Exploring cold and hot water consumption patterns in residential buildings

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Abstract

From a water consumption point of view, the water-energy nexus is frequently split into the urban water cycle level and the building level. The former has been more explored and comprehends the abstraction, treatment and supply of potable water and the drainage, treatment and disposal of wastewater. At the building level the water-energy nexus manifests mainly by pumping and water heating.

Water heating in buildings can represent a significant consumption of energy, which in many cases is difficult to quantify. In fact, in many countries residential water heating takes place within the home / apartment using sources of energy common to other domestic activities, making it difficult to split by end-use.

The present communication explores a dataset comprising 3 years of monthly records of cold and hot water consumption in apartment buildings in Brussels by means of statistical analysis to assess cold and hot water consumption correlation. The aim is to provide a basis for extrapolation for other contexts were hot water consumption data is not available.

Keywords

water consumption pattern; domestic hot water; domestic cold water; statistical analysis.

1 Introduction

The buildings sector is responsible for 30% of the final energy consumption and more than 55% of the global electricity demand worldwide. Within it, the residential buildings represent around 25% of the global energy consumption and 17% of the global CO_2 emissions [1]. As such, buildings are central to most countries energy efficiency policy, particularly the more developed where the per capita energy consumption is still substantially higher [2]. In the EU, improving the energy performance of the building stock is crucial to achieve not only the EU's 2020 targets but also to meet the longer term climate change target of 80% CO_2 emission reduction by 2050.

Three specific targets were set by the European Commission [3] to be met by 2020 (relative to 1990 levels): reduce greenhouse gas emissions (GHG) by 20%, increase energy efficiency by 20%, and increase contribution from renewable energy sources equivalent to 20% of the final energy consumption. Concerning buildings specifically, the Energy Performance in Buildings Directive (EPBD) recast (Directive 2010/31/EU) requires that member states shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings; and after 31 December 2018 new buildings occupied and owned by public authorities are nearly zero-energy. A nearly zero-energy building is defined as "a building that has very high energy performance…" and its nearly zero or very low amount of energy demand is provided by renewable energy systems, which are either on-site or nearby [4].

The definition set in the EPBD for nearly zero energy building is 'broad' and embraces a wide range of possible solutions. The Directive is performance-based by defining the end-results that must be achieved by every Member State. The national authorities have to adjust their laws and policies/strategies to meet these goals, but the solution to do so is flexible and possible to adjust to each region's specific context [4].

The largest portion of energy consumption in buildings is for space heating, but water heating accounts for more than 20% of the energy consumption in buildings depending on the country [5], [6]. However, in many countries it is not easy to know the energy consumed to heat water in dwellings since only total amounts of water and energy consumed are available and their split per end-use is unknown. This contributes to explain why, in different countries, measuring campaigns on cold and hot water consumption in buildings have been launched [7-12], besides other actions allowing a better understanding of the consumption patterns and more accurate design of water systems in buildings to tackle various issues, including Legionella-related problems [13-15].

In order to assess the amount of energy consumed to heat water, a fundamental required information is the knowledge of the proportion of hot water in the overall water consumption. In that regard, the present communication explores monthly cold and hot water data consumption records with the objective of obtaining a relation between the total water consumption and the hot water consumption. This information will contribute to enable a more accurate evaluation of the benefits from water and energy efficiency measures in the cases where hot water consumption is not measured.

2 Case study

In this study, the water consumption records collected by [11] were analyzed. Data consists on monthly consumption records of cold and hot water acquired over a period of 3 years for each apartment, between 2008 and 2012. Further details on the data and its collection can be found in [11].

The approach adopted in the present research encompasses the following steps: i) dataset screening; and ii) dataset analysis. The dataset screening involved excluding all cases of incomplete (e.g., no water consumption in all or several months), wrong (e.g., negative water consumption values) or anomalous information (e.g., outliers). For the outliers identification the Tuckey criterion was used. The dataset analysis was carried out resorting to regression models with the aim of relating: i) cold and hot water consumption; ii) total and hot water consumption.

Analyzing each year individually, the data present an evident proportionality between cold and hot water consumption, with lower hot water consumption corresponding to lower values of consumed cold water and higher hot water consumption to higher values of cold water consumption, respectively (Figure 1).

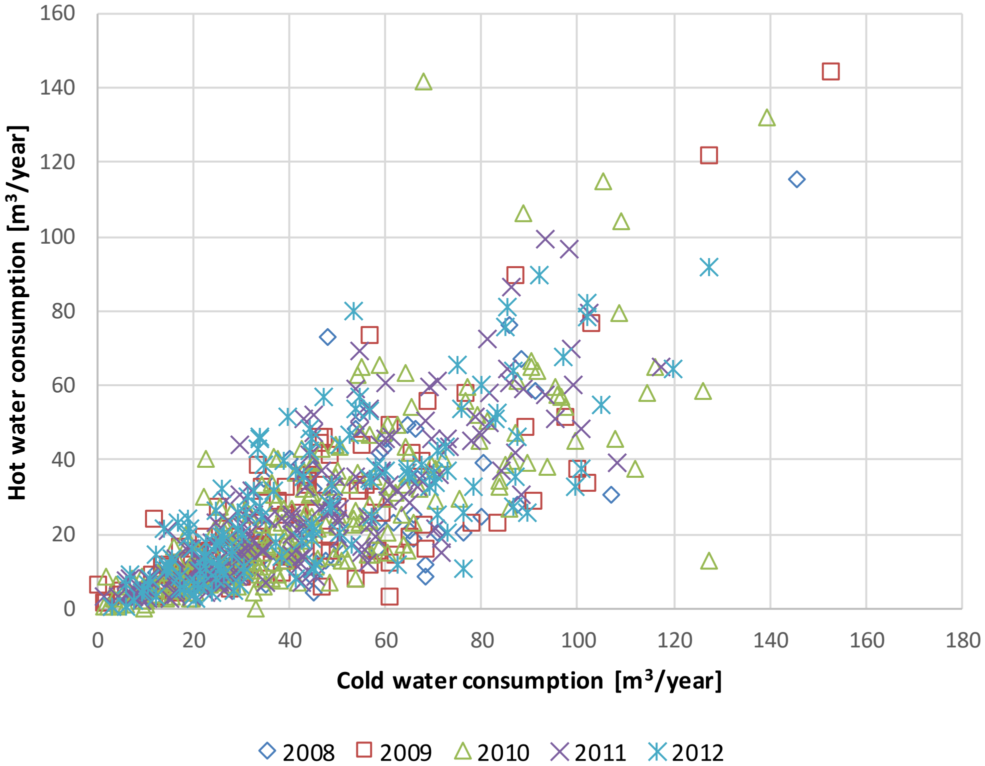

Figure 1 – Relation between cold and hot water consumption.

Not so intuitive are the results from the comparison between total and hot water consumption (Figure 2). Although for the year of 2010 a correlation between total and hot water consumption seems to exist, the relation is not so obvious for the other years, that clearly reveal a distinct pattern.

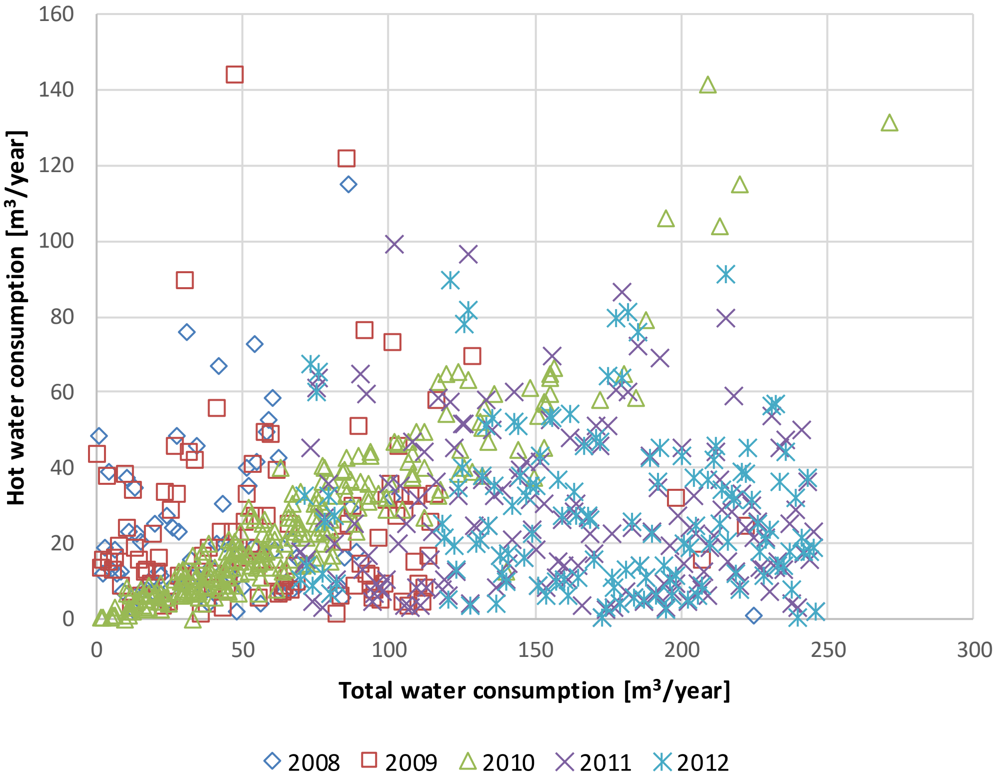

Figure 2 – Relation between total and hot water consumption.

In order to disregard yearly variations, the data were rearranged by averaging the monthly water consumption values of the 3 years of measurement. This averaging reduces the data available to a single value of cold, hot and total annual water consumption for each apartment.

Although the relation between cold and hot water presents the same trend as the raw data (Figure 3), surprisingly, the apparently not so correlated data between total and hot water consumption from Figure 2 presents a strong correlation when averaged in the 3 years period (Figure 4). This implies that, with time, the inter-annual variability tends to fade of and while estimating the hot water consumption from the total water consumption in each year may present significant error, over several years the errors will tend to cancel.

Two equations are proposed to correlate hot water consumption with cold and total water consumption data, respectively. The last equation (Figure 4) is particularly relevant to predict hot water consumption in dwellings where only cold water is distributed and part is heated within the dwelling to fulfil the users requirements for hot water. In these cases, only the total water consumption is measured and the estimation of hot water consumption has to be done indirectly.

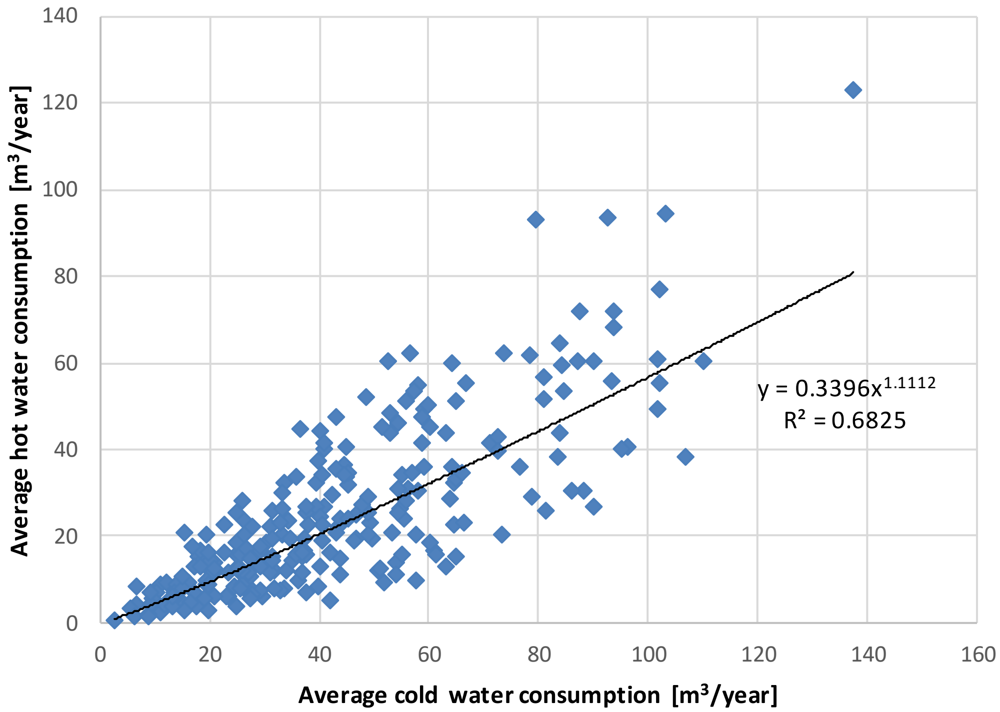

Figure 3 – Relation between yearly averaged cold and hot water consumption.

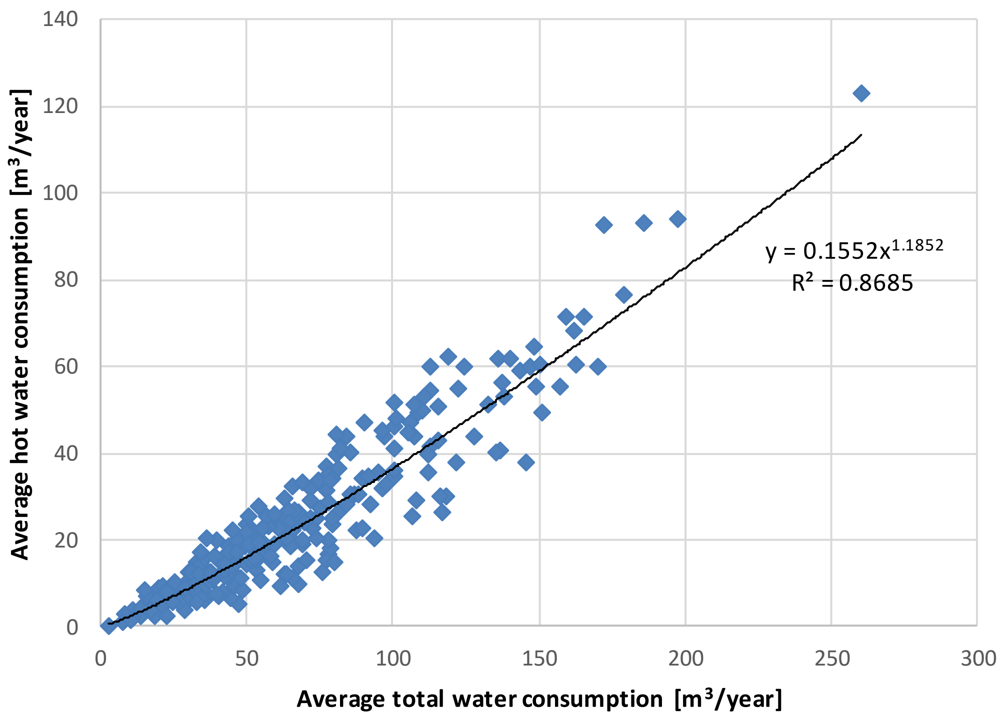

Figure 4 – Relation between yearly averaged total and hot water consumption.

The relation between cold water consumption and the hot water fraction (*hot water fraction = hot water consumption / cold water consumption*) was also explored (Figure 5). Similarly, in Figure 6 the hot water fraction is related with the total water consumption.

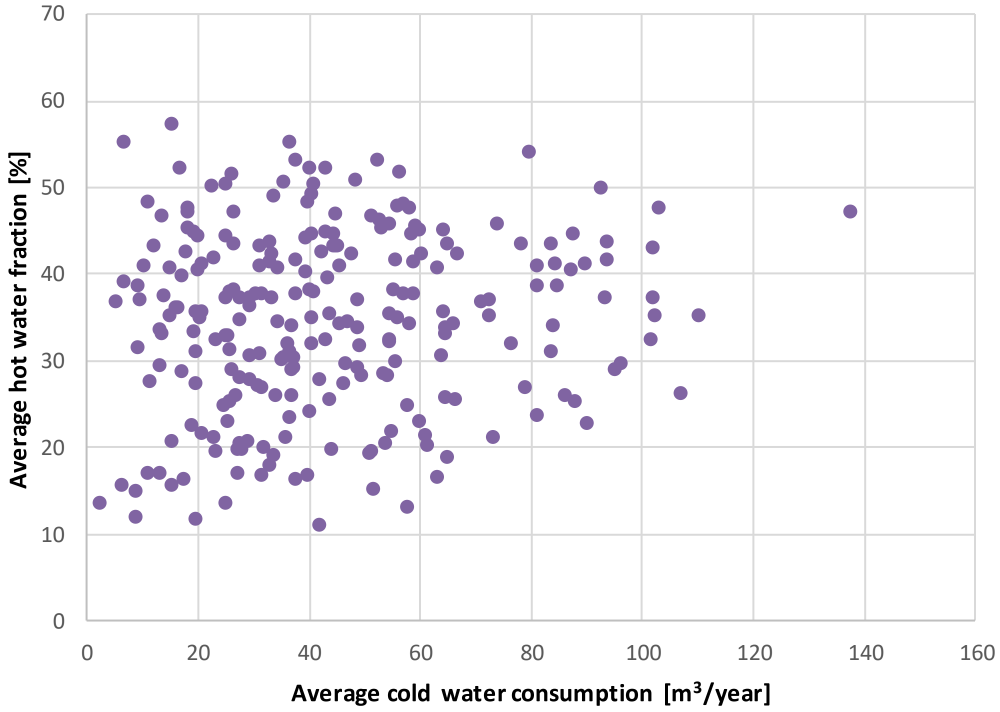

Figure 5 – Comparison between yearly averaged cold and hot water consumption.

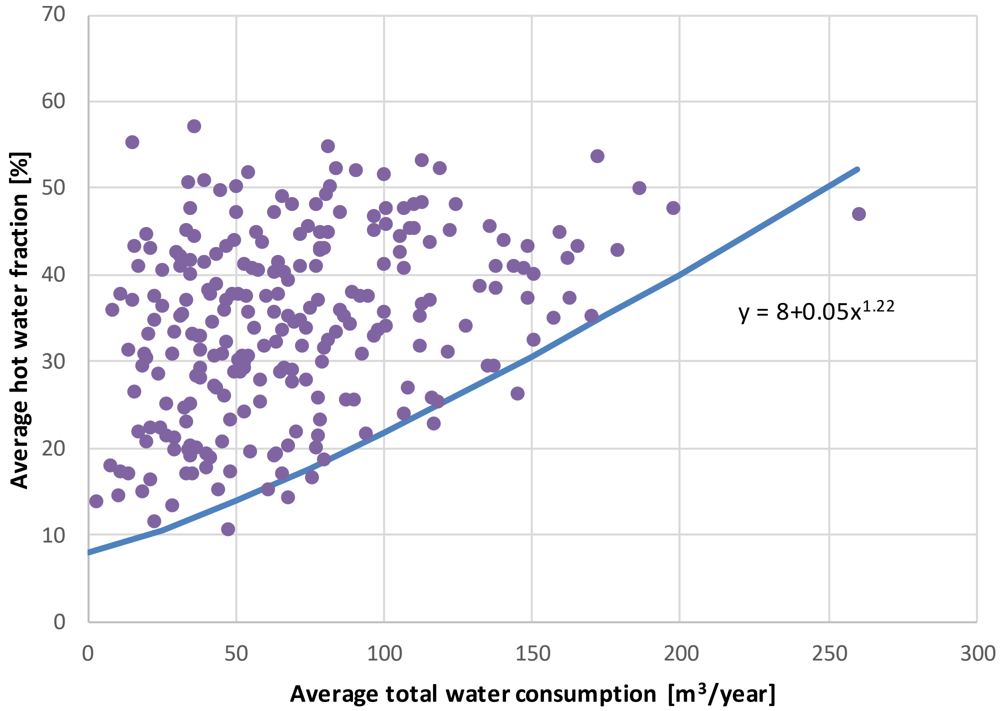

Figure 6 – Comparison between yearly averaged total and hot water consumption.

Although data is dispersed, it can be noticed that with the increase in cold and total water consumption, respectively, the minimum hot water fraction tends to increase, as can be observed by the frontier expression presented in Figure 6 for the latter situation. This reveals that with the increase in the total water consumption there is an increase in the average proportion of hot water.

4 Discussion and conclusion

In this study an analysis is performed in order to evaluate the pattern of hot water consumption in relation to cold and total water consumption. A significant correlation between both cold and total water consumption with hot water consumption is observed. The relation between total and hot water consumption is particularly strong and useful for countries where only the total water consumption per dwelling is measured. The expression proposed is particularly useful to enable water-energy nexus efficiency studies. Since hot water is mainly consumed in shower heads and kitchen taps, measures that directly reduce water consumption in these devices will directly reduce energy consumption, contributing to both water and energy efficiency.

Lastly, it can also be observed that smaller and larger water consumers do not have the same behaviour (see Figures 5 and 6), with the larger water consumers consuming more hot water, in proportion. This is a very useful information, namely to guide water governance strategies.

In conclusion, this study contributes to shed some light on the evaluation of residential water and energy consumption, providing a procedure to predict missing base data. This is essential for comprehensive water and energy efficiency studies, both in terms of technical and behavioural performance, with the intention to fulfil the requirements of the specific targets set by the European Commission in order to reduce greenhouse gas emissions and increase water and energy efficiency.

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