply: about 80% of consumers are connected to the centralized sources in this country. The share of consumers of the centralized heat supply is rather high in some other countries: 55% in China, 42% in Denmark, 35% Finland [2]. The share of the centralized heat supply in Sweden, Lithuania, Poland is high too.

Numerous consumers, receiving heat from the centralized sources and the high social importance of this industry prove the relevance of the research in this area. That is also confirmed by a significant quantity of publications by various authors, made according to the results of the heating systems study.

Serious research is devoted to the matters of maintenance of the comfortable thermal mode in buildings. For example, some scientists place emphasis on the psychological component within their research of thermal comfort in buildings [3, 4, 5]. Generally, it is possible to prove that each person considers various temperature to be comfortable. Therefore, it is necessary to be guided not only by specific values of temperature, but also by feelings of a person.

There is some research devoted to the application of various energy sources for providing the centralized heat supply of rooms [6].

Research interest also considers the matters of reliability of heat supply and risk management of the heat-supplying organizations; that is reflected in some publications on this subject [1, 7, 8].

This research is devoted to the identification of indicators of the heat-supplying enterprises activity, allowing to estimate their efficiency from the position of various stakeholders in the most complete way.

## **2 Materials and Methods**

The research was based on studying of the heat-supplying enterprises in Russia. The choice for benefit of studying of indicators of activity of the Russian heat-supplying enterprises is caused by several significant reasons:

- 1) the large territory and the geographical location of Russia make the matters of heat supply especially important. The considerable part of the territory of Russia is in the zone of a temperate climate assuming the 6-7-month heating period and there is a subarctic zone as well, where the heating season lasts 8-10 months. For the systems of heat supply 320 million tons of conditional fuel, or 33% of consumption of primary energy in Russia are spent for the heat energy production, and taking into account independent heat supply this share approaches 50%. That is comparable to the Russian export of hydrocarbons [9];

2) a considerable share of the centralized heat supply. In spite of the tendency to decentralization of heat supply, the overwhelming share of consumers uses the centralized heat supply sources. However, the tendency to decentralization is recognized to be negative, as it has lower energy performance. The centralized sources of heat supply can use technology of cogeneration, i.e. joint development of heat and electrical energy;

3) the major fact characterizing the condition of energy system of Russia is the increasing volume of wear of infrastructure facilities of heat supply, as about 70% of heating systems and 20% of the heat-generating equipment work with the excess of standard service life. The share of losses of heat power in the heating systems reaches 20-30%, and that by 4 times exceeds the indicators of the European countries similar to Russia according their climatic conditions, such as Finland, Sweden, Denmark, etc. High accident rate at heating systems with the interruption in supply of the heat carrier in the heating season from several hours to several days is also noted;

4) municipalities (the state pattern of ownership, the state and municipal enterprises), and private enterprises can act as owners of the heating systems and heat-generating equipment in Russia. At the same time, some requirements of efficiency are imposed to the heat-supplying enterprises of all the patterns of ownership (minimum – self-sufficiency).

Taking into account the stated aspects, the efficiency evaluation of functioning and development of the heat-supplying enterprises has the great importance and has to be carried out according to several indicators. These indicators need to be united in a system. Such system of indicators has to give comprehensive (integrated) assessment of the heat-supplying organization activity.

The indicators should be selected taking into account some important requirements for providing the requirement of integrality of the heat-supplying enterprises activity assessment:

1. It is necessary to allocate several types of efficiency:

- technical efficiency;
- environmental efficiency;
- social efficiency;
- cost efficiency.

Indicators have to be provided for each type of efficiency.

2. It is necessary to define the main stakeholders of the heat-supplying enterprises and to define the performance indicators for each group separately. Such a need is determined by the high social importance of heat supply, by its great influence on the population comfort. Respectively, the main stakeholders of the heat-supplying enterprises include:

- state;
- consumers;
- management and employees;
- owners [10].

3. All the indicators are to have static and dynamic expression:

- static indicators have to give information on the current state of the heat-supplying enterprise. These indicators will give dot information according to the principle "here and now";

- dynamic indicators have to give information on change of the indicator in relation to data of the previous measurements. These indicators will give information on the enterprise development and trends of changes.

Identification of the indicators of efficiency evaluation of the enterprises activity is based on the application of one of the key scientific methods, i.e. the analysis method. However, the desire to present the set of significant indicators in the form of a complete system forced the author to apply the method of generalization and the system approach as well.

### 3 Results

The following conditions and restrictions were used, when forming the system of the indicators allowing to perform the integrated efficiency evaluation of the heat-supplying enterprises:

- the indicators were generally selected from the set of those already known. Selection was performed by the authors according to the requirement of the allocation of the main resulting indicators.

- several indicators are offered by the authors in order to help to receive a broader picture for all the types of efficiency;

- the novelty of the received results is provided with the author's approach to selection and classification of indicators. In total all the indicators of the system have the properties of the need and sufficiency for the versatile efficiency evaluation of functioning and development of the heat-supplying organizations.

Earlier one of authors made an attempt of classification of indicators taking into account their classification by stakeholders [11, 12]. However the classification was finished as a result of the joint survey, taking into account the efficiency type. It was also complemented with some indicators. That allows to carry out a more exact efficiency evaluation of the heat-supplying enterprises activity.

The results of selection and classification of indicators were united in the system. They were classified according to the types of efficiency, stakeholders and also divided into static (functioning indicators) and dynamic (development indicators). The system of the indicators of efficiency evaluation of the heat-supplying enterprises is presented in Table 1.

**Table 1.** The system of the indicators allowing to conduct the integrated efficiency evaluation of the heat-supplying enterprises.

Type of efficiency	Static indicators	Dynamic indicators
Technical efficiency	<b>State</b>	
	quality of heat supply, %: $Q = \frac{Bc}{Bs} * 100\%$ where Bs - quantity of buildings, supplied by the heating systems; Bc - quantity of buildings, received complaints about the operation of the heating system [13]).	Growth rate of the heat supply quality indicator, %
	Reliability of heat supply which is expressed through the accident rate (the quantity of accidents per 1 km of a heating system)	Growth rate of the heat supply reliability indicator (growth rate of the accident rate), %
	<b>Consumers</b>	
	Certainty of heat supply (the quantity of interruptions in heat supply because of accidents)	Dynamics of certainty of heat supply, % (calculated as the growth rate)
	<b>Management and employees</b>	
	Ratio of the actual losses of heat in the heating system in comparison with the standard [11], %	Gain of the actual losses of heat in comparison with the standard (as the growth rate), %
	Ratio of thermal load and thermal power, %	Growth rate of loading of the heat-supplying organisation in relation to its power, %

	Ratio of expenses on capital repair and depreciation expenses, %	Growth rate of the ratio of expenses on capital repairs and expenses on depreciation, %
	<b>Owners</b>	
	Wear of the heat-generating facilities, %	Growth rate of wear of the heat-generating facilities, %
	Wear of heating systems, %	Growth rate of wear of heating systems, %
Environmental efficiency	<b>State. Consumers. Management and employees. Owners</b>	
	Level of emissions in the atmosphere	Growth rate of level of emissions in the atmosphere, %
	Cost of ecological damage	Growth rate of cost of ecological damage, %
	The raw materials volume used for production and/or transfer of 1 kW of heat power) [14]	Growth rate of volume of the raw materials used for production and/or transfer of 1 kW of heat power), %
	The water volume used for production and/or transfer of 1 kW of heat power) [14]	Growth rate of the volume of water used for production and/or transfer of 1 kW of heat power)
Social efficiency	<b>State</b>	
	Share of consumers, provided with access to the municipal infrastructure of heat supply, %	Growth rate of the share of consumers, provided with access to the municipal infrastructure of heat supply, %
	<b>Management and employees</b>	
	Quantity of jobs at the heat-supplying enterprise	Growth rate of quantity of jobs at the heat-supplying enterprise, %
	Ratio of the average salary of the heat-supplying enterprise staff to the average level of the salary in the region	Growth rate of a ratio of the average salary of staff of the heat-supplying enterprise to the average level of the salary in the region, %
	<b>Owners</b>	
	The number of the inhabitants included in the social programmes implemented by the heat-supplying enterprise	Growth rate of the quantity of the inhabitants included in the social programmes, implemented by the heat-supplying enterprise
	Positive/negative image of the heat-supplying enterprise in the local community	-
	<b>Consumers</b>	
	Complaints of the population about the quality and reliability of heat supply (totally, coming to the homeowners' Association and local government authorities) [10]	Growth rate of the quantity of complaints, %
	Quantity of hours of temperature deviation in the dwellings in comparison with the standard [13]	Growth rate of the quantity of hours of the temperature deviation in the dwellings, in comparison with the standard %
Cost efficiency	<b>State</b>	
	Availability / lack of the state support (subsidies, etc.)	-
	Share of budget expenses on functioning of the heat-supplying enterprise (% of the total amount of	Growth rate of the income coming to the budget from functioning of the heat-supplying organization

	expenses on its functioning)	
	Budget revenues arriving from functioning of the heat-supplying enterprise (tax assignments)	Growth rate of the income coming to the budget from functioning of the heat-supplying enterprise (tax assignments)
<b>Consumers</b>		
	Tariff size	Growth rate of the tariff, %
	Share of expenses on heat supply in utilities expenses, %	Growth rate of expenses on heat supply in utilities expenses
	Share of expenses on heat supply in the volume of expenses, %	Growth rate of expenses on heat supply in the volume of expenses, %
<b>Management and employees</b>		
	Amount of accounts receivable for heat supply services	Growth rate of accounts receivable for the services of heat supply, %
	Average cost of production of heat power (prime cost per 1 kWh)	Growth rate of average cost of production of heat power, %
	Net profit of the organization, thousand roubles.	Growth rate of net profit, %
	General profitability of the organization, %	Growth rate of profitability, %
<b>Owners</b>		
	Dividends per 1 share	Growth rate of dividends per 1 share, %
	Return on equity, %	Growth rate of return on equity, %
	EVA (economic value added)	Growth rate of EVA, %

Integrated efficiency evaluation of the heat-supplying enterprises activity has rather high practical importance for making managerial decisions by the enterprise management and owners as well as for forecasting of possible versions of decisions of stakeholders, which are external in relation to the enterprise. For example, it is possible to allocate several possible options of actions of external stakeholders depending on the evaluation result.

**Table 2.** Options of actions of stakeholders, external in relation to the heat-supplying enterprise depending on its efficiency.

Stakeholder	Positive efficiency evaluation and positive dynamics	Negative efficiency evaluation and positive dynamics
State	Creating favourable conditions for the development (release from tax audits for a certain term; granting preferential terms for obtaining permissions in case of expansion, for example, during construction of new heating mains), etc.	Request of the explanations and development plans allowing to reduce negative results, support of the competing heat-supplying enterprises development (allocation of subsidies for the development, i.e. the increase in the production capacity)
Consumers	Loyalty to the heat-supplying organization, fee without requirements about cost reduction as a result of low-quality services rendering	Installation of the individual heat-generating equipment, replacing a supplier in favour of a competitor, presentation of claims on the service quality and the requirement on the decrease in the service fee in case of non-compliance with the regulatory indicators

## 4 Conclusions

The provided indicators of the performance of functioning and development of the heat-supplying enterprises are generalized in the system, allowing to give integrated efficiency evaluation of the heat-supplying enterprises activity. Regular monitoring of the indicators, united in such a system will give the necessary information basis for the acceptance of

high-quality management decisions on the development of the heat-supplying enterprises. It is extremely important, that the interests of various stakeholders will be considered. Owners and management of the enterprise are interested in obtaining high economic results, first of all. However, we should keep in mind the social environmental efficiency, which creates the basis for the long-term and sustainable development of the enterprise and the community in the territory of which it functions.

The maximum effect of application of the developed system of indicators can be reached in case of regular collecting and information analysis. It means the need of regular monitoring of indicators. It will allow to estimate the enterprises of heat supply in dynamics. Accumulation of information will allow to build trends, to carry out factor analysis, etc. It will strengthen the possibilities of the use of indicators for the purposes of planning and forecasting. In general, it will increase the managerial potential at the heat-supplying enterprises considerably.

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