Showering behavioural response to alarming visual display monitors: longitudinal mixed method study

Rodney A. Stewart*a, Rachelle M. Willisb, Kriengsak Panuwatwanichc and Oz Sahinch

*aCentre for Infrastructure Engineering & Management, Griffith University, Gold Coast Campus 4222, Australia; bAllconnex Water, PO Box 8042, Gold Coast, 9726 Australia; cGriffith School of Engineering, Griffith University, Gold Coast Campus 4222, Australia

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Residential households have the potential to conserve water, especially in behaviourally influenced end uses such as showering. Visual display monitors detailing shower water consumption parameters provide householders with a better understanding of their water use consumption and serve as a prompt to conserve. This longitudinal study first applied high resolution smart meters to create a registry of shower end use event parameters (i.e. shower duration, flow rate and duration) before and after the introduction of an alarming visual display monitor. The study showed a statistically significant mean reduction of 15.40 L (27%) in shower event volumes shortly after the implementation of the shower monitor. However, two subsequent smart metering reads indicated that shower end use water consumption savings diminished over time and mean showering volumes reverted back to their pre-intervention level after 4 months. That is, the longitudinal study provides empirical evidence that technological devices informing resource consumption may not be effective unless instilled habits or attitudes can be also modified; old habits die hard. Follow-up questionnaire surveys allowed for qualitative interpretations of the behavioural findings, through demographic summaries, residents’ perceptions on shower monitor performance and their use of device over time, to name a few.

Keywords: smart meters; resource consumption display monitors; water conservation behaviours; water end use; water demand management; water micro-component

1. Background

1.1. Improving urban water security

From a worldwide perspective, many governments and public utilities who are similarly impacted by water crises are investing significant funds in the development and implementation of water strategies to ensure future water demands can be met. Predictions and estimations of future demand and potential savings through the introduction of demand management strategies or source substitution options are now commonplace (Willis et al. 2009). Demand management strategies include water metering, water restrictions, rebate programmes for water efficient devices, water efficiency labelling, water conservation or education programmes and pressure and leakage management (Inman and Jeffrey 2006). Source substitution or ‘fit for use’ water involves replacing specific potable end uses such as toilet flushing and irrigation with recycled, grey or storm water (Willis et al. 2010). Water savings achievable from such programmes are calculated through a variety of assumptions but, once in place, limited consideration is given to determining the actual water savings associated with these strategies. It is well documented that more data and information should be collated on the effectiveness and sustainability of demand management techniques, to improve long-term forecasting (Chambers et al. 2005). After decades of inadequate metering of water use, organisations have come to the realisation that it is impossible to manage water services without adequate measuring and monitoring practices in place (Hearn 1998).

1.2. Domestic water consumption and conservation

Residential water consumption can account for up to 67% of the total supplied water in urban centres as was the case at the Gold Coast, Australia in 2010. Residential water consumption has previously been determined to be influenced by seasonal changes and water demand management (WDM) strategies such as water metering, water restriction levels, water efficient devices and education (Nieswiadomy 1992, Mayer et al. 2004, Inman and Jeffrey 2006). Although prior research has occurred, it is well established that there is a need for specific country and location based research
as different community attitudes and behaviours can influence the effectiveness of WDM strategies (Corral-Verdugo et al. 2003, Turner et al. 2005). To grasp the effectiveness of WDM strategies high quality data are required, hence the development and implementation of smart metering techniques (Stewart et al. 2010).

1.3. Advent of smart water metering and end use analysis

The need for smart water metering stemmed from the fact that traditional systems do not provide real-time water consumption data or sufficient data points to determine usage patterns. Conventional water meters count litres of water as it passes through the meter without the ability to record when (i.e. time of day) and where the consumption takes place (e.g. clothes washing, leakage, shower use, etc.). Water consumption readings are generally recorded manually on a quarterly or half yearly basis. Under most situations, a whole year’s worth of water consumption data are described by only two to four data points (Britton et al. 2008). No further information is available to draw upon should there be any queries (Hauber-Davis and Idris 2006). Obviously, this conventional water metering system produces limited, delayed water consumption information and is unable to provide effective support for water planning and management processes (Stewart et al. 2010). Moreover, it is not adequate to meet the increasing level of government scrutiny on the utilisation of water resources or the effectiveness of WDM strategies and does not assist society at large to address the pressing water security issues associated with climate change.

The concept of smart metering embraces two distinct elements: (1) meters that use new technology to capture water use information and (2) communication systems that can capture and transmit water use information as it happens, or almost as it happens. Smart water meters essentially perform three functions; they automatically and electronically capture, collect and communicate up-to-date water usage readings on a real-time basis (Idris 2006). To achieve this objective, the reed switch on traditional volumetric water meters is modified to collect a high resolution record of water use (i.e. from the traditional 2–72 pulses per litre or 0.014 L per pulse) which can then be disaggregated into individual water use events using a flow trace analysis software tool (e.g. Trace Wizard®). The high resolution water measurement information from the meter is then captured by attached high data capacity loggers (i.e. 2 million readings) recording information at a pre-set time interval (e.g. 5 s). Time scaled flow recording information is then collected in-situ through infrared cables or wirelessly through a mobile phone network. Once a representative sample of data is collected, the flow trace analysis software tool is applied to disaggregate flow traces into a list of component events assigned to a specific end use appliance or fixture (e.g. shower, toilet, clothes washing, etc.). Stock and behaviour surveys can also be utilised to help the analyst develop templates which encapsulate the appliance properties of end use events and ensure accurate end use categorisation. Once analysis has been completed a database registry of all end use events occurring during the sampled period is established and can subsequently be utilised for water planning and management research as demonstrated herein.

Therefore, a smart meter is a high resolution water meter (e.g. 72 pulses per litre) linked to a device (a data logger) that allows for the continuous reading of water consumption (Willis et al. 2010, Willis et al. 2011a). Smart metering allows for communication of captured data to a broad audience, e.g. utility managers, consumers and facility authorities. Smart metering is an established technology which is now cost-effective enough to be applied to collect, store and distribute real-time water consumption data (Hauber-Davis and Idris 2006). An automated meter reading system with this capability provides benefits for both consumers and water authorities for monitoring and controlling water consumption. Understanding and collecting empirical evidence of where and how water is used, through smart metering, allows planners and conservationists to determine the relative water saving of WDM strategies.

1.4. Engineered water conservation appliances and fixtures

The development of water efficient devices such as low flow shower roses or dual flush toilets has led to ongoing water savings within households. Several studies have been undertaken to determine the relative water savings attributed to the installation of engineering water conservation fixtures and appliances. The replacement of high water consuming devices with those of engineered water efficiency has resulted in indoor water consumption savings between 35 and 50% (Mayer et al. 2004, Inman and Jeffrey 2006).

A variety of water-saving devices are available on today’s market which attempt to reduce water end use consumption. Such devices include toilet dams, AAA rated shower roses, dual flush toilets (3/4.5 L/flush), water pressure limiting devices and tap aerators, to name a few. With respect to showers, the trend of lower shower consumption volumes with more efficient devices has previously been established by Mayer et al. (2004). In more recent times, the development of visual...
display technologies and alarming devices designed to influence both water and energy conservation responses at the end use level have become more readily available. Therefore, in addition to retrofitting appliances and fixtures with those of a higher efficiency, such display technologies provide a dynamic feedback to resource consumers, ultimately influencing behaviours.

1.5. Display technologies influencing resource conservation behaviours

While houses with water-saving devices typically demonstrate reduced end use water consumption, evidence also exists which indicates that engineered savings can often be diminished by human behaviour. For instance, a study by Inman and Jeffrey (2006) resulted in an increase in water consumption after the installation of water-saving devices. This was due to the residents’ misguided belief that they were saving water through their efficient devices and hence took longer showers which often resulted in higher consumption volumes. The ‘Human Exception Paradigm’ is a basic belief that humans are above nature and therefore do not have to regard it as they consume resources (Bechtel et al. 1999). Thus, these primitive beliefs can serve to inhibit conservational behaviour. A study into the link between environmental behaviour and water conservation behaviour determined that general environmental beliefs influenced the specific beliefs regarding the use of water, which in turn correlated with the measure of water consumption (Corral-Verdugo et al. 2003). Waisbord (1999, p. 2) states that ‘interventions are needed to provide people with information to change behaviour’ and that it is a lack of knowledge which contributes to problems in development. Education is a key component for changing behaviour and attitudes towards water use (Webb 2007). If people are made aware of their water usage, more importantly their water wastage, they are much more likely to actively reduce their consumption.

Essentially, the use of electronic visual and/or alarming monitoring devices provides instantaneous feedback to resource users. Compared with written feedback such as quarterly bills, electronic devices provide quicker and more frequent feedback, thus better informing the consumer of the consequence of their specific behaviours (Darby 2006, Midden et al. 2007). It is especially effective when information is given frequently, which is the case with continuous electronic feedback (Abrahamse et al. 2007). In general, feedback enables people to be more conscious of the relevance and influence of their own behaviour but more so when users have better aligned attitudes towards information technology usage (Davis 1989, Bhattacherjee and Sanford 2009) and perceive that it is compatible with their needs (Kwon et al. 2007, Zhang and Xu 2010). When resource consumption is closely linked to specific appliances and activities, the relevance and direct effect of behaviour becomes clearer. Through appliance-specific feedback, the consumer can determine how a certain appliance or a particular way of using it affects the amount of water or energy resource consumed. This allows the consumer to curb poor behaviours and to use resource consuming appliances more effectively to achieve higher savings and shift towards sustainable consumption habits (Fischer 2008).

In the electricity sector, immediate feedback through electronic devices has been regarded to be successful in helping to conserve energy (Wood and Newborough 2003). Specifically, electronic visual displays have proven to be useful in promoting energy conservation behaviour in people, based on extensive research conducted worldwide. In the US, McClelland and Cook (1979) carried out a study using the Fitch Energy Monitor (FEM) that displays the total electricity usage and reported a 12% reduction in electricity usage in households with the FEM compared with those without it. Similarly, in Canada, Dobson and Griffin (1992) investigated the use of the residential electricity cost speedometer (RECS) system, which measured household electricity consumption and presented cost and electricity consumption for various end uses displayed on an hourly, daily, monthly and annual basis. The results showed that the use of the RECS system helped reduce the average daily energy consumption by 12.9%. The above findings appear to be consistent with those found in Japan by Ueno et al. (2005, 2006), who conducted a series of experiments on the use of a computerised interactive ‘energy consumption information system’ that displays daily energy consumption for all the domestic appliances within a household. They found that the use of such a tool led to 9–12% reduction in power consumption and that energy-conservation awareness influenced not only the power consumption of the appliances explicitly shown on the display monitor but also other household appliances implying a change in consumption behaviours. In the UK, Wood and Newborough (2003) compared the effectiveness of providing paper-based energy-use/saving information with electronic feedback of energy consumption via smart meters and energy consumption indicator (ECI) displays. The findings showed that the average reduction for households employing an ECI was 15%, whereas those that were only given paper-based energy saving information reduced their electricity consumption, on average, by only 3%.

In the water sector, research on the impact of visual displays and alarming devices on water conservation is
still limited. In the US, Arroyo et al. (2005) developed a device called ‘WaterBot’ that presents immediate feedback in the form of visual and auditory reminders. The device is to be installed on household faucets to motivate people to turn off the tap when the water is not being used. Although there has been no systematic experiment conducted to quantify the water savings from installing the device, pilot studies through observations and user reports suggested a behavioural change that could reduce water consumption by the presence of the device. Recently, Kappel and Grechenig (2009) developed a shower water meter (show-me) that displays the amount of water used during one shower in the form of LEDs assembled on a stick, and installed the device in several households in Austria. The results showed a decrease in the mean shower water consumption of approximately 10 L. This suggested a promising water-saving potential in the shower with regards to using visual displays for delivering feedback.

In the case of this study, the WaiTEK® Shower Monitor® is an innovative device that provides the alarming visual feedback intervention (Figure 1). This educational engineering device provides a digital read-out of shower parameters such as flow rate, duration and temperature. Also, the device illustrates diagrammatically the volume of water remaining, before the alarm will sound, enabling users to monitor the progress of their shower against a set target. While most water-saving devices physically limit the volume or flow rate of water that can be used, this monitor does not affect the shower in any way. Rather, it simply provides the information necessary to allow households to shower more efficiently. At the end of the predetermined shower duration (i.e. 40 L in the case of this study), it will beep for duration of 1 min to indicate that it is time to get out of the shower. The beep is sufficiently loud to annoy the person showering and also be heard throughout an average household; however, a resident could become accustomed to this noise and continue showering if so desired. This device aims at educating the public on their shower water consumption as it is essential to encourage and develop behaviour leading towards sustainable water consumption, rather than simply enforcing a restriction. Armed with this information, shower users can supervise their own habits to ensure they adequately conserve water.

1.6. Achieving long-term resource conservation behaviour change

Water conservation represents one of the main environmental challenges to be faced by humanity in the twenty-first century to achieve a sustainable way of life on this planet. Solutions for this challenge have to be found by combining technological and socio-behavioural strategies to promote water conservation in populations throughout the world (Corral-Verdugo et al. 2003). In general, residential water demand is influenced by numerous factors such as the price of water, climate conditions, household income, number of people per household, number and efficiency of water using appliances and other factors. There have been a number of strategies to reduce water consumption across the globe, with mixed success, including water restrictions, information campaigns, pricing structure and retrofitting. Aitken et al. (1994) showed that water use feedback treatments were effective in reducing consumption.

The implementation of the above mentioned approaches for reducing residential water consumption has the potential to achieve water conservation. The enduring success of these approaches may also have some dependency on the concurrent modification of users’ attitudes and habits. Thus, changing the attitudes, habits and lifestyles of users is critical to instilling resource conservation behaviours (Willis et al. 2011b). Behavioural change is fast becoming the ‘holy grail’ of sustainable development policy, but this process is far from straightforward (Jackson 2005). In the energy sector, two accepted models of human behaviour generally have been used to promote conservation: the rational choice model and the attitude-behaviour model (McKenzie-Mohr et al. 1995).

The rational choice model assumes that individuals systematically evaluate alternative choices, such as the purchase of an air-conditioner or the installation of insulation, and then act in accord with their economic self-interest (Rolls 2001). However, this model fails to recognise the limitations on an individual’s ability to take deliberative actions, and the way in which individuals respond to affective or emotional...
influences. Individuals use a variety of mental ‘shortcuts’ such as habits, routines, cues and heuristics, which reduce the amount of cognitive processing needed to act and often bypass cognitive deliberation entirely. A degree of routine enters our behaviour, making it much more difficult to change, thereby undermining a key assumption of the rational choice model (Jackson 2005).

The attitude–behaviour model is based on the assumption that people’s behaviour is determined by their attitudes to particular issues such as conservation, and that their behaviour can be influenced by changing their attitudes (Rolls 2001). However, intended behaviour is not always observed behaviour, there are other factors preventing people from implementing their intention. Ajzen (1991) argues that for the behaviours considered, personal considerations tended to overshadow the influence of perceived social pressure. The major contributing drivers of intentions to conserve water were explained by subjective normative feelings (i.e. perceived peer pressure) and the exogenous variable age (Ajzen and Fishbein 1980, Ajzen 1991).

Similarly, other studies on conservation behaviour have confirmed that individual performance of a given behaviour is primarily determined by a person’s intention to perform that behaviour. The intention is determined by a person’s attitude towards the behaviour and by the influence of a person’s social environment or subjective norm (Hassel and Cary 2007).

Information campaigns have been widely used for achieving public interest goals. These campaigns are designed to encourage voluntary water conservation. Syme et al. (2000) argues that these are seen as an adjunct to other measures and as a public relations exercise for the public utility and can result in significant (up to 25%) water savings in short-term or crisis situations. However, they concluded, the effectiveness of such campaigns in the longer term has yet to be demonstrated. Furthermore, some studies found that their impact only lasted as long as the publicity (Syme et al. 2000). Outcomes of many research studies on consumption behaviours in the energy industry were similar to those in the water industry. Rolls (2001), who analysed a number of programmes relating to the promotion of energy-related behaviour change, concluded that there are few studies that assess the long-term persistence of the desired behaviour changes. Only one study found that behaviour change lasted longer than 12 months and that study only required a minor change in behaviour.

Community-based social marketing (CBSM) is an approach used to develop behaviour change strategies and is based on behaviour theory. This approach involves using behaviour change tools such as prompts, feedback, social norms, commitment and incentives to minimise or remove the barriers to, and enhance the benefits of, adopting the behaviour. McKenzie-Mohr and Smith (1999) argue that, by influencing a small part of the community, wider public behaviour can be influenced through the display of social norms. People are more likely to participate in an activity if those around are participating in the activity.

However, according to Jackson (2005), inducing lasting change in habitual or routine behaviours such as using an energy efficient appliance is much more difficult than influencing one-off behaviours such as turning off lights. Graymore and Wallis (2010) identified a number of barriers to the adoption of water-saving behaviours. The barriers identified were cost, trust in the water authority, perceptions of water abundance, lack of understanding about greywater, knowledge on other ways to save water and garden importance. Achieving environmental goals through behaviour change presents a difficult communication challenge, as the goals are often based on complex or uncertain science and require long-term collective action (Hassel and Cary 2007).

In general, most applications and models attempting to promote water conservation yielded varied outcomes. It may be concluded that there is no single method to establish sustainable behavioural change. A combination of several strategies seems to be more effective in promoting environmentally sustainable behaviour among domestic water users.

2. Research objectives

WDM and ‘fit for purpose’ water consumption have changed the current focus to demand, rather than supply side measures, to meet the ever increasing requirement on diminishing water resources. However, water authorities still have vague indications on the actual effectiveness of these programmes. This article provides an in-depth investigation into the effectiveness of an alarming visual display device, the WaiTEK® Shower Monitor®, on shower water end use properties.

The key objectives of this research are to:

- Determine the baseline water consumption end uses for a sample of households;
- Establish baseline shower end use event characteristics (e.g. volume, duration and flow rate) for 151 households in the Gold Coast Residential End Use Study (GCREUS);
- Evaluate the water-savings potential of the WaiTEK® Shower Monitor® in a sub-sample of households (N = 44) participating in the greater GCREUS sample;
- Determine households’ response to the alarming visual display device through reduced, or
otherwise, shower volumes, durations or flow rate;

- Identify changes in the showering habits of residents over time; and
- Evaluate householders perceptions on their behavioural response to the shower monitor and compare with recorded behaviours.

Research outcomes provide water authorities and government officers with both empirical and qualitative evidence on the effectiveness of alarming visual display technologies. The research method adopted to achieve the above mentioned objectives is provided below.

3. Research method

The greater GCREUS study participants (\(N = 151\)) were recruited through a multi-staged process of letters and door knocking. Selection of participants was based on a number of criteria including household ownership status (renting/owning) and household makeup, willingness to be part of the research for a period of two years, acceptance to having water consumption monitored over period, several questionnaire surveys, involvement in a range of potential interventions and involvement in a household water fixture/appliance stock audit. It should also be noted that historical household volumetric readings were analysed for the consenting sample to ensure that they are representative of Gold Coast City, located in the State of Queensland, Australia.

Upon completion of recruitment, the existing standard residential water meters were replaced with high resolution water meters and data loggers to obtain end use water consumption data. The modified Actaris CTS-5 water meters pulse at a rate of 72 counts per litre of water consumed; this equates to an individual recording every 0.014 L of water use. Aegis DataCell D data loggers were connected to water meters to record water consumption. Data loggers were set to record information every 10 s over a 2-week period. Figure 2 illustrates the smart metering equipment installed in the field. This resulted in 14 days of end use data for each household. Trace Wizard® software was utilised to synthesise data into water end uses. This software provides the analyst with powerful processing tools and a library of flow trace patterns for recognising a variety of residential fixtures. Once the raw data has been downloaded from the data logger and processed, it can then be loaded into Trace Wizard®. This software displays the data via a flow rate versus duration graph, whereby any consistent flow pattern or event can be isolated, quantified and categorised based on an established series of end use templates with specific information regarding a particular household’s water usage patterns. Summary data for each water event is then calculated, including, duration, volume, mode flow rate, mode flow frequency, as well as start and stop times for each episode. The software has the ability to recognise two simultaneous events. Once analysis has been completed, the file is converted to a database format, whereby a complete registry of end use event information is stored. For the purposes of this study, this database allowed researchers to create relative and cumulative frequency distributions for shower end use event durations, volumes and flow rates. Figure 3 details a schematic diagram illustrating the process for data acquisition, capture, transfer and analysis of water flow data into a registry of discrete end use events.

![Figure 2. Smart metering equipment installation.](image)
The baseline data utilised in this article was collected during winter 2008. During this time there were no water restrictions in place in Gold Coast City as its primary water source (i.e. Hinze Dam) was higher than 95% capacity. In total, the 151 households were monitored in the GCREUS baseline sample. In addition to monitoring water consumption, questionnaire surveys soliciting descriptive information were developed and distributed to all the sample households. Surveys were conducted to solicit household demographic information, including (1) household address and region; (2) resident numbers, gender, age, employment, weekly income, education status and relationship of people within the house; and (3) household ownership status (Willis et al. 2010). Household stock inventory surveys were also conducted to ascertain the characteristics of water fixtures and appliances (e.g. star rating of washing machine, flow rate of taps, etc.) as well as hot-water heating systems.

A sub-sample from the 151 households in the GCREUS was recruited to participate in the herein mentioned shower monitor retrofit study. A total of 44 households were included in the sub-sample, and all of their utilised showers were fitted with the alarming visual display device (Figure 1) that was locked to a 40 L shower event (i.e. based on a 5 min shower at a flow rate of 8 L/min). The device was set to alarm after the 40 L volume was consumed so individuals would know when it was time to get out of the shower. The shower monitors were all locked with a four-digit pin code that was retained by the researchers for the majority of the study period to ensure that settings were not changed.

Following the implementation of the shower monitors, three post-retrofit data-sets were collected following the same process described above for the baseline GCREUS study. The first post-retrofit end use data (PR1) was collected over a 2-week period in winter 2009. Then, a second (PR2) and third post-retrofit (PR3) end use data registry was collected 1 month and 3 months after the PR1, respectively. The last two reads were performed in order to understand whether the shower monitors influenced long-term water conservation behaviour change. Before the final read (PR3), the shower monitors pin code and

![Figure 3. Schematic illustrating water end use analysis process.](image-url)
instructions for changing settings were provided to the participants. This enabled householders to change the display and alarm settings as desired.

Analysed and verified trace analysis files for the pre- and post-shower monitor retrofit were converted to database files whereby all shower events could be listed and categorised based on event duration (based on event start and end time), volume or flow rate. Relative and cumulative frequency distributions for sub-sample shower event characteristics were then established along with their associated mean, median and standard deviation values. This data analysis process enabled shower event comparisons to be conducted pre- and post-installation of the shower monitor. The baseline water consumption end use results, with a particular focus on shower end use is presented in the next section, followed by the comparative assessment pre- and post-implementation of the shower monitors.

Following the final read (PR3), a questionnaire survey was completed to determine how the participants perceived the influence of the shower monitor to influence their showering behaviour over time. The objective of this post hoc stage of the study was to gain a deeper understanding on the households’ interaction with the shower monitor and to align perceived and actual behavioural response and to discuss any evident differences.

4. Baseline water consumption end use analysis
The break down of the baseline end use water consumption for the sampled households in the GCREUS (N = 151) for winter 2008 is presented in Figure 4. According to this figure, the average baseline consumption for the sampled Gold Coast households (N = 151) was 157.2 litres per person per day (L/p/d). The highest end use was showering, with each person consuming almost 50 L of water a day or 33% of total use. Clothes’ washing was the next highest end use at 30 L/p/d or 19% of total consumption. Tap use, toilet flushing and irrigation follow with end use percentages of 17%, 13% and 12%, respectively. Bath use, dishwashing and leaks make up a small component of water end use with percentages ranging from 1% to 4%. Many of the prior mentioned end use studies show irrigation consuming a higher proportion of the total household water consumption, especially in summer months. This data collection period occurred shortly after a period of drought where irrigation was severely restricted. Moreover, higher than average rainfall and low temperatures resulted in minimal irrigation demand. It has become evident that this drought instilled a community culture shift whereby brown grass became more acceptable in dry periods.

Figure 5 demonstrates the descending order distribution of the end use water consumption break down for each of the measured 151 households. It also shows the proportion of sampled households within each of the Queensland water commission (QWC) restriction regime categories, to which the Gold Coast local government area (LGA) must conform (i.e. Target 140: extreme level; Target 170: high level; Target 200: medium level and Target 230: permanent water conservation measures). The average total consumption of sampled households in the study and distribution are representative of the Gold Coast at the time of study.

While there were no restrictions at the time on the Gold Coast, almost half of the research population (46%) consumed less than 140.0 L/p/d. Water consumption is highly varied between individual households. The highest per capita use equated to 390.0 L/p/d while the lowest use was as small as 38.4 L/p/d. This substantial difference between the highest and lowest per capita consumption volumes demonstrates that a spread of water users is present in this research sample. Figure 5 illustrates that shower end use in many households is the major contributor to the total water consumption level. The extracted water end use distribution of this specific activity is presented in Figure 6.

Figure 6 shows that 13% of the sampled households consumed 30% of the total volume of water utilised for showering purposes. This highlighted sub-sample (13%) constitutes a non-linear shower use pattern as opposed to the remaining research population (87%) which shows a reasonably linear rate of
change in consumption. The distribution of shower use, as illustrated in the Figure 6 insert, demonstrates that half of the population used less than 40 L/p/d of water for showering which is equivalent to a 5 min shower at 8 L/min. For the remaining categories, 37% of households use between 41 and 80 L/p/d with the high user group (13%) consuming on average more than 80 L/p/d in the shower. The high level of shower end use consumption and its variability identified in the baseline study instigated the design for the shower monitor intervention study described in the next section.

5. Quantitative study: analysing shower end use events pre- and post-shower monitor

As described in the research method, the categorised shower end use event features were compiled into a database for both the pre- and post-shower monitor implementation. Three of the shower event features, namely, event duration, volume and mode flow rate, were summarised in a clustered relative and cumulative frequency distribution histogram. Moreover, the mean and median values for these features pre- and post-implementation were determined and compared. As mentioned previously, readers should note that the
fixed 40 L volume is a function of flow rate and duration and the device compensates for variation in these variables. The following sections provide the results and discussion relating to changes in shower duration, volumes and flow rates, respectively.

5.1. Influence on shower duration

Variations in the relative and cumulative frequency distribution for shower event durations for pre-retrofit as well as the three post-retrofit measurements are shown in Figure 7. From these four measurements, the impact of the alarming device on end users’ sustainable water use behaviour was explored. As seen in Figure 7, before the introduction of the shower monitor, the frequency of shower event durations between 1 and 7 min accounted for 61.0% of total shower events. After the installation of shower monitor, the frequency of shower events between 1 and 7 min initially increased from 61.0% to 75.6%, and the mean shower duration decreased from 7.19 to 5.86 min, or 18.5% as shown in Table 1. That is, shortly after the introduction of the shower monitor there was a significant reduction in shower durations ($t = 6.62; p < 0.0005$). However, as demonstrated in subsequent end use data analysis reads PR2 and PR3, showering durations steadily increased and were only 3.89% lower (i.e. 6.91 min) than the pre-retrofit level (i.e. 7.19 min) at the last read.

PR3 data shows that, compared with the pre-retrofit level, shower events less than 4 min and greater than 10 min decreased by 4.3% and 3.3%, respectively, while the frequency of shower events between 7 and 10 min increased by 2.9%. The result indicates the existence of a slight upward trend towards 7–10 min shower events from upper and lower interval categories after the shower monitors had been installed for more than 3 months.

In summary, while data obtained from PR1 measurement indicates that the installation of the shower monitor encouraged residents to reduce their shower duration initially, analysis of subsequent measurements indicate that this was largely not sustained and households reverted back to their original behaviours. Reasoning to this rebound in behaviours to original habits will be explored subsequently.

5.2. Influence on shower volumes

Figure 8 details the relative and cumulative frequency of shower event volumes pre- and post-installation of the shower monitor. Prior to the installation of the shower monitor, 39.9% of shower event volumes were less than 40 L. After the installation, shower event volumes less than 40 L initially increased to 59.3%, and then, as observed from PR2 and PR3, the shower events with a volume less than 40 L reduced to 34.7% and 37.8%, respectively. Although the mean shower event volume initially decreased from 57.37 to 41.97 L (i.e. 26.8% reduction), indicating significant water savings ($t = 8.93; p < 0.0005$) shortly after the shower monitor retrofit (PR1), data derived from consecutive reads (PR2 and PR3) demonstrates that residents

![Figure 7.](image-url)
gradually reverted to their initial water consumption level (Figure 8 and Table 1). PR2 shower event mean volumes rebounded up to 53.35 L and PR3 to 58.47 L. The last read (PR3; 58.47 L) is 1.1% higher than the pre-retrofit read (i.e. 57.37 L) indicating that the shower monitor had no influence on long-term showering habits. The reason for this rebound in behaviours to original habits will be explored in the later sections of this article.

5.3. Influence on shower flow rates

The shower event mode flow rate relative and cumulative frequency distribution for sampled households is presented in Figure 9. Comparing the cumulative frequency distributions pre- and immediately post-retrofit (i.e. PR1) shows that after the installation of the shower monitor, residents having a shower with a flow rate more than 8 L/min reduced from 59.3% to 48.0%. The mean flow rate decreased from 9.98 L/min to 8.98 L/min (10.02%), which represented a significant reduction ($t = 5.78; p < 0.0005$). However, following a similar trend to duration and volume parameters, the subsequent PR2 and PR3 data reads revealed that this initial behavioural change was not sustained and flow rates rebounded to be slightly higher (4.11%) than the pre-retrofit level (Table 1). A summary assessment on the quantitative shower end use data analysis is provided.

5.4. Summary assessment

The quantitative shower end use monitoring stage of the study provides empirical evidence that visual display technology induced a short-term shift in showering behaviours. Having direct display information and being warned (i.e. alarm sounds) about their water consumption, residents initially responded accordingly and changed their showering habits, which resulted in a significant reduction in water usage.

Table 1. Shower end use event characteristics pre- and post-retrofit of shower monitor.

<table>
<thead>
<tr>
<th>Study stages</th>
<th>Flow rate (L/min)</th>
<th>Duration (min)</th>
<th>Volume (L)</th>
<th>Flow rate difference (L/min)</th>
<th>Duration difference (min)</th>
<th>Volume difference (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-retrofit</td>
<td>9.98</td>
<td>7.19</td>
<td>57.37</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Post-retrofit 1 (PR1)</td>
<td>8.98</td>
<td>5.36</td>
<td>41.97</td>
<td>-1.00</td>
<td>-10.02</td>
<td>-18.50</td>
</tr>
<tr>
<td>Post-retrofit 2 (PR2)</td>
<td>10.76</td>
<td>6.63</td>
<td>53.35</td>
<td>0.78</td>
<td>7.82</td>
<td>7.79</td>
</tr>
<tr>
<td>Post-retrofit 3 (PR3)</td>
<td>10.39</td>
<td>6.91</td>
<td>58.47</td>
<td>0.41</td>
<td>4.11</td>
<td>3.89</td>
</tr>
</tbody>
</table>

Figure 8. Relative and cumulative frequency distribution for shower event volumes.
However, such reductions were only sustained for a very short period and showering habits reverted back to those prior to the installation of the shower monitor after a few months (Figure 10). The shower monitors contribution to long-term water conservation habits to sustain water savings is not evident from the quantitative data; in fact, it is quite the contrary. This might be a result of residents’ reluctance to make enduring changes to their showering habits. Nonetheless, it is clear from the results that bringing about sustained water conservation behaviour change among residents cannot be achieved solely by the introduction of display devices and/or alarming devices.

Often proponents of technological devices claim long-term conservation savings based on translating short-term savings, demonstrated through in house testing, over longer periods. The empirical results from this study indicate that the shower monitor device does not lead to any sustainable long-term change in showering behaviours; the device may only serve to reinforce existing good habits and not lead to changing habits in those residents that are not so inclined. It is interesting to note that there was a small reduction in shower durations over the study period but also a small increase in flow rates, indicating that some residents may have believed that they could increase flow rates without penalty with respect to the 40 L volume where the display monitor alarm was set. Moreover, given the device was set to alarm at 40 L, many households during reads PR1, and particularly PR2, must have regularly endured or consciously ignored the 1-min alarm and continued showering. Also, others would have changed the shower monitor settings prior to PR3 to enable them to revert to their old habits without any feeling of guilt. Such long-term responses of users, eluded here, required further in-depth explanation.

Figure 9. Relative and cumulative frequency distribution for shower event flow rates.

Figure 10. Overall mean/median shower event volume comparative assessment.
From the quantitative study, it is evident that the government must look further than technological ‘know-how’ in order to achieve sustainable long-term water conservation practices. The empirical results presented, indicate that visual display monitors alone will not achieve reductions in domestic demand. The results indicate that further research in this field may need to further explore the socio-psychological aspects of showering habits to unlock clues as to how showering habits can be influenced over the longer term. The quantitative study provides hints that particular individuals within the household may only change when seeking change themselves or being influenced by social norms. Moreover, the lack of sustained change from the technological device suggests that social marketing and education programmes are potentially better strategies for reducing excessive showering. The following section provides a discussion on the post hoc survey study results revealing how residents perceived the influence of the shower monitor device on their households’ showering behaviours.

6. Questionnaire survey: post hoc shower end use study evaluation

A questionnaire survey was conducted after the final end use read (PR3) with 34 of the 44 households participating in the shower monitor intervention study. The main purpose of the survey was to obtain residents’ opinions in relation to the shower monitor, its impact on their shower use behaviour and their interaction with it. Data obtained from the survey was examined to understand how residents used consumption feedback from the alarming devices. Through a telephone survey, residents were requested to answer 17 questions constructed in a mix of dichotomous (yes/no answers), multiple choice, as well as some 5-point scaled Likert response formats. One respondent was requested to represent the household and respond to the survey questions, however, they were asked to consult with other householders to gain consensus where necessary. These questions were divided into four main sections:

- Section 1 aimed to confirm whether the residents have the shower monitor installed in their house, to determine the number of shower monitors installed and if they were still in use;
- Section 2 was concerned with age groups and make-up of the household and who generally used the shower monitor (adults, children or guest);
- Section 3 was concerned with the respondents’ overall reaction to the shower monitors and aimed to determine the actual impact of the monitors on their shower behaviours within the first month of installation, and whether these shower use behaviours change over time, prior to and after receiving the pin code to unlock the monitor; and
- Section 4 was concerned with the respondent’s overall perception on the longer term use of shower monitors.

The results from the first section of the questionnaire confirmed that all of the 34 sampled residents had the shower monitor installed. The majority (67.6%) indicated that they have only one monitor in their house, while the remaining (32.4%) have two monitors installed. Most respondents (94.1%) reported that the monitors were still operating at the time of the survey.

Table 2 presents a summary of households’ demographic information from the second section of the survey. Analysis of the number of persons usually resided in a household shows that there was a small proportion of single person households (2.9%) and a greater proportion of larger households with four or more persons (64.7%). Most households (97.1%) had two or more adults residing in them (over 18). The result also shows that 85.3% of households have no teenager and 41.2% have no young children (3–12). None of the participating households have children younger than 3 years old. Furthermore, Table 3 shows that the majority of shower monitors (70.6%) installed in residents’ ensuite are used by adults, while only 44.1% installed in their main bathroom are used by adults.

<table>
<thead>
<tr>
<th>Number of people</th>
<th>Adult (+18)</th>
<th>Teenager (13–17)</th>
<th>Young children (3–12)</th>
<th>Toddlers (0–2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>%</td>
<td>Frequency</td>
<td>%</td>
<td>Frequency</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>29</td>
<td>85.3</td>
<td>14</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2.9</td>
<td>2</td>
<td>5.9</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>76.5</td>
<td>3</td>
<td>8.8</td>
</tr>
<tr>
<td>3 or more</td>
<td>7</td>
<td>20.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>100</td>
<td>34</td>
<td>100</td>
</tr>
</tbody>
</table>
Results from the third section of the questionnaire revealed that 88.2% of the respondents were initially satisfied with their shower monitor. Residents were further asked how they reacted to the beeping of the shower monitor. The survey results show that most residents stopped the shower when the monitor beeped (85.3%). Consistent with this, most residents (79.4%) responded that they actively used the shower monitor to watch the time they spent in the shower.

Residents were further asked what changes they noticed in the way the shower monitor altered shower behaviour after the first month of shower monitor installation. As shown in Table 4, respondents seem to perceive that, to a large extent, the shower monitor helped to understand how long they spend in the shower (Mean = 4.18; Median = 5.00) and shorten their shower time (Mean = 3.65; Median = 4.00). This finding is in line with responses from the previous questions that residents generally stopped the shower after the monitor alarmed and that the shower monitors were used to keep an eye on their shower duration. More importantly, the finding is corroborated by post-installation (PRI) results which clearly indicate that the shower monitor had a significant impact on reducing water consumption within the first month of installation, particularly among residents using less than 50 L per shower.

In addition, the residents perceived on average that the shower monitor reduced, to a moderate extent, the volume of water used (Mean = 2.97; Median = 3.00), influenced change in shower use behaviour in general (Mean = 3.29; Median = 3.00) and assisted with adjusting the temperature (Mean = 3.03; Median 3.00). Only to some extent did the residents perceive that the shower monitor assisted in reducing the flow rate of their shower (Mean = 2.32; Median = 2.00). Although residents acknowledged that the shower monitor initially helped to understand the time spent in the shower and aided potential reductions in showering times, their response to questions relating to perceived long-term savings achievable from the device are more closely aligned with their actual behaviours.

The third section of the questionnaire asked respondents to indicate their perceived changes in shower use behaviour in subsequent months after monitor installation but prior to receiving the pin code. As shown in Table 5, about two-third of the respondents replied that they usually finished showering before the

Table 3. Shower monitor users in particular household bathroom.

<table>
<thead>
<tr>
<th></th>
<th>Ensuite bathroom</th>
<th>%</th>
<th>Main bathroom</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>24</td>
<td>70.6</td>
<td>15</td>
<td>44.1</td>
</tr>
<tr>
<td>Teenagers</td>
<td>3</td>
<td>8.8</td>
<td>4</td>
<td>11.8</td>
</tr>
<tr>
<td>Children</td>
<td>8</td>
<td>23.5</td>
<td>13</td>
<td>38.2</td>
</tr>
<tr>
<td>Guests/Others</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4. Respondents' perception on the influence of the shower monitors.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortened the shower time of those that showered with it?</td>
<td>3.65</td>
<td>4.00</td>
<td>1.070</td>
</tr>
<tr>
<td>Assisted in reducing the pressure or flow of the shower?</td>
<td>2.32</td>
<td>2.00</td>
<td>1.408</td>
</tr>
<tr>
<td>Reduced the volume of water used?</td>
<td>2.97</td>
<td>3.00</td>
<td>1.446</td>
</tr>
<tr>
<td>Helped the user understand how long they were showering for?</td>
<td>4.18</td>
<td>5.00</td>
<td>1.141</td>
</tr>
<tr>
<td>Assisted with adjusting/setting the temperature?</td>
<td>3.03</td>
<td>3.00</td>
<td>1.605</td>
</tr>
<tr>
<td>Effected shower use behaviour change in general?</td>
<td>3.29</td>
<td>3.00</td>
<td>1.115</td>
</tr>
</tbody>
</table>

Table 5. Impact of monitor on showering behaviours.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Yes Frequency</th>
<th>%</th>
<th>No Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users generally completed their shower before the monitor alarmed?</td>
<td>22</td>
<td>64.7</td>
<td>12</td>
<td>35.3</td>
</tr>
<tr>
<td>Users generally got used to the 1 min of beeping and continued showering</td>
<td>19</td>
<td>55.9</td>
<td>15</td>
<td>44.1</td>
</tr>
<tr>
<td>until it stopped?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generally users turned off the shower and then turned it back on again to</td>
<td>2</td>
<td>5.9</td>
<td>32</td>
<td>94.1</td>
</tr>
<tr>
<td>avoid the beeping?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generally users had more showers of lower durations (i.e. have two short</td>
<td>9</td>
<td>26.5</td>
<td>25</td>
<td>73.5</td>
</tr>
<tr>
<td>showers less than 40 L rather than one long shower)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
monitor alarmed. However, 55.9% also stated that they got used to the 1-min beeping and continued showering until it stopped. This contradicts with the residents’ responses to the previous question, but is consistent with the actual PR2 and PR3 behaviours recorded, which demonstrated that the residents showed a tendency to revert to their pre-intervened water consumption habit. While residents were not tempted to turn off the shower for greater than 1 min and to turn it on again to avoid beeping (only 5.9%), a reasonable portion (26.5%) were inclined to increase their total number of showers to compensate for the reduced duration of each shower event. These survey findings support the quantitative study that the monitor may not have had the desired influence on water conservation and thus may not alone be effective in reducing shower end use water consumption.

Another line of questioning sought to determine how the residents behaved after receiving a letter with the pin code to change the ‘locked’ settings of the shower monitor (i.e. can turn off or change alarm settings). In total, 30 respondents confirmed that they received the letter and all of them reported that they did not turn off the beeper completely. However, some of these respondents (11.8%) indicated that they had altered the shower duration on the monitor. Analysis results of data-sets obtained from the PR3 read indicate that a significant portion of households were still showering after the monitor alarm sounded or had changed alarm settings. Although the majority of the residents continued using the monitor, its conservation benefits diminished over time; indicating that it did not induce any sustained behaviour change. The survey findings revealed that this is most likely because residents became desensitised to the alarm and potentially ignored the device features altogether.

The results from the last section of the survey (Table 6) showed that 97.1% of the residents indicated that they were happy to continue using the shower monitor. Surprisingly, given their prior responses, the majority (88.2%) also believed that the shower monitor has induced long-term shower use behaviour change in their home. When compared with the pre- and post-installation data analyses and the above survey findings, these results show that people intend to change their behaviour, however, fail to take deliberate action to do so. In addition, almost all respondents (94.1%) believe that there are no better products or approaches to influence shower use and 97.1% of them reported that they would recommend this product to a friend or relative. However, 76.5% of respondents stated that they would not purchase this product when they were told that its retail cost was AUD$155. All of the respondents agreed that this product or a similar one should be offered cheaper through a government rebate scheme (e.g. receive AUD$100 rebate). It appears that the residents are not very sure whether the monetary benefits of using the shower monitor outweighs the purchasing cost.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Yes</th>
<th>%</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will you and your family continue to use the shower monitor?</td>
<td>33</td>
<td>97.1</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>On average, do you believe that the shower monitor has induced long-term shower use behaviour change in your home?</td>
<td>30</td>
<td>88.2</td>
<td>4</td>
<td>11.8</td>
</tr>
<tr>
<td>Do you believe there are better products or approaches to influence shower use?</td>
<td>1</td>
<td>2.9</td>
<td>33</td>
<td>97.1</td>
</tr>
<tr>
<td>Would you recommend this product to a friend or relative?</td>
<td>33</td>
<td>97.1</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>The shower monitor is valued at $155 per unit. Would you purchase this product knowing its cost?</td>
<td>8</td>
<td>23.5</td>
<td>26</td>
<td>76.5</td>
</tr>
<tr>
<td>Do you think this product or a similar product should be offered cheaper under a government rebate scheme?</td>
<td>34</td>
<td>100.0</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### 7. Concluding remarks

This article presented findings from a longitudinal study evaluating the influence of an alarming visual display device on shower end use durations, flow rates and volumes. Changes in showering behaviours were examined to determine the extent to which the monitor influenced residents’ habits over time. Additionally, post hoc questionnaire surveys of residents participating in the study were completed to explore how they responded to the device.

The quantitative and survey findings presented above showed mixed results. The quantitative study initially showed participating residents on average, reducing their showering volumes very close to the 40 L set target, however, these reductions were not sustained for any meaningful period and soon users reverted to their pre-retrofit levels of shower consumption. The survey study findings revealed that the majority of participants were aware of the importance of water conservation and indicated a willingness to reduce their showering water consumption.
The quantitative results demonstrated that reductions in residential water consumption can be achieved by providing feedback information through the shower monitor in the very short term. However, monitoring of actual long-term behaviour indicates that this information display device loses its influence over time and householders inevitably revert back to old showering habits. Besides, as the survey findings confirm, residents’ beliefs about water use do not correspond to their actual water use behaviour as presented herein. The study demonstrates that there is a discrepancy between residents’ perceived water use behaviours and their actual water consumption. It seems that actual water consumption behaviour or habit does not align with their perceived behaviour.

The findings detailed herein are consistent with a very recent study in the Netherlands, which examined the impact of home energy monitors on households’ habitual energy saving behaviour over the medium term (van Dam et al. 2010). Similar to this study, van Dam et al. (2010) results demonstrated that the initial 7.8% saving in electricity consumption was not sustained in the medium- to long-term. Syme et al. (2000) suggest that the lack of savings might be due to a user’s belief that they had done their part for water conservation by merely installing the resource conservation device. But as demonstrated in both research conducted by van Dam et al. (2010) and this study, instilling sustained behaviour change is the best response strategy for addressing water conservation problems. However, old habits die hard even when they are obviously inadequate or unfavourable. People inherently resist changing their accustomed behaviour.

This study shows that the existing showering habits quickly return, thereby impeding the effectiveness of the shower monitor examined in this study. It is apparent that behaviourally influenced water consumption is essentially complicated and will not occur by technology alone. It would be inappropriate to assume that engineered information leads to awareness, and awareness to sustainable water conservation action. The longitudinal study disputes the assumption that feedback alone provided by the alarming shower monitor would reduce water consumption over time. However, it is still contended that without feedback, it is considerably more difficult for residents to learn and establish water conservation habits effectively.

Observed short-term reductions in showering behaviours and the survey results support the view that alarming visual display monitors have capacity to support more conservational showering habits through providing immediate feedback. However, such feedback will only serve to support residents who actively seek to modify their current habits or to maintain existing good habits.

It also requires an understanding of what causes people to change behaviour. People might need help in interpreting the information from the monitoring device and in deciding what courses of action to take further. Furthermore, it is necessary to understand underlying motives which may influence residents to revert back to their previous habits. Hence, changing the minds, habits and lifestyles of users is critical to achieve long-term conservation goals. Establishing a sustainable change in habitual behaviours is very difficult and may be achieved more effectively by combining several strategies to promote water conservation, such as, more frequent and informative billing, pricing, public awareness programmes, smart water-saving appliances, government rebates, etc.

Therefore, further research is required to determine which individual (e.g. shower monitor, social marketing, etc.) or combinations of strategies (e.g. shower monitor and social norms feedback) for changing routine behaviours have most potential to achieve long-term water-saving goals. This study steers government and water industry practitioners/advisors towards WDM policies that effectively integrate technological strategies with socio-behavioural strategies for reducing water consumption in domestic settings.

References


Willis, R.M., et al., 2011a. Residential potable and recycled water end uses in a dual reticulated supply system. Desalination, 272, 201–211.

