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## Regional management of district heating

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**Abstract.** Nowadays in Russia we see rapid modernization of power engineering and transport systems. Under these conditions the issue concerning improvement of regional heat supply system energy-efficiency has gained a new importance. The aim of this study is to find new development directions of the public-private partnership (PPP), specifically from the perspective of its energy efficiency. Amid the financial crisis and economic sanctions the formation of public-private partnership allows increasing of energy efficiency of regional fuel and energy complex by means of regional energy service company creation. This paper will be useful both for central and local government and for private business.

### Introduction

After the acceptance of the Federal Act No.261 "On energy saving and energy efficiency" the Russian Federation acceded the modern global trend on energy saving.

This Act concerning reduction of power consumption became a necessary measure amid the existing energy crisis and market relations. When comparing this situation with the countries of West Europe and USA, which deal with the problem of energy efficiency from the beginning of the 70s, we should study their experience of real energy economy in energetics and construction, as well as laws providing the priority for companies and citizens, which use energy-saving technologies and solutions. It should be noted, that almost simultaneously with energy crisis in USA, the first complex document - Energy Act 1992 - appeared, which denoted the basic problems and their possible solutions for energy-saving. The Government launched the program of perspective standards and other normatives, aimed at energy saving at various industry branches. This program was based on so-called "performance standards", i.e. it was oriented at the end result, which is energy economy. Enormous funding was invested in public promotion of the energy-saving program and clarification of its targets. In 2004 The USA Congress declared the successful implementation of the Energy Act 1992 and adopted a



new Energy Act 2004 document. Also they developed the so-called Road Maps for various industry branches [1].

As for Germany, the Federal law initially included the public-private partnership, federal granting for modern materials and technologies usage, and various motivations. Also we should mention the "20-20-20 Program", which is the first stage of the ambitious plans of the European Union. These plans are for 90% reduction of greenhouse gases emission up to the year 2050 (in comparison to the year 1990) and energy consumption savings from 175 to 320 bln Euro annually between 2010 and 2050 (the initial investments are 270 bln Euro).

Nowadays legal regulation of the energy-saving has become even more urgent due to orientation of the countries at energy-efficiency and energy-saving. The investigation of mechanisms of government influence in the sphere of energy, estimation of efficiency of legal regulations influence and energy-efficiency increase are the main factors for lawmaking concerning private-public partnership (PPP) development. This fact is approved by gathered world experience at PPP working conditions.

Nowadays Russian heat-and-power engineering is characterized by insufficient reliability and energy-efficiency of the heat supply system, as well as danger of accidents. The majority of the enterprises have worn equipment and utilities, low production efficiency, lack of funding and the absence of concurrence. The main priorities of the Government policy for heat-supply are the following:

- Heat supply reliability according to the technical regulations;
- Heat supply and consuming energy-efficiency;
- Development of district heating networks;
- Balance the economical interests between the heat-supply organizations and consumers;
- Economically-reasonable profitability of current activity of the heat-supplying organizations and investments;
- Non-discriminatory and stable conditions for heat-supply business;
- Environmental safety;
- Safe operation of heat supply units.

The issues concerning reforming of public utilities and improvement of its performance in the Russian Federation are the key points for the following researchers: Andryushenkov A.F., Basin E.V., Vihrev YU.V., Gorbunov V.N., Demidova N.V., Kurbatov K.A., Chernyak V.Z., CHernyshov L.N., etc. A.S. Plekhanov studied experience of the European countries. V.G. Ignatov and V.I. Bytov studied the role of local self-government of housing and communal services at East Europe countries. The work of T.B. Kytakova is devoted to condominium creation experience.

The problems of energy-efficiency improvement in various fields of industry are investigated in [2-31], the estimation of Federal law on energy-efficiency applicability for heat consumption efficiency improvement is presented in [32-35]. The question of training academic and teaching staff for engineering and heat-and-power industry is of urgent interest [36-39].

## **Main Text**

The aim of the investigation is analysis of the problems arised at investment of heat-supply system of the Vologda region and development of recommendations for improvement of regional management of this area. The object under study is Vologda region, the subject under study is Government management of the heat-supply system.

The analysis of foreign development experience was conducted [40,41]. So, the degree of government authorities participation in economic activities of the heat-and-power organizations varies from one country to another. However, the predominant activities are various types of concessions involving private investors, in particular, operation according to the two accepted models:

1. The model of the "single-buyer" The resource provider (thermal energy supplier/heating network operator) purchases thermal energy from the producers (all thermal energy sources) and sells it to the consumers under equal conditions and at equal prices. It is possible to use this model upon condition that one company is responsible for the thermal energy sale to the final consumer. The "single-buyer" model is the most common.

2. The model of "open heat networks". The thermal energy producer has a guaranteed access to the heat network upon condition that he sells the thermal energy directly to his own clients to the extent required for consumers (this model is almost not applied in practice).

When setting the tariffs for the thermal energy the following approaches are implemented:

A) "Fare construction" (this market model doesn't allow dominant suppliers to set the monopolic prices, the control for thermal energy market operation for the purpose of compliance of the existing competition law regulations is implemented by a special agency, is applicable in Finland, Denmark, Sweden, Germany, Austria, France, Great Britain, Belgium);

B) "Maximum level": the maximum tariff value is determined according to the established methodology for each company-producer, are approved by an independent national regulator. At this the resource-providing company might decrease the thermal energy price (Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, Bulgaria, Macedonia);

C) "Fixed level" for the tariff setting is conducted according to the established methodology and is approved by a regulator. Here the heat-supply company cannot digress from the fixed tariff level (Russia, Belorussia, Romania, Ukraine).

Table 1 - Length of heat and steam networks along municipal areas and city districts of the Vologda region

	Total, km	Including need changing, km	Worn networks among them, km	The ratio of worn networks, %	Were changed in terms of two-pipes, km	Worn among them, km
<b>At the territory of the region</b>	<b>1805.0</b>	<b>794.2</b>	<b>650.6</b>	<b>36.0</b>	<b>24.0</b>	<b>20.9</b>
Babaevskij	35.6	17.9	17.9	50.2	0.2	0.2
Babushkinskij	5.5	0.5	0.5	9.0	0.1	0.1
Belozerskij	21.4	6.2	4.8	22.4	0.7	0.4
Vashkinskij	10.2	1.0	0.9	8.8	-	-
Velikoustyugskij	91.1	45.1	43.1	47.3	0.2	0.2
Verhovazhskij	10.1	2.6	2.5	24.8	0.2	0.2
Vozhegodskij	21.4	-	-	-	-	-
Vologodskij	145.1	25.5	21.1	14.5	2.5	2.4
Vytegorskij	20.8	10.9	10.4	50.0	0.6	0.6
Gryazoveckij	81.6	7.0	5.5	6.7	1.0	0.7
Kadujskij	83.8	36.5	26.1	31.1	0.7	0.6
Kirillovskij	28.8	12.9	12.9	44.8	0.2	0.2
Kichm.-Gorodeckij	3.6	1.2	-	-	-	-
Mezhdurechenskij	12.3	7.3	3.2	26.0	-	-
Nikol'skij	22.7	4.3	2.7	11.9	0.9	0.8
Nyuksenskij	27.4	0.8	0.8	2.9	0.1	0.1
Sokol'skij	112.0	45.2	44.8	40.0	0.9	0.7
Syamzhenskij	16.0	0.7	0.6	3.8	0.8	0.8
Tarnogskij	7.6	1.7	0.9	11.8	0.1	0.1
Totemskij	81.3	17.0	10.9	13.4	0.5	0.5
Ust'-Kubinskij	7.4	5.2	5.2	70.3	-	-
Ustyuzhenskij	43.4	26.2	20.0	46.1	0.2	0.2
Harovskij	43.3	5.2	1.2	2.8	3.0	1.1
Chagodoshchenskij	44.6	26.9	24.5	54.9	0.8	0.8
Cherepoveckij	73.2	34.2	33.5	45.8	1.7	1.7
Sheksninskij	62.5	14.4	1.0	1.6	0.1	-
Vologda	362.2	193.2	111.7	30.8	8.0	8.0
Cherepovec	330.1	244.6	243.9	73.9	0.5	0.5

At the Vologda region 803 sources of thermal energy are operating, the heat network length is 1805

km, among them 44% should be changed, the worn networks change rate is 21.8%, which is apparently insufficient for providing of pipeline wear and tear reduction, the amount of emergency situations has increased for 47%. The amount of thermal energy sources has reduced for 5% because of closure of inefficient (obsolete) ones and enlargement of heat-supply zones. These actions contribute to improvement of thermal energy production and allocation efficiency (Tables 1,2).

Table 2 - Heat losses and the amount of breakdowns in networks for municipal areas and city districts of the Vologda region

	2014			2015		
	Heat losses		Amount of breakdowns	Heat losses		Amount of breakdowns
	Total, ths. GCal	%		Total, ths. GCal	%	
<b>At the territory of the region</b>	<b>908.3</b>	<b>8.8</b>	<b>34</b>	<b>831.1</b>	<b>8.3</b>	<b>50</b>
Babaevskij	12.8	13.1	-	16.6	19.6	-
Babushkinskij	1.0	6.5	-	1.0	7.0	-
Belozerskij	4.4	14.1	-	7.6	13.9	-
Vashkinskij	3.8	23.8	-	3.6	24.4	-
Velikoustyugskij	53.9	21.2	4	45.5	20.6	1
Verhovazhskij	1.5	7.7	5	1.4	8.3	1
Vozhegodskij	9.4	20.2	-	8.8	19.7	-
Vologodskij	41.8	10.6	-	40.5	12.0	-
Vytegorskij	6.5	13.2	9	8.6	13.5	-
Gryazoveckij	45.0	14.0	-	43.7	14.9	-
Kadujskij	37.9	14.6	1	26.8	11.5	30
Kirillovskij	4.8	14.0	10	4.5	11.2	10
Kichm.-Gorodeckij	0.9	6.1	-	1.0	7.2	-
Mezhdurechenskij	2.9	16.3	-	2.7	16.4	-
Nikol'skij	2.5	6.0	1	2.2	5.9	-
Nyuksenskij	13.2	30.6	-	14.6	34.4	-
Sokol'skij	46.2	18.5	-	40.1	13.0	-
Syamzhenskij	3.0	14.7	-	2.5	13.0	-
Tarnogskij	3.3	16.7	-	3.1	15.8	-
Totemskij	22.8	16.9	-	20.8	15.5	-
Ust'-Kubinskij	1.5	10.5	-	3.0	21.0	5
Ustyuzhenskij	10.7	19.7	3	7.3	14.4	3
Harovskij	6.4	8.1	-	8.9	8.0	-
Chagodoshchenskij	15.3	22.3	1	13.6	22.2	-
Cherepoveckij	24.5	10.3	-	32.3	17.9	-
Sheksninskij	26.3	8.1	-	23.7	9.6	-
Vologda	71.6	8.1	-	62.0	2.9	-
Cherepovec	434.4	15.1	-	384.6	14.0	-

The specific energy costs for release of thermal energy unit from source collectors into the heat networks, as well as transportation of the thermal energy along the heat networks to the consumers characterize the energy-efficiency of the heat supply system operation (specific fuel consumption is the indicator) (kgoe/GCal).

Heat source efficiency is the value, which is inversely proportional to specific fuel consumption for 1GCal of thermal energy production taking into account energy equivalent of GCal thermal energy, expressed in kg of oil equivalent (142.86 kgoe/GCal).

For the Russian Federation territory the indicators for oil equivalent consumption per unit of the produced heat are 178.8-190.1 kgoe/GCal on the average. Consequently, the average efficiency of the boiler houses is 75.1% -79.9% (Table 3). The weighted-average efficiency of Vologda region boiler houses operation is 84%. This corresponds to average specific fuel consumption for heat release from

the boiler houses collectors, which is equal to 170 kgoe/GCal.

Table 3 - Specific energy costs for release of thermal energy unit

Region	Actual fuel consumption per thermal energy unit, kgoe/GCal			boiler house efficiency, %		
	2012	2013	2014	2012	2013	2014
Russia	183.2	178.8	190.1	78.0	79.9	75.1
Central Federal District	183.4	179.4	195.1	77.9	79.6	73.2
Northwestern Federal District	168.2	166.8	165.5	84.9	85.6	86.3
South Federal District	162.5	162.5	163.7	87.9	87.9	87.3
CKΦO	162.9	158.4	164.5	87.7	90.2	86.8
Privolzhsky Federal District	178.6	178.4	204.6	80.0	80.1	69.8
Ural Federal District	162.9	161.8	173.9	87.7	88.3	82.2
Siberian Federal District	227.5	211.5	213.4	62.8	67.5	66.9
Far Eastern Federal District	176.2	174.2	174.2	81.1	82.0	82.0

The highest efficiency of the thermal energy sources have Cherepovetsk region, Cherepovetsk, Velikiy Ustyug and Vologda, where this indicator exceeds 90%. For the boiler houses located at Vashkinskii, Sokol'skii, Babushkinskii, Syamzhenskii, Kirillovskii districts and Sokol town, the efficiencies are less than 50%.

After the comparison of heat supply system operation indicators (Table 4) for the Northwestern Federal District at the existing heat network length, the estimated heat losses ratio appeared to be 8.3%, the amount of breakdowns is 2.7 per 100 km.

Table 4 - Comparative characteristics of operation indicators for heat supply systems of Northwestern Federal District regions.

	the Republic of Karelia	Vologodskaya Oblast'	Novgorodskaya Oblast'	Murmanskaya Oblast'	Arkhangel'skaya Oblast'	The Republic of Komi	Kaliningradskaya Oblast'
Heat networks length, km	951.3	1805.0	942.7	1068.4	1880.2	1956.8	996.5
Annual heat losses (total), %	5.6	8.3	12.6	8.7	10.8	14.1	14.8
The amount of breakdowns at heat networks per 100 km	3.0	2.7	9.0	4.6	6.4	1.0	14.2

The main costs at production and allocation of the thermal energy are expenditures for fuel and power resources (42%), labour expenditures (20%), material and equipment maintenance expenditures (17-18%). The amortization expenses are 5-6%, miscellaneous expenditures are 14% (rent, expenditures for manufacturing measures, payments for negative impact on the environment, doubtful debts, etc) of the total production cost. This doesn't allow the enterprises to form their own investment sources for modernization of basic production funds.

Basing on the conducted analysis, we highlight the following problems, which hinder the development of regional heat supply system:

- Wear-and-tear of the basic production funds leads to system management losses, reliability decrease, impossibility of the required quality service provision;
- Insufficient investment for implementation of program activities, reduction of capital investments for basic production funds modernization (non-fulfillment of activities provided at the investment programs by heat supply organizations);
- due to unstable economics and absence of long-term funding, attraction of private investment to

the communal sphere possesses high risks both for potential investor and consumer;

- insufficient amount of high-efficient thermal energy sources, absence of energy-efficient projects, aimed at production cost reduction.

At modern economics conditions the majority of the countries tend to implementation of infrastructure projects with attraction of extrabudgetary funds and private investors, which results in relieve of budgetary pressures and improves quality and efficiency of industry objects exploitation. Public-private partnership (PPP) is one of the most widespread instruments for attraction of private investments for infrastructure projects [42-48].

Public-private partnership is a system of mutually-beneficial contract relationship between public and private partners. This partnership is aimed at co-funding of projects for development of socially important government-regulating industry branches of services [49,50].

According to the investigation of Association "Centr razvitiya GChP" ("PPP development Center"), nowadays there are more than 1300 projects of public-private partnership in Russia, among them are the following:

- 15 projects of the federal level;
- 191 projects of the region level;
- 1100 projects of the local level.

The analysis of the accomplished public-private partnership projects, has shown that annual average rate of investment attraction using this mechanism is rather high. It is driven by development of laws concerning concession agreements, additional guarantee instruments for investors have appeared, the institute for private concession initiative was created [51, 52].

According to the Russian Federation region rating, prepared by the "Centr razvitiya GChP" ("PPP development Center") and RF Ministry of Economic Development in 2015 [53], in 2014-2015 Vologodskaya Oblast' is a region with moderate potential for public-private partnership project development. It is on the 35 position of the rating. The subject was characterized as a region, where the initial experience is established for public-private partnership, at this the conditions for harmonic PPP development are created at the region.

During our investigation, we have denoted basic types of energy-service contracts, which are definitely attractive just for the heat supply system:

1. Energy service agreement with economies division (SharedSavings). This type of agreement implies funding of energy-efficient activities of the energy-service company with further compensation through technology-implementation economy. Savings from implementation of energy-saving technologies are divided between owner (Energy Service Customer) and energy-service company. The contract period duration is from 3 to 10 years (depending of the payback period).

2. Energy service agreement with guaranteed investment return (FirstOut). This agreement also implies funding of energy-efficient activities by the energy-service company with further compensation through technology-implementation economy. But in this case the contract period might be changed depending of the actual level of economy.

3. Energy service agreement with short payback time (First-Out, FirstPay-Out). This agreement implies investor cost recovery in the first place. When using this agreement the energy-service company receives all 100% of the gained economy until it will pay all expenses for project implementation.

The main stages for energy-saving project realization are shown in Figure 1.

Advantages of energy-service agreements are the following: economic efficiency increase, reduction of energy consumption at thermal energy production; release of funds at the end of the contract; absence of initial investment expenditures; the expected maximum efficiency for contractor service, as the contractor income is directly dependent on the achieved economy level, and the risk of not achieving the economy is born by the contractor.

The earlier investigations have shown [54] that this investment mechanism is practically absent at Vologodskaya Oblast'. However, this type implies implementation of projects with funds provided by the contractor with upcoming fund return at the expenses of the achieved economy for energy resources expenditures and doesn't need further funding.

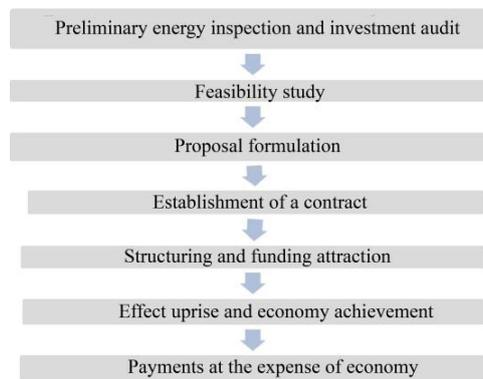


Figure 1 - Stages for energy-saving project realization

### Conclusions and proposals

We believe that the following administrative mechanisms are appropriate for stimulation of the scheme implementation process and transition to the energy service contracts of the heat supply organizations. First of all, development of regional and municipal energy-service companies, as well as organizations with government and municipal contributions, which provide information and methodological support of energy-efficiency improvement and realization of energy-saving programs at regional and municipal levels. The scheme for interaction of the potential process participants is presented in Figure 2.



Figure 2 - The scheme for interaction of participants of energy-service contract implementation process

Department of fuel and energy complex of the Vologodskaya Oblast' should be denoted as the authorized agency responsible for creation of regional energy-service company, as well as the founder in Vologodskaya Oblast', which is responsible for implementation of government energy-saving policy and energy-efficiency increase. This decision should be fixed by appropriate regulations and legislation.

The process for Vologodskaya Oblast' Regional energy-service company development includes three sequentially implemented steps:

Step 1: analysis of energy-service organizations, operating at subject territory; estimation of the existing conditions for activity (analysis and monitoring of the regional energy-service markets, development of object database, which are appropriate for implementation of energy-efficient activities; determination of energy-saving potential);

Step 2: Determination and development of priority company activities; estimation of funding sources; development of corporate structure;

Step 3: Formation of energy-efficient technology register, which are applicable for public service; development of methodological materials for activity organization of energy-service potential participants (government and municipal agencies, enterprises); definition of potential risks at major task implementation; development of a financial plan.

Secondly, formation of energy-efficient technology register, which are applicable for public service. In order to create a methodological basis for potential customers and investors, which are interested in attraction of funding, the regional energy-service company should carry out monitoring of agencies and enterprises with high energy-efficient potential, as well as enterprises with ineffective and expensive production and transfer of thermal energy. The analysis of production capacities of heat supply organizations, performed by the regional energy-service company, results in formation of energy-efficient technology register, which are applicable for public service at the subject territory.

We suggest to divide the activities included into the energy-efficient technology register, into the two groups: organizing, which are directly implemented by the Regional energy-saving company (energy audit, training of job responsible persons, information supply, development and actualization of heat supply schemes), and technical, which are implemented directly at the objects (replacement of worn and obsolete boiler units).

The suggested activity complex allows one to obtain not only economical effect (annual money economy of 1.8 bln rubles), but to improve the quality of the heat supply services, reduce the amount of thermal energy supply breakages for 25-30% (according to the experts opinion), reduce the amount of citizen complains up to 70%, decrease heat losses in heat networks for 1%.

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