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The Observation of Targets Achieved during District Heating Development in Riga City

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Abstract: The rehabilitation project of the district heating system of Rīga city envisaged elimination of district heat substations, reconstruction of individual heat substations and district heating networks. Inefficient medium and small scale heat sources were closed and the relevant consumers were connected to the networks of large scale heat sources. The major heat sources of JSC "Rīgas Siltums" were reconstructed during the project in order to provide more efficient and environmentally friendly heat production. In the course of implementing the rehabilitation project the arrangement of the heat metering, improvement of the service quality and provision of the heat consumption control to heat consumers were provided.

Key words: district heating, network, rehabilitation project

1. Introduction

The good energy policy should combine two aspects — reduction of energy consumption and efficient use of available resources [1].

District heating has started its development by local boiler plants in the second half of the 19th century [2] and become more and more attractive particularly in the cold climate regions due to the capacity of more efficient utilisation of the available energy resources. It is well known that the major benefit of the district heating systems is the capacity to use different types of energy sources, starting from fossil fuels up to natural gas and biomass residues.

Today the district heating system represents the complicated interconnected system with energy production based in the modern cogeneration plants with wide range of fuel types [1, 2]. The approximate number of district heating systems operated in European Union is around 5000 [3]. It is evaluated that today about 40% of the building stock is connected to the district heating network in countries like Poland, Estonia and Latvia. The major part of the district heating networks in the Easter Europe was built during the Soviet Union when the district heating systems were subsidised and fuelled by cheap hydrocarbon fuel [4, 5].

The district heating system in Riga has also been built in 1960s and 1970s when new residential district have been actively constructed. During that period the primary energy resources were inexpensive [6]. Due to that the heat sources had low efficiency, the district heating network was characterised with high transportation losses and heat substations providing heat and hot water supply to the building were inelastic and inefficient.

The aim of this paper is to show how the inefficient district heating system can be transferred in a modern, sustainable and environmentally friendly energy production and supply entity. It was achieved in several steps during the district heating rehabilitation project that considered the following issues:

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(1) reliable and efficient heat and hot water supply to the dwellings;

(2) reconstruction of the district heating network, including both — reconstruction of heat networks and replacement of compensators and shut-off fittings;

(3) closing of small and inefficient boiler plants and replacement of the inefficient systems in the heat production sources;

(4) installation and commissioning of heat meters reading system;

(5) project of heat payment distributors (allocators) installation.

2. General Information

The Joint Stock Company "Rīgas Siltums" is the biggest heat supply utility not only in Latvia, but also in the Baltics. The company was registered with the Enterprise Register of the Republic of Latvia on 14 March 1996 and started its operations on 1 May 1996. The shareholders of the company are Riga City Council with 49% shareholding, the state of Latvia (the Ministry of Economy) with 48.995% shareholding, SIA "Enerģijas risinājumi RIX" with 2% shareholding and the Joint Stock Company "Latvenergo" with 0.005% shareholding. The fiscal year of JSC "Rīgas Siltums" is from 1 October to 31 September. The major directions of operations of the company include heat supply (89.8%), electricity generation (7.6%), service of the heating and hot water systems of buildings (2.4%) and other types of economic operations (0.2%).

76% of heat consumers in Rīga are connected to the district heating system and 75% of the heat delivered via the district heating system is used for space heating and hot water supply of residential buildings. JSC "Rīgas Siltums" purchases approximately 70% of heat and produces the remaining 30% of heat by itself for the needs of the city. 6,638 contracts have been concluded for supply and consumption of heat. The operations of the Company are ensured by 28 structural units. Heat is produced at 5 large-scale heat plants with the capacity ranging from 50 to 405 MW and two of them operating in a cogeneration mode, and at 38 automated gas-fired boiler houses with the capacity ranging from 0.05 to 20 MW and two of them operating in a cogeneration mode. The total installed capacity of the heat sources of JSC "Rīgas Siltums" equals 900 MW. The total length of the district heating networks in Riga city exceeds 800 km, including 684 km of the district heating networks owned by JSC "Rīgas Siltums" and approximately 116 km of the district heating networks owned by state and municipal institutions, cooperatives of apartment owners, etc.

3. The Initial Status of the District Heating System of Riga City in 1996

In 1996 when the company started its operations there were 6 heat plants, 111 non-automated boiler houses, including 18 gas fired boiler houses and 93 fossil fuel fired boiler houses. Approximately 50% of the heat consumers connected to the district heating system of Riga city received heat via 185 district heat substations. Usually heat substations are placed in buildings to which heat is supplied. However, in the 1960s and 1970s when new residential districts were built, the so called district heat substations for delivering heat and hot water to a group of buildings were constructed. District heat substations are placed in special buildings and comprised heat and hot water heat exchangers, heating and hot water pumps, heat and cold water meters, water treatment equipment, etc. Heat was transmitted to consumers for providing space heating and hot water from the district heat substation via a four-pipe scheme.

For the purpose of securing essential improvement of the efficiency of the district heating system of Riga city, ensuring its competitiveness and minimising the environmental impact of district heating, implementation of the rehabilitation project of the district heating of Riga city was commenced in 1996. It envisaged elimination of district heat substations,

reconstruction of individual heat substations and district heating networks, closing of inefficient medium and small scale heat sources and connection of the relevant consumers to the networks of large scale heat sources, as well as reconstruction of the major heat sources of JSC "Rīgas Siltums". In the course of implementing the rehabilitation project, the arrangement of the heat metering, improvement of the service quality and provision of the heat consumption control to heat consumers was viewed as priority areas. In the course of implementing the rehabilitation project of the district heating system in Riga, priorities were set and it was decided to perform modernisation of the district heating system in two stages. The first stage comprised the process of elimination of district heat substations and installation of modernised automated individual heat substations in buildings, and the second stage comprised modernisation of district heating networks and heat sources.

4. Riga City Heat Supply Rehabilitation Project

Under the heat supply rehabilitation project in Riga city the following activities have been planned and implemented:

(1) reconstruction of district heating substations;

(2) modernization of heat networks;

(3) modernization of heat sources.

4.1 Elimination of District Heat Substations

The demand side of the district heating is composed by the buildings having different thermal loads and different indoor space heat distribution systems [2]; simultaneously requiring the domestic hot water with the temperature of 55°C or higher supplied to the customers. The installation of modern automated individual heat substations has been realised in order to provide the reliable and demand oriented heat and hot water supply to the customers of the district heating system.

The program of elimination of district heat substations was composed of several steps and consisted of the following measures:

(1) elimination of district heat substations and installation of modernised individual heat substations in all the buildings receiving heat via district heat substations;

(2) transition from a four-pipes system to a two-pipes system and elimination of hot water networks. As district heat substations were located in special individual buildings where heat was produced for the space heating and hot water needs of a group of buildings, a four-pipe system had been constructed for heat transmission consisting of space heating networks and hot water networks. When modernised individual heat substations were constructed in each building, all the hot water networks were eliminated and space heating networks were reconstructed in order to ensure heat transmission required for all the buildings.

(3) installation of modernised individual heat substations at the sites of Riga City Council;

(4) reconstruction of modernised individual heat substations in buildings that were not connected via district heat substations.

Space heating systems of buildings were mainly connected to district heating networks based on the dependant scheme by using an elevator reducing the static pressure and temperature in radiators by mixing the return water with the forward water. Individual heat substations of this type did not ensure accurate heat supply of buildings depending on the ambient temperature, thus causing overheating of rooms in the beginning and at the end of the heating season and not ensuring the required level of comfort in rooms during the heating season, also their accurate operation depended on the stability of the system hydraulic regimes. In buildings with this type of heat substations residents had minimum heat consumption control possibilities. By implementing upgrading of individual heat substations in buildings they were

connected based on the independent scheme and industrially manufactured automated heat substations with a complete hot water and space heating part (space heating and hot water heat exchangers, pumps, regulators, etc.) and with heat and cold water metering were installed. In the course of implementing the rehabilitation project, in order to provide the required amount of heat at the required quality level to consumers, to improve the security of heat supply and to achieve more efficient consumption of heat, in the result of implementation of the program of elimination of district heat substations and construction of modernised individual heat substations by JSC "Rīgas Siltums", 3008 modernised individual heat substations were constructed, all the 185 district heat substations were eliminated and all the hot water networks with the total length of 135 km were dismantled by the end of 2001.

Of the total number of 8147 heat substations 8138 individual heat substations were modernised during the time period until 2015.

Installation of modernised automated individual heat substations allowed heat consumers to adjust temperature in rooms, to set the required hot water temperature, to maintain a stable hydraulic regime in the space heating system of the building, generally allowing consuming heat more efficiently.

4.2 Heat Networks Modernization Measures

The modernization of district heating network comprises the reconstruction of outdated and worn pipelines, as well the replacement of compensators and shut-off fittings.

4.2.1 Reconstruction of Heat Networks

The historical development of the district heating network is composed by four different stages. First, the network is built as small islands around the heat source. During the next step the network has more complicated structure named by "tree". During the further development of the district heating network leads to interconnection of different parts and forming either ring or mesh [3]. The district heating network in Riga before the reconstruction had all types of the above mentioned networks, see Fig. 1.

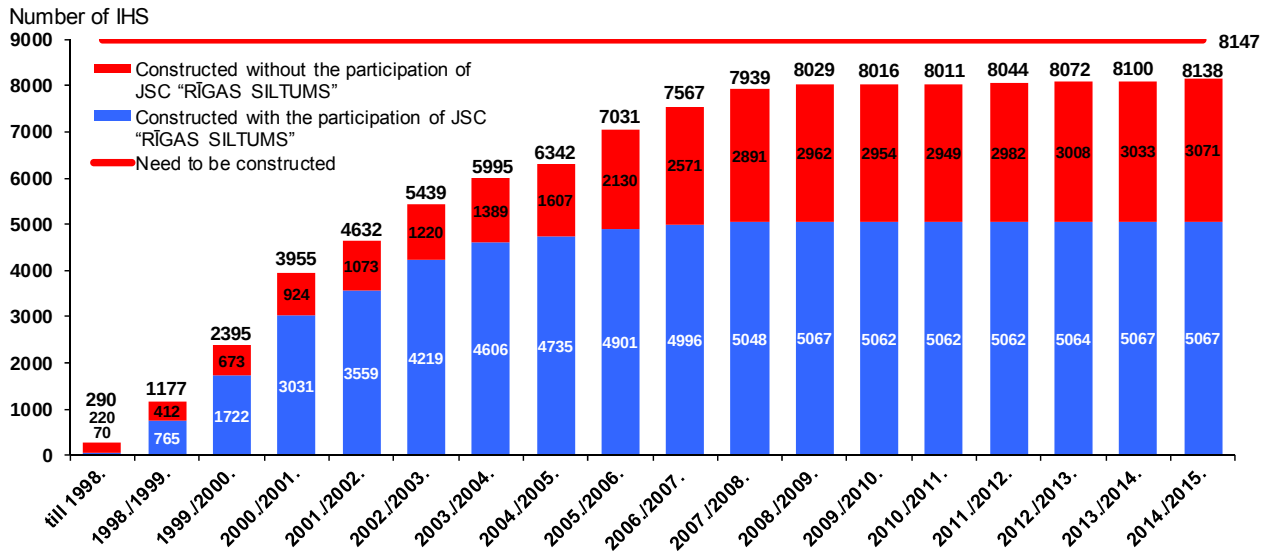

Fig. 1 The number of constructed automated individual heat substations.

At commencing its operations JSC "Rīgas Siltums" took over the district heating networks in a very bad technical condition. The total length of the district heating network was 1000 km at that time and 135 km of this were hot water networks. The bad technical condition of the district heating network in 1996 was confirmed by the fact that heat loss there amounted to 1,126 thous. MWh/year or 20% of the heat transmitted

to the district heating network and leakages of the heat carrier amount to 204.5 t/h. The security of heat supply and the continuity of heat supply are determined to a large extent by the technical condition of district heating networks. In order to maintain it at a high level, repairs and reconstruction of the sections of the district heating networks in an unsatisfactory technical condition are performed on annual basis as it is shown in Fig. 2. First of all, the sections of the district heating network where there is a high number of damages resulting in disturbances or interruptions of heat supply to consumers, where internal and external corrosion of pipelines has been found, where heat insulation is worn are replaced. Almost 400 km of the district heating networks accounting for 58% of the district heating networks owned by JSC "Rīgas Siltums" have been replaced, constructed or optimised since 1996. During this time period also a considerable increase of the proportion of pre-insulated non-channel pipelines has been achieved. Thus, in 2015 the length of non-channel district heating networks was 240 km accounting for 35% of the district heating networks owned by JSC "Rīgas Siltums".

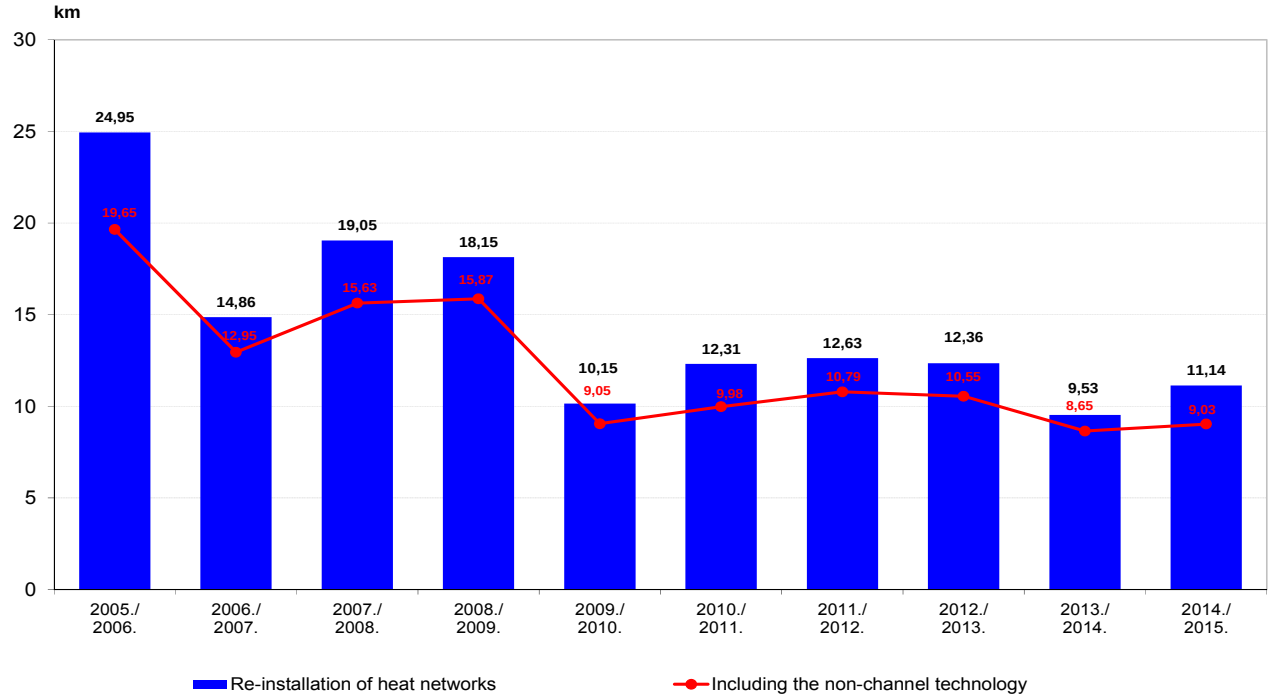

Fig. 2 Replacement of heat networks during last ten years.

Use of pre-insulated pipelines allowed achieving a considerable decrease of heat loss in district heating networks because polyurethane foam was used for heat insulation and their heat conductivity is lower than that of other materials, thus heat losses in these pipelines were much lower than in the pipelines that were replaced. It should also be noted that pre-insulated pipelines are equipped with a special alarm system allowing fast identification of leakages and accurate location of the damage in district heating networks resulting in faster elimination of defects and minimum costs contrary to the existing channel district heating networks where it was not possible to timely identify leakages by performing surveys.

4.2.2 Replacement of Compensators and Shut-Off Fittings

In order to ensure continuous heat supply, to perform fast switching or disconnection of district heating networks, as well as to compensate thermal expansion of district heating networks at various temperatures of the heat carrier, it was necessary to put in order compensators and shut-off fittings

presenting one of the most important elements of the district heating system. The security of the whole district heating system depends on the technical condition of compensators and shut-off fittings. Operation of compensators which were mainly installed in underground heat chambers was complicated because it was necessary to regularly follow up the compression of the gland and the gland material had to be replaced frequently and its replacement was very labour-intensive. A large amount of the heat carried leaked via the gland compensators and seals of the shut-off fittings and there was no assurance as to the sealing of shut-off in cases of damage to district heating networks and in cases of disconnection of consumers (switching of consumers).

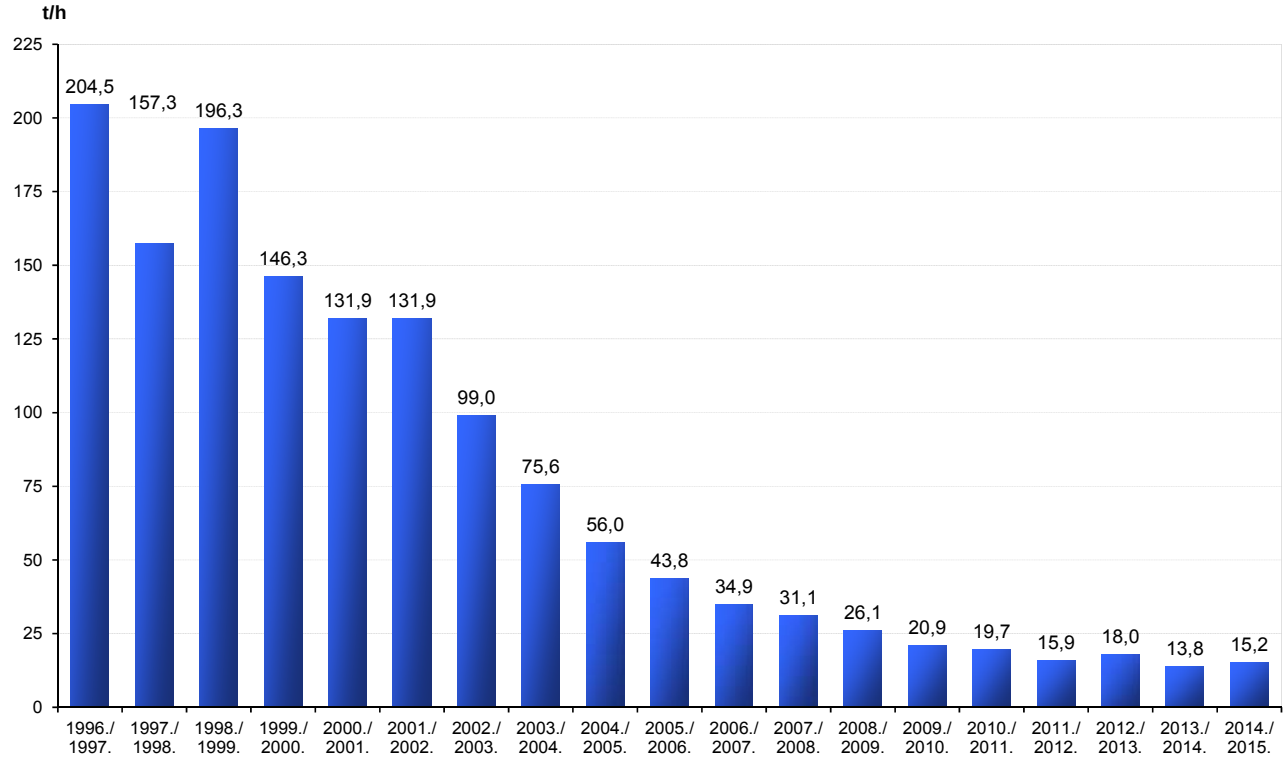

Fig. 3 Change in the annual consumption of feed water per fiscal years.

1111 syphon type compensators up to DN1200 were installed in the place of gland compensators and 2164 shut-off fittings up to DN800 were installed in the result of implementation of the program of replacement of compensators and shut-off fittings from 2002 to 2006. This program presented an opportunity:

(1) to disconnect individual sections of district heating networks in a fast and safe manner, thus reducing the amount of leakage of the heat carrier in case of damage to district heating network and the time required for elimination of damages;

(2) to change heat supply regimes by improving efficiency of the district heating system;

(3) to minimise the number of disconnected heat consumers in cases of damages in district heating networks.

The usefulness of the measures implemented in district heating networks is also attested by the reduction of the mean hourly amount of feed water in district heating networks of JSC “Rīgas Siltums”. The program of replacement of the district heating networks elements along with other implemented measures allowed reducing the consumption of feed water in district heating networks by 189.3 t/h in

comparison to fiscal year 1996/ 1997, from 204.5 t/h in fiscal year 1996/1997 to 15.2 t/h in fiscal year 2014/2015, see Fig. 3.

4.2.3 Reduction of Heat Losses in District Heating Networks

As it is presented in Fig. 4, the reduction of transmission heat losses presents a major direction in the process of improvement of the efficiency of the district heating system. The major measures allowing reduction of heat losses comprise the following:

(1) reconstruction of district heating networks based on the non-channel technology by using pre-insulated pipes;

(2) replacement of insulation in above the ground district heating networks and district heating networks placed in building basements;

(3) replacement of heat insulation in heat chambers;

(4) use of modern shut-off fittings in district heating networks (ball-type fittings, syphon compensators, etc.);

(5) systematic search for and elimination of leakages;

(6) systematic monitoring of the return temperature of the heat carrier at heat consumers and prevention of the reasons behind temperature increase;

(7) periodic flushing and cleaning of the drainage system of district heating networks; in order to protect district heating networks against the impact of ground waters, district heating networks were equipped with a single-direction or double-direction drainage system discharging ground water to the rain sewage system. Under the impact of ground waters external corrosion of pipes and damage (soaking) of heat insulation took place resulting in an increase of heat loss. Therefore, maintenance of the drainage of district heating networks in a good technical condition was among the measures for prevention of damages and minimisation of heat loss;

(8) use of new technologies for connection of heat consumers to district heating networks;

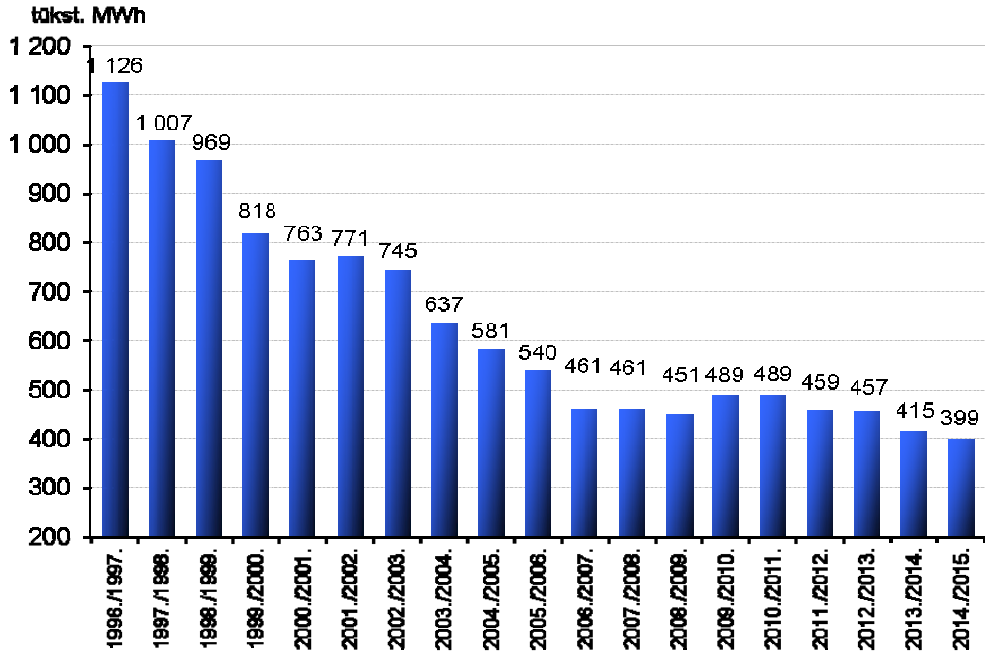

Fig. 4 Transmission heat loss.

(9) hydraulic tests in district heating networks; JSC "Rīgas Siltums" performs continuous monitoring of the technical condition of district heating networks by means of visual inspections, the control system of non-channel district heating networks, thermal vision materials, as well as regular testing of district heating networks for pressure loss, etc. The hydraulic tests of district heating networks are among the main methods

of testing the technical condition of district heating networks. They are performed on annual basis by increasing pressure to 16 bar. District heating networks have passed the test if the test pressure (16 bar) is maintained for minimum 10 minutes. The essence of the hydraulic test of district heating networks is to "provoke" damages in district heating networks in order to ensure secure and continuous heat supply during the heating season;

(10) reading of heat meters. The biggest reduction of heat loss was obtained by performing the set of measures in district heating networks mainly implemented during the annual repair campaign. Generally, since 1996, thanks to implementation of measures intended for reduction of heat loss, transmission heat loss has been considerably reduced. The heat losses amounted to 1126 thous. MWh per year in 1996/1997 and in fiscal year 2014/2015 this amount was down to 399 thous. MWh, thus the heat losses have been reduced approximately 2.8 times or by 727 thous. MWh.

4.3 Modernization of Heat Sources

In the major part of district heating system in the countries of former USSR it was a common practice to use the auxiliary boiler for heat only generation [4]. In the course of implementation of the rehabilitation project of the district heating of Riga inefficient small and medium scale boiler houses, including fossil fuel fired boiler houses, were eliminated. Heat consumers were connected to efficient boiler houses or new automated gas fired boiler houses were constructed resulting in reduction of the specific fuel consumption per unit of heat production and reduction of environment pollution. The implemented measures resulted in considerable reduction of coal and diesel fuel consumption and use of HFO was discontinued. During the period from 1997 to 2001 the proportional share of natural gas in fuel consumption increased from 92% to 96% and wood chips, firewood, coal and diesel fuel accounted for the rest in the fuel balance. Improvement of the energy efficiency of heat sources is mainly related with improvement of the efficiency rate in heat production which is among the most important indices of efficient operation of heat sources. Therefore, in the course of modernisation of the heat sources of JSC "Rīgas Siltums", highly efficient equipment compliant with modern requirements were installed, including cogeneration plants, modulated burners of furnaces, gas and steam turbines, an absorption type heat pump, condensation economisers for water heating boilers, flue gas condensators for biofuel fired boilers; efficient biofuel combustion technologies were implemented. It is well known that the biomass based boiler plants are among the most important issues towards renewable and sustainable energy system [7].

During the last five years, following introduction of new efficient equipment, the total efficiency rate of heat production at the heat sources of JSC "Rīgas Siltums" has increased from 96% to 99%, see Fig. 5. This means that the required amount of heat is produced by consuming less fuel and the amount of harmful emissions to the environment is also reduced.

5. The System of Reading Heat Meters

In order to establish the accurate monthly and instant heat consumption at consumers and to provide remote control of the system operation, in 2011 a fixed radio network based two direction data transmission system was commissioned allowing to read heat consumption data for each individual multi-apartment house by sending these data to the data base of JSC "Rīgas Siltums". The system also provides information about various disturbances in operation or damages, including damages of heat meters, power supply interruptions or communication disturbances between existing system units. The infrastructure of the heat meters reading system of Riga city (300 km^2) consists of 41 base stations (transmitters-receivers), 45 retranslators and 7500 connection points. The heat meter reading system is

multifunctional and maintains the functions like reading of individual heat meters upon request, remote software update of modules, parallel (asynchronous) collection of data from heat meters, transmission of the alarm signal regarding damages in the power network, breaking in the site. In order to ensure continuous monitoring of the operation of district heating networks, the control system of non-channel district heating networks is connected to the heat meter reading system, thus information of any damages in the district heating networks constructed by using pre-insulated pipes according to the non-channel method is received with no delay. Creating of the automated network of reading heat meters will allow:

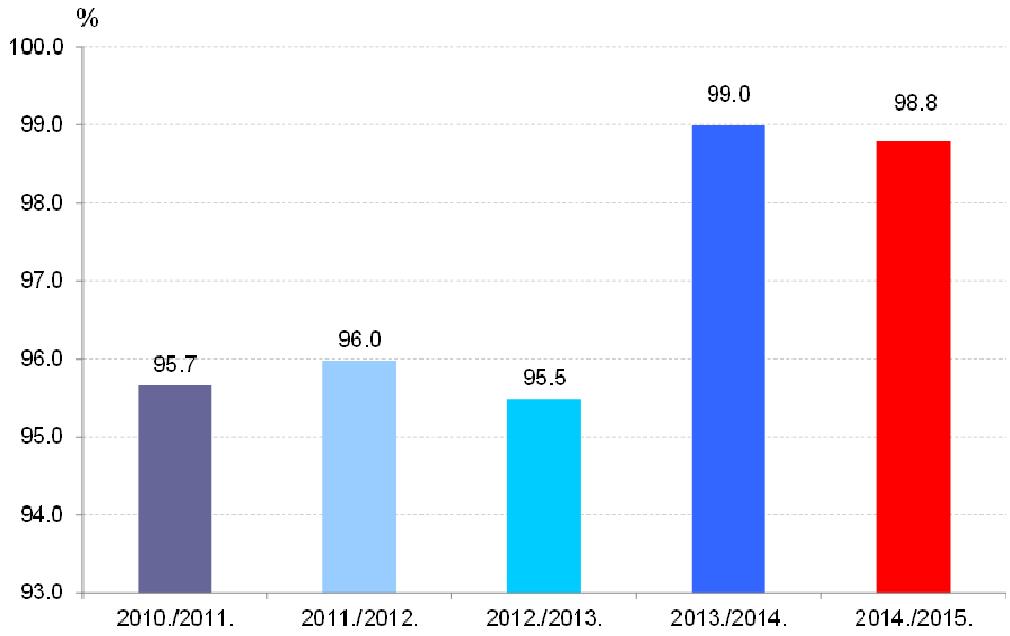

Fig. 5 Total operational efficiency of heat sources of JSC "Rīgas Siltums".

(1) fast identification of the cases of non-compliance with the regimes of heat consumption (exceeded permitted maximum heat load, high return temperature of the heat carrier, etc.);

(2) receipt of operational information about various disturbances or damages at heat substations (damages of heat meters or other devices, disturbances in power supply, etc.), thus minimising eventual commercial loss;

(3) obtaining an accurate monthly heat balance by performing simultaneous reading of heat meters;

(4) ensuring provision of operational information on eventual leakages by performing monitoring of the control system of non-channel district heating networks.

The fact that minimum resources are required for collecting data from 7500 connection points located in the territory of more than 300 km^2 is among the major advantages of the meter reading system. The heat meter reading system is integrated with the data base of JSC "Rīgas Siltums" allowing implementation of the technological control of various measurements and more detailed evaluation of measurements. Considering the possibilities presented by the introduced system, JSC "Rīgas Siltums" performs data collection every morning at 9 a.m. thus enabling the control of heat consumption by individual consumers or groups of consumers.

The introduced system is secure also under extreme operational conditions. Secure communications are ensured with more than 99% of the 7500 connection

points to the system. The introduced programs allow the employees of JSC "Rīgas Siltums" to implement continuous control of the operation of individual heat substations of buildings and to notify the service organisation of any problems in relevant situations.

6. Installation of Allocators

Implementation of the modernisation program of individual heat substations of buildings within the rehabilitation project of the district heating system of Riga allowed saving approximately 8-10% of the heat consumed in buildings. Considering that heat supply is an expensive service and utilities payments account for more than 15% of the household budget. JSC "Rīgas Siltums" offers the possibility to heat consumers to save not only on the house level, but also individually in each apartment by installing heat payment distributors (allocators) and equipping radiators with heat regulators providing control of the temperature in rooms. In Riga residential buildings are mainly equipped with a single pipe heating systems which do not provide for control of the temperature in rooms, however, as the times change, heat consumers want to receive services adjusted to their needs and to pay for their own consumption. An allocator is not a heat meter, it cannot be used for metering the amount of heat consumed for heating a particular building, and however, it can be used for identifying the proportional share of heat consumed by the particular apartment in the total heat consumption of the building.

Allocators should be installed in buildings where it is possible to control temperature in apartments, i.e., there should be a heat regulator at each radiator for ensuring that residents receive their heat bills corresponding to the temperature maintained in rooms. When there are no heat regulators, residents should install them.

In order to practically introduce heat payment distributors (allocators), to ensure operation of allocators and to identify their impact on changes in heat consumption in practice and to assure the efficiency of heat payment distributors a pilot project was implemented in 2014 for which the municipal building at 13 Ulbrokas Street, building 5 which is one of five similar houses in the group of newly constructed buildings at Ulbrokas Street commissioned in 2011 and being the biggest newly constructed micro district since the restoration of independence of Latvia was selected, see Fig. 6. There are twelve floors and 168 rent apartments in the

Fig. 6 Implementation of the pilot project of installation of allocators in a new municipal building.

building. In the building there is a double pipe system to which 504 radiators equipped with heat regulators are connected. The building was suitable for the pilot project because its heating system complied with the requirements for installing allocators, as it was equipped with heat regulators and Buildings 1, 3 and 5 at 13 Ulbrokas Street are of the same design and location. This allows comparing changes in the heat consumption of Building 5 versus both the preceding season and also among several buildings.

In the course of implementation of a pilot project in autumn 2014, in the selected building 504 allocators were installed on all the radiators. Installation works were performed by the employees of JSC "Rīgas Siltums" who ensured technically correct placement of allocators and not only measured radiators during installation for establishing the heat production rate, but also assured the technical condition of heat regulators. In addition, a heat meter was installed in the building heating circuit metering heat used for space heating in the building and allowing accurate assessment of the heat used for space heating by separating the heat used for hot water production.

Evaluation of the heat consumption in the new municipal building prior to and after implementation of the pilot project revealed that, in comparison to the preceding heating season, the residents of the house where allocators were installed saved approximately 20% of heat. At the same time, residents of similar new buildings where allocators were not installed consumed approximately 2% more heat than during the preceding heating season.

JSC "Rīgas Siltums" continues studying the impact of the measures of energy efficiency solutions upon the reduction of heat consumption in cooperation with the current heat consumers and by attracting new sites for next studies.

7. Conclusion

Evaluation of the policy of development of the district heating system of Rīga city since the foundation of JSC "Rīgas Siltums" allows concluding that it has been successful. Implementation of each individual program of the rehabilitation project of the district heating of Rīga city allowed achieving considerable improvement of the efficiency of district heating, costs reduction, service quality improvement, minimisation of the negative environment impact, improvement of the heat supply security. The fact that the heat price in Rīga is lowest among the capitals of the Baltic countries serves as the confirmation of achievements.

Thinking about future, JSC "Rīgas Siltums" is actively working for reduction of operational costs which would allow reducing prices and at the same time providing high service quality and security of heat supply, efficient use of natural resources by minimising the negative environment impact.

It is expected in the coming future that the efficiency of the district heating systems will increase for two more reasons: the decrease of the heat supply temperature in the district heating network and more intensive utilisation of renewable energy resources [2].

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