

Seasonal variation of hot and cold water consumption in apartment buildings

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Abstract

Correct interpretation of measurements of water consumption in buildings over a short period of time, e.g. one or two weeks, requires knowledge of the seasonal variation of this consumption.

In this study the seasonal variation of water consumption in 8.046 apartments of in total 390 apartment buildings in Belgium has been analysed. The data available consist in monthly consumption records of hot and cold water for each apartment, and this over a period of 3 years for each apartment, between 2008 and 2012 for all buildings.

In the domestic hot water (DHW) consumption a seasonal variation was found : in winter DHW consumption was found to be about 12% higher than the average consumption, whilst in summer this consumption was almost 13% lower than average. This seasonal variation affects as well the mean daily consumption as the peak consumption on a short time base, i.e.10 minutes. The influence of the seasonal variation of the cold water temperature on the hot water consumption was identified as an important influencing factor.

Keywords

water consumption, apartment buildings, seasonal variation, domestic hot water (DHW), domestic cold water (DCW)

1 Introduction

As the energy-use for space heating continues to diminish due to better performances of the building envelope, the energy use for hot water production becomes increasingly relevant. Since the recast of the Energy Performance of Buildings Directive [1] stipulates that by 2020 all new buildings in the European Union should be almost near zero energy buildings, reducing the energy use for hot water production, whilst maintaining the desired comfort level for the buildings occupants, will become one of the challenges for the future.

Therefore it becomes ever more important to design hot water production and distribution installations inside our buildings -of which apartment buildings are an important part- in a more efficient way. Given the fact that in Belgium currently used methods for sizing hot water production systems in apartment buildings rely on consumption data of the seventies [2] or the eighties [3], it is evident that there is an urgent need to obtain current and reliable data on water consumption in buildings.

But an optimal design of the drinking water system (hot and cold) is also an even more important necessity in order to guarantee the hygienic quality of the water at the taps : avoiding Legionella-problems means no stagnation of the water in oversized hot water vessels and no too low velocities due to the oversizing of the piping. This concern requires also a better knowledge of the water consumption in our buildings.

Finally, the still growing concern about water conservation is a third reason for trying to have more precise data on the water consumption in the buildings, i.e. in order to be able to design correctly the piping system for the distribution of non-drinking water (e.g. rainwater) to specific taps, all WCs for instance .

This explains why, in different countries, measuring campaigns on cold and hot water consumption in buildings have been launched [4], [5], [6], [7], besides other actions allowing more precise dimensioning [8], [9], [10].

One of the main problems in interpreting the results of measurement campaigns *in situ*, is the fact that, for practical reasons, the monitoring is typically limited in time e.g. from 1 week up to two months for each building, while previous studies [11] have shown that in Europe a seasonal variation in hot water consumption might be expected. So several questions arise with respect to a correct interpretation of in time-limited observations:

- Are seasonal variations still common and to what extent?
- And if these variations are to be expected, do they only have an effect on the mean daily consumption, or also on the peak flows in the installation?

Both these questions will be addressed in this paper.

2 Data analysed

In recent years, metering of water consumptions (hot and cold) in apartments has become increasingly frequent. The main objective of this metering is to invoice the apartment's occupants based on their actual consumption rather than on a fraction of the buildings total consumption. Through this metering a lot of data became available (dataset n°1), which can be used to confirm the existence and the possible extend of a seasonal variation.

To establish whether seasonal variations also have an effect on peak consumption, measuring data over several years with a relatively high time resolution (1/10 min) were used (dataset n°2).

Following overview gives more details on the data used in this study:

- 1) Dataset n° 1 – ‘*Techem*’: Monthly consumption data of both hot and cold water for each of the 8.046 apartments (of in total 390 apartment buildings) and this over a period of 3 years for each building, between 2008 and 2012. These apartments are mainly situated in and around the Belgian town of Brussels.
- 2) Dataset n°2 – ‘*Building 1*’: 10-min consumption data (1/10 min) of hot water in a building with 40 social apartments, located in the centre of Brussels, between 2004 and 2010 (7 years). Hot and cold water temperatures were also measured.

3 Analysis of data

3.1 Variation over the year of daily hot and cold water consumption

Erro! Fonte de referência não encontrada. shows for the dataset n°1 the relative variation over the year of the average daily consumptions of domestic hot water (DHW), domestic cold water (DCW) and of total water (DTW), compared with their yearly daily average. The yearly average of DTW consumption is 173 l/d and per apartment (=100% DTW).

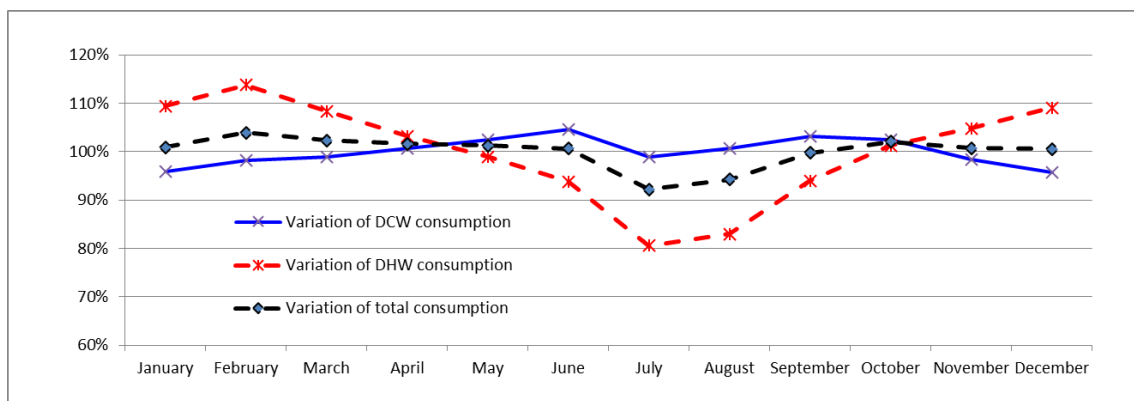


Figure 1 : Relative variation of the daily water consumption in apartments over the year

These results show that the cold water consumption is quite constant over the year: a variation between 96% and 104% with respect to the yearly average of 110 litres a day per apartment (= 100% DCW).

However, the hot water consumption varies more significantly: between 81% and 114% with respect to the yearly average of 63 litres per day and per apartment (=100% DHW), with the lesser consumption occurring in the summer months and the more important consumption in the winter months. With respect to the mean daily consumption over the year, these results allow defining the monthly correction factors indicated in Table 1.

When compared to correction factors identified in previous studies [11] we can conclude that both studies show a comparable trend in hot water consumption, but the amplitude in the Techem dataset is smaller (0.81 – 1.14) compared to the previous study (0.5 – 1.4).

	Jan	Feb	March	Apr	Mai	June	July	Aug	Sept	Oct	Nov	Dec
Techem	1.09	1.14	1.08	1.03	0.99	0.94	0.81	0.83	0.94	1.01	1.05	1.09
[12]	1.25	1.2	1.1	1.05	1	0.8	0.5	0.6	0.9	1.05	1.15	1.4
Cold water temperature for Brussels (°C)	3.5	3	7	9	13	15.5	17.5	17.5	15	11	7	4.5

Table 1 : Monthly DHW correction factors based on Techem data (bold) and as established by Bienfait [11] - Mean monthly cold water temperature in Brussels

The above discussed domestic hot water volume V_{DHW} will be mixed to some cold water in order to have water at the desired temperature of use. It is obvious that in case the volume of mixed water V_u would be constant over the year, the DHW-consumption would be only dependent on the temperature of the cold water. This dependency can be expressed as follows:

$$\frac{(VDHW)_i}{(VDHW)_m} = \frac{\frac{T_u - T_{ci}}{T_{DHW} - T_{ci}}}{\frac{T_u - T_{cm}}{T_{DHW} - T_{cm}}}$$

Where:

- $(V_{DHW})_i$: the average daily consumption of domestic hot water in month i; (l/d.apart)
- $(V_{DHW})_m$: the yearly averaged daily consumption of domestic hot water; (l/d.apart)
- T_u : the temperature of the mixed water (°C)
- T_{ci} : the temperature of the cold water in month i (see table 1)
- T_{cm} : the yearly averaged temperature of the cold water (°C)
- T_{DWH} : the temperature of the domestic hot water (°C)

The result of the calculations of the above equation with $T_u = 40^\circ\text{C}$ and $T_{DWH} = 60^\circ\text{C}$, for the different months, is shown in figure 2.

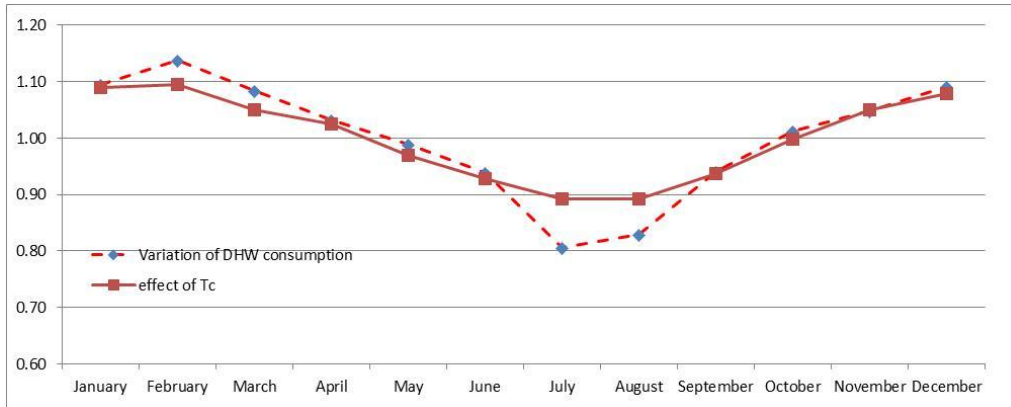


Figure 2 : Effect of the cold water temperature on the domestic hot water consumption

This figure shows that the variation of the domestic hot water consumption over the year is mostly due to the variation of the temperature of the cold water, used for preparing water at the desired temperature of use. It seems thus quite probable that the differences seen in table 1 between the ‘Techem’ data and those of Bienfait [11] could be explained by different cold water temperature profiles.

3.2 Variation of peak consumption over the year

In the previous section, we showed that the domestic hot water consumption varies over the year, mainly as a result of the variation of the temperature of the cold water and we identified monthly factors to take this variation into account. It seems logical that this variation will also have an effect on the peak flow, i.e. that one might expect to have greater domestic hot water peak flows in winter than in summer.

In order to verify this we selected in dataset n°2 the maximum volume of hot water consumed in 10 minutes for each day. This gave us, for each day of the year, 7 values, their variation over the year being given by the thin lines in figure 3 (a different colour for each year). From these 7 values available for each day, we took then the average, i.e. the bold line in Figure 3.

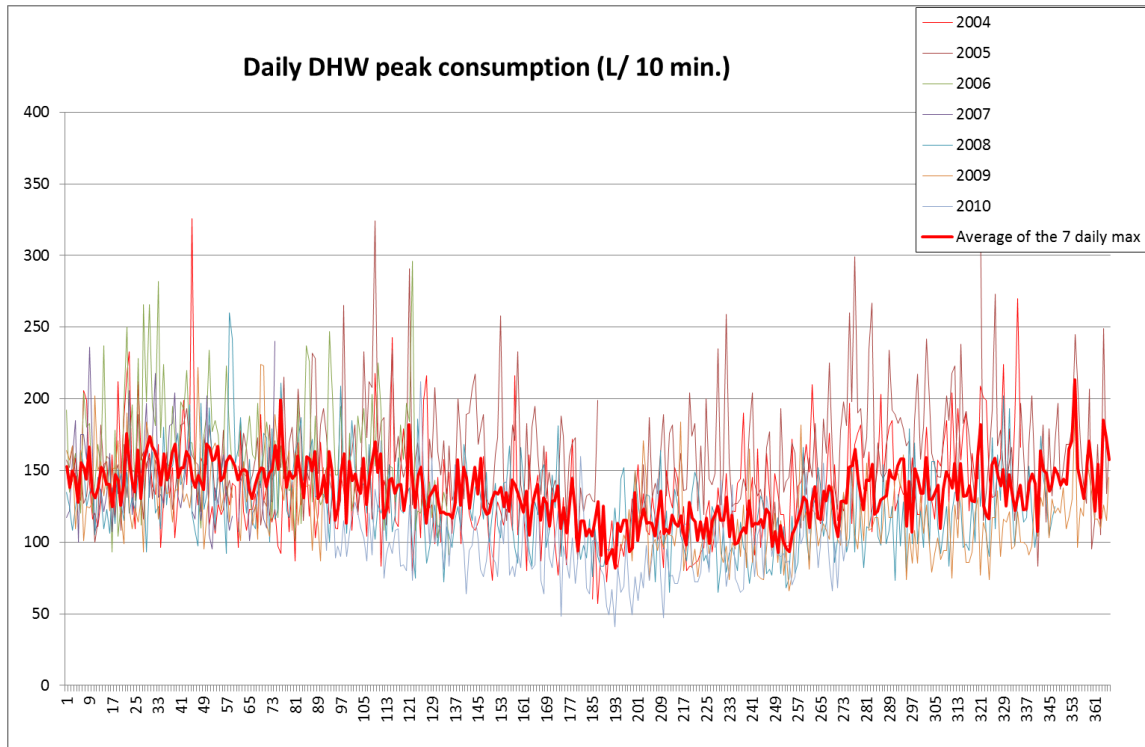


Figure 3 : Variation over the year of the DHW peak consumption in 10 minutes in Building 1.

The daily DHW peak consumption varies strongly over the years but the average peak consumption also clearly shows a trend : lower average peak consumption in summer and a higher average peak consumption in winter. The peak flow shows a seasonal variation.

3.3 Applicability of monthly correction factor on peak consumption data

In Figure 3 Figure 4 the above indicated parameters are combined with the average of all 10 minutes values from dataset 2 – the interrupted horizontal line- and with the monthly correction factors from table 2 (the interrupted line is corresponding to the correction factor 1).

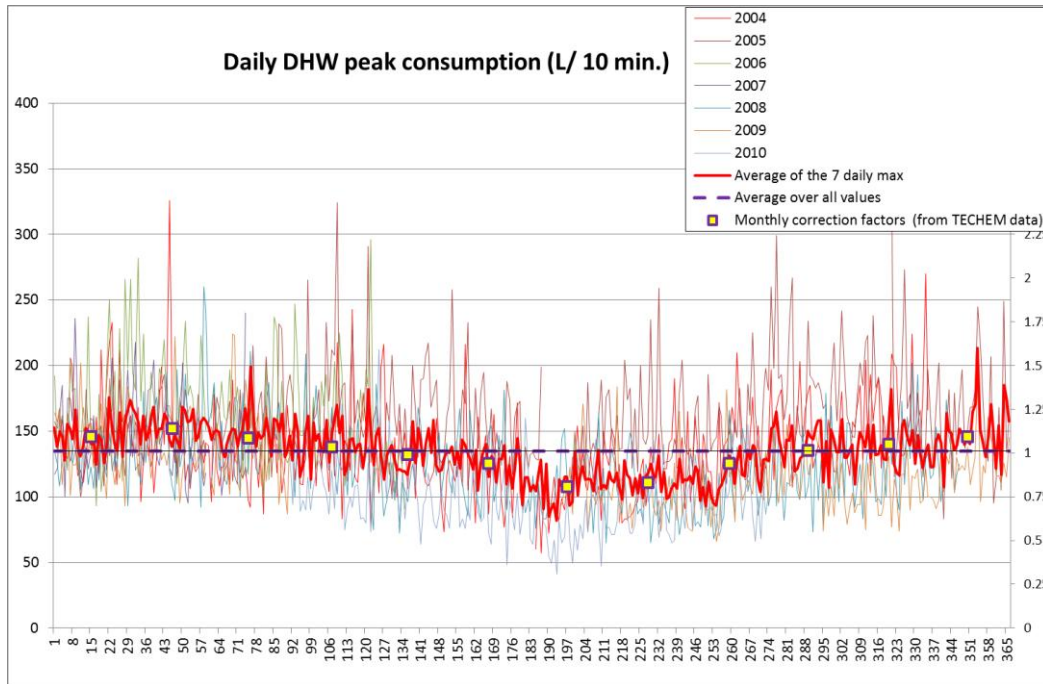


Figure 4 : Correlation between monthly correction factors and peak consumption data for Building 1

This figure clearly shows that there is a good correlation between the variation of the average peak consumption (bold line) and trend set out by the monthly correction factors. So peak consumptions also have to be corrected in order to take into account a seasonal variation.

5 Conclusions

The presence of seasonal variation in DHW consumption in apartment buildings in Belgium has been demonstrated : in winter DHW consumption was found to be about 12% higher than the average consumption, whilst in summer this consumption was almost 13% lower than average. The variation in cold water temperature is the major reason for the variation in DHW consumption.

This variation has also an influence on the peak consumption on short time intervals (10 minutes) and thus probably also on the peak flow. Peak flow measurements done over a short period of time, e.g. a few weeks, in order to characterise the real consumption profile of building must therefore be corrected for seasonal effects. From our current results it seems that the monthly average correction factors derived from monthly data can be used for this purpose.

In the future, it shall be investigated how the variability of the peak consumption over the years could be estimated from the variability calculated over short-time measurement periods.

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7 Presentation of Authors

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