Supporting Information:

Simulating the Impact of Water Demand Management Options on Water Consumption and Wastewater Generation Profiles

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This document consists of 41 pages, 7 Tables and 28 Figures.

Table of Contents
S1 Water-efficient appliances.................................................................................................................. 6
  S1.1 Water-efficient toilets .................................................................................................................. 6
  S1.2 Taps .................................................................................................................................................. 7
  S1.3 Dishwashers and washing machines ............................................................................................. 7
  S1.4 Shower heads .................................................................................................................................. 7
S2 Influencing factors on water consumption ......................................................................................... 7
  S2.1 Influence of weekday ...................................................................................................................... 8
    S2.1.1 Influence of weekday on toilet usage .................................................................................... 9
    S2.1.2 Influence of weekday on tap usage ...................................................................................... 11
    S2.1.3 Influence of weekday on shower usage ................................................................................. 11
    S2.1.4 Consistency of usage throughout the week .......................................................................... 12
  S2.2 Influence of the season on water consumption ........................................................................... 13
  S2.3 Influence of household characteristics on water consumption ................................................ 14
    S2.3.1 Influence of occupancy on water consumption ................................................................. 15
    S2.3.2 Influence of the household type on water consumption .................................................... 16
S3 Diurnal variations of water consumption ......................................................................................... 19
S4 Diurnal variations of wastewater discharge ...................................................................................... 25
S5 Break-down of water consumption based on different water use appliances ................................... 31
S6 Diurnal variations of water consumption when a greywater recycling system is installed .............. 37
S7 Calculation terms in Scenarios ‘Very efficient’ and ‘Efficient’ ......................................................... 39
S8 distribution of households by dwelling type and occupancy ............................................................... 39
S9 Aspects and parameters considered in the simulation tool ............................................................... 42
S10 Tool components ................................................................................................................................. 43
  S10.1 User interface ................................................................................................................................ 43
  S10.2 Database ....................................................................................................................................... 43
S11 Dataset .................................................................................................................................................. 44
  S11.1 Random dataset (large-scale study) ............................................................................................. 44
  S11.2 Time series dataset (small-scale study) ....................................................................................... 44
S12 References .......................................................................................................................................... 47
List of Tables

Table S1: Frequency of water consumption (per person per day) .......................................................... 8
Table S2: Uses of appliances throughout week (in % of the weekly number of uses from a given appliance)........................................................................................................................................... 12
Table S3: Appliance usage (in uses/person.day, except the tap in L/person.day) ................................. 13
Table S4: Comparison of the calculation terms in Scenario ‘Very efficient’ with those in Scenario ‘Efficient’.......................................................................................................................................................... 39
Table S5: Distribution of households in the large-scale survey by dwelling type and occupancy ....... 39
Table S6: Distribution of households in the small-scale survey by dwelling type and occupancy....... 40
Table S7: Per capita consumption versus household occupancy................................................................. 42
Table S7: Example aspects analysed in the simulation tool ......................................................................... 42
List of Figures

Figure S1: Influence of weekday on the diurnal variations of wastewater discharge: (a) from toilets in the small-scale survey; (b) from toilets derived from the large-scale survey; (c) from taps in the small-scale survey; (d) from taps derived from the large-scale survey; (e) from showers in the small-scale survey; and (f) from showers derived from the large-scale survey ................................................................. 10

Figure S2: Influence of season on the diurnal variations of wastewater discharge: (a) from toilets derived from the small-scale survey; (b) from taps derived from the small-scale survey; and (c) from showers derived from the small-scale survey ........................................................................................................ 14

Figure S3: Relationship between household occupancy and number of uses per household per day for (a) toilet; (b) shower; (c) washing machine; and (d) dishwasher ......................................................................................... 15

Figure S4: Frequencies of appliance usages for (a) baths, showers, washing machines and dishwashers according to occupancy; (b) tap (water consumption per household); and (c) toilets according to occupancy ................................................................................................................................ 17

Figure S5: Frequencies of appliance usages according to dwelling type (a) for baths, showers, washing machines and dishwashers per household; (b) for tap (water consumption per household); (c) for toilets per household; (d) for baths, showers, washing machines and dishwashers per capita; (e) for tap (water consumption per capita); and (f) for toilets per capita ......................................................................................................................... 18

Figure S6: Diurnal variations of water consumption when dual-flush toilets are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more .............................................................. 19

Figure S7: Diurnal variations of water consumption when low-flow taps are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more .............................................................. 20

Figure S8: Diurnal variations of water consumption when water efficient baths are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more .............................................................. 21

Figure S9: Diurnal variations of water consumption when shower restrictors are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more .............................................................. 22

Figure S10: Diurnal variations of water consumption when water-efficient washing machines are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more .............................................................. 23

Figure S11: Diurnal variations of water consumption when water-efficient dishwashers are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more .............................................................. 24
Figure S12: Diurnal variations of wastewater discharge when dual-flush toilets are installed for: (a) the group of 1 occupant; (b) the group of 2 occupants; (c) the group of 3 occupants; (d) the group of 4 occupants or more; and (e) the whole group........................................................................................................................................ 25

Figure S13: Diurnal variations of wastewater discharge when low-flow taps are installed for: (a) the group of 1 occupant; (b) the group of 2 occupants; (c) the group of 3 occupants; (d) the group of 4 occupants or more; and (e) the whole group........................................................................................................................................ 26

Figure S14: Diurnal variations of wastewater discharge when water efficient baths are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group........................................................................................................................................ 27

Figure S15: Diurnal variations of wastewater discharge when shower restrictors are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group........................................................................................................................................ 28

Figure S16: Diurnal variations of wastewater discharge when water-efficient washing machines are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group........................................................................................................................................ 29

Figure S17: Diurnal variations of wastewater discharge when water-efficient dishwashers are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group........................................................................................................................................ 30

Figure S18: Water consumption breakdown based on different water use appliances in Scenario 'Efficient' when dual-flush toilets are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.......................................................................................................................................... 31

Figure S19: Water consumption break-down based on different water use appliances in Scenario 'Efficient' when low-flow taps are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.......................................................................................................................................... 32

Figure S20: Water consumption break-down based on different water use appliances in Scenario 'Efficient' when water efficient baths are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.......................................................................................................................................... 33

Figure S21: Water consumption break-down based on different water use appliances in Scenario 'Efficient' when shower restrictors are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.......................................................................................................................................... 34

Figure S22: Water consumption break-down based on different water use appliances in Scenario 'Efficient' when water-efficient washing machines are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.......................................................................................................................................... 35

Figure S23: Water consumption break-down based on different water use appliances in Scenario 'Efficient' when water-efficient dishwashers are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.......................................................................................................................................... 36

Figure S24: Diurnal variations of water consumption for the households with 1 occupant when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices)........................................................................................................................................ 37

Figure S25: Diurnal variations of water consumption for the households with 2 occupants when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices)........................................................................................................................................ 37
**Figure S26:** Diurnal variations of water consumption for the households with 3 occupants when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices) ................................................................. 38

**Figure S27:** Diurnal variations of water consumption for the households with 4 occupants when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices) .............................................................................................. 38

**Figure S28:** Distribution of water consumption by different appliances (a) according to dwelling type; (b) in different studies/years.............................................................................................................. 41

**Figure S29:** Distribution of household water consumption: (a) established in Edwards and Martin (1995); (b) reported in Butler and Memon, (2005); (c) determined in Fidar et al. (2010); (d) reported in Makki et al. (2013); (e) reported in Bello-Dambatta et al., (2014), (f) stated in Happold (2019) without efficiency measures, (g) reported in Happold (2019) with efficiency measures and (h) derived from the random dataset in this study. ........................................................................................................................................ 46

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**S1 Water-efficient appliances**

In this study we considered a range of water-efficient (water-use) appliances e.g. WCs, water taps, dishwashers, washing machines and showers:

**S1.1 Water-efficient toilets**

The easiest solution for decreasing water consumption from toilets is in reducing the cistern volume and can be achieved by inserting a heavy bag inside or introducing a cistern dam. According to manufacturers, this type of solution could yield up to 50% of water savings for toilets use. As this solution is cheap and easy to install, it can be adopted as a water reduction measure in buildings that are already in use.

Low-flush toilets also reduce water consumption. They range from dual-flush toilets to compressed air toilets. Dual-flush toilets were allowed recently in the UK and could yield significant water savings, as long as people use them correctly. If it is assumed that a person uses 4 half flushes and one full flush a day (See leaflet on water-efficient WCs and retrofits), a 3/6 litre nominal toilets will consume on average 3.6 L/use. As cisterns start to refill while flushing has not ended, more water than the nominal volume is often consumed. WCs with delayed action inlet valve do not present this increase in water consumption and could then save water, from 1.4 to 3.5 litres/flush, depending on the water pressure in pipes (EA,
Vacuum or compressed air toilets use air rather than water to remove waste. They are claimed to consume 1.2L/flush, but their high costs could prevent their installation.

Waterless toilets lead to the largest reduction in water consumption from WCs. The main systems are incinerating and composting toilets. The first system uses a great amount of energy and prevents it from being cost-effective in a household. The second system requires a composting chamber. Liquid waste is removed every few months, while ‘solid waste are removed every few years’. These wastes could be used as fertilizers for ornamental plants.

### S1.2 Taps

In households, installing low-flow taps and tap restrictors could reduce tap consumption. In low-flow taps, water is forced out ‘in the form of a mist or is mixed with air bobbles’. Thus, the amount of water is still sufficient to wash one’s hands, but water consumption is reduced. Tap restrictors consist of restrictor valves fitted directly to the stem thread of the tap within the pipe system. They keep flow at taps constant, even if supply pressure varies. Fidar et al., (2017) assessed the performance of a range of water taps and reported that the water use of these water efficient basin taps range from 1.7 to 8.6 l/min while that of kitchen taps vary between 2.0 and 12.0 l/min.

### S1.3 Dishwashers and washing machines

Water-efficient dishwashers and washing machines should keep suitable cleaning performance. Machines incorporating fuzzy logic based control system are estimated to present the lowest water consumption, as they are able to adjust water consumption to the load of clothes. Very efficient dishwashers consume 8 l/use, while water-efficient washing machines consume 39 l/use on average (Fidar et al., 2010, 2017).

### S1.4 Shower heads

Water consumption through shower in old and new properties is significantly different (Fidar, 2011); this is due to the installation of water efficient shower heads. The principle is the same as for water efficient taps. Manufacturers quoted in EA, (1999) stated that shower restrictors could save up to 50% of the water consumption. Environmental Agency has divided showers available in the UK into three main types: electric showers (e-showers), low-pressure gravity fed showers and mains-pressure or power showers (EA, 2003). The typical flow rates of e-showers vary from 3 to 8 l/min, whereas, those of the other two types of shower range from 3 to 15 l/min (Fidar, 2011).

### S2 Influencing factors on water consumption

Here we present and discuss the results showing the influence of different water consumption factors, reported in the literature or identified in this study:
S2.1 Influence of weekday

A number of studies reported that people generally have different activities on weekdays and on weekends. Butler, (1993) showed that weekdays have an impact on water consumption; in particular the pattern of usage was found different, especially pertaining to the time and magnitude of usage during the morning peak. Mostafavi et al., (2018) in their study monitored over 700 homes for different appliances. They have reported that the variation between different types of appliances in weekdays and weekends are significant in terms of number, time and magnitude of the peaks during both. Matos et al., (2013) reported that water consumption in weekday and weekend is different due to changes in people’s habits and behaviour; however, they have reported that the variation is not very significant. In this study, the small-scale survey took place during two complete weeks, therefore enough data was available to estimate differences in uses of water-related appliances between weekdays and at the weekend. Patterns of wastewater discharge for weekdays and weekends were also derived from the random dataset, even though its nature was different from the small-scale survey. Information available on large-scale study revealed that the encompassed surveys had different durations, ranging from less than one week to more than one month in total. As data was randomly extracted to generate the dataset for the large-scale survey, days of records were not likely to be consecutive and certain days of the week might have been represented more than others. Processing of this data showed however that around 14% of the total events were recorded each day of the week and that the distribution in the number of events recorded was quite close to that of the small-scale survey.

As illustrated in Table S1, water-related appliances are used more often at the weekend than on weekdays in the small-scale survey. Higher frequency of toilet and tap usages may come from longer stay at home during weekends, while higher frequency of bath and shower usages could have its origin in the increase in leisure time during weekends. Washing machines are more used during weekends, and this could be explained by the increase of time for cleaning activities. The highest frequency of dishwasher use might come from the fact that people are more likely to have lunch at home.

Table S1: Frequency of water consumption (per person per day)
| Appliances (units) | Weekday | Weekend |
|-------------------|---------|---------|
| Toilets (times)   | 4.03    | 4.54    |
| Tap (minutes)     | 8.2     | 11.3    |
| Bath (times)      | 0.30    | 0.34    |
| Shower (times)    | 0.59    | 0.64    |
| Washing machine (times) | 0.24 | 0.33 |
| Dishwasher (times) | 0.18    | 0.38    |

Diurnal variations of wastewater discharge are also likely to vary between weekends and weekdays. To estimate the impact of these variations on wastewater treatment plants or receiving watercourses, it might be useful to analyse them according to the day of the week. The next section will present the diurnal variations of wastewater discharge from toilets, showers, and taps, since a great amount of data was available to examine the influence of weekday on wastewater discharge.

Figure S1 illustrate the diurnal variations of wastewater discharge derived from both surveys. The ordinates of the figures derived from the small-scale survey are frequencies in uses per 10 minute per 100 person, as used in Butler, (1993) and Butler and Memon, (2005). The ordinates of the figures derived from the large-scale survey are percentages of the daily discharge of wastewater recorded in the random dataset.

**S2.1.1 Influence of weekday on toilet usage**

Figure S1(a) and Figure S1(b) show the diurnal variations of wastewater discharge from toilets, derived from the small-scale survey and the large-scale survey respectively. Both figures illustrate that a major peak of wastewater discharge from toilets occurs in the morning, at about 07:30 on weekdays and about 09:00 at the weekend. During weekdays, one or two minor peaks appear in the evening, at about 22:30 in both surveys, and also around 19:00 in the large-scale survey. Minor peaks of similar levels take place consistently between 10:30 and 23:30 hours at the weekend on both figures.

The results show that the morning peak appears between 07:00 and 08:00 hours on weekdays and its value is about 7.5 uses/10min/100hd, which is quite close to the result from the small-scale survey. At the weekend, the morning peak takes place between 08:30 and 11:00 hours, reaching the value of 6 uses/10min/100hd. The morning peak in this study is then more widespread than the one in the small-scale survey.
Figure S1: Influence of weekday on the diurnal variations of wastewater discharge: (a) from toilets in the small-scale survey; (b) from toilets derived from the large-scale survey; (c) from taps in the small-scale survey; (d) from taps derived from the large-scale survey; (e) from showers in the small-scale survey; and (f) from showers derived from the large-scale survey.

The variations of wastewater discharge from toilets in the small-scale survey seem coherent with people habits. These variations may indicate that the participants get up later at the weekend. The participants could have used their toilets more at the weekend, because working people are more likely to be home during this period of the week. The last evening peak occurs at the same time in both periods in the week. This may indicate that the participants prepared for bed at the same time, whatever the day.

Findings on the diurnal variations of wastewater discharge from toilets show that the weekday has an influence on water consumption, hence wastewater discharge. The next section investigates the influence of weekday on tap usage.
S2.1.2 Influence of weekday on tap usage

Figure S1(c) and Figure S1(d) illustrate a time lag between the morning peaks on weekdays and at the weekend, as for toilets, reinforcing the idea that participants get up later at the weekend. In both surveys, the value of the morning peak is significantly higher at the weekend, maybe because food preparation for (proper) breakfast is likely to take place on the weekend. A second quite significant peak appears, at the weekend, between about 12:30 and 14:00 hours in the small-scale survey and between about 12:00 and 13:30 hours in the large-scale survey. Activity on weekdays is quite low between about 11:30 and 15:30 hours in both surveys. This situation should correspond to households where most of the occupants are away from home at lunchtime during the week, but gather at the weekend for lunch. Peaks also appear in the evening. Wastewater discharge is more widespread at the weekend in the small-scale study, while it is the contrary in the large-scale survey.

Wastewater discharge from basins presents a major peak in the morning on weekdays (at 08:00 hours) and at the weekend (between 08:00 and 11:00 hours). Between about 10:00 and 17:00 hours, activity is fairly stable, as in both of the present surveys. Two minor peaks take place between about 17:00 and 23:00 hours, presenting a pattern resembling more to that of the small-scale survey. Wastewater discharge from sinks follows a different pattern; while fairly consistent between 08:00 and 23:00 hours at the weekend, activity during weekdays peaks at about 18:30 hours and at about 08:00 hours. The peak at 18:30 hours is higher than the one at 08:00 hours. Minor peaks are observed between these two peaks on weekdays.

The diurnal variations of wastewater discharge from taps also show that weekdays influence water consumption. Differences between weekdays and weekends are even more visible for taps than for toilets in the evening.

S2.1.3 Influence of weekday on shower usage

The diurnal variations of wastewater discharge from showers derived from the surveys are presented in Figure S1(e) and Figure S1(f). Morning peaks do not occur at the same times on weekdays and at the weekend, as seen for toilets and taps. Activity from showers peaks between about 07:00 and 09:00 hours on weekdays and between 08:00 and 10:30 hours at the weekend. In the small-scale survey, the major morning peak at about 09:00 hours is followed by a slightly lower one, around 10:30 hours at the weekend. This could mean that some participants get up later than others at the weekend. This situation could also explain the minor peak of wastewater discharge from taps observed at about 10:00 hours, at the weekend, in the small-scale survey. Wastewater discharge from showers is fairly low between 11:00 and 17:00 hours on weekdays and at the weekend. The major evening peak takes place at the same time in the small-scale survey. In the large-scale survey, it occurs about 2 hours before at the weekend. Evening peaks of wastewater discharge from showers are higher at the weekend than during weekdays.

The diurnal variations of wastewater discharge from showers seem to confirm that two periods of main activity related to personal hygiene take place, in the morning and evening, both on weekdays and at the weekend. Significant differences in values and times of peaks of activity between weekdays and weekends illustrate the influence of the weekday on water consumption. The diurnal variations of wastewater discharge from toilets, taps, and showers show that they are different on an average weekday.
and on average day of the weekend. The next section will further investigate the influence of the weekday, by examining the distribution of usage frequencies for each appliance throughout the week.

S2.1.4 Consistency of usage throughout the week

Table S2 illustrates the distribution of appliance usages throughout the week. The weight of one use in the weekly total of uses is also given for reference. All the figures were derived from the number of uses per day, except for the tap. For taps, they were derived from durations of usage for this appliance. The distribution of uses from toilets, taps, showers and baths was available from both surveys, while the distribution of uses from washing machines and dishwashers was only derived for the small-scale survey.

Table S2: Uses of appliances throughout week (in % of the weekly number of uses from a given appliance).

|          | Toilets | Tap ('R-M') | Bath | Shower | Washing machines (S) | Dishwasher (S) |
|----------|---------|-------------|------|--------|----------------------|---------------|
| Weekday  | S*      | L**         | S    | L      | S                    | L             |
| Monday   | 13.62   | 13.53       | 12.87| 12.61  | 11.21                | 11.72         | 13.61 | 11.94 | 15.7  | 16.3 |
| Tuesday  | 13.03   | 14.80       | 13.72| 14.36  | 12.62                | 11.72         | 13.86 | 11.41 | 10.7  | 13.0 |
| Wednesday| 14.13   | 14.83       | 14.52| 15.54  | 13.08                | 16.12         | 14.60 | 12.73 | 14.6  | 10.9 |
| Thursday | 14.27   | 12.73       | 13.14| 12.56  | 14.49                | 11.36         | 13.37 | 17.51 | 11.2  | 10.9 |
| Friday   | 13.89   | 14.16       | 14.82| 13.92  | 17.29                | 15.02         | 14.36 | 13.00 | 12.9  | 12.0 |
| Saturday | 15.33   | 15.12       | 14.52| 16.03  | 14.02                | 15.75         | 14.36 | 15.65 | 19.7  | 17.4 |
| Sunday   | 15.74   | 14.80       | 16.40| 14.98  | 17.29                | 18.32         | 15.84 | 17.77 | 15.2  | 19.6 |
| Number of uses recorded | 2923   | 3777        | -    | -      | 214                  | 273           | 404   | 377   | 178   | 92   |

* S stands for small-scale survey
** L for large-scale survey

Toilets were more used at the weekend and less used on Tuesdays in the small-scale survey, while they were more used on Saturdays and less on Thursdays, according to the data extracted from the large-scale survey.

In the small-scale survey, taps were longer used at the end of the week, especially on Sundays, while shorter used on Mondays. In the large-scale survey, taps were longer used at the end of the week and on Wednesdays, whereas shorter usage of taps occurred on Mondays and Thursdays. Higher activity from taps at the weekend should come from the fact that participants are more likely to be at home and, therefore, consume more water. Wednesday might have been a day of special water-related activities, such as cleaning the floor, in some households. In the small-scale study, people seemed to
have bath rather on Fridays and Sundays, whereas in the large-scale survey, favoured days for bathing were Sundays in first place and Wednesdays in second.

Showers were quite evenly distributed throughout the week in the small-scale survey, with highest usage on Sundays. From the large-scale study, more shower uses were recorded at the weekend and on Thursdays. Washing machines appeared to be significantly more used on Saturdays. Sundays and Mondays were also days of high washing machine usage. Dishwashers are used the less from Tuesdays to Fridays. The most significant usage of dishwashers was Sunday. This could come from a greater preparation of food at the weekend, where more time is available and more participants are likely to be home.

S2.2 Influence of the season on water consumption

The characteristics of both surveys enable to assess the influence of season on water consumption and wastewater discharge. The small-scale survey was conducted during two weeks, the first one in winter and the second one during the summer. The same number of days was then surveyed for both seasons. The large-scale study encompasses surveys from different periods of the year. As data are partially available, the number of days surveyed in the four seasons is not the same. Data for summer and spring are the more numerous.

The first step was to evaluate the potential influence of season on the total water consumption by appliance. Table S3 shows the frequencies of usage for each appliance in winter and summer, derived from the small-scale study. While frequencies of usage for washing machines and dishwashers are exactly the same during both seasons, those for the rest of the appliances are higher during the summer. The table shows that taps, baths, and showers present higher consumption in summer. This situation is in line with the fact that people need drinking and refreshing their body more in summer.

| Season | Washing machine | Dishwasher | Bath | Shower | Toilets | Tap |
|--------|-----------------|------------|------|--------|--------|-----|
| Summer | 0.26            | 0.21       | 0.35 | 0.61   | 4.46   | 41  |
| Winter | 0.26            | 0.21       | 0.27 | 0.59   | 3.89   | 31  |

Figure S2(a) illustrates the diurnal variations of wastewater discharge from toilets, derived from the small-scale study. It shows that the morning peak is more widespread in summer. This could be explained by the fact that some participants may have been on summer holidays and got up later. Activity between about 18:30 and 23:30 hours is higher in summer. This could results from the fact that some participants go to bed later in summer, as daylight lasts longer.
Figure S2: Influence of season on the diurnal variations of wastewater discharge: (a) from toilets derived from the small-scale survey; (b) from taps derived from the small-scale survey; and (c) from showers derived from the small-scale survey.

Figure S2(b) shows the diurnal variations of wastewater discharge from taps, derived from the small-scale study. The figure clearly shows that water consumed from taps is higher in summer, especially at peak times. This could have its origins in the physiological needs of the participants. The diurnal variations of wastewater discharge from showers in the small-scale study are illustrated in Figure S2(c). The morning peak is slightly more widespread in the summer. The evening peaks occur later in the summer, between 18:30 and 21:00 hours, while they appear between about 17:00 and 20:00 hours in winter. These differences in variations may confirm that participants stay up longer in summer.

Both water consumption and diurnal variations of wastewater discharge show that season has an influence on water consumption and wastewater discharge. More water is consumed during summer. The highest increase of water consumption from winter to summer comes from taps, showers, and baths. This reflects that fact that physiological needs are different throughout the year. Differences in times of evening peaks from toilets, taps and showers suggest that participants stayed up longer in the summer, probably because days are longer in summer.

**S2.3 Influence of household characteristics on water consumption**

In this study we have studied the influence of two household characteristics on water consumption (a) the occupancy, described in Section S2.3.1, and (b) the household type, discussed in Section S2.3.2.
S2.3.1 Influence of occupancy on water consumption

Higher occupancy leads to higher water consumption in households, however, per capita water consumption is likely to decrease with occupancy, as reported in a number of studies for example, (Butler, 1993; Butler and Memon, 2005; Edwards and Martin, 1995; Parker and Wilby, 2013; Sadr et al., 2016, 2015). Occupancy should therefore influence water consumption in the households of the small-scale survey.

Households with 1 to 9 occupants were surveyed in the small-scale study. Only one household comprises 9 occupants and was excluded from the investigation on the influence of occupancy. Households were clustered by occupancy. Households with 4 to 6 occupants were less numerous and were therefore classified in a single cluster, the occupancy of which is 5. Figure S3(a) shows that the average frequency of bath uses increases with occupancy. The range of frequencies are however quite large, which may indicate that bath usage greatly varies among households of same occupancy. The maximal frequency of bath uses in 2-occupant households is more than 1.5 uses/household.day. This may question the occupancy assessment. For example, there might be more occupants than stated and the number of occupants declared is maybe underestimated.

In Figure S3(b), it is observed that shower usage increases with occupancy, except that 3-occupant households present much higher shower usage than those of 4 occupants. As the maximal frequency of shower usage for 3-occupant households is more than 3 uses/household.day, this could indicate that...
certain 3-occupant households encompass more than 3 occupants in reality. The same remark applies to 1-occupant and 2-occupant households, since the maximal frequencies exceed one use/person.day. Figure S3(a) shows that the average frequency of toilet uses increases with occupancy, except that 2-occupant households present higher toilet usage than 3-occupant households. This could be explained by the activities of the survey participants, with more participants from 2-occupant households spending longer time at home.

Washing machine usage increases with occupancy; see Figure S3(c). Average frequencies of washing machine uses of 2-occupant and 3-occupant households are quite close. This may come from the underestimation of occupancy in certain 2-occupant households. Figure S3(d) shows that dishwasher usage increases with occupancy (similar to that of washing machines usage), except that 3-occupant households present higher dishwasher usage than 4-occupant households. This could be explained by the underestimation of occupancy.

Figure S4 illustrates the frequencies of usages in uses per head per day, except for the tap, according to occupancy. For taps, per capita water consumption was represented in litres per households per day. In general, participants who share their place with a higher number of occupants consumed less water. Exceptions occurred for the same situations as in the relationship between occupancy and water consumption from a household.

**S2.3.2 Influence of the household type on water consumption**

In this study, four types of dwelling (household) types were considered, namely: (i) detached, (ii) flat, (iii) semi-detached, and (iv) terraced. However, only one household occupied a flat, this dwelling type was excluded from the investigation. The figures 5.19 to 5.21 show the frequencies of appliance usage in the small-scale study.

Frequencies of dishwashers, showers and toilets show that households living in semi-detached houses use these appliances the most, followed by those in detached houses (see Figure S5(a) and Figure S5(d)).

The rank is not the same for frequencies of bath uses, since households in semi-detached houses present the highest frequency of bath uses, followed by those in terraced houses. Washing machines are more used in detached households, and then in semi-detached ones. Studying water consumption per house can mask the potential influence of the dwelling type, as occupancy differs in households from the same dwelling type. On average, the occupancy of terraced houses was 1.0, while the occupancy levels of detached and semi-detached houses were 2.3 and 4.1 respectively. Frequencies of uses/head/day are shown in Figure S5(d), Figure S5(e) and Figure S5(f).

Occupants of terraced houses present the highest water consumption for taps, followed those of detached houses. The rank is the same for frequencies of usage for washing machines, showers and toilets. Dishwashers are used the most by occupants of detached houses, followed by those of semi-detached houses. The rank is reverse for frequencies of bath usage. High frequencies of bath and shower uses in terraced houses may indicate than the number of occupants was underestimated.
Figure S4: Frequencies of appliance usages for (a) baths, showers, washing machines and dishwashers according to occupancy; (b) tap (water consumption per household); and (c) toilets according to occupancy.

These results on per capita water consumption are quite difficult to interpret, since the occupancy levels in the different groups of dwelling type were quite different. The same level of occupancy in each group of dwelling type should help assess the influence of the dwelling type more accurately. In the small-scale study, it was not possible to isolate smaller group from each dwelling type, so that mean occupancy was the same.
Figure S5: Frequencies of appliance usages according to dwelling type (a) for baths, showers, washing machines and dishwashers per household; (b) for tap (water consumption per household); (c) for toilets per household; (d) for baths, showers, washing machines and dishwashers per capita; (e) for tap (water consumption per capita); and (f) for toilets per capita
Figure S6: Diurnal variations of water consumption when dual-flush toilets are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S7: Diurnal variations of water consumption when low-flow taps are installed for the group of:
(a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S8: Diurnal variations of water consumption when water efficient baths are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.
Figure S9: Diurnal variations of water consumption when shower restrictors are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S10: Diurnal variations of water consumption when water-efficient washing machines are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S11: Diurnal variations of water consumption when water-efficient dishwashers are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
S4 Diurnal variations of wastewater discharge

Figure S12: Diurnal variations of wastewater discharge when dual-flush toilets are installed for: (a) the group of 1 occupant; (b) the group of 2 occupants; (c) the group of 3 occupants; (d) the group of 4 occupants or more; and (e) the whole group
Figure S13: Diurnal variations of wastewater discharge when low-flow taps are installed for: (a) the group of 1 occupant; (b) the group of 2 occupants; (c) the group of 3 occupants; (d) the group of 4 occupants or more; and (e) the whole group.
Figure S14: Diurnal variations of wastewater discharge when water efficient baths are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group
Figure S15: Diurnal variations of wastewater discharge when shower restrictors are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group.
Figure S16: Diurnal variations of wastewater discharge when water-efficient washing machines are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group
Figure S17: Diurnal variations of wastewater discharge when water-efficient dishwashers are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; (d) 4 occupants or more; and (e) the whole group.
Figure S18: Water consumption breakdown based on different water use appliances in Scenario ‘Efficient’ when dual-flush toilets are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S19: Water consumption break-down based on different water use appliances in Scenario ‘Efficient’ when low-flow taps are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S20: Water consumption break-down based on different water use appliances in Scenario ‘Efficient’ when water efficient baths are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S21: Water consumption break-down based on different water use appliances in Scenario 'Efficient' when shower restrictors are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.
Figure S22: Water consumption break-down based on different water use appliances in Scenario ‘Efficient’ when water-efficient washing machines are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more
Figure S23: Water consumption break-down based on different water use appliances in Scenario ‘Efficient’ when water-efficient dishwashers are installed for the group of: (a) 1 occupant; (b) 2 occupants; (c) 3 occupants; and (d) 4 occupants or more.
S6 Diurnal variations of water consumption when a greywater recycling system is installed

**Figure S24**: Diurnal variations of water consumption for the households with 1 occupant when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices)

**Figure S25**: Diurnal variations of water consumption for the households with 2 occupants when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices)
Figure S26: Diurnal variations of water consumption for the households with 3 occupants when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices)

Figure S27: Diurnal variations of water consumption for the households with 4 occupants when the followings are installed: (a) no GWR nor water saving devices; (b) only GWR (tank capacity: 10 L); (c) only GWR (tank capacity: 50 L); (d) only GWR (tank capacity: 100 L); (e) only GWR (tank capacity: 150 L); and (f) GWR (tank capacity: 100 L and all water saving devices)
**S7 Calculation terms in Scenarios ‘Very efficient’ and ‘Efficient’**

Table S4: Comparison of the calculation terms in Scenario ‘Very efficient’ with those in Scenario ‘Efficient’

|                      | Water consumption                                      | Wastewater discharge                                      |
|----------------------|--------------------------------------------------------|-----------------------------------------------------------|
| **Same terms**       | From sink, washing machine, dishwasher, shower, bath, hand basin | From toilets, sink, washing machine, dishwasher           |
| **Different terms**  | From potential mains top-up to flush toilets, if the volume of greywater stored is less than the volume of a toilet flush required. | From potential wastewater discharge from shower, bath and hand basin, if the storage tank is full. |

**S8 distribution of households by dwelling type and occupancy**

Table S5: Distribution of households in the large-scale survey by dwelling type and occupancy

| Household types |  |
|-----------------|---|
### Table S6: Distribution of households in the small-scale survey by dwelling type and occupancy

| Number of occupants | Detached | Semi-detached | Terraced | Flat | Bungalow | The large-scale study | UK census from 2003 | UK census from 2016 |
|---------------------|----------|---------------|----------|------|----------|-----------------------|--------------------|--------------------|
| 1                   | 27       | 29            | 27       | 9    | 5        | 18.8%                 | 30%                | 28%                |
| 2                   | 62       | 69            | 42       | 6    | 15       | 37.5%                 | 36%                | 35%                |
| 3                   | 16       | 22            | 12       | 0    | 4        | 12.5%                 | 15%                | 16%                |
| 4                   | 26       | 24            | 21       | 0    | 1        | 12.5%                 | 16%                | 13%                |
| 5                   | 8        | 12            | 5        | 0    | 1        | 6.2%                  | 5.8%               | 5.0%               |
| 6                   | 2        | 1             | 1        | 0    | 0        | 15.0%                 | 1.5%               | 3.0%               |
| 7                   | 1        | 0             | 0        | 0    | 1        | 12.5%                 | 12.5%              | 12.5%              |
| 8                   | 0        | 1             | 0        | 0    | 0        | 5.8%                  | 5.8%               | 5.8%               |
| 9                   | 0        | 1             | 0        | 0    | 0        | 3.2%                  | 3.2%               | 3.2%               |

Large-scale study: 31.8% Detached, 34.3% Semi-detached, 24.4% Terraced, 3.2% Flat, 6.2% Bungalow

| Number of occupants | Detached | Semi-detached | Terraced | Flat | Bungalow | The small-scale study | UK census from 2003 | UK census from 2016 |
|---------------------|----------|---------------|----------|------|----------|-----------------------|--------------------|--------------------|
| 1                   | 1        | -             | 2        | -    | -        | 25%                   | 37%                | 25%                |
| 2                   | 2        | 3             | -        | 1    | -        | 56.3%                 | 27.8%              | 27.8%              |
| 3                   | -        | 2             | -        | -    | -        | 12.5%                 | 12.5%              | 12.5%              |
| 4                   | 1        | -             | -        | -    | -        | 6.2%                  | 6.2%               | 6.2%               |
| 5                   | -        | 2             | -        | -    | -        | 12.5%                 | 12.5%              | 12.5%              |
| 6                   | -        | 1             | -        | -    | -        | 12.5%                 | 12.5%              | 12.5%              |
| 9                   | -        | 1             | -        | -    | -        | 12.5%                 | 12.5%              | 12.5%              |

Small-scale study: 25% Detached, 56.3% Semi-detached, 12.5% Terraced, 6.2% Flat, 12.5% Bungalow

UK census 2011: 37% Detached, 27.8% Semi-detached, 25.1% Terraced, 9.9% Flat, 6.2% Bungalow
Figure S28: Distribution of water consumption by different appliances (a) according to dwelling type; (b) in different studies/years
**Table S7:** Per capita consumption versus household occupancy

| Occupancy | Reference |
|-----------|-----------|
| - - 137 - - - - - | (Webster, 1972) |
| - - 98 - - - - - | (Thackray et al., 1978) |
| - - 100 - - - - - | (Thackray et al., 1978) |
| - - 108 - - - - - | (Bailey et al., 1986) |
| - - 154 - - - - - | (Russac et al., 1991) |
| 222 158 133 122 98 96 104 55 | (Edwards and Martin, 1995) |
| 211 154 130 122 103 103 108 54 | (POST, 2000) |
| 205 173 144 119 - - - - | (WRc, 2005) |
| 193 162 130 99 - - - - | (EA, 2007) |
| 154 143 140 134 128 123 123 123 | (EST, 2013) |
| 135 125 115 95 85 80 - - | (Critchley, et al., 2015) |
| 149 138 122 112 104 98 93 - | (CCW, 2018) |
| - - 134 - - | Current study |
| 182 150 127 115 104 100 107 77 | ← Mean values

**59 Aspects and parameters considered in the simulation tool**

**Table S8:** Example aspects analysed in the simulation tool

| Aspects                                                                 | Units                                                                 |
|------------------------------------------------------------------------|----------------------------------------------------------------------|
| Water consumption                                                      | m³/day, l/person.day                                                 |
| Water saving                                                           | m³/day, l/person.day, % of the standard water consumption           |
| Distribution of water consumption by appliance                         | m³/day                                                               |
| Wastewater discharge                                                   | m³/day, l/person.day                                                 |
| Reduction in wastewater discharge                                      | m³/day, l/person.day, % of the standard wastewater discharge         |
| Greywater productions, with associated potential water saving and water consumption | m³/day                                                                 |
| Diurnal variations of water consumption                                | l/10 min                                                            |
Diurnal variations of water consumption by appliance

| Distribution of water consumption by appliance | % of the total water consumption |
| Diurnal variations of wastewater discharge | l/10 min |

S10 Tool components

S10.1 User interface

The tool provides an interface to the user for entering the following characteristics concerning the households, for each occupancy level considered: i. Number of households; ii. Water-efficient appliances installed, and iii. GWR system present in the house. The user interface also includes an output visualisation facility which allows visualising the results in the form of tables and graphs (shown in Section 4).

All the results derived are stored in ‘WaterRef.xls’ and they are displayed on ‘WaterSaving.xls’. These two files are interlinked. The results are either displayed in tables or on graphs in ‘WaterSaving.xls’. Table S7 in the Supporting Information (SI) shows the types of results that can be obtained. They are provided for the whole group of households, as well as for each group of households according to the occupancy level. The result visualisation features enable the user to compare the total water consumption from the three scenarios. The variations of water consumption over 24 consecutive hours are also given to help determine times where most of the reduction of water consumption might take place in the efficient and very efficient scenarios. These variations are shown on a graph, where peaks of water consumption can also be characterized in terms of volume per 10 minutes. Results on wastewater discharge are similarly available.

Other results help assess the contribution of each appliance to the total water consumption, and the amount of total greywater. Volumes of water consumption are provided and pie charts illustrate these figures, showing the distribution of water consumption by appliances in all the three scenarios. Four types of greywater were distinguished in the tool (namely: very strong, strong, medium and weak). The daily volume of each type of greywater produced is shown to help assess the water saving potentials.

S10.2 Database

Data used for building the tool were derived from the small-scale survey outlined below, and were stored in ‘WaterRef.xls’. Distinguishing households according to their features should increase the accuracy of the tool, as characteristics of households’ impact on water consumption (see the SI, Section S2). The households considered in the survey were characterised by their dwelling type and occupancy. However, the amounts of data by dwelling type were not consistent in the survey, contrary to those of data by occupancy. Households were therefore characterised by their occupancy in the simulating tool. In fact, according to Makki et al., (2013), the existing water demand forecasting models, which are reliable, have considered household size as one of the most important parameters e.g. Willis et al., (2010); WSAA and ISF, (2008).

The database of the tool was then made up by four sets of data, corresponding to four levels of occupancy: one, two, three or more than three occupants. Data on the household with 9 occupants were not incorporated into the database, as they were considered atypical. The data on water consumption from
dishwashers in 1-occupant households was not consistent and it was therefore assumed that 1-occupant households do not own dishwashers.

The database is made up of 4 datasets, corresponding to each occupancy level. Those datasets are divided into 2 subsets: The first one encompasses data on water consumption, while the second one contains data on wastewater discharge. Each of these subsets is made up of the diurnal variations of water consumption or wastewater discharge from every appliance. The database is the basis to the calculations presented in the following section (Section 2.2.3).

The dataset of each household occupant number consists of diurnal variations of water consumption and wastewater discharge from one household for the six types of water use appliances as given in the small-scale survey (see Section 3). Certain types of data from this survey were directly processed and incorporated into the database of the simulation tool (e.g. for toilets and showers), whereas others necessitated assumptions to be made before processing. For example, tap usage was split into two categories of usage: emptying a bowl and running to waste, since water-efficient taps were considered to reduce the second type of usage considerably (see the SI, Section S1).

S11 Datasets

Two datasets (i.e. Identiflow® output files), each containing about 20,000 observations, were available for this study: i. random dataset (large-scale study) and ii. time series dataset (small-scale study). Each dataset provides information on: household types, number of occupants and water-use events (e.g. type of appliance used, date, start time, volume and duration of water consumption). The two datasets are further discussed below:

S11.1 Random dataset (large-scale study)

The random dataset is about 5% of randomly extracted data points (events) provided by WRc from a large-scale study. In this study, 450 households were surveyed across England in different seasons, and the data verified against various studies to ensure relevance and applicability (as outlined below). They were chosen in order to give a range of dwelling types and occupancies typical of water companies’ customers. The household distribution with respect to dwelling type and occupancy for the random dataset is given in Table S5, in the SI. Of the surveyed houses, the share of detached houses (31.8%) slightly varies from the UK census figures (see Table S5, in the SI), however the occupancy distribution is broadly comparable with the census data except that for households with one resident. The greater fraction of the households is with low occupancy (1-2 people).

S11.2 Time series dataset (small-scale study)

The second dataset is a compact whole dataset of water consumption records from 16 households. This represents time-series of water use in the households and provides more precise information on the frequency and duration of use of any specific appliance (washing machine, dishwasher, taps, toilet, bath and shower). The distribution of dwellings with respect to their type and occupancy is shown in Table S6, in the SI. Owing to the number of houses surveyed, the distribution of dwelling types and occupancy were found to be different from that of the random dataset.

Although the two datasets contain a large number of observations (total 40,000 data points), establishing their reliability before generating hydraulic profiles was considered necessary. This was investigated by
comparing various aspects of the two datasets with the data previously obtained by Butler, (1991); Edwards and Martin, (1995); Hall et al., (1988); and William et al., (2016).

The dataset from the large study consists of data points chosen randomly and do not provide sufficient information (i.e. continuous time series consumption details and therefore appliance use frequency). However, the data analysis revealed (Figure 2) that the consumption share (% of total recorded consumption) for each appliance is broadly similar to the figures given in Edwards and Martin (1995); Butler and Memon, (2005); Fidar et al., (2010); Makki et al., (2013); Bello-Dambatta et al., (2014); Happold (2019) for households without efficiency measures; and Happold (2019) for households with efficiency measures. These are shown in: Figure 2(a), Figure 2(b), Figure 2(c), Figure 2(d), Figure 2(e), Figure 2(f), Figure 2(g) and Figure 2(h), respectively.

Additionally, although the distributions of water consumption by appliance are not the same for each dwelling type (see Figure S28(a), in the SI), it was found that they are similar to the average distribution established. The results seem to be coherent with the usual distribution of water consumption by appliance found in the literature e.g. Butler and Memon, (2005); Edwards and Martin, (1995); Fidar et al., (2010). This increases confidence in the use of these data sets (see Table S7 and Figure S28(b), in the SI). The minor differences between the distributions in Figure 2 arise from variability in study methods, sampling, locations, appliances included and analysis.

The time series dataset from the small scale survey showed close similarities with the observations made in previous studies despite the small number of participating households. Table S7 shows the average daily consumption of water from a single household with occupancy of one to eight. Water consumption in this study for the households with three residents (134 litres per person per day (l/person.day)) is broadly similar to the figures reported in Webster, (1972), Edwards and Martin, (1995) and (EA, 2007), of 137, 133, and 130 litres per person per day respectively. The average per capita water consumption in this study of 136 l/person.day is similar to those stated in Hall et al., (1988) (131.6 l/person.day) and Edwards and Martin, (1995) (145 l/person.day). The per capita water consumption distribution in the present study was found to be of log normal nature and its shape is broadly similar to the one reported in Edwards and Martin, (1995). The dataset from the large study consists of data points chosen randomly and do not provide information on continuous time series consumption details. However, the data analysis revealed (Figure S29) that the consumption share (% of total recorded consumption) for each appliance is broadly similar to the figures given in Edwards and Martin (1995); Butler and Memon, (2005); Fidar et al., (2010); Makki et al., (2013); Bello-Dambatta et al., (2014); Happold (2019) for households without efficiency measures; and Happold (2019) for households with efficiency measures. These are shown in: Figure S29(a), Figure S29 (b), Figure S29 (c), Figure S29 (d), Figure S29 (e), Figure S29 (f), Figure S29 (g) and Figure S29 (h), respectively.
Figure S29: Distribution of household water consumption: (a) established in Edwards and Martin (1995); (b) reported in Butler and Memon, (2005); (c) determined in Fidar et al. (2010); (d) reported in Makki et al. (2013); (e) reported in Bello-Dambatta et al., (2014), (f) stated in Happold (2019) without efficiency measures, (g) reported in Happold (2019) with efficiency measures and (h) derived from the random dataset in this study.
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