Construction Science

10.2478/cons-2013-0006

2013 /14

Heat Consumption Assessment of the Domestic Hot Water Systems in the Apartment Buildings

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Abstract. **This study presents the analysis of energy consumption for domestic hot water in apartment buildings in Riga. The aggregate data contains information about 39 apartment buildings, including heat energy consumption and domestic hot water (DHW) consumption. The analysis is focused on the heat energy consumption in the DHW system.**

The analysis characterizes the DHW consumption, energy consumption for DHW and energy losses in the DHW systems in apartment buildings.

***Keywords*: heat consumption, domestic hot water (DHW), apartment buildings.**

I. Introduction

The Energy Performance of Buildings Directive (EPBD) [1] in the version of 2010, the so-called recast EPBD, demands in annex I 'Common general framework for the calculation of energy performance of buildings (referred to in Article 3)' that '(1)the energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs'. This is one of essential requirements already established by the EPBD in the version of 2002 [2].

In Latvia, EPBD requirements have been transposed by the Law on the Energy Performance of Buildings (13th March 2008). The calculation procedures are prescribed by the Regulation onthe Calculation of Energy Performance of Buildings (No. 39 as of 13th January 2009) [3].

The structure that should be used for the calculation of energy use in space heating systems and domestic hot water systems in buildings is specified in standard EN 15316-1 [4].

The objective of the calculation is to contribute to the evaluation of the annual energy use of the space heating and domestic hot water systems. If there is seasonal heating in the building, the year should at least be divided into two calculation periods, i.e., the heating season and the rest of the year. Different levels of detail may be used for the different sub-systems of the heating system. However, it is essential that the results correspond to the defined output values of the sub-system: – energy input; – energy output; – system thermal losses; – recoverable system thermal losses; – auxiliary energy; in order to ensure proper links to calculations for the following sub-systems and development of a common structure. [5]

According to the CEN standards, the energy consumption for domestic hot water (DHW) production is calculated using a three-step approach: 1) building DHW needs, 2) distribution and 3) generation. The correct estimation of the domestic hot water needs is essential. This results in volume and time of hot water needs throughout the year (the gross hot water demand) and tapping patterns. Tapping patterns are important for the calculation of distribution and generation losses. Also the estimation of the contribution of each heat generator (e.g., thermal solar) depends on the tapping patterns. The second step comprises the calculation of the distribution systems. This part of a domestic hot water system is all between the generation system and the point of tapping. Important aspects to be considered in this respect are heat losses and pump energy. The distribution losses can be higher than the domestic hot water needs. The gross hot water needs are delivered by heat generators. There are several types of generators available, andmany of them are also used to provide space heating. Space heating and domestic hot water have some distinctively different properties, so there are separate standards on DHW and space heat generation. DHW is different from space heating in that the heat demand has an interval character and a different temperature level [6].

The correct characterization of hot water needs is important because the losses of boilers and the distribution system are very sensitive to the couple of frequency and energy content of heat up and cool down at any tapping. Therefore, the needs are defined by the energy amount and also by the tapping patterns. The energy amount of hot water needs could represent about 25% of the final heating needs (or 20 to 25 kWh/m² per year) in existing residential buildings. The percentage of hot water needs increases in well-insulated houses [7].

The standard EN 15316-3-1 [8] gives four methods for calculation of the energy needs of the delivered domestic hot water:

-energy need related to tapping programs,

-energy need related to volume needs,

-energy need linear with floor area,

-energy need from tabulated values for different building types or functions.

For all methods a national annex is required. The annexes to the standard provide default values. Countries need to decide which method they prefer and which specific energy need, depending on a building type, is suitable.

The EN 15316-3-2 [9] gives methods for calculation of heat losses, the recoverable heat losses and the auxiliary energy of the domestic hot water distribution system.

Domestic hot water distribution systems may consist of a circulation system and/or distribution pipes. Distribution pipe losses are dominated by the heating up and cooling down of the pipes at any tapping, so these losses are sensitive to the tapping pattern [10].

The standard gives five calculation methods for distribution pipe losses:

-heat losses related to floor area,

-heat losses related to pipe lengths – simple method,

-heat losses related to pipe lengths – tabulated data method,

-heat losses related to tapping pattern,

-heatlosses based on detailed calculation method.

Circulation systems are in general operated at constant temperature. Therefore circulation system losses do not depend on tapping patterns. Loss reduction may be achieved by applying pipe insulation and night set-back.

The standard gives the following methods to calculate circulation system losses:

-heat losses related to circulation pipe length,

-heat losses based on detailed calculation method,

-heat losses while circulation is off.

The total heat losses are the sum of distribution pipe losses (no circulation loop) and circulation system losses (collective part with circulation loop).

Also methods are given to determine auxiliary energy consumption for:

-pumps for circulation systems,

-ribbon or trace heating.

For all methods a national annex is required. The annexes to the standard provide default values.

Dwelling houses are one of the largest district heat users in Latvia. In 2010, Latvian households consumed 70% of all district heat energy produced [11]. Usually apartment buildings have a single heat meter for both heating and DHW in Latvia. Therefore, if the calculation of energy performance of buildings is carried out, the energy use for heating, DHW consumption, circulation loop and others should be assessed separately.

Analysis of the data helps to find the right solution to apply in case where the appropriate data are not available on evaluating energy performance of apartment buildings. The authors hope to find an appropriate solution to develop a suitable method or tabulate values.

II. Methods

The authors have analysed the heat energy consumption and water consumption in apartment buildings in Plavnieki and Purvciems area in Riga in the year 2011.

The aggregate data contained information on 39 buildings with 3167 households and total heated area of 158189 m^2. The total population in these buildings is 7139 inhabitants. Buildings wereconstructed from 1966 to 1988;the average heated area of buildings is3164 m^2. Average area per person is 22.3 m^2. Buildings have 5 to 12 floors and 1 to 6 sections.

Investigated buildings are connected to the district heating network of JSC "RīgasSiltums". All buildings have the automatic heating unit equipped with the heat counters, as well as hot and cold water meters. The measuring equipment belongs to "B" class meter with error limit ± 3 percent. There is no separate heatmetering for heating and DHW.

The average annual water consumption in the investigated buildings is 110.7 l per m^{2}per month, of which 46.3 l per m^{2}per month – for DHW and 64.4 l per m^{2}per month – for cold water. The consumption of domestic cold water and hot water per m^{2}per month is shown in Fig. 1.

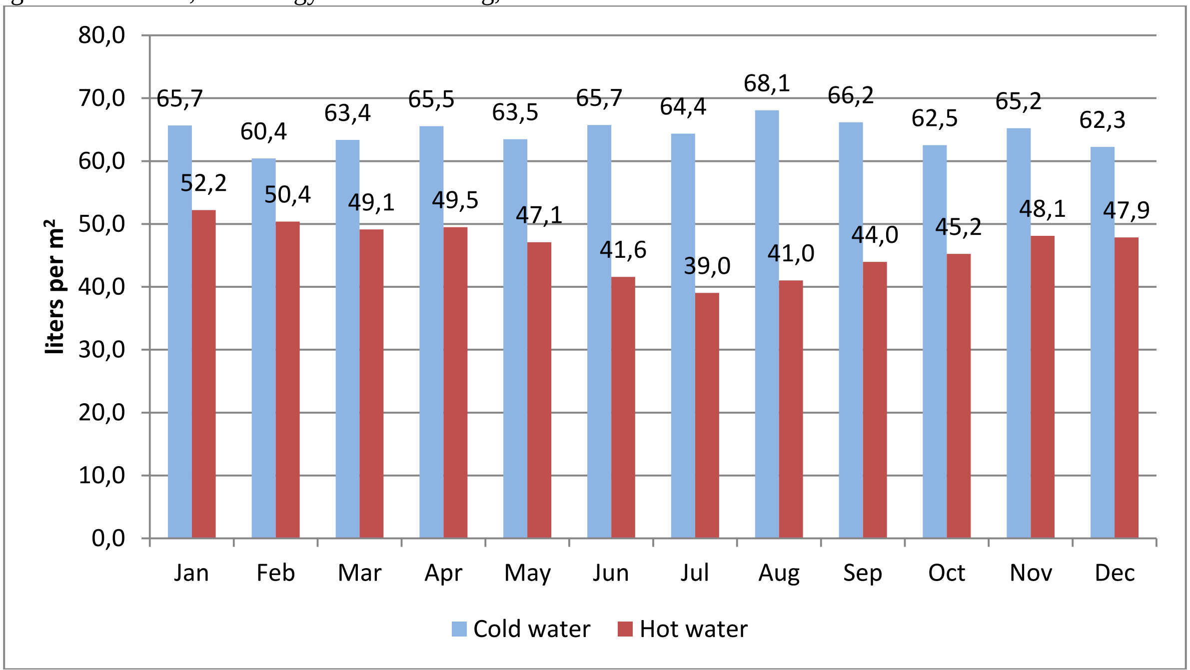

Fig. 1. Monthly consumption of domestic cold water and hot water in apartment buildings.

Average annual DHW consumption ratio is 42% of total consumption. Fig. 2 shows DHW consumption ratios per month.

To achieve the objective of the study, the authors have analysed data on DHW consumption and heat consumption in the DHW system.

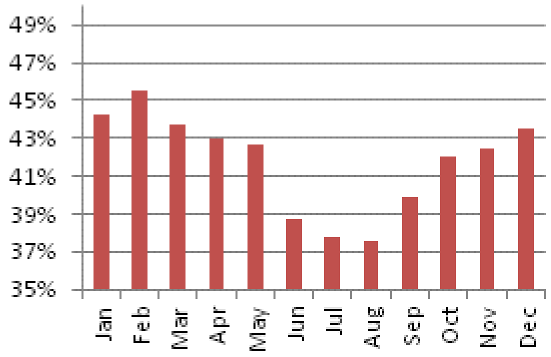

Fig. 2. The ratio of consumption of domestic hot water to the total consumption in apartment buildings per month.

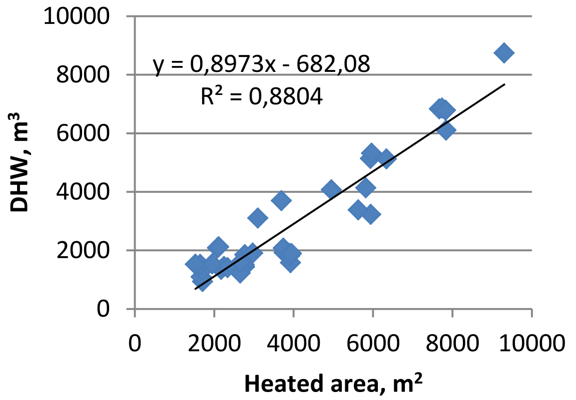

Fig. 3. Correlation of DHW consumption (m^3) to heated area (m^2).

III. RESULTS

The study shows specific DHW indicators on the heated area per household and per person (Table I) and correlation of DHW consumption of these indicators (Figures 3–5). The most accurate data on DHW consumption is per person (Fig. 5).

TABLE I

DHW CONSUMPTION INDICATORS

	Minimum	Maximum	Average
DHW yearly consumption, m^3 per year			
- per m^2	0.40	1.00	0.72
- per household	20.34	52.04	33.86
- per person	8.85	21.96	14.95
DHW daily consumption, litres per day			
- per m^2	1.10	2.12	1.53
- per household	55.7	112.5	76.2
- per person	24.2	48.6	34.8

By comparingDHW daily consumption indicators to default values set out inAnnex A “Tapping Program for Single Family Dwellings” of standard EN 15316-3-1, the authors have found out that average DHW daily consumption of 34.8 litres per person per day is very close to the default value of 36 litres per person per day, determined in Table A.1 ‘Tapping program No. 1’.

DHW daily consumptionmaximum value of 76.2 litres per household is less than default values of 100.2 litres per dwelling, determined in Table A.2 (‘Tapping program No. 2.’) and is very different from the default value of 199.8 litres per dwelling, determined in Table A.3 (‘Tapping program No. 3.’).

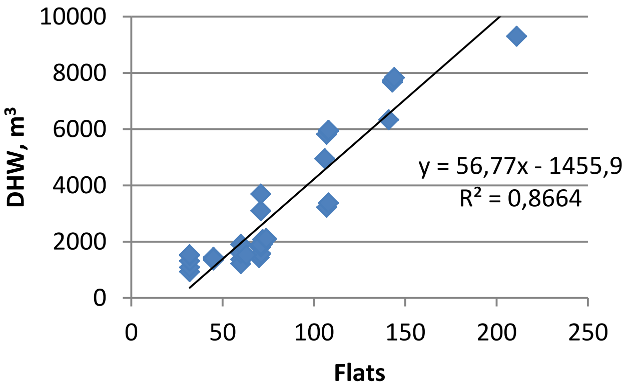

Fig. 4. Correlation of DHW consumption (m^3) to the number of households.

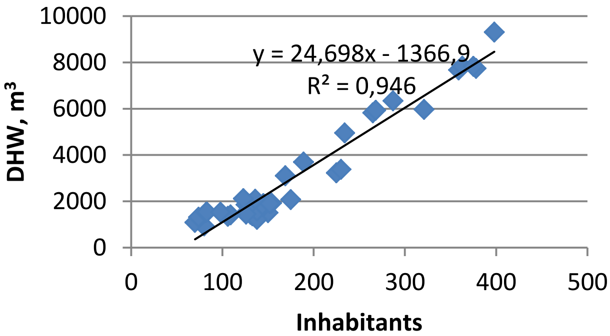

Fig. 5. Correlation of DHW consumption (m^3) to the number of inhabitants.

In addition, the study shows that DHW consumption differs by season:

- 94% of yearly average consumption in the non-heating period (May–September),
- 106% of yearly average consumption in the heating period (November–March).

Data on October and April are not taken into account because heating is started or stopped in these months.

Total heat consumption in the investigated buildings is from 164 to 225 kWh per m^2. The specific heat consumption indicators are shown in Table II.

TABLE II

TOTAL HEAT CONSUMPTION INDICATORS

	Total yearly heat consumption,		
	kWh per m^2	MWh per household	MWh per person
Minimum	164	5.90	3.36
Maximum	225	10.98	5.62
Average	189	9.47	4.24

To determine the energy consumption for DHW consumption and DHW circulation loop, the authors used data on energy consumption and DHW consumption in the non-heating period (May–September).

The energy consumption Qw for DHW heating for a period is calculated as follows (1):

$$Q_w = V\frac{\rho_w C_w}{3600}\cdot(\theta_{w.del} - \theta_{w,o}) \quad (1)$$

where Q_w – the energy consumption for DHW heating, kWh; V – the DHW consumption per period, m^3; ρ_w – the water density at temperature $\theta_{w,o}$, kg/m^3; C_w – the water specific heat capacity, J/kg K; $\theta_{w,del}$ – the temperature of cold water (C^o); $\theta_{w,o}$ – the temperature of DHW (C^o); 3600 – number to take into account for conversion from mega joules to kilowatt hours.

In the investigated buildings, the delivered temperature of cold water ranges from 8 to 13 C^o; temperature of DHW – from 50 to 55C^o (in the calculation used temperature difference is 42 degrees).

Calculation results of heat energy average values per m^2 of heated area per month are shown in Fig. 6. Heat losses from DHW circulation loop in April and October are calculated by extrapolation.

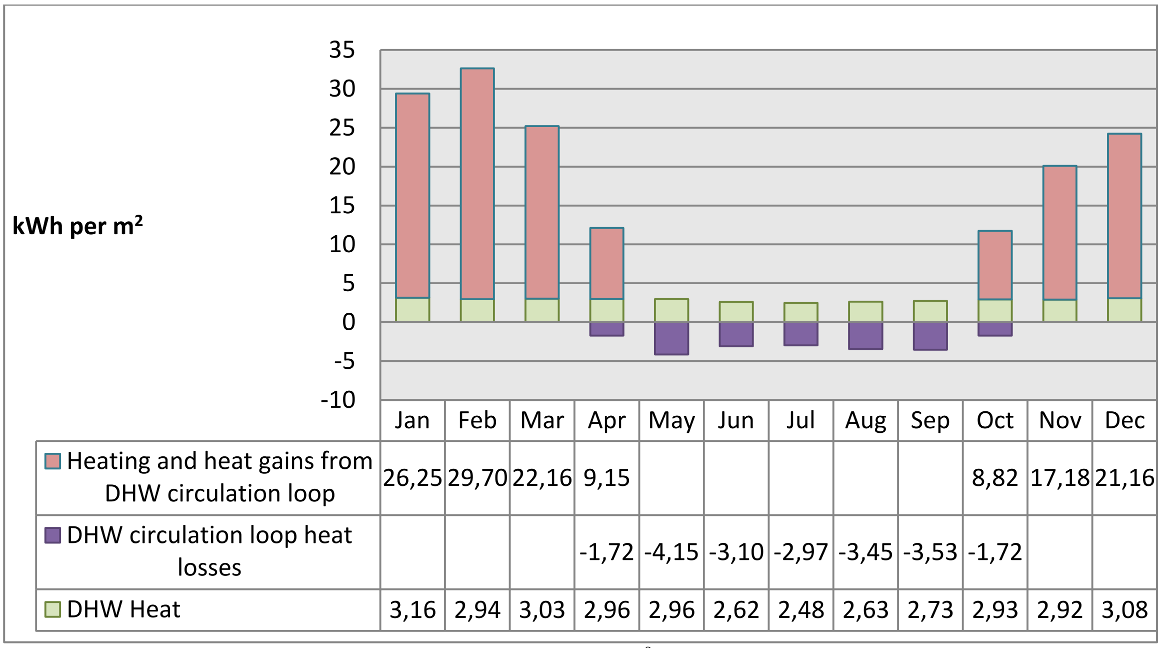

Fig. 6. Heat energy average values per m^2 of heated area per month.

During the non-heated season, the ratio of DHW circulation loop losses in the investigated buildings ranges from 35 to 79% from total heat consumption, and the average loss ratio is 56%.

The DHW circulation losses in most cases range from 14.2 to 27.0 kWh per m^2 in the investigated buildings during the non-heating season. There are two extremely different results (6.2 and 38.9 kWh per m^2), which are outside normal values. Average DHW circulation losses are 20.5 kWh per m^2, 1.50MWh per households, 0.46MWh per person during the non-heated season (Table III).

TABLE III

HEAT LOSSES FROM DHW CIRCULATION LOOP INDICATORS

	Heat losses from DHW circulation loop during the non-heating season		
	kWh per m^2	MWh per household	MWh per person
Minimum	14.2	0.59	0.30
Maximum	27.0	1.04	0.77
Average	20.5	1.49	0.46

The evaluation of DHW circulation losses correlation to the heated area and to the number of households showed that more accurate data can be obtained from the heated area (Figures 7–8).

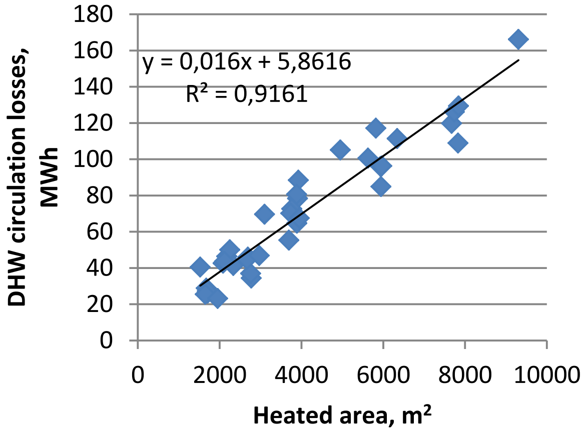

Fig. 7.Correlation of DHW circulation losses to the heated area (m^2).

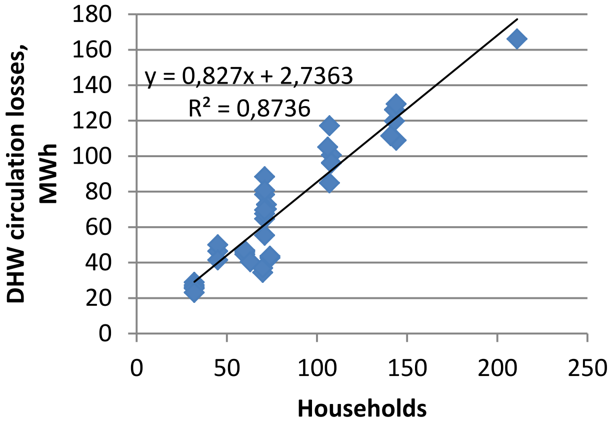

Fig. 8.Correlation of DHW circulation losses to the number of households.

In addition, the authors have compared DHW circulation losses by different design types of apartment buildings. The authors have found out that heat losses from DHW circulation loop during the non-heating season differ by different design types (Table IV).

The authors intend to carry out further research to find additional features that affect the hot water circulation losses in various types of buildings.

TABLE IV

DHW CIRCULATION LOSSES BY VARIOUS TYPES OF APARTMENT BUILDINGS

Characteristics of apartment building type							Heat losses from DHW circulation loop during the non-heating season		
Design type	Number of buildings	Year of construction	Number of floors	Average number of flats	Average area of buildings/ flats, m^2	Average number of inhabitants	kWh per m2	MWh per household	MWh per person
316	2	1966	5	70	2764/ 39.5	138	15.5	0.61	0.31
104	2	1987	5	74	2655/ 47.3	130	22.2	1.07	0.44
602	15	1971-1988	9	113	3363/ 35.9	267	19.5	0.70	0.40
467A	7	1977-1987	9	54	2838/ 29.7	124	20.0	1.02	0.43
464A	7	1969-1977	5	54	2535/ 52.3	127	20.6	1.08	0.47
104	5	1979-1981	12	71	3910/ 55.1	141	23.3	1.28	0.65

IV. DISCUSSION

The DHW consumption differs by season in apartment buildings with district heating in Riga. DHW consumption was 94% of yearly average in the non-heating period (May–September). It should be taken into account when evaluating energy consumption of DHW system in buildings with a single heat meter for both heating and DHW systems.

In the case of lack of metered data on DHW consumption in the apartment building, most accurate data can be determined based on the number of inhabitants; less accurate data can be determined by the number of flats and by the heated area using data provided in Table 2.

The DHW circulation losses in most cases range from 14 to 27 kWh per m^2 and from 0.59 to 1.49 MWh per household in the investigated buildings. Average DHW circulation losses are 20.5 kWh per m^2 and 1.04 MWh per household. In the case of lack of metered data on heat energy consumption, for evaluation of DHW circulation losses average data on kWh per m^2 can be used.In addition, in this study it is shown that heat losses from DHW circulation loop differ by different design types.

The study has also detected that some consumption characteristics of DHW for apartment buildings are different from the values given in the standardEN 15316-3-1(Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements)); therefore, the standard should be specified in national annexes. The appropriate national annexes of EPBD standards for DHW systems are not developed in Latvia.

ACKNOWLEDGEMENTS

The authors express many thanks to JSC “Rīgas siltums” and Ltd.“Rīgas namu pārvaldnieks” for support in this research.

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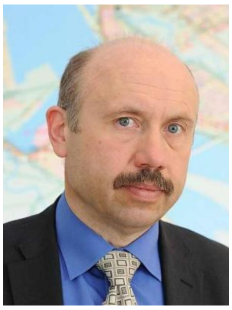

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