LATVIAN JOURNAL OF PHYSICS AND TECHNICAL SCIENCES
2011, N 3

DOI: 10.2478/v10047-011-0018-5

# INFLUENCE OF CHANGES IN HOT WATER CONSUMPTION ON THE DHS DEVELOPMENT

Z. Budjko, V. Zēbergs

Institute of Physical Energetics,
21 Aizkraukles Str., Riga, LV-1006, LATVIA

The methodology proposed in the paper is based on the concept of Energy Efficiency Uninterrupted Development Cycle (EEUDC). The goal of the authors was to clarify how the district heating system (DHS) development is affected by the heat consumption. The primary emphasis was given to the hot water consumption, with its noticeable daily fluctuations as well as changes caused by those in the inhabitants' way of life. The methodology, which is in good agreement with the ideology of advanced management of DHS development, employs the ISO 14000 series of standards (widely applied in the sphere of environment management). In the work, experimental results are presented that have been obtained through monitoring the hot water consumption. The results evidence that this consumption and its usage indices correspond to the level achieved by Western (in particular, North-European) countries. This circumstance changes considerably the input data for calculation of DHS elements, making it possible to work out appropriate measures in order to improve the DHS efficiency through step-by-step replacement of the elements with high energy loss.

**Key words:** *DHS development, environment management methods, hot water consumption*.

## 1. INTRODUCTION

The development of district heating systems (DHSs) in the Central European and East-European countries (including Latvia) hides a huge potential of increasing the energy efficiency, with the domino effect on the power industry economy and environment protection. The DHSs in these countries are widely used, even though they were developed using old technologies, and have therefore become dilapidated. At the same time, the activity of heat consumers (as concerns the heating of buildings, etc.) is now reduced: in particular, the heat consumption for heating and hot water preparation is now ever decreasing. The connection of new heat consumers to the system (new residential areas or industrial plants) can raise considerably the heat load on various elements of a DHS. Thus, it is of importance to study the DHS development process in a given complicated and unstable environment. Since it is impossible to replace the whole system of a DHS and its elements simultaneously (energy sources, heat network, etc.), it is necessary to develop a methodology for managing gradually the development of DHS in order to improve its worst elements, with due consideration for the heat consumption processes and their changes.

## 2. METHODOLOGY OF THE ENERGY EFFICIENCY UNINTERRUPTED DEVELOPMENT CYCLE

The methodology of the energy efficiency uninterrupted development cycle (EEUDC) is based on the environment management system (EMS). The aim of the research was to adapt this methodology to the purposes of improving the management of DHS energy efficiency and exploring the influence of various factors on the DHS development including the observed decrease in the heat consumption.

The research shows that the management of energy is in many aspects similar to that of environment, as the decrease in the consumption of energy is directly associated with limitation of the emissions that arise due to production of this energy, and, on the whole, with the ideology of environment protection.

The standards of ISO 14000 series have been worked out with the aim of assisting the relevant companies to develop the effective EMS elements that would be interconnected with other management aspects.

The ISO 14001 standard provides methodological assistance to the companies and state institutions in order to:

- carry out the analysis of environment effects;
- set appropriate goals and tasks;
- perform monitoring of the environmental situation and achieved results;
- ensure continuous improvement of the environmental situation.

These tasks correspond very closely to the motivation for introduction of an energy management system, which would be engaged in the saving of raw materials and energy − in optimization of the energy production methods, improvement of the energy management efficiency, and increase in the effectiveness of energy use.

Figure 1 shows an ISO 14001 model of the environment management system.

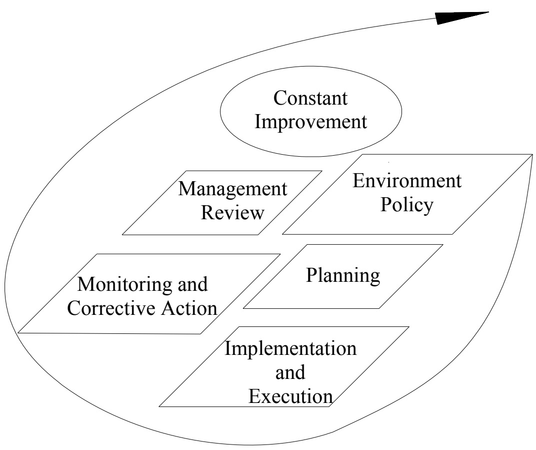


*Fig. 1*. The environment management system (model ISO 14001).

The ISO 14001 model of the environment management system has already been incorporated into the following Latvian standards: LVS, EN ISO 14001:1996.

In the present research, the EMS is developed with the aim to improve the management of DHS heat energy effectiveness, as this energy makes up an important part in the energy sector, ensuring the industrial development and higher life quality.

## 3. PLANNING OF THE DHS EFFICIENCY IMPROVEMENT

In each cycle ($i_1$, $i_2$, $i_3$ …. $i_n$) of the DHS development management of high importance is planning the energy efficiency growth in order to reduce maximally the heat loss $\Sigma\Delta Q_{in}$ at available costs $\Sigma E_{in}$ in a given cycle ($i_n$). All the worst elements ($j_1, j_2, j_3$ … $j_m$) of the DHS should be analyzed (e.g., a section of the heat network pipelines).

If we assume that in a DHS there are "bad" elements (determined based on the hydraulic and thermal pipeline calculations), for the maximum reduction in the heat losses we will have:

$$\Delta Q = \Delta q_{j1} + \Delta q_{j2} + \Delta q_{j3} + \ldots + \Delta q_{jm} + = \max \tag{1}$$

at the corresponding minimum costs:

$$\Delta e_{j1} + \Delta e_{j2} + \Delta e_{j3} + \ldots + \Delta e_{j1m} = \sum e_j \leq \sum E_{in} \tag{2}$$

taking into account the discounted cash flow in each case of efficiency increment ($\Delta q_j$). In the absence of special arguments, e.g. inclusion into the plan of the $i_n$-th cycle of measures for improving the energy efficiency of "bad" elements ($j_1, j_2, j_3$ … $j_m$) of a DHS, we can write the following ranking for the specific costs of measures:

$$\frac{\Delta e_{j1}}{\Delta q_{j1}} < \frac{\Delta e_{j2}}{\Delta q_{j2}} < \ldots \frac{\Delta e_{jm}}{\Delta q_{jm}}\,. \tag{3}$$

The duration of single-cycle operation $i_n$ depends on that of the execution of energy efficiency measures, the possibility to attract funds for execution of such measures in a next cycle, or the necessity of urgent reconstruction under the accident threats. In practice this duration can be 3–5 years.

So far, the influence of heat consumption changes on the DHS development has mostly been studied in the heating aspect. With respect to buildings this means that only heat consumption for heating is accounted for, while the hot water supply rearrangement would not necessarily result in lower heat consumption, and is more dependent on the residents' lifestyle and the water regime. Thus, the hot water consumption in the Western Europe is approximately by half lower than in the Eastern Europe. Furthermore, keeping in mind that this consumption is characterized by large fluctuations over the twenty-four hours of a day, the heat power required for its supply reaches the power of that for heating.

In order to work out a measure for increasing the effectiveness of the hot water supply of the $j_m$-th element of a network according to the EEUDC planned cycle $i_n$, it is necessary that the supply system is sustained in compliance with the proposed technology (i.e. taking into account the expected hot water consumption and the water regime). This would allow determination of the expected flow of heat carriers in the $j_m$-th element of a given DHS, and, therefore, of the corresponding efficiency increment $\Delta q_{jm}$ together with the costs of this measure $\Delta e_{jm}$.

For the practical experiment under Latvian conditions a living house was chosen that had a hot water supply system arranged in compliance with the new technology and standards.

## 4. CURRENT DHW CONSUMPTION IN RESIDENTIAL BUILDING STOCK IN LATVIA

By now, the domestic hot water (DHW) supply system has been organized in compliance with the Latvian building normative LBN 221-98: „Buildings' Internal Water Supply and Sewerage System" [1]. Up to the 1st of August 1998, the former USSR building norms SNiP 2.04.01-85: „Buildings' Internal Water Supply and Sewerage System. Project norms." [2] were applied for this purpose.

The daily DHW consumption per person is defined by two parameters: the amount of hot water (litres per person per day) and temperature (°C). According to the Latvian building standard LBN 221-98, the DHW consumption is defined depending on the level of building amenities − 105 l daily (3.2 $m^3$ per month) on the average, with the temperature of 55 °C and the irregularity coefficient $k_{ir}$ =2.5.

Currently, at the time when energy savings have become highly topical in view of commercial metering of the heat energy spent to hot water preparation as well as of 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, the DHW consumption is not very high. For example, in Denmark the DHW consumption is 50 l per day per person, or 180 l for a 3.5-person statistical family [3, 4].

In order to determine a typical DHW daily consumption, the present investigation considers a 32-apartment 8-storey building (Fig. 2) built in 1985 in Riga (the Plavnieki District), with approx. 100 inhabitants.

The building under investigation is connected to the "Rigas Siltums" district heating network; it has a modern automatic heating substation, and is equipped with up-to-date heat counters as well as hot and cold water meters.

*Fig. 2.* The apartment building chosen for monitoring the DHW consumption.

The DHW is delivered to the bathrooms and sinks of the building; the hot water system has been partly renovated.

The measuring equipment includes a DHW meter ("B" class, error ±3 − ±5 of the indication).

According to the Latvian building standard LBN 221-98, article 148, the DHW flow rate is measured in the heat units by a cold water meter, which is installed in front of the water heater.

It is important to mention that in the house the inhabitants with different incomes are living; they work at the enterprises and institutions with different working conditions (beginning of the work, lunch time, end of the work, number of shifts, etc.).

In order to determine the factual DHW consumption in the building, experimental monitoring was performed, for which measurements from the heating substation of the building were taken. The choice of building was of no importance for the experiment, since all multi-compartment dwelling buildings are quite similar as to the engineering and technical solutions involved. The measurements of DHW consumption were performed hourly during the whole time of experiment.

In the dimensional analysis, the irregularity coefficient of water consumption is defined according to the Latvian building standard LBN 221-98, article 194, by the formula:

$$k_{ir} = \frac{q_{hr}}{q_T}, \qquad (4)$$

where: $k_{ir}$ is the irregularity coefficient of the daily maximum water consumption hours (domestic hot and cold water);

$q_{hr}$ is the maximum water consumption per hour (domestic hot and cold water), l/h;

$q_T$ is the average water consumption per hour, l/h.

In order to make evaluation and comparison of the DHW measurement results, an electronic table (Table 1) was composed.

*Table 1*

**Test conditions**

| Day | $q$ (l) | $q_T$ (l/h) | $q_{hr}$ (l/h) | $k_{ir}$ | $q_{fact}$ (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- 7-03 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 the measurement time | 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 |

N o t e: $q$ is the DHW daily consumption, l;
$q_{fact}$ is the factual DHW consumption per one inhabitant, l/(d·c).

In the first column the measured values of DHW daily consumption are shown; in the second – the average consumption per hour; in the third – the maximum consumption; in the fourth – the irregularity coefficient; in the fifth – the factual DHW consumption per inhabitant. In the dimensional analysis of importantce is also the ratio of daily average-to-maximum consumption.

In order to compare the values of DHW consumption per inhabitant of the dwelling house a diagram was constructed (Fig. 3). The deviation from the average daily DHW consumption in the days of measurements is 14±18%.

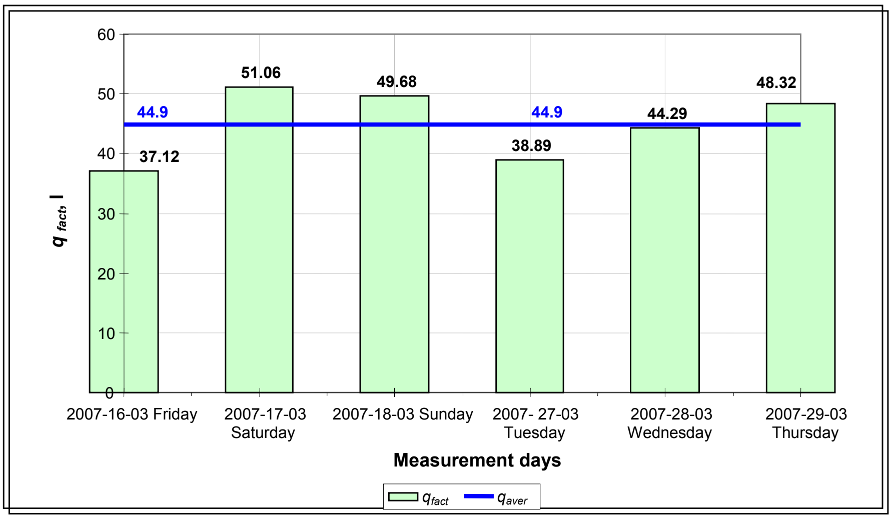


*Fig. 3.* Daily domestic hot water consumption per inhabitant in the apartment building.

The DHW consumption profiles (Figs. 4–7) are constructed based on the results of practical measurements. The profiles are shown for characteristic days of week (Friday, weekend, workday).

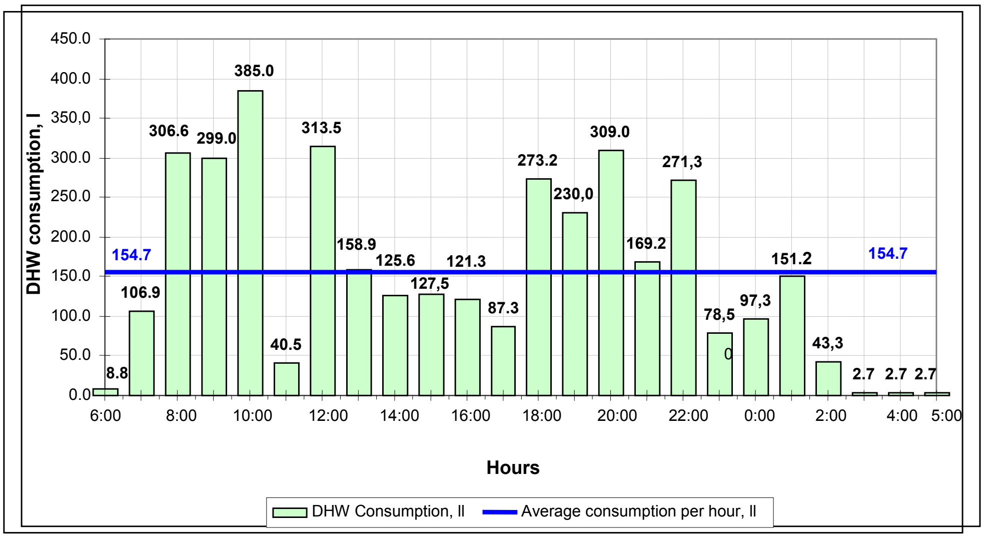


*Fig. 4.* DHW consumption profile of the 32-apartment building under consideration. (Fri. 2007-03-16).

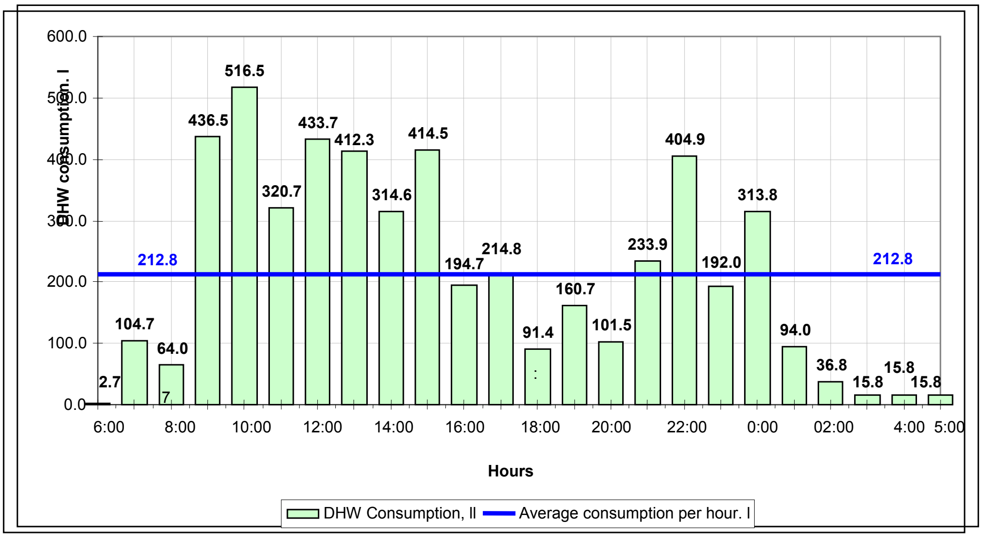


*Fig. 5.* DHW consumption profile of the 32-apartment building under consideration.
(Sat. 2007-03-17).

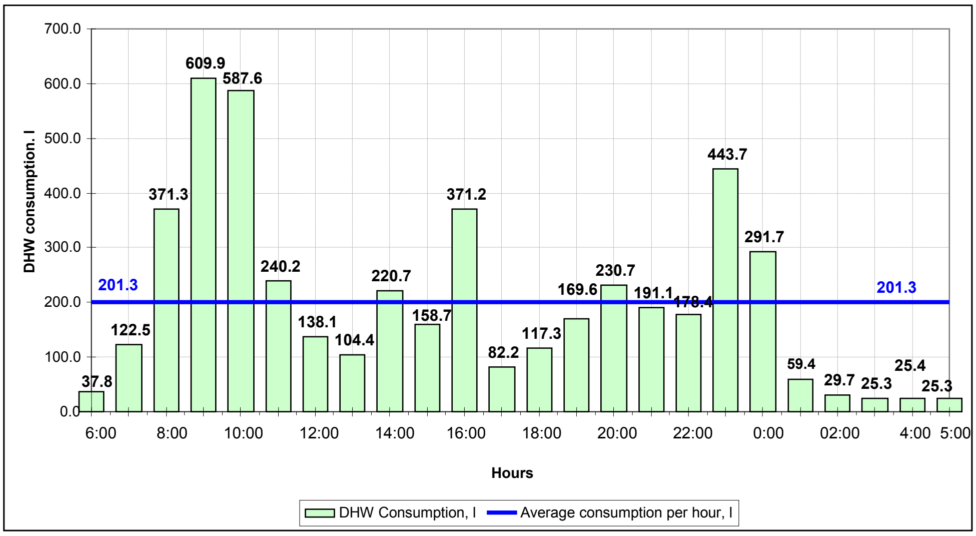


*Fig. 6.* DHW consumption profile of the 32-apartment building under consideration.
(Thu.. 2007-03-29).

As can be seen from Figs. 4–6, the DHW consumption maxima are observed in the mornings (8–10 a.m.) − in contrast to 1970–1990-ies, when such maxima were reached in the evenings [5]. The profiles of DHW consumption shown in these figures are close to those typical for the USA [6].

## 6. CONCLUSIONS

The research results have shown that for managing the DHS energy efficiency the "Energy efficiency uninterrupted development cycle" methodology can be successfully employed.

Analysis of the experimental monitoring with the aim to determine the DHW consumption in a dwelling house (Riga) has shown the following:

- The data on the domestic hot water consumption differ noticeably from the normative values. As practice shows, one person spends averagely 44.90 l/d·c of hot water or 1.35 $m^3$ per month. As compared with the normative values ($q$ = 105 l/c·d or 3.2 $m^3$/month), the factual consumption is lower by half.
- With domestic hot water consumption decreasing, the irregularity coefficient does not differ much from the literature data ($k_{ir}$ = 2.5) – it varies within the interval from 2.39 to 3.03.
- During the experiment it was verified that the domestic hot water consumption maxima are achieved in the mornings (8–10 a.m.) − in contrast to 1970–1990-ies, when such maxima were observed in the evenings.
- The domestic hot water consumption profiles of the apartment building under consideration are close to those characteristic for the North Europe.
- The results of research evidence that in designing the domestic hot water systems it is not reasonable to use the old normative value (e.g. $q$ = 105 l/c·d). since its derivatives are overestimated.

## REFERENCES


1. The Cabinet of Ministers of the Republic of Latvia. Regulations on Building Standard LBN 221-98 "Buildings' Internal Water Supply and Sewerage System". *Latvijas Vēstnesis*. 219/220. 1998 (in Latvian). (http://www.likumi.lv)
2. 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».)
3. Vrubļevskis, V., Zēbergs, V., Zeltiņš, N., & Puikevica-Puikevska, I. (2007). Additional energy saving in a building with improved insulation. *Latv. J. Phys. Tec. Sci., 44* (2). 32–41.
4. PHARE programme. (22 Apr. 1993). Strategy of Energy Economy. *The Journals of Communal Services. Working Group*. (in Latvian).
5. Chistyakov, N.N., Grudzinskiy, M.M., & Livchak, V.I. (1988). *Improvement of Operation Efficiency of Domestic Hot Water Systems*. Moscow: Stroyizdat (in Russian: Чистяков, Н.Н., Грудзинский, М.М., Ливчак, В.И. и др. *Повышение эффективности работы систем горячего водоснабжения*. Москва: Стройиздат, 1988)
6. Fairey, P., & Parker, D. *A Review of Hot Water Draw Profiles Used in Performance Analysis of Residential Domestic Hot Water Systems*. Research Institute of the University of Central Florida. 2004. (www.fsec.ucf.edu)


## KARSTĀ ŪDENS PATĒRIŅA IZMAIŅU IETEKME UZ CSAS ATTĪSTĪBU

Z. Budjko. V. Zēbergs


K o p s a v i l k u m s

Darbā apskatīta centralizētas siltumapgādes sistēmas (CSAS) efektivitātes paaugstināšana, kas notiek tās attīstības gaitā pakāpeniski nomainot elementus ar lieliem enerģijas zudumiem. Pētīts siltuma patēriņa izmaiņas iespaids uz CSAS attīstību, sevišķi siltā ūdens apgādei, kas būtiski svārstās diennakts laikā un izmainās laika gaitā līdz ar iedzīvotāju dzīves veida maiņu. CSAS attīstības pētījumā izmantota metodoloģija, kas balstās uz ISO 14000 standartu sēriju, ko plaši pielieto

vides pārvaldības pilnveidošanā. Šī metodoloģija atbilst CSAS attīstības vadības sistēmas pilnveidošanas, ieskaitot nepārtrauktas enerģijas efektivitātes paaugstināšanas ciklu, ideoloģijai. Darbā atspoguļots praktisks siltā ūdens patēriņa monitorringa eksperimenta rezultāts, kas parāda, ka patēriņš, kā arī patēriņa režīma rādītāji atbilst Rietumu (tai skaitā arī Ziemeļeiropas) valstu līmenim. Tas būtiski izmaina CSAS elementu aprēķinu izejas datus un enerģijas efektivitātes optimizācijas rezultātus.

27.04.2011.