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RESEARCH AND ANALYSIS

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# The influence of consumer behavior on energy, greenhouse gas, and water footprints of showering

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## Abstract

Understanding variability in consumer behavior can provide further insights into how to effectively reduce environmental footprints related to household activities. Here, we developed a stochastic model to quantify the energy, greenhouse gas (GHG), and water consumption footprints of showering in four different countries (Australia, Switzerland, the United Kingdom, and the United States of America). We assessed the influence of two broadly distinct categories of behavior on the footprints of showering: habitual behaviors and one-off reasoned actions. We also investigated whether changing showering behavior has a substantial impact on the associated energy, GHG, and water footprints. Our results show that the variation in environmental footprints within the countries due to differences in consumer behavior is a factor of 6–17 (95th percentile/5th percentile) depending on the country and the indicator selected. Both consumers' reasoned actions (especially the choice of a specific heater and shower type) and habitual behaviors (length of showering in particular, are the dominant sources of footprint variability. Significant savings are achievable by making better one-off decisions such as buying an efficient water heater and by taking shorter showers.

**KEYWORDS**
consumer behavior, energy consumption, GHG emissions, industrial ecology, variability assessment, water consumption

## 1 | INTRODUCTION

Many everyday consumer behaviors are habitual. The behaviors are fairly automatic, cued by stimuli in the environment and usually unaccompanied by much conscious reflection (Kurz, Gardner, Verplanken, & Abraham, 2015; Verplanken, Aarts, Van Knippenberg, & Moonen, 1998). For instance, showering has become a routine and consumers do not give much thought to how long they shower for, what temperature they set the shower at, or how much shower gel, shampoo, or conditioner they use in the shower. In contrast to these routine behaviors, other actions and decisions taken by consumers can be more deliberative. These actions are goal-directed and guided by more conscious evaluation of the pros and cons of the behavioral choice (Kurz et al., 2015; Strack & Deutsch, 2004). For example, in the case of showering, one-off actions such as the installation of a water heater or the selection of a new showerhead are largely driven by conscious considerations. In this paper, we use the dual process models of human behavior that describe how everything we do is regulated by two interacting brain processes (conscious and nonconscious), as a framework for assessing the differences in environmental impact due to differences in everyday consumer behavior (Kahneman & Egan, 2011).

Analyzing differences in showering behavior is of particular interest for assessing the environmental footprint of consumer activities because showering is a major contributor to domestic water and energy use. It has been estimated that showering accounts for 28%, 25%, and 20% of the indoor domestic water use in Australia, the United Kingdom, and the United States of America, respectively, and contributes to 39% of the domestic hot water use in the United States (Beal, Stewart, Huang, & Rey, 2011; Energy Saving Trust, 2013; Kenway et al., 2008; Water Research Foundation, 2016). Moreover, while the water use in clothes washers, toilets, and dishwashers in the United States significantly decreased between the years 1999 and 2016 (up to 39%), water use per shower held steady during the same period (Water Research Foundation, 2016).

A number of studies have reported the water use associated with showering (Beal et al., 2011; Kordana, Słyś, & Dziopak, 2014; Makki, Stewart, Panuwatwanich, & Beal, 2013; Unilever and the UK Water Companies, 2015; Water Research Foundation. 2016; Waterwise, 2009; Wilkes, Mason, & Hern, 2005; Willis, Stewart, Panuwatwanich, Jones, & Kyriakides, 2010) and other studies (Ableitner, Schöb, & Tiefenbeck, 2016; Beal et al., 2011; Staake, Tiefenbeck, Schöb, & Kupfer, 2016) have estimated the corresponding energy use. Results of these studies indicate that showering behavior can be highly variable between individuals in a country. For example, according to a study by Unilever and the UK Water Companies (2015), which investigated consumer showering behavior in the UK, the median shower time in the United Kingdom is 5.6 min. However, 25% of the shower events are longer than 8.3 min and 5% of the showers even last more than 14.3 min. Showering behavior also varies between countries. While the average flow rate, shower time, and shower temperature in Switzerland are 11 L/min, 4 min, and 36°C, respectively (Ableitner et al., 2016), the same parameters for the United States were found to be 5.1 L/min, 7.9 min, and 40°C (Water Research Foundation, 2016; Wilkes et al., 2005). These studies have focused on the potable water and energy used during one shower event, which can be used as input in the assessment of life cycle environmental impacts of showering.

Life cycle assessment (LCA) is widely used as a tool for environmental footprinting of household activities, although behavioral variability is typically not addressed in these studies (Golsteijn et al., 2015; Koerner, Schulz, Powell, & Ercolani, 2010; Ross & Cheah, 2017; Yuan, Zhang, & Liu, 2016). Quantification of variability in the environmental footprints and calculating the contribution of different variables as well as different types of behavior to the overall variance provides a better understanding of the environmental footprints and their key drivers (Di Sorrentino, Woelbert, & Sala, 2016). This helps to identify the most effective policy options to lower the environmental impact of household activities.

The objective of this study was to quantify the variability in life cycle energy use, GHG emissions, and water consumption of domestic showering associated with the two type of consumer behavior. We applied one shower event as our functional unit and focused on four countries with different climatic conditions, different infrastructures for energy and water provision, and with sufficient data for the analysis, that is, Australia, Switzerland, the United Kingdom, and the United States. We applied Monte Carlo simulation to propagate the variability in consumer behavior—for example, shower duration, flow rate, etc.—to the variation in the environmental footprints. We also quantified the contribution to variance associated with variability in the two different types of consumer behavior.

## 2 | MATERIALS AND METHODS

### 2.1 | Data sources

The foreground data related to consumer behavior including sample size, type of behavior, source of data, and the corresponding distributions used to calculate the environmental footprint indicators across the four selected countries are summarized in Table 1. We used measured data—collected by sensors and data loggers—from studies instead of self-reported data for the key behavioral variables of the model, that is, flow rate, shower duration, and shower temperature, as consumers do not always accurately remember their showering behavior due to the automatic nature of habits (Chung & Leung, 2007; Verplanken, Myrbakk, & Rudi, 2005). Note that selection of a showerhead is a reasoned action, whereas how much a consumer opens the tap is a habit. Given that, variability in the water flow rate is derived by the variability in a mix of behaviors. However, our analysis of variance on the U.S. data shows that the variance in the flow rate between different showerheads is significantly higher than the variance within the showerheads ($F$-statistic = 38.2). This is in line with the results of Beal et al. (2011) and Ableitner et al. (2016). Therefore, the selection of a showerhead dominates the variability in the shower flow rate and consequently flow rate is considered as a reasoned action in this study. Country- and industry-related background variables such as GHG emissions per kWh of electricity and the footprints related to the production of unit amount of ingredients and packaging materials are presented in Supporting Information Table S1-1. Depending on the type of variable and the availability of data, we fitted distributions for the different input variables of the model. Where we had access to the raw data with a sufficient sample size, we fitted normal and lognormal distributions and selected the distribution with the best goodness of fit. When our access was limited to a minimum, a maximum, and a most likely value, we fitted a BetaPERT distribution to the data. Given that, we applied a lognormal distribution for shower duration, cold water temperature, and product dosage. We also included a lognormal distribution for water flow rate in the United Kingdom and the United States, while normal distribution was a better fit for water flow rate in Australia and Switzerland. We derived a BetaPERT distribution for shower temperature and for the energy efficiency of the water heaters. The fitted distributions have been graphed and explicit rationales have been given for each variable (in Sections 2–5 of the Supporting Information S1).

For shower duration, shower flow rate, shower temperature, and cold water feed temperature, we used measured data as explained in Sections 2–5 of the Supporting Information S1. For the type and energy efficiency of water heaters, we derived data from country-specific reports as presented in Supporting Information Table S1-1 and explained in Section 6 of the Supporting Information S1. For the number and types of products used per showering event, we used Unilever empirical data from a UK study (Unilever and the UK Water Companies, 2015) and assumed that the same distribution is applicable to the other three countries. Based on the frequencies reported by this study for the products used per day, we

**TABLE 1** Behavioral variables used in this study and their corresponding characteristics

| Variable | Country | Sample Size | Distribution | Type of Behavior | Reference |
|---|---|---|---|---|---|
| Water Flow Rate (FR) in (L/min) | AU | 252 Households | Normal (7.9,2.8) | Reasoned Action | Beal et al. (2011) |
| | CH | 5,610 Shower events from 636 households | Normal (11,2.5) | | Ableitner et al. (2016) |
| | UK | 276 Households | Lognormal (7.3,1.6) | | Unilever and the UK Water Companies (2015)[a] |
| | US | 2,428 Shower events from 103 showers | Lognormal (4.7,1.5) | | Water Research Foundation (2016) |
| Shower Duration (ShD) in (min) | AU | 252 Households | Lognormal (5.5,1.5) | Habit | Beal et al. (2011) |
| | CH | 5,610 Shower events from 636 households | Lognormal (3.2,1.9) | | Ableitner et al. (2016) |
| | UK | 6,977 Shower events from 276 households | Lognormal (5.6,1.8) | | Unilever and the UK Water Companies (2015) |
| | US | 2,428 shower events from 103 showers | Lognormal (7.2,1.7) | | Water Research Foundation (2016) |
| Shower Temperature (Tshower) in (°C) | AU | 7 households | BetaPERT (25,40,47) | Habit | Kenway et al. (2016), Binks et al. (2016) |
| | CH | 5,610 shower events from 636 households | BetaPERT (25,36,47) | | Ableitner et al. (2016) |
| | UK | 7 households | BetaPERT (25,40,47) | | Kenway et al. (2016), Binks et al. (2016) |
| | US | 7 data points | BetaPERT (25,40,47) | | Wilkes et al. (2005) |

| Variable | Country | Heater Type | Distribution | | Type of Behavior | Reference |
|---|---|---|---|---|---|---|
| Penetration Rate of Different Types of Water Heaters (PR) in (%) | AU | Electric<br>Gas<br>Solar<br>Heat pump | Custom | 39<br>45<br>13<br>3 | Reasoned Action | Energy Rating (2014) |
| | CH | Electric<br>Gas<br>Solar<br>Heat pump<br>Oil | Custom | 28<br>25<br>3<br>2<br>42 | | Prognos (2015) |
| | UK | Electric<br>Gas | Custom | 13<br>87 | | Boait et al. (2012) |
| | US | Electric<br>Gas | Custom | 44<br>56 | | Maguire et al. (2013) |
| Energy Efficiency of Water Heaters (EE) | AU, CH, UK, US | Electric<br>Gas<br>Oil<br>Heat pump | BetaPERT (0.77,0.85,1)<br>BetaPERT (0.40,0.68,0.98)<br>BetaPERT (0.40,0.65,0.98)<br>BetaPERT (2,2.35,2.73) | | Reasoned Action | Boait et al. (2012), Maguire et al. (2013), Whaley et al. (2014), Prognos (2015), Waterwise (2009) |
| | AU | Solar | BetaPERT (0.85,1.6,7) | | | |
| | CH | | BetaPERT (0.85,1,7) | | | |

| Variable | Product | Distribution | Type of Behavior | Reference |
|---|---|---|---|---|
| Product Dosage (D) in (g/Shower) | Liquid facewash men | Lognormal (2.75,1.83) | Habit | Ficheux et al. (2016) |
| | Liquid facewash women | Lognormal (2.70,2.10) | | |
| | Shower gel men | Lognormal (9.04,1.93) | | |
| | Shower gel women | Lognormal (8.03,2.00) | | |
| | Shampoo men | Lognormal (4.81,1.90) | | |
| | Shampoo women | Lognormal (8.40,1.92) | | |
| | Hair conditioner men | Lognormal (5.00,1.33) | | |
| | Hair Conditioner Women | Lognormal (7.62,2.09) | | |

(Continues)

**TABLE 1** (Continued)

| Variable | Product | Distribution | | Type of Behavior | Reference |
|---|---|---|---|---|---|
| Number and type of products used | 0 | Custom | 6% | Habit | Unilever and the UK water companies (2015) |
| | 1: Shower gel | | 19% | | |
| | 2: Shower gel and shampoo | | 27% | | |
| | 3: Shower gel, shampoo, and conditioner | | 27% | | |
| | 4: Shower gel, shampoo, conditioner, and face wash | | 14% | | |
| | 5: or more | | 7% | | |

*Notes:* Where a normal distribution is used, the arithmetic mean and the arithmetic standard deviation are reported in the parenthesis. Where a lognormal distribution is used, the geometric mean and geometric standard deviation are reported in the parenthesis. Where BetaPERT distribution is used, minimum, likeliest, and maximum values are reported in the parenthesis. Where a custom distribution is used, the probability associated with each number is reported. (AU: Australia; CH: Switzerland; UK: United Kingdom; US: United States).

[a]Using a shower monitor based on sensor technology, reliable and objective data on showering behavior in the UK were gathered in a representative sample of UK households based on the acorn type consumer classification system (CACI, 2014). For the sample collection protocols in the other countries, please refer to the corresponding references as provided in Table 1 and Supporting Information Table S1.

considered a specific order of products used, as specified in Table 1. For the dosage relating to each of the considered products, we used data from Ficheux et al. (2016) and assumed 50% of the consumers are men and 50% are women. We estimated the showering products footprints by using Unilever product specifications and life cycle inventory data from ecoinvent v3.3 (Wernet et al., 2016) and other literature sources as presented in Section 7 of the Supporting Information S1. With regard to the packaging, we used data from Product Environmental Footprint (Cosmetics Europe, 2014). See Section 7 of the Supporting Information S1 for more details.

## 2.2 | Environmental footprints

The environmental footprint associated with one shower event in country *i*, $FP_i$ (in MJ primary energy, $gCO_2$-eq or L water consumed) was calculated by summing up the footprints related to (a) heating the water, (b) water provision and wastewater treatment, and (c) manufacturing of the shower products (including the packaging):

$$FP_i = FR_i \cdot ShD_i \cdot \left( \frac{C \cdot (Ts_i - Tc_i)}{EE_{i,k}} \cdot EIE_{ik} + EIW_i \right) + \sum_p \sum_h EIP_h \cdot Q_{hP} \cdot D_p \quad (1)$$

Where $FR_i$ is the water flow rate in country *i* (L/min), $ShD_i$ is the shower duration in country *i* (min per event), *C* is the heat capacity of water (4.2 MJ·L·°C ), $Ts_i$ is the shower temperature in country *i* (°C), $Tc_i$ is the ambient water feed temperature in country *i* (°C), $EE_{ik}$ is the energy efficiency of the water heating type *k in country i* (dimensionless), $EIE_{ik}$ is the environmental impact to deliver one MJ of energy type *k* in country *i* (*MJ/MJ*, $gCO_2$*-eq/MJ, or L/MJ*), $EIW_i$ is the environmental impact related to the provision and waste treatment of 1 L of water in country *i* (MJ/L, $gCO_2$-eq/L or L/L ), $EIP_h$ is the environmental impact related to the production of material *h* (MJ/gram, $gCO_2$-eq/gram or L/gram), $Q_{hP}$ is the amount of material *h* per unit of product *p* (gram/gram) and $D_p$ is the amount of product *p* used in the shower in (gram per event). We excluded any potential heat loss in the water heater system and the place where shower temperature was measured.

Water consumption is defined as the freshwater that is not released back to the original watershed (Pfister, Saner, & Koehler, 2011). We assumed that water returns to its original watershed after being used in the households and in the cooling systems of electricity generation plants. Evaporation due to electricity generation and product manufacturing as well as evaporation during water provision and wastewater treatment are included as sources of water consumption. Water included in the shower product formulations is also considered as water consumption.

## 2.3 | Model simulation

To quantify the variability in the environmental footprints for each country, a Monte Carlo simulation (Frey, 1992) with 10,000 iterations was performed in Oracle Crystal Ball (11.1.2.4.600). In each iteration, a number was randomly selected from the distributions of the input variables to calculate the environmental footprints. To include the role of water heater types and their associated energy efficiency in different countries, we first developed four discrete custom distributions (one for each country) each having probability values equal to the penetration rate (*PR*) of the different water heaters in the four countries. Then, for each country and at each iteration, individual values were randomly selected for each parameter using its probability distribution. We used the same sampling approach to account for the number of products used in the shower. We

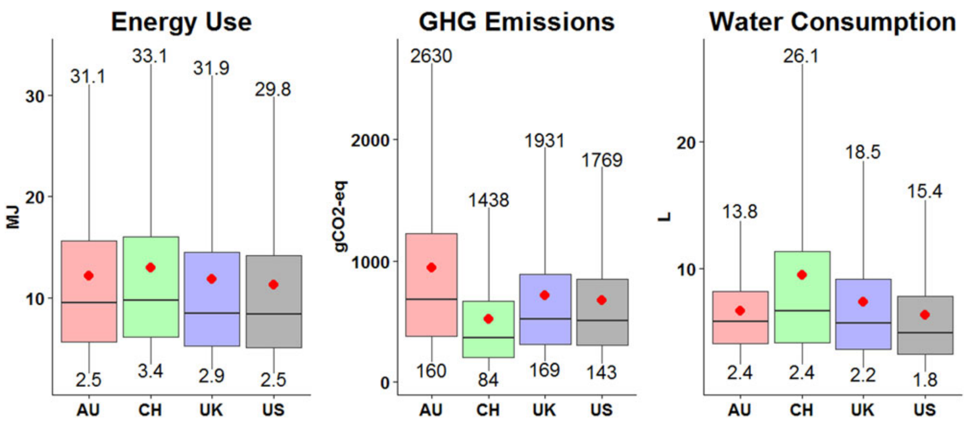


**FIGURE 1** Life-cycle footprints associated with one showering event. The box plots show 5th, 25th, 50th, 75th, and 95th percentiles and the red dots show the arithmetic means (AU= Australia; CH= Switzerland; UK= United Kingdom; US= United States)

first developed a discrete custom distribution with probability values equal to the probability of the use of *n* (*n* in {1: 5}) products, and then, in each iteration, we sampled one value from this distribution. Environmental footprints were then calculated using Equation (1).

The variability in the environmental footprints within a country was summarized by dividing the 95th percentile by the 5th percentile of the output distribution (see also Slob, 1994). We also presented the geometric standard deviation of each output variable in the supporting information.

Finally, to assess the relative influence of the various input parameters on the variability in the footprints, we quantified the contribution to variance for the different variables of the model. For the categorical variables (i.e., heater type and gender), we first performed a 2-way analysis of variance (ANOVA). Contribution to variance for each categorical variable was then calculated by dividing the sum of squares of each variable by the total sum of squares. The corresponding equation and ANOVA results are provided in Section 8 of the Supporting Information S1.

The remaining variability is explained by the continuous variables (shower duration, flow rate, product dosage, etc.). For these variables, we divided the squared Spearman's rank correlation coefficient for each input parameter with footprint of interest by the sum of all squared rank correlation coefficients of the continuous input parameters.

## 3 | RESULTS

### 3.1 | Variability in the environmental footprints

Figure 1 shows the variability in the environmental footprints of showering in the four selected countries. The differences in the intra-country variabilities are caused by the variability in the showering behavior of the consumers as well as the differences in the efficiency of the countries' energy provision infrastructure. Figure 1a shows that the intra-country variability (95th percentile/5th percentile) associated with energy consumption ranges between a factor of 10 and a factor of 12 in the selected countries. Figure 1b shows that GHG emissions vary between a factor of 11 in the United Kingdom and the United States up to a factor of 17 in Australia and Switzerland. Intra-country variability in the GHG emissions is larger than that of primary energy use. This is due to the fact that variability in the GHG emission factors between heating technologies is generally higher than the variability in primary energy requirement (see Supporting Information Table S1-1). Figure 1c shows that intra-country variability related to water consumption varies from a factor of 6 in Australia up to a factor of 11 in Switzerland. Numeric results associated with Figure 1 are presented in Supporting Information Table S1-6.

Figure 2 shows the contribution and variability in the three footprints relating to water provisioning and treatment, water heating, and to product usage. Water heating has a dominant contribution to the life cycle energy use and GHG emissions of showering in all countries. Water consumed for water provision and wastewater treatment has the highest contribution to the water consumption footprint in all countries. Numerical values associated with the footprints by each contributor are presented in Supporting Information Table S1-7.

### 3.2 | Variability importance analysis

Figure 3 shows the importance of the variability in the input variables to the variability in the environmental footprints calculated by the use of 2-way ANOVA and rank correlation analysis. Both consumers' reasoned actions and consumers' habits have a major influence on the variability in the footprints. Of the habits, shower duration contributes most, while shower temperature, the number of products used per shower event, and the dosage have a minor influence on the variance. Choice of shower flow rate (which is dependent on the showerhead fitted in the shower) and water heater are the major contributors to variance among the one-off reasoned actions.

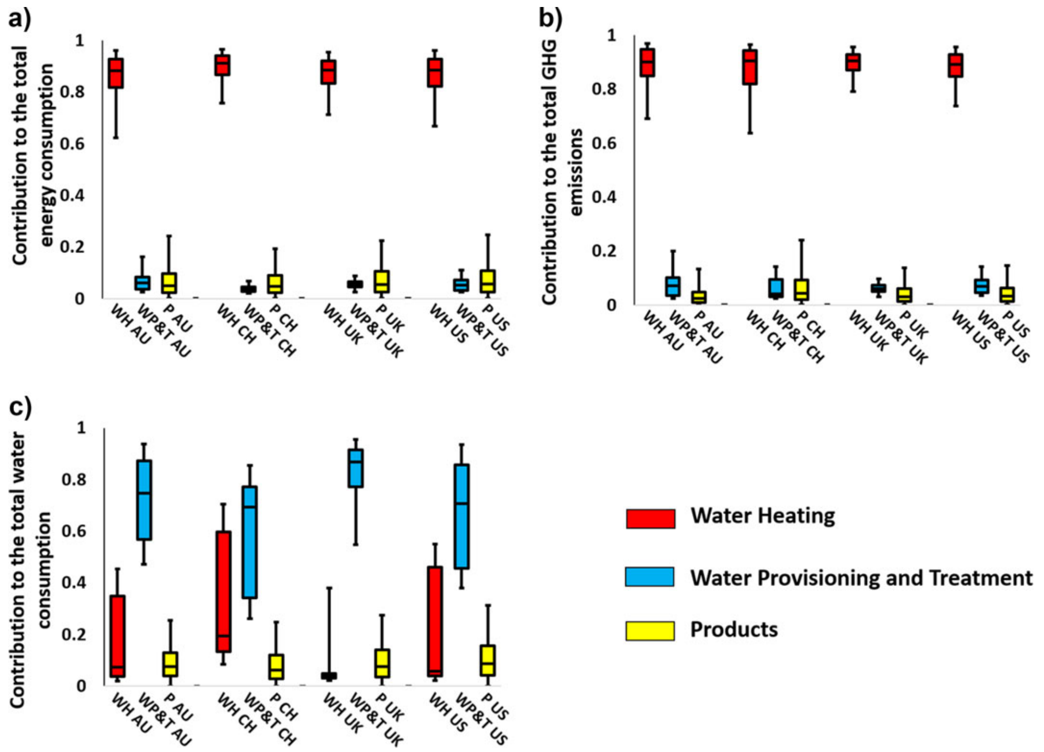


**FIGURE 2** Variability in the footprints by contributor (WH: water heating; WP&T: water provisioning and treatment; P: products,) and by country (AU = Australia; CH = Switzerland; UK = United Kingdom; US = United States of America)

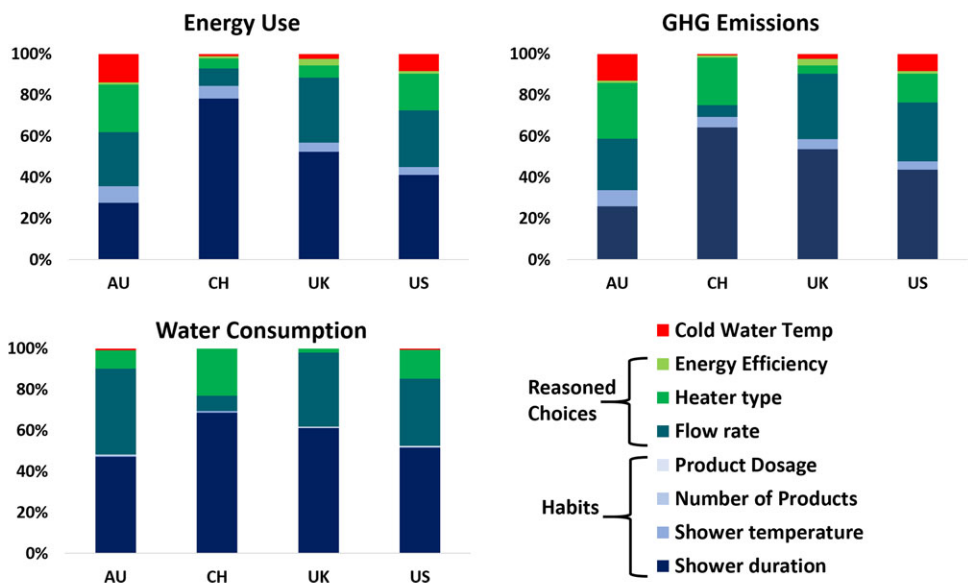


**FIGURE 3** Contribution to variance associated with the four environmental footprints of the model (AU= Australia; CH= Switzerland; UK= United Kingdom; US= United States)

### 3.3 | Relationship between the volume of water used in the shower and the environmental footprints

Although the indicators quantified in this study are important from an environmental point of view, some of them are not fully tangible for consumers, as they often do not know how much water and energy is consumed in the upstream processes to deliver water and energy to their homes. In addition, the amount of water and energy used in the upstream processes is dependent on the volume of heated water, which is directly used by consumers in the shower. Therefore, we quantified the variability for each footprint per water heater type—a reasoned choice—given the volume of water used in the shower—derived by a habit, that is, duration and a reasoned choice, that is, showerhead flow rate—(see Supporting Information Figures S1-6–S1-8). Figure 4 shows that, in Switzerland, despite the fact that primary energy use associated with electric water heaters is typically higher than that of oil and gas water heaters, the GHG emissions associated with them are typically much lower than those of oil and gas water

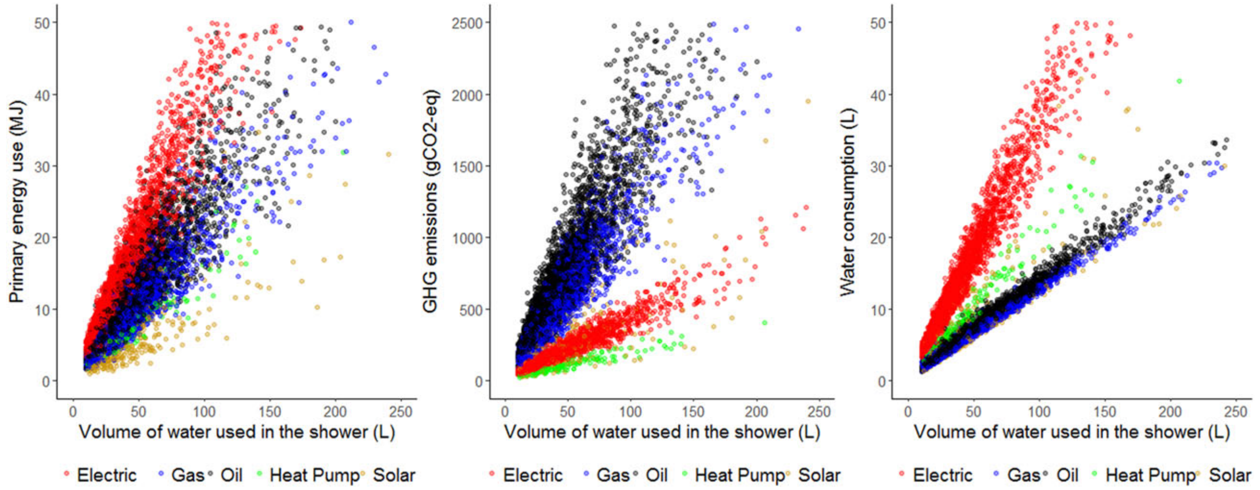


**FIGURE 4** The variability for each footprint per water heater type, given the volume of water used in the shower events in Switzerland

heaters. This is because the majority of electricity used in Switzerland is produced by nuclear and hydro power, which have a lower emission intensity compared to fossil fuels. In the other countries where electricity generation is highly dependent on fossil fuels, GHG emissions associated with electric water heaters are higher than those of gas heaters.

Electric water heaters have typically the highest water consumption. This is due to water evaporation during the cooling processes of thermoelectric generation. The variability associated within each water heater type is caused by the variability in the efficiency of the technologies used to produce energy.

## 4 | DISCUSSION

### 4.1 | Assumptions

An alternative to the functional unit of "environmental impact per shower event," as used in our study, could be the "environmental impact of showering per person per day." This alternative functional unit requires information on the variability in the frequency of taking a shower. Wilkes et al. (2005) showed that the frequency of taking a shower in the United States is typically one shower per day (60% of the population), but could also be zero showers (22%), two showers (17%), or more than two showers (1%). The overall average frequency is found to be 0.98 showers per person per day. So, our findings for the United States are representative for the environmental footprint of the average shower frequency, but typically range from no environmental impact for zero showers in 22% of the cases to double the environmental impact for 17% of the cases. For other countries, we did not find information on the variability in the frequency of taking a shower.

The data sources we used for the two key behavioral variables of the model, that is, shower duration and flow rate provided us with measured—collected by sensors and data loggers—rather than self-reported data on a large number of shower events recorded recently. We also used recent data (2012–2015) for the penetration rate of the different types of water heaters. However, our results are not without uncertainty because of a number of assumptions in our input data and in our analysis. First, uncertainty is caused by the implementation of footprint data of simplified showering products. We used five representative ingredients (based on median inclusion levels in a range of Unilever product formulations) for the predominant functional classes of chemicals in body and hair wash products compared to a total number of over 100 chemicals (see Section 7 of the supporting information S1). However, our calculations include the major ingredients and hence give a reasonable estimate of the impact of such product types. Second, uncertainty also exists due to lack of country-specific distributions for shower temperature in the United Kingdom (see Section 4 of the supporting information), and for cold water temperature in Switzerland (see Section 5 of the supporting information). However, as the results showed, these variables have minor effect on the overall variabilities and we do not expect changes in these figures to have significant impact on our results. Third, our references often provide us with demographically representative data that cover a wide range of consumers with various characteristics. We, however, cannot fully exclude the selection bias in the sample (e.g., proenvironmental behavior).

Finally, we neglected the potential correlations among the different input variables of the model. Our analysis on the UK and the U.S. data showed weak correlation between shower duration and shower flow rate ($R = -0.14$ and $R = -0.09$, respectively). The Swiss study (Ableitner et al., 2016) also reports small correlations among the variables shower duration, flow rate, and shower temperature. They found that the correlation between shower duration and flow rate was –0.08, the correlation between shower temperature and duration was 0.40, and the correlation between shower temperature and flow rate was –0.02. We also derived a weak correlation ($R = 0.26$) for the number of products used and the shower duration from the UK showering habits data (Unilever and the UK Water Companies, 2015). According to Smith, Ryan, and Evans (1992), in the presence of weak correlations, dependencies between the input parameters have only limited influence on the Monte Carlo simulation.

### 4.2 | Implications for policy makers, industries, and consumers

The need to move toward more sustainable showering with lower resource use and impacts typifies the challenge facing many policy makers where consumer behavior is involved. Our analysis has highlighted the differences in impact associated with showering and the contribution to the variance in impacts from reasoned decisions and habitual behavior in four consumer markets. It illustrates the need for multiple policy interventions that act both on one-off reasoned decision such as the choice of energy supply and shower equipment and on habitual consumer behavior such as length of shower. However, it is important for policy makers and product designers to understand which type of behavior they are trying to influence and the barriers involved as this is likely to determine both the rate and the size of change achievable.

In the case of showering, national policies should be focused on more efficient water heating and shower equipment and lower carbon-intensity energy supply. As shown in Supporting Information Figure S1-7, given the current electricity generation systems, electric water heaters have often the highest GHG emissions. However, if grid decarbonization policies are placed and pursued, electricity could be the most efficient source of water heating. Switzerland is a good example of this argument as the electricity consumed in Switzerland is mostly generated by hydro and nuclear power plants.

Energy Saving Trust (2013) and Energy Rating (2014) argue that replacing the electric hot water systems with solar water heaters and replacing the old showerheads with efficient showerheads can significantly reduce both water and energy demand. Investment in new infrastructure and adoption rates for new equipment at a national level may be slow. However, such policy interventions can be successful as illustrated by the United States where a lower flow shower standard has been in place since 1992 and where only 5% of the showers now have a flowrate over 9 L/min compared to 80% in Switzerland and 35% in Australia. As another example, if all consumers in Australia switch to solar boosted water heaters, our calculations show that there will be a 39% reduction in primary energy use, 33% reduction in GHG emissions, and 4% reduction in water consumption. The saving potentials due to switching to solar boosted water heaters in Switzerland will be 54% in primary energy use, 52% in GHG emissions, and 17% in water consumption. Although we assumed solar water heaters in Australia have a higher energy efficiency, the savings could be greater in Switzerland. This is mainly because the penetration rate of solar water heaters in Australia is already larger than that of Switzerland (See Table 1).

Changing consumer habits such as the length of the shower is also challenging particularly where it is associated with multiple functions and consumer satisfaction and not simply one function such as cleaning one's body or hair (Kurz et al., 2015). Such consumer habits tend to be engrained and resistant to change especially when a new behavior such as taking shorter showers may result in lower comfort and enjoyment (Poortinga, Steg, Vlek, & Wiersma, 2003). Verplanken and Wood (2006) argue that attempts to change people's beliefs and intentions are unlikely to be successful in changing habitual behavior. For example, research on energy conservation shows that mass media campaigns and information workshops can increase the knowledge level of consumers but does not necessarily result in behavior change (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Gardner & Stern, 2008). Verplanken and Wood (2006) also argue that successful interventions for changing old habits and establishing new ones requires three key elements: (a) Changing the context cues that stimulate the existing habits, (b) providing incentives that encourage new actions, and (c) encouraging repetition of new behaviors in stable conditions to form links between features of the environment and the action in the consumer's memory. For example, both providing feedback on energy consumption levels (Karlin, Ford, & Squiers, 2014) and reinforcement through monetary rewards have been reported to have a positive effect on energy savings. However, several studies suggest that the effects of these interventions may be short-lived and might diminish over time (Slavin, Wodarski, & Blackburn, 1981; Stewart, Willis, Panuwatwanich, & Sahin, 2013).

In the case of showering, there is a need for coordinated and concerted action and communications to consumers by all parties involved in showering namely, energy and water providers, shower manufacturers, and shower product manufacturers, on how consumers can shower more sustainably. Examples could include the visualization of shower times and flow rates through the use of timers and in-shower displays as well as financial incentives to support water and energy savings. The development of products that avoid the need for showering such as dry shampoos could also be an option. However, it is important to recognize that changes involving technological interventions, as opposed simply reducing shower times, will invariably result in trade-offs across other environmental impact categories not necessarily addressed in this study. It is, therefore, important that interdisciplinary approaches that link psychological, socio-cultural, and technological aspects are applied to any behavioral interventions intended to reduce the environmental footprints or impacts of consumer products (Staats, Harland, & Wilke, 2004; Steg & Vlek, 2009).

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## CONFLICT OF INTEREST

The authors have no conflict to declare.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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