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The analysis of the hot water consumption and energy performance before and after renovation in multi-apartment buildings

K Tumanova[1], A Borodinecs[1] and A Geikins[1]

[1]Riga Technical University, Riga, Latvia

E-mail: karina.tumanova@inbox.lv

Abstract. The article presents the results of hot water supply system analysis. Taking into account that the current consumption of hot water differs from normative values, real measured data of hot water consumption in multi-apartment buildings from year 2013 until year 2015 have been analyzed. Also, the thermal energy consumption for hot water preparation has been analyzed. Based on aggregated data and taking into account the fact that renovated systems of hot water supply in existing multi-apartment buildings have same pipelines' diameters, it was analyzed how these systems are economically and energy efficient. For the study, residential buildings in Riga, which have different architectural and engineering solutions for hot water supply systems, were selected. The study was based on thermal energy consumption measurements, which were taken at the individual heating system's manifolds. This study was done in order to develop database on hot water consumption in civil buildings and define difference in key performance criteria in unclassified buildings. Obtained results allows to reach European Regional Development Fund project "NEARLY ZERO ENERGY SOLUTIONS FOR UNCLASSIFIED BUILDINGS" Nr. 1.1.1.116A048 main targets.

1.Introduction

Most of the high-rise residential buildings as well as other unclassified buildings such as police departments, fire stations, military buildings and other unclassified buildings in Latvia were built 50–60 years ago. Building energy consumption, which accounts for 20 – 40% of the total primary energy use in developed countries, has drawn more and more attention. Energy consumption in residential and public buildings was more than 40% of the total energy usage in the European Union.[10, 11] Domestic hot water (DHW) heating has a significant contribution to the energy use in the building sector. Many countries have reported that DHW heating is the second largest source of energy use, after space heating. In the UK, 20% of the total domestic consumption has accounted for the DHW heating. [13,14] Residential buildings have consumed 72% of total DHW volume where as 12% and 16% are required for small and large-scale office users.[13]

At that time, no particular attention was paid to thermal energy savings. In terms of hot water supply systems of the buildings, even at the building's design stage due attention to thermal insulation of pipes and development of rational system was not given.

Mostly, only the distribution pipelines were insulated, but sanitary engineering devices were added to the circulation risers. A few factors contributed to the hot water supply system's high operating costs.

Unfortunately, in majority of buildings the hot water supply systems remain in the unaltered state even now. They are both physically and morally obsolete, and cannot ensure the effective use of thermal energy. Such obsolete systems do not enable reducing thermal energy consumption without limiting the consumer's lifestyle. Currently, central thermal points (CTPs) have been replaced with individual thermal knots (ITK), which enable to fine-tune the temperature of hot water and reach thermal energy savings by maintaining water temperature at the required level.
Heat loss reduction in hot water supply systems for households is possible through reduction of unjustified water losses by imposing efficient thermal insulation of pipelines (for main pipelines and risers), providing hot water circulation. Water pressure inside the water intake fittings, which are located in the lower floor of the building, should not exceed 0.45 MPa. [1,2]

1.1. Hot water consumption – the current situation
Water consumption in the country decreased repeatedly. Accordingly, the hot water consumption in the household sector also decreased. Water consumption reduction contributed to the installation of water meters, heat supply tariff increases, hot water-saving measures. [3]

Now that the energy saving became very topical because of commercial thermal energy calculation which is consumed for hot water preparation, and because of high tariffs, specified standards (depending on the grade of building's amenities the average index makes 105 liters per day [9]) can be classified as maximum. Hot water consumption in Latvia as another Nordic countries (averaged at 33 to 50 liters) [3,4,5,12,13,14]. Continuous centralized hot water supply system's operation indicates that according to the standard calculation at hot water standards of 105 liters per day, the estimated maximum thermal energy consumption for hot water preparation does not reach its maximum value because the situations when multiple hot water consumers use hot water at the same time have not been virtually observed.

1.2. Hot water optimum temperature selection
Selection of optimum temperature for heating the water in hot water supply systems can be considered an important problem. Temperature reduction in hot water supply systems is economically justified because heat losses in the pipeline are reduced, but decreasing the water heating temperature forms less calcium carbonate in it. Optimum temperature for heating the water depends on the pipeline heat losses. [6]

Hot water supply systems should be designed with water circulation in risers with balance beams. The minimum temperature for circulation in the riser – 40°C. In a hot water supply system with individual circulation risers the water cooling temperature makes not more than 1.5–3°C, if the water circulation is correctly adjusted in the system. Therefore, the output water temperature is calculated to be around +53°C. Such hot water supply system's solution is characterized by an increased material capacity. Besides, at the active hot water consumption, the water circulation in the system decreases, towel dryers stop running exactly when it is necessary to heat the bathroom. [7]

Efficiency of hot water supply system's zoning and pumping equipment's optimization is influenced by pipeline's thermal insulation. It sets for main pipelines, supply and circulation pipelines, including risers. Thickness of thermal insulation layer should be not less than 10 mm, and thermal conductivity – not less than 0.05 W/(m°C). Heat losses decrease at the efficient thermal insulation of hot water supply system's risers. With less heat losses the circulation water consumption decreases, thus – the power consumption. [6]

Calculations in the residential buildings with four risers with Dn 32 in one section show that each apartment (if hot water supply system's risers are not insulated) loses 1 kJ of thermal energy per hour, but the required circulation water consumption makes around 31 l/h. By insulating hot water supply system's risers, heat loss is reduced to 0.5 kJ per hour, but the required water circulation consumption – up to 20 l/h. [6]

In cold period of the year, the heat, which is delivered from hot water supply system's risers, is being efficiently used for the heating of premises. But in the warm periods, the heat gains from the

system's risers are not appropriate. Such heat losses can make 1100 GJ from 1,000 apartments annually. If risers are efficiently insulated in apartments, then the total cost of such measure pays off in the first year of operation, and the power consumption may make around 20 MWh per 1,000 apartments. [6]

2. Materials and methods

The study results are based on actual measurements. There were 25 different types of standard design for apartment buildings selected in Riga (types No. 119, 602, 318 and "Special design" were selected for the study). All the buildings were connected to the centralized heating with separated system, identical parameters for hot water preparation were set at individual thermal knots. In the period from 2013 to 2014, hot water temperature at the output from heat exchange made +53°C, in 2015 – +55°C. Average annual heat consumption, kWh for 1 m³ of hot water preparation, is set out for each house individually. For heating period, this amount is determined on the basis of the period of summer thermal energy consumption for hot water preparation as an average level for the period from May to October of the relevant heating period. When calculating the thermal energy consumption for hot water preparation of the winter months, cold water temperature reduction in comparison with summer period was taken into account; during the summer, cold water in the networks makes around +12°C, but during the winter it makes +5°C. In addition, thermal energy averages were increased by applying a coefficient of 1.11. [7,8]

The aim of the research to analyze the changes in hot water and thermal energy consumption before and after hot water supply system's renovation.

3. Hot water consumption analysis

In order to assess the actual hot water consumption in residential buildings, an analysis of the collected measurements was carried out. For the study, the selected residential buildings were divided by types of standard designs. After analyzing the hot water consumption dynamics during three years, it can be concluded that its average values did not change significantly in the surveyed period.

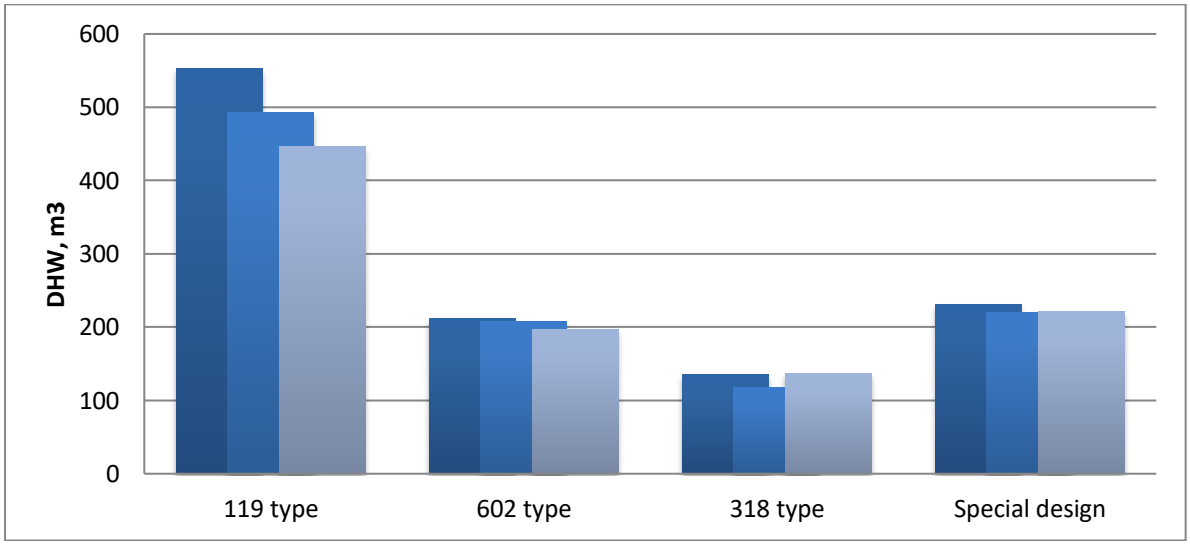

Figure 1. Annual average of hot water consumption.

Also, an analysis of hot water consumption rate for one consumer during the day was carried out (see Table 1). After analyzing the collected data on hot water consumption during three years, it can be seen that the average values range from 39 l/day up to 45 l/day per consumer. Similarly, also the average values are not significantly different in three years time.

Table 1. Average hot water consumption.

Type of standard design	2013	2014	2015	Average
	l/d per person	l/d per person	l/d per person	
119	46.34	43.15	41.12	43.54
602	41.67	40.23	38.99	40.30
318	40.23	36.00	41.61	39.28
Spec. design	46.06	44.16	43.99	44.74

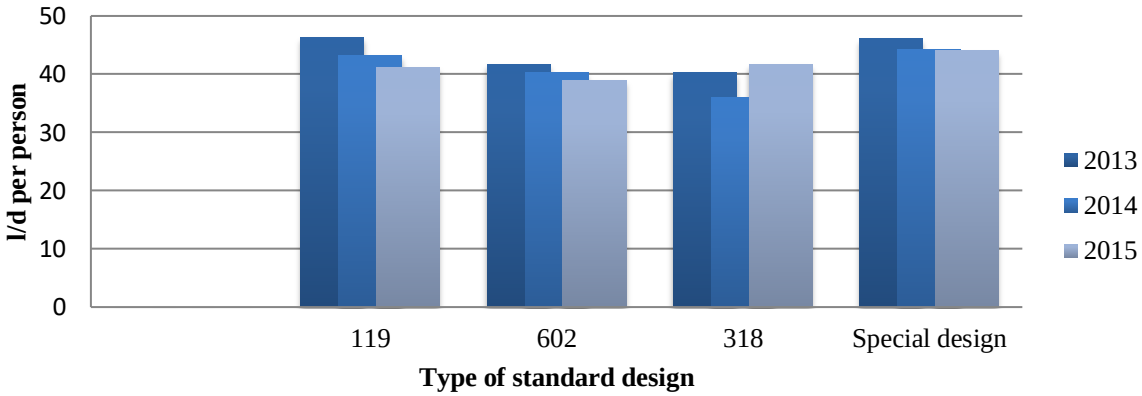

Figure 2. Average hot water consumption per person during the day.

4. Thermal energy consumption for hot water preparation

The standardized annual specific heat energy consumption, kWh/m², is determined by the equation [7,8]:

$$qst = qheat\frac{Gst}{G} + qh.w.\frac{A}{30n}, \qquad (1)$$

q_{st} – standardized specific heat energy consumption, kWh/m², per year; q_{heat} – measured specific heat energy consumption for premises heating in rating year, kWh/m² per year; $q_{h.w..}$ – measured heat energy consumption for the hot water preparation in rating year, kWh/m² per year, G_{st} – degree days of a standard year in favourable economical conditions; G – degree days of the heating period in rating year; A – heated area, m²; 30 – standard occupancy level, m² per person; n – number of inhabitants, persons.

Table 2. Specific thermal energy consumption.

Type of standard design	2013		2014		2015	
	q,kWh/m²	qst,kWh/m²	q,kWh/m²	qst,kWh/m²	q,kWh/m²	qst,kWh/m²
119	61.18	46.56	61.00	46.2	69.21	62.68
602	66.20	47.65	67.19	56.07	72.98	56.90
318	58.61	37.16	61.44	38.99	72.05	42.41
Special design	76.28	49.28	78.05	50.46	75.81	51.96

The table 2 presents actual measurement results. To determine the average specific thermal energy consumption for hot water preparation, kWh/m², factors of climatic conditions and population density level (factors, which cannot be influenced by consumer's choice) were taken into account – standard year specific thermal energy consumption.

By analyzing the collected data, it can be concluded that the specific thermal energy consumption for hot water preparation is not same both by years and by types of residential buildings. The lowest values were detected in buildings of type 318, but the highest – in buildings of type 602 and Special design. Thermal energy consumption, observed in 2015, is related to hot water temperature increase from +53°C to +55°C. The calculated values are applied to all buildings.

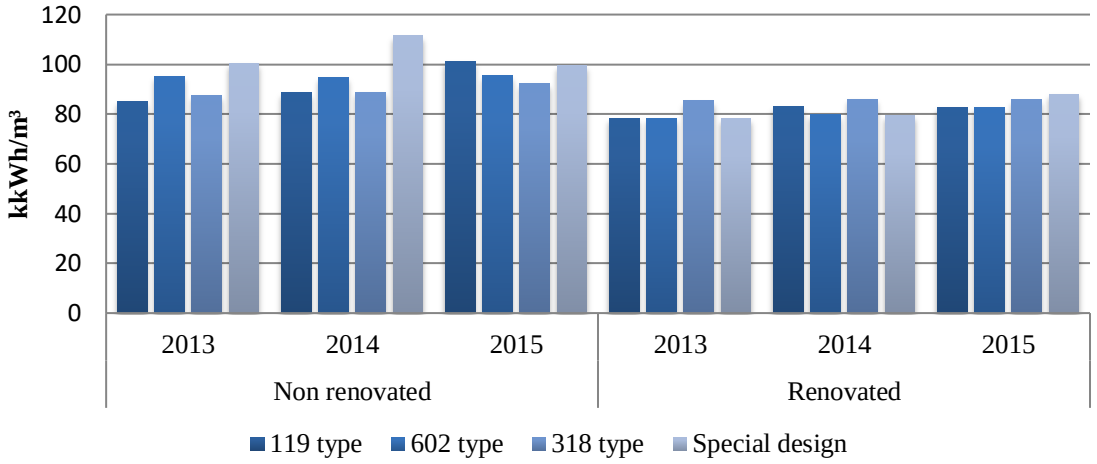

Figure 3. Thermal energy consumption for 1 m³ of hot water preparation.

On Figure 3 a diagram of thermal energy consumption for the preparation of 1 m³ of hot water is constructed. By analyzing the collected results, it can be concluded that the highest thermal energy consumption for 1 m³ of hot water preparation is required in Special design residential buildings, where the average values reach 104 kWh/m³.

Table 3. Thermal energy consumption for 1m³ of hot water preparation.

Type of standard design	Non renovated			Average	Renovated			Average
	2013	2014	2015		2013	2014	2015	
	kWh/m³	kWh/m³	kWh/m³	kWh/m³	kWh/m³	kWh/m³	kWh/m³	kWh/m³
119 type	85.15	88.56	101.28	91.66	78.17	82.90	82.80	81.29
602 type	95.16	94.87	95.54	95.19	78.18	79.83	82.76	80.26
318 type	87.38	88.8	92.18	89.45	85.33	85.98	85.70	85.67
Special design	100.23	99.66	111.41	103.77	78.38	79.38	88.02	81.93

This table summarizes the results of the performed measurements and calculations. Residential buildings are divided by types of standard design into two groups: the first one – residential buildings where no renovation of hot water supply system was carried out, the second one – residential buildings where renovation of hot water supply system was carried out. Residential buildings of both groups have same technical solutions for utilities, therefore it is possible to carry out a comparison analysis of how the renovation through pipelines and thermal insulation replacement influences the thermal energy consumption for hot water preparation.

After carrying out the analysis of data contained, it can be concluded that the average thermal energy consumption for 1 m³ of hot water preparation decreased in the range of 4% to 21% depending on the residential building's type after renovation. Also, it can be seen that in 2015 an increase in thermal energy consumption was observed: it is related to the hot water temperature increase from +53°C to +55°C. An increase of thermal energy consumption for 1 m³ of hot water preparation during the year, compared to average values before and after the temperature setting changes, was observed from 9% to 26%, averaging 16%.

5.Conclusions

Hot water consumption analysis was carried out for the period from 2013 to 2015. It concluded that hot water consumption during the surveyed period of time has not changed significantly.

Hot water consumption per person differs significantly from what LBN 221-15 "Buildings internal water supply and sewerage system" offers, ranging within 39 l/day up to 45 l/day, averaging 42 l/day (in another Nordic countries hot water consumption per day ranging within 20 l/day – 46 l/day).

Thermal energy consumption analysis for 1 m³ of hot water preparation was carried out. Summing up the results of the actual measurements, it can be concluded that the consumption of thermal energy depends on the hot water supply systems' engineering solutions, and it differs based on hot water supply systems in the residential buildings of standard design types. The reduction of up to 22% in thermal energy consumption for 1 m³ of hot water preparation was observed after the hot water supply system's renovation (the average value 82,29 kWh/m³ for renovated hot water systems and 97,17 kWh/m³ for non renovated systems).

Acknowledgement

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