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WATER USE IN COLLECTIVE STUDENT HOUSING

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Abstract

Today, there is limited information available about actual cold and hot water use in collective student housing. Furthermore, equally little is known about how this water use is distributed throughout the day and how it is divided over all end users (e.g. toilet, shower, sink). Understanding water use at buildings is important because assessing the performance of existing buildings allows to better manage the water use, to identify opportunities to establish refurbishment interventions or to improve design standards for new buildings. Although some water use patterns can be found in standards and literature, it is not clear whether these water uses and water use patterns can be applied for collective student housing. By analysing the water use of the water meter from 2015 till 2020 and by performing short term measurements, water use of six collective student housing is presented. For four of the six collective housing the average water use per capita was lower than average residential water use in Belgium. The higher water use in the other buildings cannot immediately be explained. The first hypothesis is the presence of a leak, but is less likely. The second hypothesis is user behaviour. However, further research is needed to confirm these hypotheses. Furthermore, the share of water use for toilet flushing was in the order of magnitude of the values found in literature and the daily hot water use was in line with the values according to the national Standard.

Keywords: Water Use, Collective Student Housing, Hot Water Use, Total Water Use

1. INTRODUCTION

Concerns regarding the availability of crucial natural resources, amongst them water and energy, are growing rapidly due to excessive global consumption in every sector [1]. The European Union has identified the building sector as a key player in the fight against the wastage of water resources [2]. As residential, commercial, industrial, and other development expands, so does the use of the limited potable water supply[3]. One type of building that is expanding is student housing. The demand for student housing is consistently growing across Europe and worldwide [4]. For example, in 20 years the number of students in Ghent, Belgium increased by 34 000 (excluding exchange students), and while 59% of students live in student housing, only 3 800 recognized housing units for students were added [5]. To keep this demand for student housing, existing buildings are renovated, as well new buildings are constructed. Because natural resources are becoming more scare, several building owners have the ambition to build more sustainable. Besides, also a part of the student population demands better quality accommodation that corresponds to a sustainable lifestyle [6]. Regarding water use, sustainable student housing implies two things:

- The first is water use itself. In a world where access to clean potable water has become a global risk, no cause for waste is acceptable. This implies good water management and hereby avoiding water spill and leaks.
- The second is to decrease energy use related to water use. A share of the drinking water in the building is heated which requires energy. Thus besides water use in general, also the share of hot water use is important.

However, today, there is limited information available about actual cold and hot water use in collective student housing. Furthermore, equally little is known about how this water use is distributed throughout the day and how it is divided over all end users (e.g., toilet, shower, sink). Therefore, the overarching aim of this research is to gain insight into water use and water use patterns of student housing by assessing water use in existing student housing. Assessing the performance of existing buildings is crucial to meet the needs and expectations of both users and managers [7]. A better knowledge of water use allows to better manage the water use. Moreover, assessing the performance of existing buildings identifies opportunities to establish refurbishment interventions or to improve design standards for new buildings [7]. Furthermore, having more correct water tap profiles in the design phase will inevitably contribute to a more optimised dimensioning of cold and hot water systems. This allows to decrease system energy use (less distribution losses), to ensure comfort, and also decrease health risks of such systems. Namely, with an oversized system, there is more stagnation of water, resulting in higher *Legionella* risk.

This paper is organized as follows. Section 2 presents an overview of previous studies on water use in student housing. Also national standards are included. Section 3 describes the methodological framework proposed, followed by Section 4 in which the case study and results are presented. Section 5 presents the conclusions.

2. LITERATURE REVIEW

2.1. Types of student housing

Student housing are housing unit students stay in for the period of their studies. There are several types of student housing worldwide. However, this paper focusses on student housing in Belgium. In Belgium there are two main groups of student housing: non-collective and collective student housing [8]. The first group, non-collective student housing, consists of private houses where rooms are rented out to students. Most of the time the occupation of these houses is limited to ten students. As this type of student housing is not generic and lays close to a residential configuration, this paper will not focus on this type. The second group, collective student housing, contains the medium and large scale housing complexes, which made their advance in the last ten years. Collective student housing can be private or owned by a government agency such as an educational institution. The upcoming success of the companies such as Upkot, Brick and Xior, who built and manage collective student housing, contributes to the increasing professionalisation of the student housing market. Therefore, more and more students live in buildings with more than 50 units [9]. This typology of student housing will be the focus of this research.

In general collective student housing in Belgium consists of individual rooms. A division can be made based on the available facilities, i.e. self-contained rooms (flats and studios) and non-self-contained rooms. In both types a sink providing hot and cold water is present, but the difference depends on whether or not the other facilities, i.e. kitchen, bathroom and toilet, are shared [8]. The minimal number of shared showers and toilets is imposed in the standards for residential quality and fire safety for a student facility. Following the Flemish Housing Code [10], it is required to have at least one shared shower (or bath) for every ten students and one toilet per six students. The rental price of the room includes all costs except for the use of energy, water and telecommunications. That is why classically, in addition to the rent, an allowance is requested. This can be either an all-in price (fixed price) per month, or an individual calculation is made based on measured use. The second options implies that each room has its own meter for electricity, heating and water.

2.2. Water use and water system design

Two types of quantification of water use are of interest. The fist quantification of water use is the total water use, i.e. the sum of water used during a day or a month. Total daily or monthly water use provides information to estimate for instance the water use throughout the year. Besides total water use, the total hot water use enables to estimate monthly or yearly energy demand for water heating.

A second type of quantification of water use is a water use pattern (e.g. second or minute based) during a day or a part of a day. Designing hot water production systems that have storage tanks requires knowing the daily hot water use patterns. Design of instantaneous, semi-instantaneous and semi-accumulative hot water production systems, however, require a more refined hot water consumption pattern to identify peak demand. Also sizing of the distribution system requires knowledge of peak flows and simultaneity of use of tapping points.

In the following paragraphs water use found in literature and standards are presented. However, one must be aware of the gap between measured values and values presented in standards.

2.2.1. Total water use

Most of the studies found in literature deal with water use for single-family houses and apartment buildings [11-13]. The average value of water use for Europe is 128l/resident/day [14]. Hereby, it is important to notice that the total amount of water used might vary for different countries according to the different lifestyles of the people [15, 16]. In Belgium the average residential water use is 89.5 l/day/resident, varying from 108 l/day to 75 l/day depending on the size of the family.

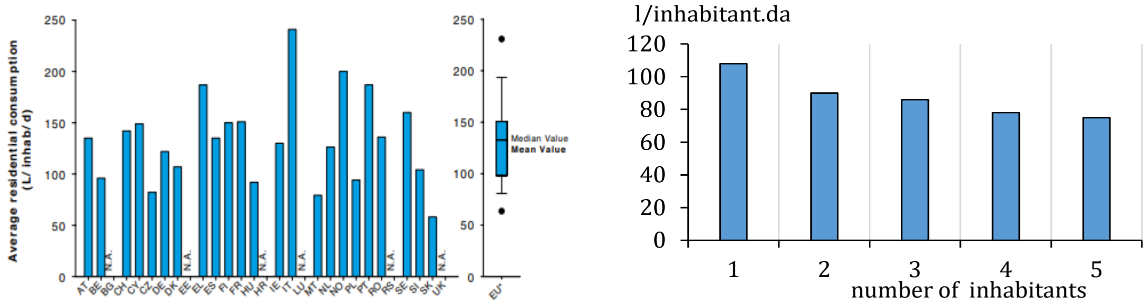

Figure 1. Left: Average daily water use per person in Europe [14]. Right: Average residential daily water use per person in Belgium related to the number of inhabitants [14]

Furthermore, some individual case studies of student housing were found. In a study of Lehman et al. [17], a student housing in Geneva is analysed. It consists of eight apartments that housed a total of 40 students. They observed that daily water use was similar to the residential sector: 123 l/student per day. Furthermore, water use showed to be about 30% lower during July - August and December due to a lower occupancy rate during university holidays. About half of the water (63 l/student per day) is used as hot water.

Similarly, KWR (The Netherlands) concludes that water use of a student housing is similar to residential use; the residential type "studio" in the national standard (ISSO 55 – 2013) can be used for student housing [18]. Furthermore, other studies also observe values around 100l/student per day was observed. For example, Valentukevičienė [19] observed 48 l/student per day for showering, and 31 l/student per day to flush the toilets. Besides, a small amount of residual water use (15%) was related to cooking, laundry, etc.

Regarding national standards (NBN EN 806-2 [20], NBN EN 12831-3[21]), who focus on design, no specific values for average daily cold and hot water use in student housing are provided. For hot water use, a possibility is to look at the daily hot water use of residential type "apartment dwelling" provided in NBN EN 12831-3, Annex B[21] Additionally, the AICVF [22] recommendation gives values for an apartment dwelling with one bedroom and for a boarding school. Both building typologies are not the same as student housing, but their water use may be an indication of the expected hot water need.

Table 1. Average daily hot water need at 60°C (l/person. day) according to national Standard NBN EN 12831-3 and AICVF [22]

	NBN EN 12831-3	AICVF
Apartment dwelling	25-30	50
Boarding school	-	40

2.2.2. Water use patterns and peak use

In most buildings, the demand for water, and also sanitary hot water, starts in the early morning. In some buildings, as is also to be expected in student housing, peak use occurs somewhat later, between 7 and 10 a.m. After that, consumption drops slightly and rises again in the midday when the kitchens are used. Use then slightly falls back. In the late afternoon, water use rises again due to cooking and the use of sanitary facilities like showers. It is expected that the consumption at night will go back to zero, or be occasional.

In the guidelines and standards, mainly water use patterns for hot water can be found, as these are used for sizing the hot water production. system. Water use patterns for total water use are scares. In the national standard, NBN EN 12831-3 [21], a water use pattern for the student housing typology is provided, illustrated in Figure 2. Figure 2 also present other hot water use profiles of residential use of the AICVF [22] (used in France) and of SIMDEUM (used in the Netherlands). The AICVF [22] recommendation is developed in France and presents methods to design hot water systems for residential (individual and collective) and non-residential buildings. They make a distinction between weekdays, Saturday and Sunday. SIMDEUM, developed in the Netherlands, is a stochastic simulation model that was used to arrive at new calculation rules for the dimensioning of sanitary water systems in dwellings and residential buildings in the Netherlands [23, 24].

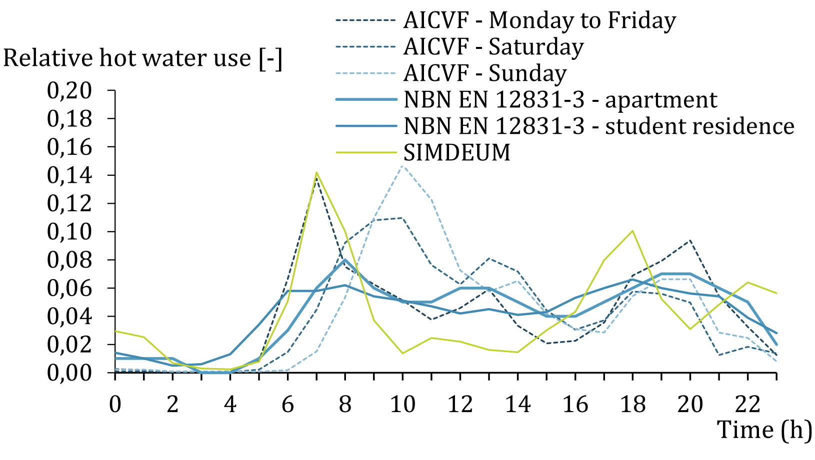

Figure 2. Water use patterns presented in different guidelines and standards

Since 2017, in Belgium the standard NBN EN 12831-3 [21] was published. As the default values for use pattern and peak flow stated in this standard do not always lead to an accurate sizing, the standard needs to be supplemented with a national annex. As this is still not available, there is referred to DIN 1988-300 standard and to DIN[25]. These residential values are a good starting point. However, as the configuration of collective student housing in Belgium slightly differs from theses described above and therefore it can be questioned whether equalizing water use to the residential water use is applicable.

Peak use is related to water use pattern as in the water use pattern a peak demand is present. In standards the peak flow is calculated based on the tap flow rate, the number of taps and a method to include simultaneity.

3. CASE STUDY

3.1. Description collective student housing

Six collective student housing of Ghent university are included in this study. All six buildings are located in Ghent, Belgium. Table 1 summarizes the room types of the collective student housing and shows the number of rooms or studios in the building. Three collective student housing consist of non-self-contained rooms, and three of them consist of self-contained rooms, with Building ID 6 being an exception as only the kitchen is shared. Table 2 elaborates on the private or shared facilities (shower, toilet, kitchen or lavatory), and if a lavatory is present. In case the facility is shared, the number of students per facility is indicated in brackets in the table.

Table 1. Overview of the studied collective student housing

Building ID	Rooms	Studios 1p	Studios 2p	Room Type
1	224	0	0	Non-self-contained
2	0	191	0	Self-contained
3	465	0	0	Non-self-contained
4	0	0	105	Self-contained
5	448	0	0	Non-self-contained
6	228	0	9	Self-contained

Table 2. Private and shared facilities in the collective student housing

Building ID	Shower	Toilet	Kitchen	Lavatory
1	Shared (4.0)	Shared (5.3)	Shared (8.0)	No
2	Private	Private	Private	Yes
3	Shared (7.3)	Shared (6.5)	Shared (14.5)	No
4	Private	Private	Private	Yes
5	Shared (5.3)	Shared (5.3)	Shared (16.0)	Yes
6	Private	Private	Shared (7.7)	Yes

3.2. Hydraulic systems

All six student housing are connected to the city water. On three of the six student housing (Building ID 2, 4 and 6) also rainwater is harvested. The other three student housing have only access to city water. The reason for this is that it concerns older buildings and that the refurbishment of the water distribution within the building has not yet been taken place and, moreover, there are no rainwater cisterns. However, since the policy is to focus as much as possible on sustainability, when refurbing these buildings in future it will be examined whether rainwater or greywater will be used. The rainfall is collected from roof areas and is filtered before use. The harvested water is reused in non-potable water demands such flushing toilets or irrigating the garden.

Hot water in all student housing is produced centrally and at basement level. Hot water is produced by one or two external heat exchangers. In case the rooms of the student housing are of the type "non-self-contained", a separate heat exchanger is used for the shared facilities and for the sinks in the rooms. The distribution system is a collective recirculation system, meaning hot water constantly circulates through the pipes, even when no water is drawn. Cold and hot water distribution pipes split at basement level and operate the different floors through the multiple technical shafts.

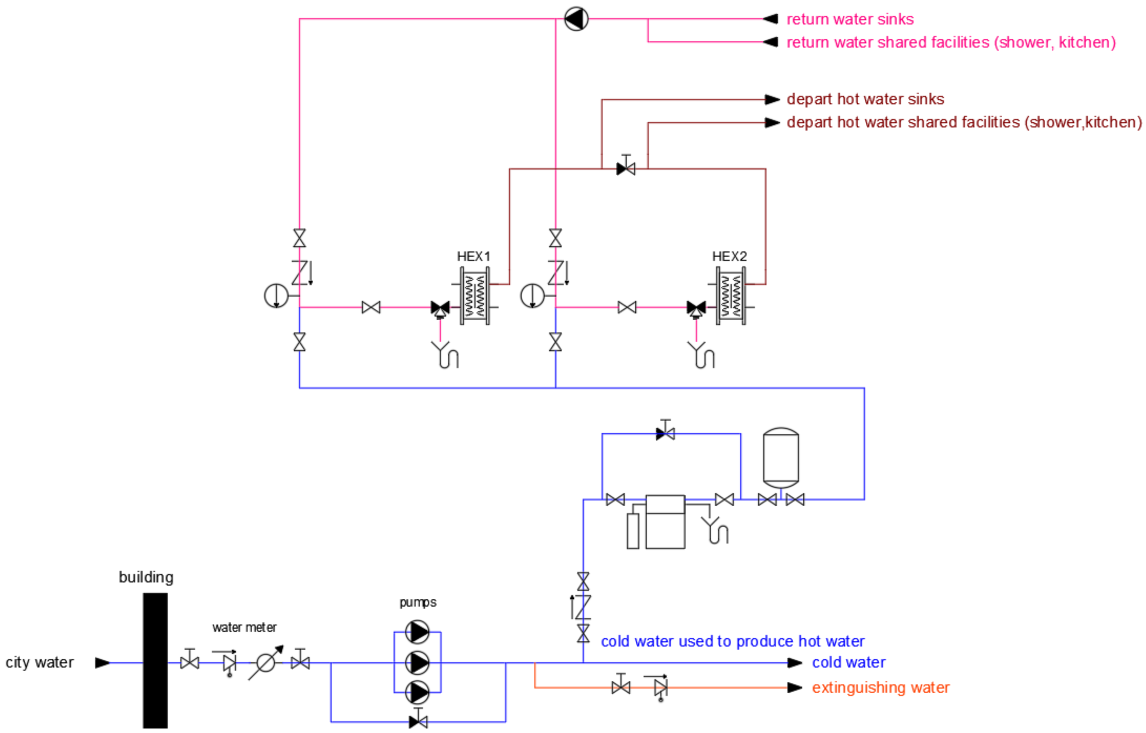

Figure 3. Schematic view of the hot and cold water flows in a student housing with non-self-contained rooms

4. METHODOLOGY USED TO DETERMINE WATER USE AND WATER USE PATTERN

Based on gathered information and measurements, total water use was determined. The number of students in the student housing was used to develop the liters per student per day (l/student.day) metric, used to compare the water performance of the different student housing. In addition to the total water use, the water use has been further analyzed, if measurement or data was available. A first division was made based on the source: city water or rain water. A further subdivision is related to the building use: cold water demand and hot water demand.

4.1. Data

Data was gathered from the Department of Infrastructure and Facility Management. The research methodology involves the collection of various data related to the water system, including hydraulic schemes, technical plans, flow fixture use values and water meter readings.

Water meters for each individual building are available and data is gathered on monthly basis. In addition to the data of the water meters, which measures the city water use, short-term measurements are conducted. The measurements include two parts. One part consists of measurements at building level. It includes flow rate measurements of the cold water that enters at building level and the flow rate of the cold water that is used for hot water production. The other part involves temperature measurements of hot and cold water distribution pipes at room and tap level. The flow rate measurements result in tapping profiles at building level and the temperature measurements provide detailed data about the frequency and duration of use of the individual tapping points.

4.1.1. Flow rate measurements

Flow rate measurements are performed using the Flexim Fluxus F601 ultrasonic flowmeter, see Figure 4. This device measures the volumetric flow rate of a liquid through a pipe by installing transducers at one side of the pipe and emitting an ultrasonic signal. Diameter, material and wall thickness of the distribution pipe are necessary input parameters for accurate measurements. Care was taken that the transducers are installed on clean pipes and acoustic coupling compound is used for better connection. The measurement interval of the ultrasonic flow meter is one second, this ensures detailed measurements of the flow rate [26].

4.1.2. Temperature measurements

HOBO external temperature data loggers are used for the temperature measurements. These devices have one or two external temperature sensors that can be attached to a hot or cold water pipe. Because the distribution pipes are made of PE or galvanized steel, and thus conduct heat, the temperature measured at the distribution pipes approximates the temperature of the water that flows through them.

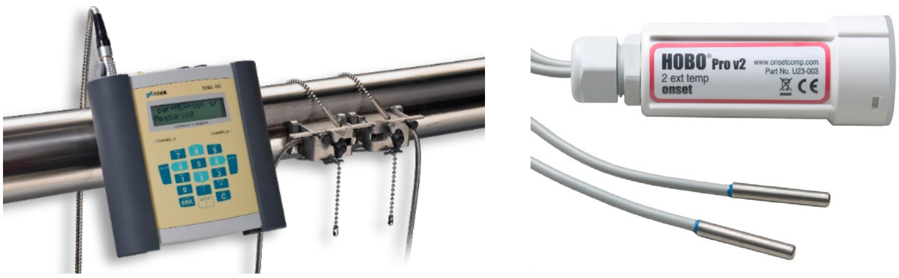

Figure 4. Left: Flexim Fluxus F601 ultrasonic flowmeter for liquids, device and transducers attached to a distribution pipe [27]. Right: HOBO external temperature data loggers

5. RESULTS AND DISCUSSION

5.1. Water use

5.1.1. Average water use

On the basis of the collected data of the water meters, water use is calculated for the years 2015-2020. It can be noted that the total water use in 2020 is lower for most of the student housing. This is due to the COVID19 pandemic. As 2020 is not representative for the water use, data from 2020 is excluded. Average water use per capita for the period 2015-2019 is highest in Building ID 2 and 6 with a value of 96 and 148l/student per day. This is almost double or triple the water use of the other student housing. The average water use per capita across the four housing types is 64, 50, 64 and 50l/student per day. Therefore, for four of the six collective housing the average water use per capita was lower than average residential water use is 89.5 l/day/resident.

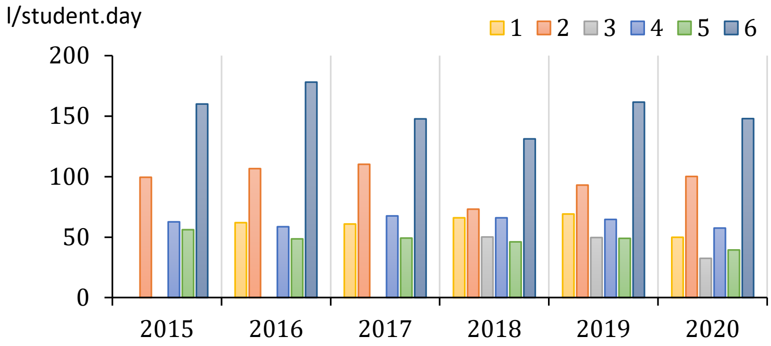

Figure 5. Yearly water use for the six student housing from 2015 till 2020

The higher water use in Building ID 6, and in Building ID 2 cannot immediately be explained. There are several hypotheses, but these still need to be studied. A first hypothesis is the presence of a possible leak. Various measurements are taken to search for possible leaks (water softener, leaking taps, etc.), but so far no leak has been identified. A second hypothesis is user behaviour. User behaviour includes different aspects. A first possibility is the difference in self-contained rooms having a private shower, as in building ID2, 4 and 6 and shared showers. A second possibility is whether the building houses national or international students. Building ID 6 is inhabited by mainly international students, in contrast to the other student housing. Unlike national students, they do not go home during weekend or on national holidays like Pentecost. Figure 6 shows the water use, measured with the flow meter, for student housing ID5 and ID6 from Thursday 11th of November till Tuesday 16th of November. Thursday 11th of November is an national holiday. Based on this short-term measurement, the figure shows that student housing ID 5 has significantly lower consumption on weekends and the public holiday. For student housing ID 6 there was no significant difference. Furthermore, when questioning the students, students who only stay in the student housing during the week do their laundry at home. Besides, they also cook less because, for example, meals are brought from home. A third possibility, is the difference in water use between different nationalities. Further research is needed to confirm these hypotheses.

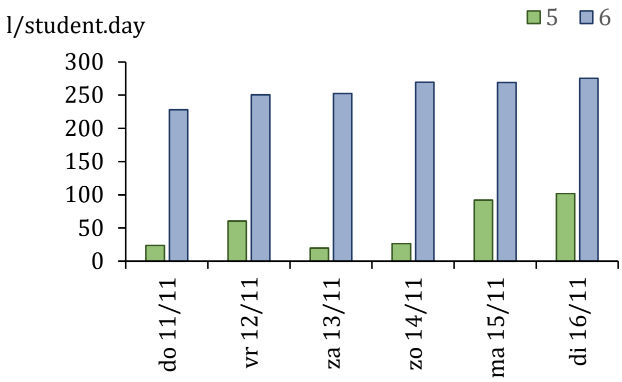

Figure 6. Measured water use for student housing ID5 and ID6 from Thursday 11th of November till Tuesday 16th of November

5.1.2. Seasonal effects

The average monthly water use in individual months for the analysed years (2015 till 2019) is presented in Figure 7. The figures shows that the water use throughout the year is diversified. During the academic year, i.e. from September till June, the water use is more or less similar. No significant increase or decrease is noticed during the months involving examinations (January and June). Low water consumption is registered for the months with holidays, i.e. July, August and December. For student housing 2, first a high use for December was observed, similar to the use of student housing 6. This was due a very high use in December 2017 and December 2018. In case these outliers are excluded, student housing 2 has also a decrease in the month December.

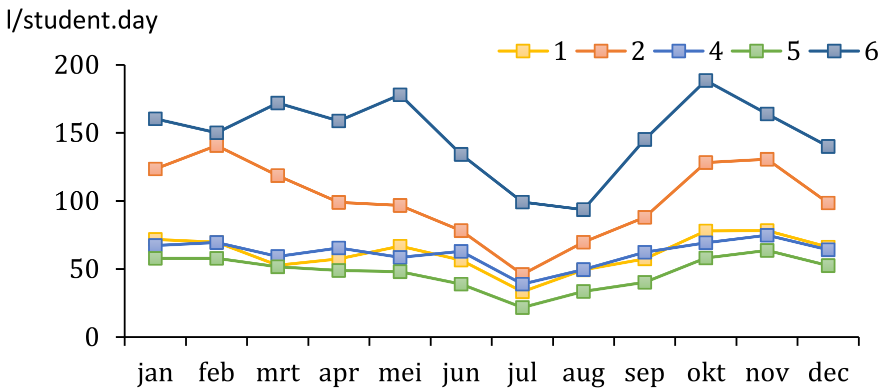

Figure 7. Yearly water use for the six student housing in the years 2015 till 2019

5.1.3. Water source

Figure 8 shows the amount of harvested rainwater and used city water for the student housing where rainwater is monitored, building ID 2 and building ID6. Furthermore, the amount of rainwater per year is illustrated. Over the period 2015-2020, the share of harvested rainwater in Building ID 2 is 23.4%. In building ID 6 it is 4.3%. The difference is explained by the size of the rainwater storage tank in relation to the number of users. Building ID2 has a storage tank of 280m^3 for 191 users, while building ID 6 has a storage tank of 160m^3 for 551 users.

Looking at the yearly evolution, it can be seen that building ID 2 follows the course of the amount of rainwater [28]. In building ID 6 the amount of harvested rainwater decreases per year, this is due to the fact that the system performance deteriorates.

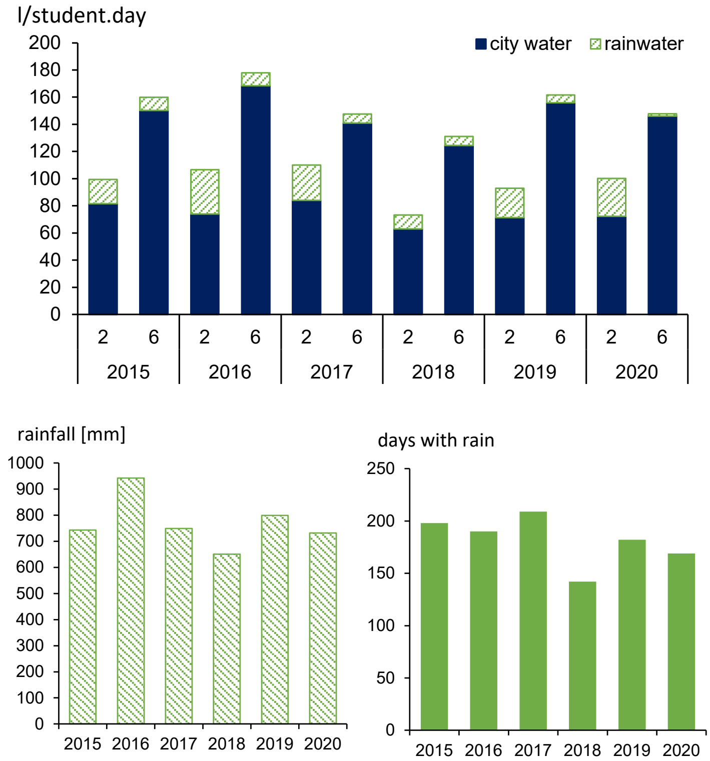

Figure 8. Above: *City water and rainwater use in Building ID 2 and 6.* Below: *Rainfall in a year [mm/year] and days with rain[28]*

5.1.4. End use of water

For Building ID2 and Building ID6 the share of water that is used for toilet flushing is analysed. The share of water use is very similar for both buildings; 38,6% and 37,4%. This is in the order of magnitude of the values stated by Valentukevičienė [19]. Both buildings also use rainwater for toilet flushing. For building ID2, 58.2% of the water use for toilets is covered by harvested rainwater, for building ID6, this is 13.1%. As explained in the previous paragraph is this because the size of the rainwater storage tank in relation to the number of users.

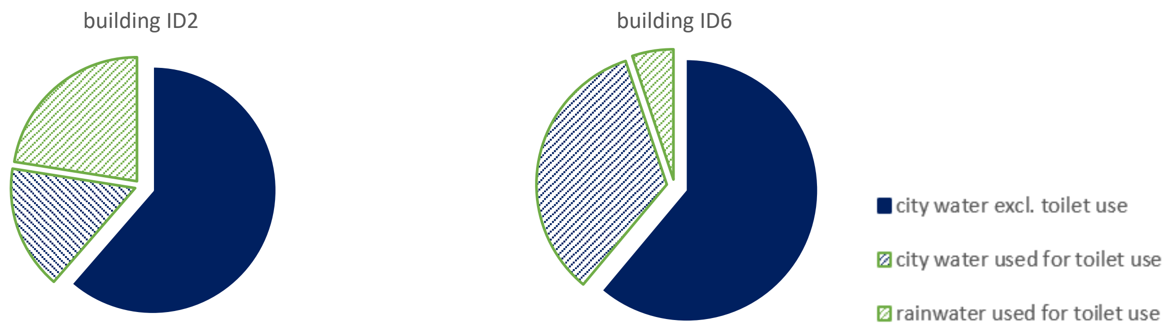

Figure 9. City water and rainwater use in Building ID 2 and 6

The share of hot water use could not be derived from the water meters, but is derived from short-term measurements. Figure 10 shows the amount of city water that serves as cold water or that is used to produce hot water in student housing ID1, 4 and 5. The hot water is used for showering and for water use at the washbasin. It should be noted that this concerns water produced at 60 °C.

The water use when using the shower or washbasin will therefore be higher, as cold water is added at the tap to reach a temperature of approximately 40 °C. The average hot water use per student per day measured 19, 27 and 34 l. The order of magnitude of these values are in line with the values according to national Standard NBN EN 12831-3 [21] or AICVF [22].

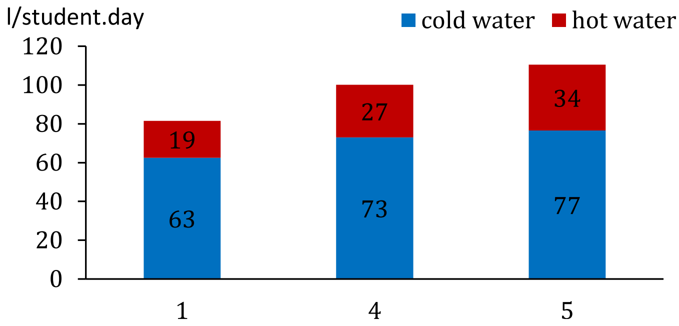

Figure 10. City water and rainwater use in Building ID 2 and 6

5.2. Water use pattern

The last part of this preliminary study on water use in collective student housing consists of detailed flow rate measurement. Currently the measured data is limited. However, the aim now is to observe if the water use pattern matches the expected pattern. Figure 11 illustrates the total water use and hot water use pattern in Building ID 1 and the total water use in Building ID 5.

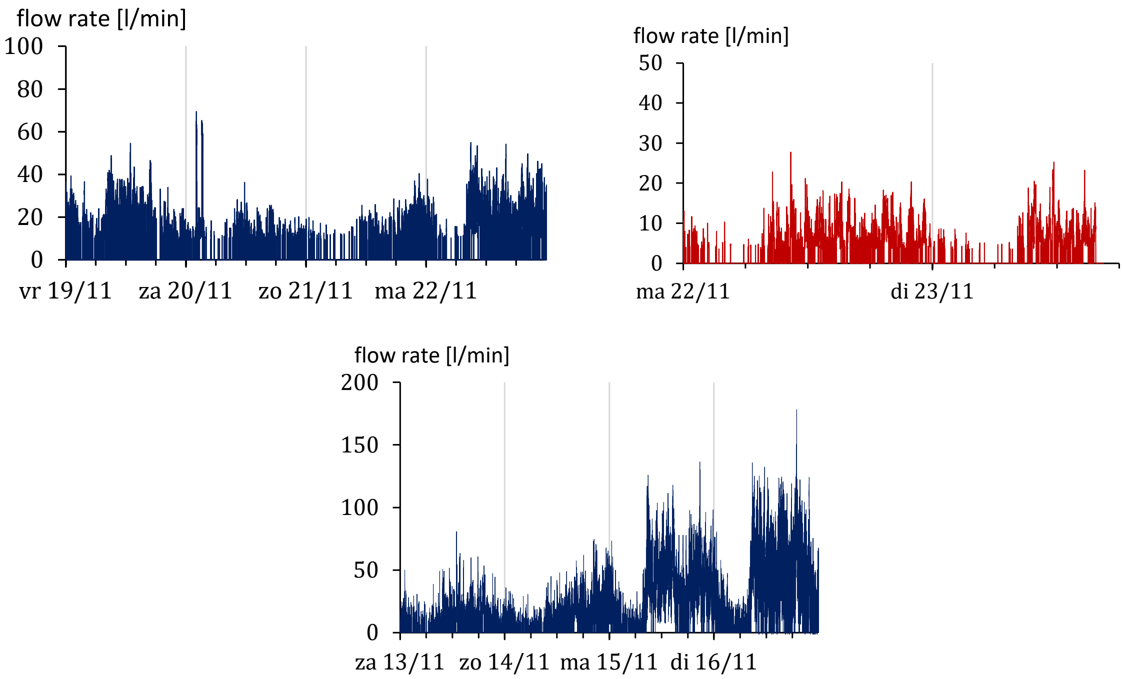

Figure 11. Water use pattern in Building ID 1 and Building ID 5

Based on the current measurements, there is a noticeable difference between day and night. During night, the water use drops to zero. However, looking at the flow rate measurement of the city water supply, there is still regular use at night; i.e. peaks of 10 to 20 l/min. For hot water, these peaks are less frequent, but there still is hot water use during night. In the morning, there is as expected a considerable increase in total and hot water use. The use throughout the day varies rather little, as is the case with the water use pattern from NBN 12931-3. Further measurements are required before generic conclusions could be drawn.

6. CONCLUSIONS

Understanding water use at buildings is important because assessing the performance of existing buildings allows to better manage the water use, to identify opportunities to establish refurbishment interventions or to improve design standards for new buildings. The outputs of the study include water use, temporal variations in water use, and end use of water of collective student housing. Data for water use had been gathered and analysed for six collective student housing. The following conclusions can be drawn on the basis of the conducted work:

1. For four of the six collective housing the average water use per capita was lower than average residential water use is 89.5 l/day/resident. The higher water use in the other buildings cannot immediately be explained. There are several hypotheses raised. The first is the presence of a leak. The second hypothesis is user behaviour. However, further research is needed to confirm these hypotheses.
2. The share of water use for toilet flushing was very similar for both buildings; 38,6% and 37,4%. This is in the order of magnitude of the values stated by Valentukevičienė [19].
3. In the short term period being analysed, the order of magnitude of hot water is in line with the values according to national Standard NBN EN 12831-3 [21] or AICVF [22].
4. In the short term period being analysed, a noticeable difference in water use is observed between day and night. In the morning, there is as expected a considerable increase in total and hot water use. The use throughout the day varies rather little, as is the case with the water use pattern from NBN 12931-3.

The study in this work was limited to only six collective student housing. Furthermore, detailed analyses of water use patterns and water end use is limited. For this reason, in the future work, there will be in first instance measured for longer periods and in second instance in a larger amount of collective student housing. For a larger amount of data, the application of different clustering methods for the analysis of water and hot water use will be tested. In addition, the user behaviour will be questioned.

7. ACKNOWLEDGMENT

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