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INVESTIGATION OF THE DOMESTIC HOT WATER CONSUMPTION IN THE APARTMENT BUILDING

KARSTĀ ŪDENS PATĒRIŅA PĒTĪJUMS DAUDZDZĪVOKĻU DZĪVOJAMAJĀ MĀJĀ

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Introduction

Dwelling houses are one of the largest heat users during a heating period in Latvia. In 2007 Latvian residential building stock consumed 73% of all heat energy produced [1]. The largest part of consumed heat had been used for heating and domestic hot water (DHW) supply for the dwelling houses.

Current situation in Latvian residential building stock

Multi-compartment dwelling houses in Latvia form 34.7 mln m^2, which makes 63.2% of the total residential building stock [2]. The large majority of dwelling houses in Latvia take serial buildings.
The parameters of each serial building are described detailed in sources [3]. Despite of the fact that buildings of various types differ visually, the internal engineering and technical structure of all buildings is practically the same in all types of buildings.

Current situation in district heat consumption systems

One-pipe heating systems with the connection to the district heating system were used to heat buildings. Till 1991 a direct connection through elevators was mainly used. Since 1997 the elevators has been gradually replaced by plate-type heat exchangers, thus moving away the internal engineering networks of the buildings from the external heat supply networks. Heating systems of the buildings were made of steel pipes.
Till 1997 DHW was mainly generated in central heating points (CHP) which served groups of 4-5 buildings. Since 1997 the generation of DHW was gradually transferred from CHP to individual boiler houses installed in each building.
Hot water supply systems were installed with the use of mainly zinc-plated steel pipes with recycle cables. Heated towel rails were usually connected to riser pipes [4].

Current situation with the normative of DHW consumption in residential building stock

Now DHW supply system is constructed accordingly to Latvian building normative LBN 221-98 „Buildings' Internal Water Supply and Sewerage System" [5]. Till the 1st of August, 1998, former USSR building norms SNiP 2.04.01-85 „Buildings' Internal Water Supply and Sewerage System. Project norms." [6] were used for DHW construction.
Daily DHW consumption per one person is defined by two parameters: the amount of hot water (*litres per person per day*) and temperature (°*C*). According to Latvian building normative LBN 221-98 DHW consumption normative amount is defined depending on the level of building amenities - the average index is mainly 105 litres daily (3.2 m^3 per month), temperature is 55 °C, and the irregularity coefficient k_{ir}=2.5.
Currently, at the time when energy savings has become highly topical in view of commercial metering of the heat energy spent to DHW preparation by every consumer and its high tariffs, the mentioned norm could be qualified as the maximum and obviously irregular. The DHW consumption in Latvia is

approaching the level of European countries, where, despite the prosperity of their population, DHW consumption is not very much. For example, in Denmark DHW consumption is 50 l per day per person or 180 l for a 3.5-person statistical family [7, 8].

Literature review

In 1970s the domestic hot water consumption was very high; for example, in former USSR it was 95 l/d per person or more.
The latest investigations in the research of the domestic hot water consumption in the dwelling houses have been carried out in the United Kingdom, Russia, Estonia, Denmark [9, 10, 11, 12, 8] show a decrease in DHW consumption. There are only minimal changes in DHW consumption profile in Russia [10].

Objectives of research

1. To define average daily DHW consumption per person in the building. To compare its value with the suggested normative (q=105 l/d·c). If DHW consumption per person differs from normative, define actual DHW consumption irregularity coefficient.
2. To define maximum consumption hours during the days of measurements.

Experimental set up

The current investigation considers one 32-apartment building (8 floors) built in 1985 in the Riga Plavnieki District. There are 100 inhabitants in the building.
The investigated building is connected to “Rigas Siltums” district heating network. The building has modern automatic heating substation, and is equipped with contemporary heat counters as well as hot and cold water meters.

Fig.1. The apartment building chosen for the monitoring of DHW consumption

DHW is delivered to the bathrooms and sinks. In the building the hot water system has been partly renovated.
The measuring equipment includes DHW meter which belongs to “B” class meter with error limit ±3-±5.
According to Latvian building norms LBN 221-98 article 148, DHW flow rate in heat units is measured by the cold water meter, which is installed in front of the water heater.
It is important to mention that inhabitants with different incomes live in the house; they work on enterprises and institutions with different work regimes (beginning of the work, lunch time, end of the work, number of shift work).
DHW experimental measurements were done in order to clarify the actual DHW consumption in an apartment building. In order to achieve this, measurements from heating substation of the dwelling house were taken. So as all multi-compartment dwelling buildings have very similar engineering and technical solution there is no difference of principle which building to choose for the experiment.
Measurements of DHW consumption (l) were performed hourly during all period of experiment.

Dimensional analysis

According to Latvian building norms LBN 221-98 article 194, the irregularity coefficient of water consumption is defined by this formula:

$$k_{ir} = \frac{q_{hr}}{q_T} \quad (1)$$

Where:
k_{ir} – irregularity coefficient of daily maximal water consumption hours (domestic hot and cold water);
q_{hr} – maximal water consumption per hour (domestic hot and cold water), *l/h*;
q_T – average water consumption per hour, *l/h*.

Analysis of experimental results

In order to make valuation and comparison DHW measurements an electronic table was made.
In the first column measurements of DHW daily consumption are shown, in the second – average consumption per hour, in the third – maximal consumption, in the fourth – irregularity coefficient, in the fifth – actual DHW consumption per inhabitant, in the sixth – the ratio of the daily average consumption to the daily maximum consumption.

Table 1

Test conditions

Day	**q (l)**	**qT (l/h)**	**qhr (l/h)**	**kir**	**qfact (l/d·c)**
2007-16-03 Friday	3712,00	154,70	385,00	2,49	37,12
2007-17-03 Saturday	5106,00	212,80	516,50	2,43	51,06
2007-18-03 Sunday	4968,60	207,00	618,80	2,99	49,68
2007- 27-03 Tuesday	3889,70	162,10	386,90	2,39	38,89
2007-28-03 Wednesday	4429,40	184,60	467,80	2,53	44,29
2007-29-03 Thursday	4832,00	201,30	609,90	3,03	48,32
Average for period of measurements	4489,62	187,07	497,48	2,66	44,90
Average for workdays	4215,78	175,66	462,40	2,63	42,16
Average for rest days	5037,30	209,89	567,65	2,70	50,37

Where:
q – DHW daily consumption, *l*;
q_{fact} – actual DHW consumption per one inhabitant, *l/(d·c)*.
In order to compare values of DHW consumption per inhabitant of the dwelling house the diagram is constructed and shown below. Daily DHW consumption deviation in days of measurements from average value is 14±18%.

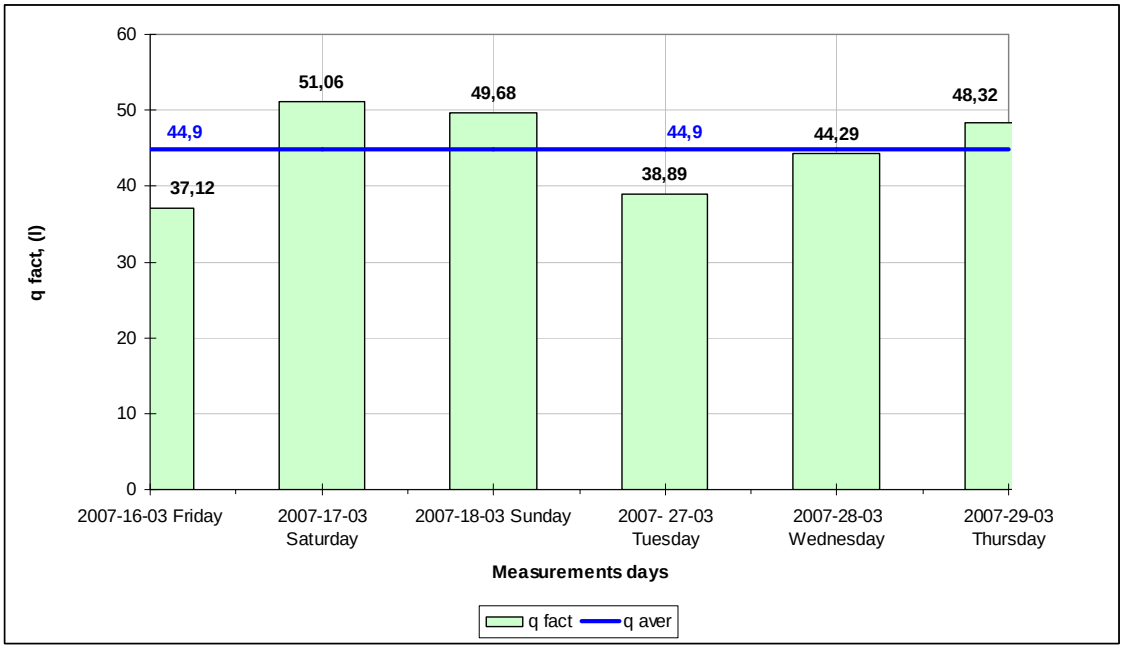

Fig. 2. Daily domestic hot water consumption per inhabitant in the apartment building

DHW consumption profile is constructed from practical measurements of DHW consumption. On profile abscise axis daily time in hours **t** is shown, on ordinate – domestic hot water consumption value.
Consumption profiles of typical days of week (Friday, weekend, workday) are shown below.

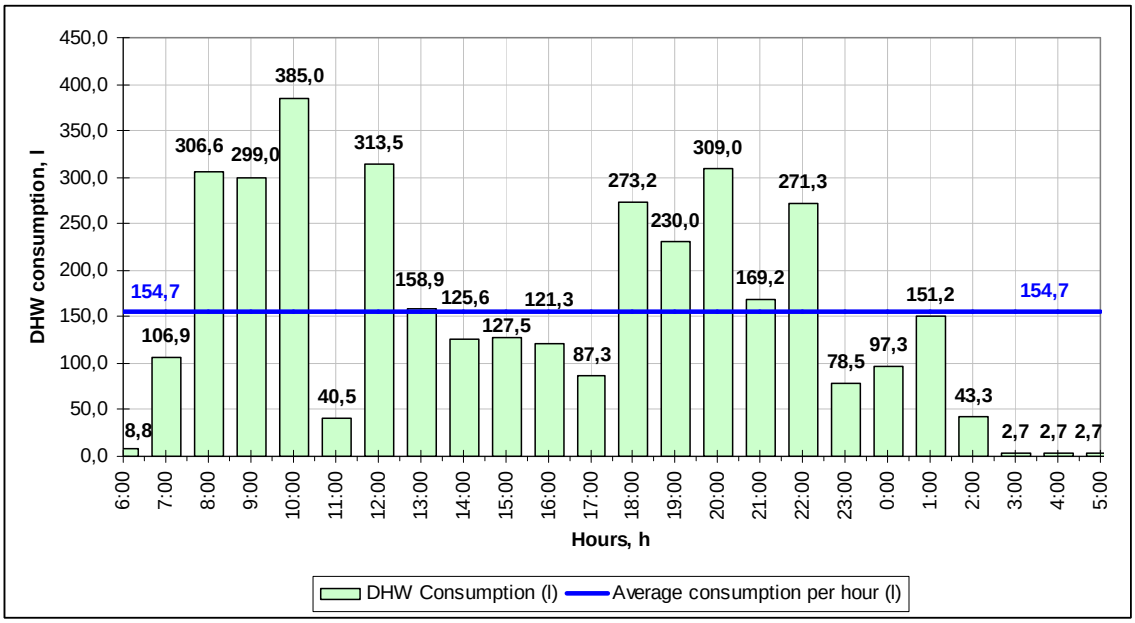

Fig. 3. DHW consumption profile of the 32-apartment building, Friday, 2007-03-16

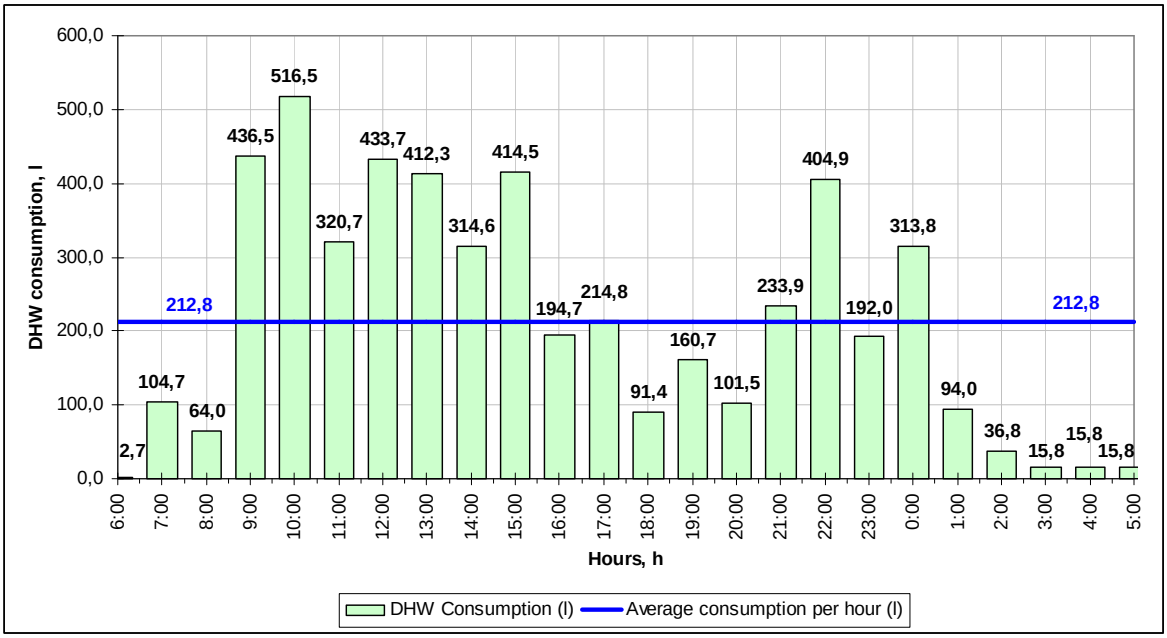

Fig. 4. DHW consumption profile of the 32-apartment building, Saturday, 2007-03-17

As it can be seen from Figures 2, 3, 4, DHW consumption maximums are observed in the mornings (8-10 a.m.) in spite of 1970-1990 when the maximums were observed in the evenings [13], and DHW consumption profiles of apartment building in Riga are close to the domestic hot water consumption profiles in the USA [14].

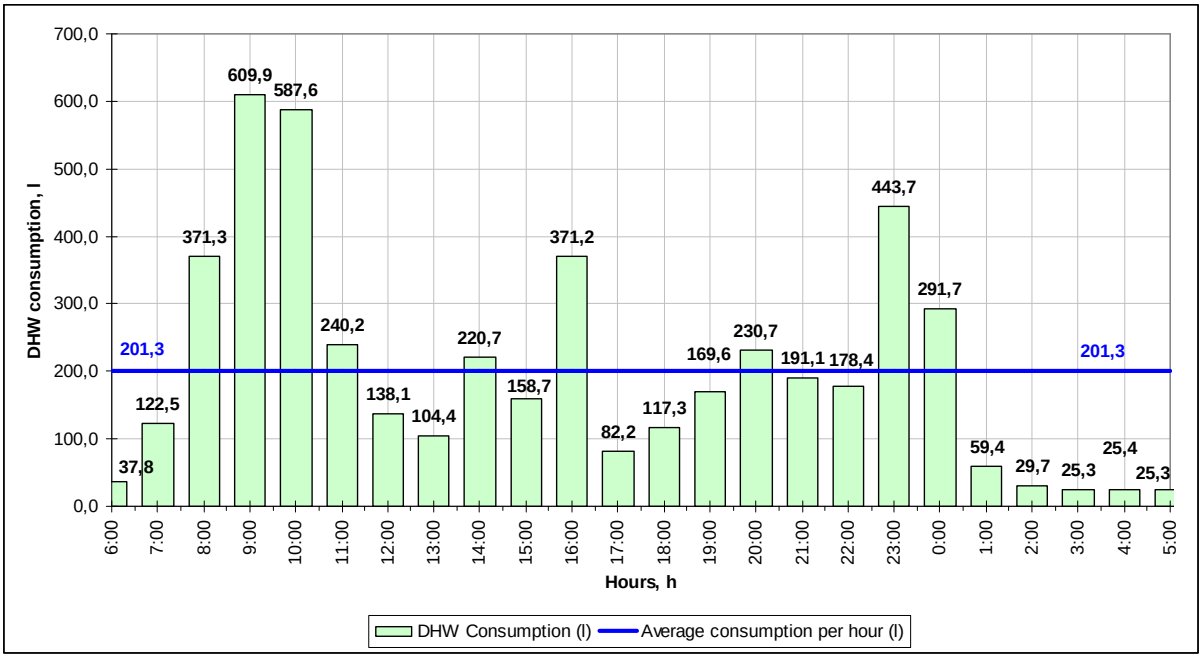

Fig. 5. DHW consumption profile of the 32-apartment building, Thursday, 2007-03-29

Conclusions

In the paper are presented the results of domestic hot water consumption experimental monitoring for a dwelling house in Riga. Analysis of results shows the following:

1. Domestic hot water consumption data differs noticeably from normative values. As practice shows, one person spends averagely 44.90 l/d·c of hot water or 1.35 m^3/per month. Comparing with normative values (q=105 l/c·d or 3.2 m^3/per month), normative and actual consumption differ almost 2 times.
2. With domestic hot water consumption decreasing, irregularity coefficient does not differ essentially from literature data (k_{ir}=2.5) – it varies within $2.39 \leq k_{ir} \leq 3.03$.
3. During the experiment it was verified that domestic hot water consumption maximums are observed in the mornings (8-10 a.m.) in spite of 1970-1990 when the maximums were observed in the evenings.
4. Domestic hot water consumption profiles of apartment building in Riga are close to the domestic hot water consumption profiles in the USA.
5. Research shows that in designing domestic hot water systems it is not reasonable to use domestic hot water consumption design value (q=105 l/c·d), because values which are derivative from it are overestimated.

In the scope of this study the analysis of domestic hot water consumption done only in the apartment building. Taking into account fact that data is limited the monitoring of domestic hot water consumption will be continued during next years. It is planned to evaluate DHW consumption in different apartment buildings.

References

1. Production, imports, exports and consumption of electricity and production and consumption of heat (in natural units) / Central Statistical Bureau of the Republic of Latvia, 2009. – www.csb.gov.lv
2. Borodinecs, A. Energy Certification in the Light of the Directive 2002/91/EC. Riga: RTU Publishing House, 2006.
3. Greķis A. Technical-economic and environmental factors for reduction of energy consumption in buildings: The Thesis for Scientific Degree of the Doctor of Engineering Sciences. Riga: RTU, 2004 (in Latvian).
4. Rubina, M. Heat Supply. Riga: FEI, 2002 (in Latvian).
5. The Cabinet of Ministers of the Republic of Latvia. Regulations on Building Standard LBN 221-98 “Buildings’ Internal Water Supply and Sewerage System”. Latvijas Vestnesis, 219/220, 1998 (in Latvian). (http://www.likumi.lv)
6. USSR Standard Norms. SNiP 2.04.01-85 „Buildings’ Internal Water Supply and Sewerage System. Project norms.” (in Russian: СНиП 2.04.01-85 «Внутренний водопровод и канализация зданий».)
7. Vrubļevskis V.,Zēbergs V., Zeltiņš N., Puikevica-Puikevska I. Additional Energy Saving in a Building with Improved Insulation. Latvian Journal of Physics and Technical Sciences, vol.2, 2007, 32-41.
8. PHARE programme. Strategy of Energy Economy. The Journals of Communal Services Working Group, 22 April 1993 (in Latvian).
9. Estimates of Hot Water Consumption from the 1998 EFUS. Implications for the Modelling of Fuel Poverty in England. BRE Housing Centre, 2005
10. Kazanov Yu.N., Zvyagin I.N. Energy Resources Accounting is Advantageous for Everyone // Housing and Communal Services. – Nr.3 (2002), p.31-32. (in Russian: Казанов Ю.Н., Звягин И.Н. Учет энергоресурсов выгоден всем / ЖКХ. – 2002. – №3, часть 1. – 31-32 с.)

11. Toode A., Koiv T.-A. Investigation of the domestic hot water consumption in apartment buildings. Proc. Estonian Acad. Sci. Eng., 2005, 11, 3, 207-214.
12. Koiv T.-A., Toode A. Trends in Domestic Hot Water Consumption in Estonian Apartment Buildings. Proc. Estonian Acad. Sci. Eng., 2006, 12, 1, 72–80.
13. Chistyakov N.N., Grudzinskiy M.M., Livchak V.I. Domestic Hot Water Systems Operation Efficiency Increasing. Stroyizdat, Moscow, 1988. (in Russian: Чистяков Н.Н., Грудзинский М.М., Ливчак В.И. и др. Повышение эффективности работы систем горячего водоснабжения. – Москва, Стройиздат, 1988. – 314 с.)
14. Fairey P., Parker D. A Review of Hot Water Draw Profiles Used in Performance Analysis of Residential Domestic Hot Water Systems. A Research Institute of the University of Central Florida, 2004. (www.fsec.ucf.edu)

Budjko Z., Zebergs V. Investigation of the domestic hot water consumption in the apartment building.
Since the independence resumption of Latvia in 1990, water consumption in the country has decreased few times. Accordingly, domestic hot water consumption in the household sector reduced.
Water consumption decrease was caused by extensive water consumption meters' installation, increased heat supply tariffs, and domestic hot water savings activities.
In this paper there are presented the results of domestic hot water consumption measurements, which were done in a dwelling house in Riga. The results were worked up using the prescribed formulas of building normative LBN 221-98.
The fluctuations of irregularity coefficient depending on domestic hot water consumption decrease was analysed in this research; as well as domestic hot water consumption fluctuations in the day time and the maximal consumption value.
Using the received results, domestic hot water consumption profiles were prepared.
The results of measuring show that the actual consumption values are less than the design values.

Budjko Z., Zēbergs V. Karstā ūdens patēriņa pētījums daudzdzīvokļu dzīvojamā mājā.
Kopš Latvijas Republikas neatkarības atgūšanas 1990. gadā, ūdens patēriņš valstī samazinājies vairākkārt. Atbilstoši samazinājies arī karstā ūdens patēriņš mājsaimniecības sektorā.
Ūdens patēriņa samazināšanas veicināja ūdens skaitītāju uzstādīšana, tarifu paaugstināšana siltumapgādē, karstā ūdens ekonomijas pasākumi.
Rakstā prezentēti karstā ūdens patēriņa mērījumi daudzdzīvokļu dzīvojamajā māja Rīgā. Rezultāti tika apstrādāti, lietojot LBN 221-98 piedāvātas formulas.
Pētījuma ietvaros analizētas neviemērības koeficienta svārstības atkārībā no karstā ūdens patēriņa samazināšanas, kā arī karstā ūdens patēriņa svārstības dienas laikā un maksimālā patēriņa lielumi.
Izmantojot iegūtos rezultātus, tika sagatavoti karstā ūdens patēriņa profili.
Pētījuma rezultāti rāda, ka karstā ūdens patēriņš ir mazāks nekā LBN 221-98 piedavātais.

Будько Ж., Зебергс В. Учет потребления горячей воды в многоквартирном жилом доме.
После восстановления независимости в 1990 г. потребление воды в жилищном секторе Латвийской республики уменьшилось в несколько раз. Соответственно, снизилось и потребление горячей воды. В частности, этому способствовала установка индивидуальных счетчиков потребления воды, повышение тарифов на водоснабжение, мероприятия по экономии горячей воды населением.
В работе представлены результаты измерений потребления горячей воды в многоквартирном доме г.Риги. Результаты обработаны, используя предложенные в строительном нормативе ЛР LBN 221-98 формулы.
В рамках исследования анализированы колебания коэффициента неравномерности в зависимости от изменения потребления воды, изменения расхода горячей воды в течение дня и величины наибольшего потребления.
Результаты измерений показывают, что фактическое потребление горячей воды существенно отличается от предложенного нормативом.