Journal of Cleaner Production 60 (2013) 107–115

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

End use water consumption in households: impact of socio-demographic factors and efficient devices

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ARTICLE INFO

Article history:
Received 22 October 2010
Received in revised form
20 May 2011
Accepted 9 August 2011
Available online 6 October 2011

Keywords:
Smart metering
Conservation attitudes
Urban water
Water demand management
Water efficiency
Water end use
Water micro-component

ABSTRACT

To assess water savings in households using efficient devices and to understand how savings vary between different socio-demographic groups in the community, high resolution end use water consumption data is required (i.e. disaggregating water use for showers, toilets, clothes washers and garden irrigation etc.). This paper reports selected findings from the *Gold Coast Residential End Use Study (Australia)*, which focussed on the relationship between a range of socio-demographic and household stock efficiency variables and water end use consumption levels. A mixed methods approach was executed using qualitative and quantitative data. The study provided evidence as to the potential savings derived from efficient appliances as well as socio-demographic clusters having higher water consumption across end uses. The payback period for some water efficient devices was also explored. The study has implications for urban water demand management planning and forecasting.

1. Introduction

1.1. Improving urban water security

The strong emphasis on ensuring a secure water supply for the population of Australia has been brought to light by the increasing frequency, severity and duration of drought events throughout the nation. Drought, coupled with growing populations has lead to numerous instances of many water supply reservoirs in South-East Queensland (SEQ) dropping below 20% over the last decade. This has forced State and Local government to implement alternative water supply schemes, along with a range of demand management interventions, in order to improve urban water security. Innovative water re-use (e.g. Willis et al., 2010a; Willis et al., 2011a) and decentralised supply solutions (e.g. Talebpour et al., 2011) are becoming increasingly viable technologies to meet city water needs but there are often many financial, behavioural and regulatory barriers to their diffusion in practice (Partzsch, 2009; Krozer et al., 2010; Giurco et al., 2011; Willis et al., 2011b). Planning studies employing holistic Integrated Water Resource Management (IWRM) models (e.g. Dvarioniene and Stasiskiene, 2007) have been applied and demonstrated that high efficiency water fixtures and appliances are a least cost planning strategy for water conservation and a good starting point for policy makers before higher cost water supply or demand solutions are commissioned (Stewart et al., 2010).

1.2. Domestic water consumption and conservation

In the Gold Coast, Australia – a city of 510,000 people – residential water consumption accounts for approximately 66% of the City's total supply (2007/2008). Residential water consumption has previously been determined to be influenced by seasonal changes and Water Demand Management (WDM) strategies such as water metering (compared with unmetered homes), water restriction levels, water efficient devices, water consumption information devices and education (Beal et al., 2010; Inman and Jeffrey, 2006; Mayer et al., 2004; Nieswaidomy, 1992; Willis et al., 2010b).

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doi:10.1016/j.jclepro.2011.08.006

Although prior research in these areas has occurred, it is well established that there is a requirement for specific country and location based research for a range of reasons, including differences in: (1) community attitudes and behaviours; (2) water appliance stock efficiency profiles; (3) environmental conditions; (4) water pricing structures; (5) government water restriction regimes; and (6) conservation message intensity. All such contextual factors have an influence on the effectiveness of WDM strategies (Corral-Verdugo et al., 2002; Turner et al., 2005; Stewart et al., 2011; Willis et al., 2011b; Beal et al., 2011). To evaluate the effectiveness of WDM strategies high quality data is required (Stewart et al., 2010). The development of smart metering technologies and end use analysis techniques allowed for the acquisition of such data in this study.

1.3. Advent of smart water metering, monitoring and management

The measurement, benchmarking and management of a process, product, project or system is an expected requirement in almost all industry sectors in the modern age (Stewart and Spencer, 2006; Stewart, 2008; Panuwatwanich et al., 2009). Such evaluation activities ensure the continual improvement of a business or industry sector, and are finally being applied in the water industry due to the advent of smart water metering technologies, which allow the collection of empirical evidence on *where in the home* and *how often* water is used, thereby allowing planners and conservationists to determine the relative water savings achievable from WDM strategies. Smart metering and management systems enable better measurement and management of valuable urban water supplies and the distribution systems that deliver this potable water to the household (Stewart et al., 2010). Conventional water meters in residential households in Australia only count the volume of water used and there is no facility to determine when and which water end use event is occurring (such as in showers, toilets, clothes washers, garden irrigation etc.). Water consumption is characteristically recorded quarterly, resulting in just two to four data points describing a whole year's water consumption (Britton et al., 2008). Smart metering couples a higher resolution water meter with data logging equipment which allows for continuous water consumption recording. Data resulting from smart metering applications allows water managers to investigate the effectiveness of WDM strategies and household water consumption patterns amongst different socio-demographic groups (Beal et al., 2010; Stewart et al., 2010).

1.4. Overview of Gold Coast residential end use study

The Gold Coast Residential End Use Study (GCREUS) commenced in 2007 as an Australian Research Council (ARC) funded collaborative research investigation by Griffith University, Gold Coast Water and the Institute for Sustainable Future (University of Technology, Sydney). The purpose of this study was to identify end use water consumption in Gold Coast homes and to evaluate the effectiveness of WDM strategies namely the application of water efficient devices and education as well as understanding water use differences between varying socio-demographic groups. Smart metering was implemented to ascertain end use water consumption data, to enable comparative analysis between varying household socio-demographic clusters and to understand the water saving potential of efficient devices. These aspects represent two objectives of the GCREUS study explored in this paper.

1.5. Engineered water efficiency

Engineered efficiency or the development of higher efficiency water using devices has seen effective reductions in water consumption. In Tampa, USA Mayer et al. (2004) determined that the retrofitting of water efficient devices can result in a reduction of up to 49.7% of water use per capita; a highly significant reduction. Inman and Jeffrey (2006) report that the comprehensive replacement of household appliances (such as showers, toilets and clothes washers) with highly water efficient appliances can reduce indoor water consumption by between 35 and 50%. Not only does this reduction in demand serve to preserve water supply security for future generations but reduces the life cycle cost of potable water treatment and distribution, as well as energy intensive wastewater treatment (Barrios et al., 2008; Mahgoub et al., 2010) and ultimately the ecological footprint of the city or nation (Friedrich et al., 2009; Hubacek et al., 2009).

1.6. Influences of socio-demographic factors

There are several previously reported socio-demographic factors that can influence water consumption. The result of the socio-demographic variable investigations by the ARCWIS (2002) indicated that owner occupied properties, higher income families and households with swimming pools consumed more water for irrigation. Loh and Coghlan (2003) reported a strong relationship between income level and outdoor water use. The occupancy and makeup of dwellings, lot size and the age of water using devices have also been found to influence water consumption with larger lot sizes generally consuming more water (Mayer and DeOreo, 1999).

1.7. Research objectives

The objectives of this paper are to:

a) Determine a household and per capita water consumption end use break down for a sample of Gold Coast households;
b) Explore the relationship between household stock survey efficiency rating clusters and water end use consumption levels; and,
c) Ascertain demographic information of water users and determine if socio-demographic factors influence water consumption.

The multifaceted objectives of the GCREUS study required the application of a mixed methods research design to obtain the required data types.

2. Method

To achieve the desired objectives of the study, a mixed methods data collection procedure including a stock survey of water using fixtures/appliances in households, end use water consumption study and a questionnaire survey, were concurrently undertaken with 151 households on the Gold Coast City, Australia.

2.1. Mixed method study design

The study adopts a mixed method design through collecting, analysing and mixing quantitative and qualitative research approaches and processes. This mixed methods approach allows the use of multiple methods to address research objectives (Creswell and Plano Clark, 2007). A mixed method approach was embarked upon as an array of data types are required to meet the developed research objectives. Namely, natural science data in the form of end use water consumption data, quantitative statistical survey data for demographic information, quantitative stock survey information, and, qualitative water behaviour data were required.

2.2. Sample

A sample of 151 homes was recruited across Gold Coast City, Australia, including the Pimpama-Coomera and Mudgeeraba suburbs. As noted by Willis et al. (2009), regions were selected according to differing socio-demographic makeup. Comparative investigation of demographic factors including household makeup (i.e. family structure and residents per household) and ownership status assisted in confirming the selected regions. Age of infrastructure was also considered with all homes subsequently being developed in the past five years (Willis et al., 2009).

2.3. Water consumption end use study

The relationship between smart metering equipment, household stock inventory surveys and flow trace analysis is shown in Fig. 1. Essentially, a mixed method approach was used to obtain and analyse water use data. Two aligned main processes were adopted: physical measurement of water use via smart meters with subsequent remote transfer of high resolution data; and documentation of water use behaviours and compilation of water appliance stock via individual household audits and self-reported water use diaries.

The collection of end use water consumption data requires the application of a smart metering set-up. The GCREUS study smart metering set-up includes high resolution Actaris CTS-5 water meters, 72 pulses per litre or a pulse every 0.014 L of water used, connected to Aegis Data Cell D data loggers which are set to collect pulse counts every 10 s. Downloaded raw data files were in the ASCII format, which were then modified into .txt files for subsequent trace flow analysis.

End use data in .txt file form was analysed by Trace Wizard© software version 4.1. Stock appliance audits (i.e. type and characteristics of each household appliance or fixture) were used to help identify flow trace patterns for each household. Once a template was created for each household, data for a sampled two-week period was analysed. Trace Wizard© software was used in conjunction with the stock appliance audits to analyse and disaggregate consumption into a number of end uses including toilets, irrigation, shower, clothes washer and taps (faucets). Readers should note that the only equipment modification necessary to undertake end use disaggregation was the replacement of the existing water meter with a high resolution smart meter and data logger at the front of the property. An MS Excel™ spreadsheet was generated as a final output for a more detailed statistical trend analysis and the production of charts.

2.4. Questionnaire survey

Questionnaire surveys were developed to obtain socio-demographic information of each household to allow for clustering and analysis between varying demographic indicators. Surveys were distributed to each smart metered household with information entered into SPSS (i.e. statistical analysis program).

2.5. Household appliance stock survey and water behaviour investigation

Household stock surveys have previously been undertaken to gain a snapshot of water consuming devices in regions (Roberts, 2003). A household water audit was undertaken for the GCREUS study to determine water using devices within the household, to assist in carrying out end use data analysis with Trace Wizard©, and to obtain a qualitative understanding of when people undertook certain water consuming activities in their home. A research officer visited homes and noted down model and serial numbers for clothes washers, dishwashers and toilets; determined the efficiency of water showerheads; the inclusion of tap flow restrictors and recorded volumes of rainwater tanks (if applicable). The research officer also asked questions as to when clothes washing or showering generally occurred, inquired about the number of showers or baths, irrigation use and a whole range of other questions surrounding water use behaviour within the home.

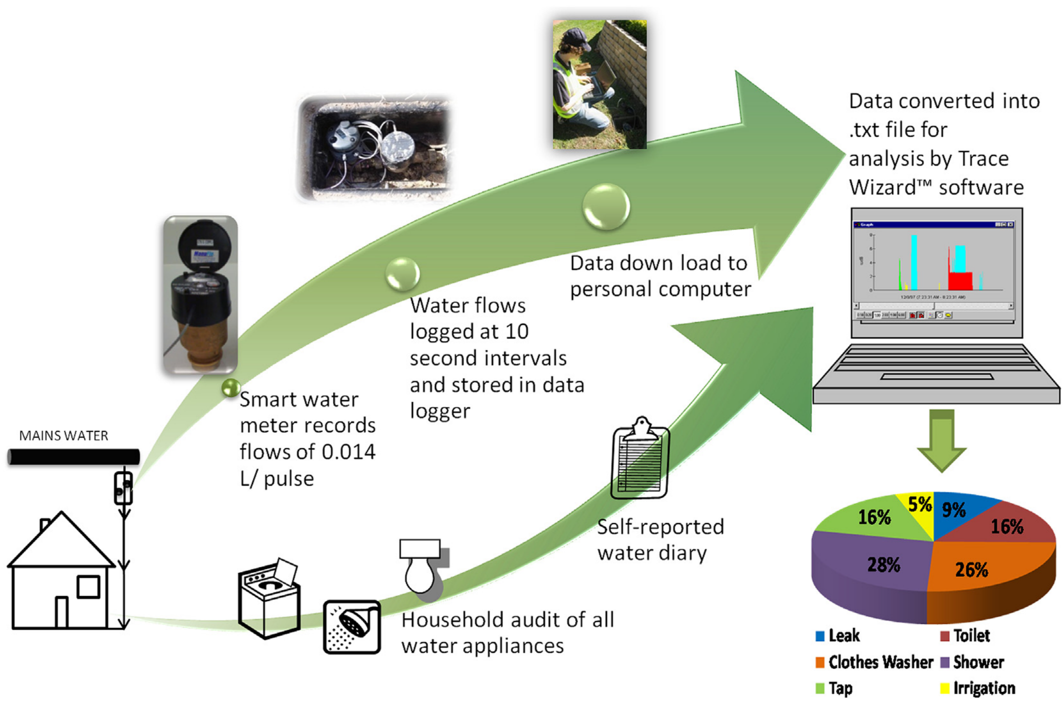


Fig. 1. Schematic illustrating water end use analysis process.

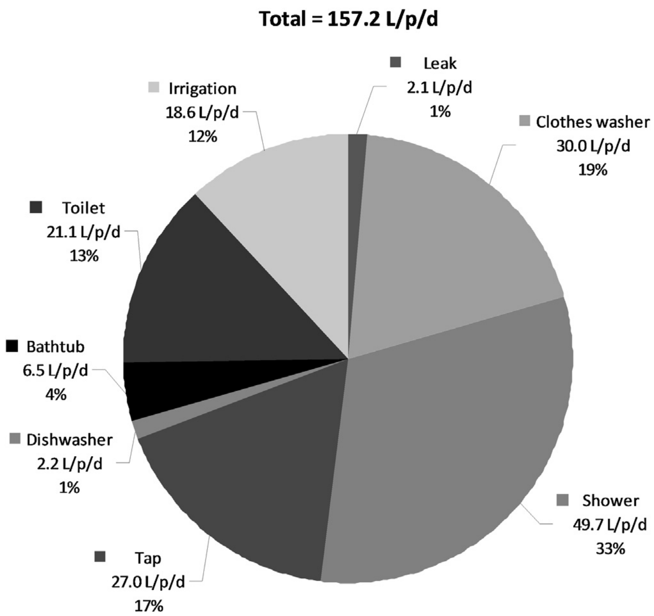


Fig. 2. Average daily per capita consumption (L/p/d): combined sample ($n = 151$).

The Water Efficiency Labeling and Standards (WELS) website[1] was consulted to obtain relevant water usage volumes for different fixtures particularly clothes washers, showerheads and dishwashers to assist in data analysis and to determine the relative water efficiency of devices.

2.6. Water end use analysis and comparison

End use data analysis was undertaken with Trace Wizard© to establish when and where water was being used in each home within the Gold Coast sample. Based on a winter 2008 data collection for the sampled Gold Coast households ($n = 151$) the average water consumption was 157.2 litres per person per day (L/p/d) (Willis et al., 2009). Fig. 2 displays the end use water consumption across the 151 households. Showering accounted for the highest use being 33% or almost 50 L/p/d with clothes washing being the next highest end use at 19% or 30 L/p/d. Irrigation was lower than previously conducted end use studies being only 18.6 L/p/d or 12% of total per capita consumption. This would be attributed to a few reasons, such as: (1) winter season has lower average demand for irrigation; (2) above average rainfall over data collection period; and (3) general trend of lower irrigation demand due to changed social habits, smaller lot sizes, family members working longer hours with less time for attending to garden irrigation and maintenance.

An overview of water end use for the GCREUS study and previous end use studies can be seen in Table 1. The finalised end use values, socio-demographic survey data and water audit data were all entered into SPSS to enable a comparative analysis between varying socio-demographic groups and household water device efficiency.

3. Results

3.1. Influence of socio-demographic factors

Analysis determined that a range of collected socio-demographic factors influenced end use water consumption levels, namely, location of household, lot size, Rain Water Tank (RWT) ownership, household income and household makeup. Some of these relationships are explored in this paper and are presented succinctly below.

3.1.1. Socio-economic region of households

Several regions in differing areas of the Gold Coast were selected to ensure that the combined water end use sample was representative. For the purpose of the GCREUS study, four socio-economic groups in distinct regions were selected and compared: (a) low (Cassia Park: $n = 42$); (b) low to middle (Mudgeeraba: $n = 36$); (c) middle (Crystal Creek: $n = 38$); and (d) middle to high (Coomera Waters: $n = 35$). The total per capita consumption for regions (a), (b), (c) and (d) were 152.3, 155.6, 156.3 and 165.8 L/p/d, respectively. Fig. 3 displays the end use water consumption for these four socio-economic regions.

Previous water consumption research indicates that individuals that are wealthier, older and live in new and larger homes consume more (Kim et al., 2007; Kenney et al., 2008). While the total per capita consumption values provide some evidence to support these existing findings, further examination of individual end use categories enables better understanding on which end uses are potentially more influenced by socio-economic region. Fig. 3 demonstrates that generally lower socio-economic groups tended to use slightly more water than those in higher socio-economic groups across most end use categories. One obvious and significant outlying variable to this trend is irrigation. Coomera Water residents, the highest of the recorded socio-economic regions, were the highest consumers per capita for irrigation, using 27.8 L/p/d with Cassia Park, the lowest socio-economic group consuming the lowest irrigation volume of 12.1 L/p/d; this represents a significant 15.7 L/p/d difference ($p < 0.001$). This opposing trend of higher socio-economic region translating to higher irrigation end use consumption could be attributed to lot size or higher concern/social pressure for garden/turf aesthetics.

3.1.2. Lot size and rainwater tank ownership

The effect of lot size (total land area) and rainwater tank (RWT) ownership on outdoor irrigation was examined ($n = 121$). Fig. 4 illustrates increased irrigation with increasing lot size for households without RWTs ($n = 86$). This result is consistent with that found by Loh and Coghlan (2003). Interestingly, houses with RWTs ($n = 35$) actually decreased irrigation consumption from the mains supply as lot sizes increased. Meaning that, irrigation was highest for smaller lot sizes with RWTs with those of large lot sizes consuming the least. The reason for this phenomenon is still unknown and may be due to error caused by a lower sample in the higher lot size clusters. One hypothesis is that the larger lot owners may have invested in higher volume RWT with pump features and irrigation lines whilst those in smaller lots may not utilise their tanks since they are small with no pump facility making householders less inclined to use this source of water. A larger sample size across all lot size clusters would be required to confirm this hypothesis.

3.1.3. Household income

108 households stated the incomes of individuals within their residences on the survey. These households were divided into three categories based on weekly household income to investigate the influence of household income on water consumption. The categories were defined as: (a) less than ($AUD) A$1200 per week ($n = 31$); (b) between A$1200 and A$2000 per week ($n = 45$); and (c) more than A$2000 per week ($n = 36$). Fig. 5 indicates that as income increased, so does water consumption. Interestingly, the water consumption of the middle to upper household income

[1] <http://www.waterrating.gov.au>.

Table 1
Comparison between national end use water consumption studies (Willis et al., 2009).

	Previous studies						Present study	
	Perth (2003)		Melbourne (2005)		Auckland (2007)		Gold Coast (2008)	
End use category	L/p/d	Percent	L/p/d	Percent	L/p/d	Percent	L/p/d	Percent
Clothes washer	42.0	13%	40.4	19%	39.9	24%	30.0	19%
Shower	51.0	15%	49.1	22%	44.9	27%	49.7	33%
Tap (faucet)	24.0	7%	27.0	12%	22.7	14%	27.0	17%
Dishwasher	NA	NA	2.7	1%	2.1	1%	2.2	1%
Bathtub	NA	NA	3.2	2%	5.5	3%	6.5	4%
Toilet	33.0	10%	30.4	13%	31.3	19%	21.1	13%
Irrigation	180[a]	54%	57.4[a]	25%	13.9	8%	18.6	12%
Leak	5.0	1%	15.9	6%	7.0	4%	2.1	1%
Other	NA	NA	0.0	0%	0.8	0%	0.0	0%
Total Consumption	335.0	100%	226.2	100%	168.1	100%	157.2	100%

[a] Note: Irrigation volume per person calculated from provided volumes per household and end use break downs.

clusters was very similar and no significant difference could be interpreted. Lower income households were shown to consume approximately 8% less than the average water consumption for the Gold Coast City sample (i.e. 157.2 L/p/d as per Table 1), however lower socio-demographic profiles (which consider factors beyond income) were shown in section 3.1.1. to use more water for end uses other than irrigation – in this case, the lower irrigation component leads to lower overall usage.

3.1.4. Household makeup comparisons

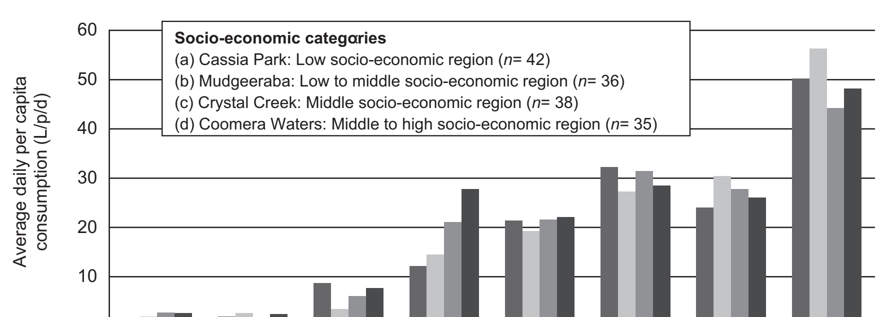
The impact of household makeup on end use water consumption was also investigated. Households ($n = 126$) were divided into four categories, namely: (a) single person ($n = 5$); (b) couple ($n = 34$); (c) small family with four or less people ($n = 64$); and (d) large family with more than four people ($n = 23$). Total per capita consumption was 211.4 L/p/d, 183.5 L/p/d, 140.6 L/p/d and 135.6 L/p/d for household makeup typologies a, b, c and d, respectively. Fig. 6 indicates that there is a general decrease in consumption per capita as family size increases. Clothes washer and toilet end use consumption oppose this trend with these end uses being higher in large families than small families. This may be due larger families being more likely to have very young children requiring extensive washing and a higher utilisation of the toilet due to increased time spent at home.

3.2. Stock efficiency versus end use consumption

Table 1 demonstrates that shower use and clothes washing account for the highest end uses of water on the Gold Coast, being 33% and 19% of total average consumption, respectively. Further analysis was undertaken to examine trends for water saving when considering the engineered efficiency of water use devices.

3.2.1. Influence of showerhead efficiency

Sample average per capita shower end use was 49.7 L/p/d or 32% of total water use which was 157.2 litres per person per day (L/hh/d). This was the highest water consuming activity on the Gold Coast as often reported elsewhere. It is well established that the installation of high efficiency, low flow showerheads can save considerable volumes of water (Mayer et al., 2004). The Australia WELS requires products to be registered and labelled with their water efficiency in accordance with the standard set under the national WELS and Standards Act 2005 (Commonwealth of Australia, 2008). These standards list that three star rated water efficient showerheads (formerly AAA) use as little as 6-7 L/min, medium efficient showerheads (AA) consume between 9 and 15 L/min and the standard non-efficient showerheads (A) can use as much as 15–25 L/min. Different dwellings have a high variation in the efficiency of their showerheads and often showerheads differ within households. Due to the variation of showerhead efficiencies within dwelling bathrooms a weighting system was applied in this study. The weighting system provided each bathroom showerhead with a rating as follows: (a) 'AAA' rated showerheads allocated a score of 5: (b) 'AA' rated showerheads a rating of 3; and (c) 'A' rated showerheads and less a score of 1. Each dwelling total score was averaged (w) based on number of showerheads. The weighting system allowed for the categorisation of households into three shower efficiency clusters which match the AAA, AA and A, WELS



	Dishwasher	Leak	Bathtub	Irrigation	Toilet	Clothes washer	Tap	Shower
Cassia Park (a)	1.8	1.9	8.7	12.1	21.4	32.2	24.0	50.2
Mudgeeraba (b)	1.9	2.6	3.4	14.5	19.2	27.3	30.4	56.3
Crystal Creek (c)	2.7	1.5	6.0	21.1	21.6	31.4	27.8	44.2
Coomera Water (d)	2.6	2.4	7.7	27.8	22.1	28.5	26.0	48.2

Fig. 3. Impact of socio-economic region on end use water consumption.

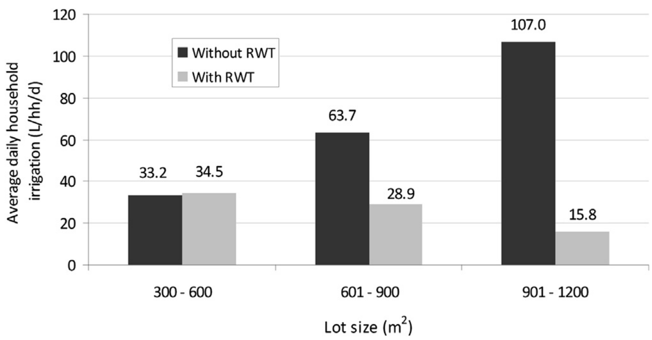


Fig. 4. Impacts of lot size and RWT installation on irrigation end use.

ratings, namely Low, Medium and High efficiency. Table 2 details the showerhead efficiency cluster results.

Table 2 provides evidence that changing low efficiency showerheads (A) to high efficiency showerheads (AAA) in each household in the Gold Coast, could result in annual per capita water savings of 11.3 kL (23.6 kL/p/a for the low efficiency group − 12.3 kL/p/a for the high efficiency group = 11.3 kL/p/a of savings). Annual household savings were slightly higher being 52.1 kL (89.7 kL/hh/a for the low efficiency group − 37.6 kL/hh/a = 52.1 kL/hh/a of savings). Readers should note that the per capita saving is more representative and transferable to other situational contexts as the household sample size varies for the three clusters from 3.0 (medium) to 3.8 (low). The ratio of savings between the Low to Medium and High efficiency categories indicates that a changeover to AAA rated showerheads yields greater savings. The savings identified herein were at the higher end of the range determined in other studies such as Melbourne at 27%, Perth at 22% and in Southeast Queensland (SEQ) at 31–54% (Roberts, 2005; Loh and Coghlan, 2003). As detailed in a later section, showerhead retrofits represent one of the least cost water demand management initiatives available to water businesses and government.

3.2.2. *Influence of clothes washer efficiency*

The end use water consumption for clothes washing for the Gold Coast sample was determined as 30 L/p/d. Clothes washing consumption was the second highest water use after showering. WELS star rating for clothes washers was based on loading type, load capacity, water consumption per wash, brand and model name. The Commonwealth of Australia (2008) state that water efficient washing machines can use a third of the water required by an inefficient model. The WELS website details the rate of water consumption per wash for each brand and model of clothes

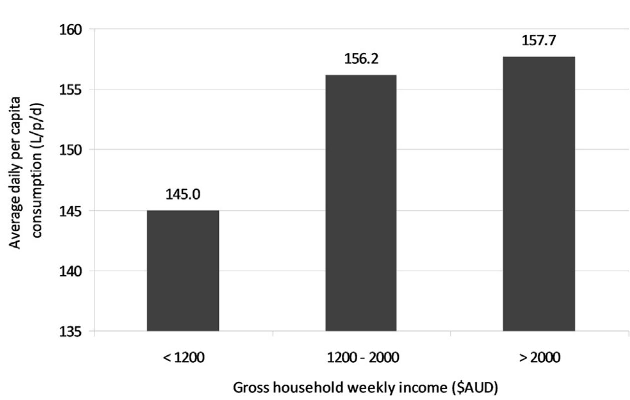


Fig. 5. Impact of gross household weekly income on total per capita water consumption.

washing machine on the Australian market. Household water audits established the specific model details (i.e. brand, model, year, etc) to assist in determining clothes washer load volumes. Household clothes washers were allocated efficiency categories based on per load water consumption; Table 3 demonstrates the results of the comparative clothes washer water end use levels for each efficiency cluster category.

Table 3 demonstrates that replacing a low efficiency clothes washer with a high efficiency model can save a staggering 14 kL per person per annum (kL/p/a). Annual household savings are also equally significant at 58.9 kL/hh/a. Again, the Low clothes washer efficiency cluster had the highest average household occupancy at 3.9 with Median and High at 3.0 and 3.1, respectively. These higher occupancy rates have resulted in the higher ratio values when examining the household savings. The more conservative per capita savings are considered more representative and transferable to other situational context. Readers should take account of the potential influence of occupancy rates when applying both per person and per household saving values. Higher occupancy can result in some lowering of the total per capita water use as there are some economies of scale effect, however there are also potentially higher clothes washing requirements related to the addition of more younger children.

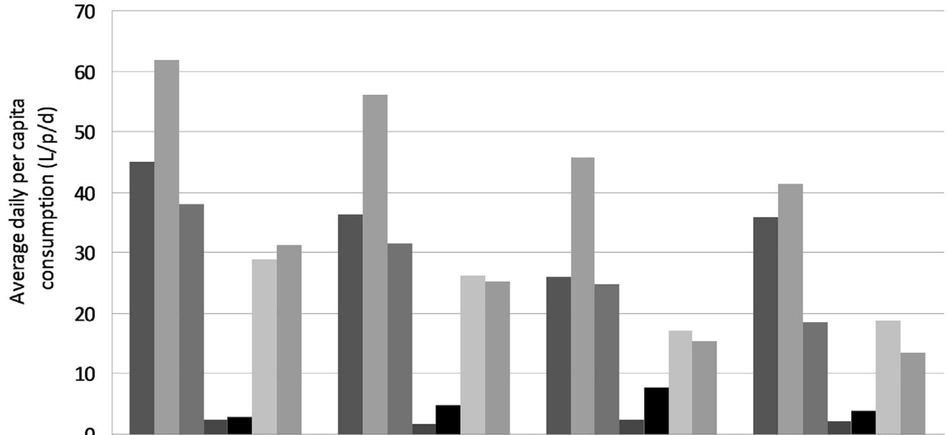
Finally, these calculated savings are higher than those listed on the WELS website and in previously reported Melbourne and SEQ water efficiency studies. In summary, replacing traditional washing machines with those with a high star rating is a highly recommended water demand management activity.

3.2.3. *Influence of rainwater tanks on irrigation end use*

Irrigation has long been identified as a high water end use, accounting for up to 54% in some regions (Loh and Coghlan, 2003). RWTs are considered by some water demand management professionals as an effective way to reduce the demand on potable supplied water. The GCREUS included a number of households ($n = 39$; 25.8%) with an installed RWT. It should be noted that these RWT were not internally plumbed and were mainly for outdoor use purposes only (i.e. irrigation, pool top-up, etc.). Whilst RWT metering was not included in the scope of this study, household water audits identified whether a tank was installed, enabling comparison between irrigation end use volumes for households with or without an RWT (Table 4).

Table 4 provides evidence that the introduction of an RWT can significantly impact on irrigation water end use consumption. The installation of an RWT can result in annual per capita and per household savings of 3.4 kL/p/a and 13.5 kL/hh/a, respectively. The ratio increase in irrigation consumption on homes with RWT was slightly higher at the household level due to the higher average occupancy of this cluster (i.e. 3.4 verses 2.9). Applying the per capita savings and the regions overall average household occupancy resulted in a slightly lower household savings due to installation of an external-only RWT at 11.3 kL/hh/a.

The end use snapshot was conducted in the winter period of a sub-tropical region. Irrigation in this region is typically highest in spring when there is relatively high day temperatures and low rainfall. To gain a better understanding on the potable water savings benefits of RWT, seasonal variations need to be explored further in future research (i.e. also examine the autumn, spring and summer periods). The study herein provides some evidence to the argument that RWT may be an effective strategy where water supply security is not guaranteed. Given that RWT installations are generally much more expensive than other residential demand management options, their capital payback periods need to be explored in detail in order to reveal their potential financial benefit to the householder.



	Single person	Couple	Small family	Large family (> 4)
Clothes washer	45.1	36.3	26	35.9
Shower	61.8	56.1	45.6	41.3
Tap	38.0	31.4	24.7	18.6
Dishwasher	2.3	1.6	2.5	2.1
Bathtub	2.8	4.9	7.6	3.9
Toilet	28.8	26.2	17.0	18.7
Irrigation	31.2	25.2	15.3	13.5

Fig. 6. Relationship between household resident makeup typologies and water end use consumption.

3.2.4. *Combined household efficiency savings*

The combined influence of introducing water efficient showerheads, clothes washers and installing RWTs was modelled to estimate total potential household savings by retrofitting/installing to higher efficiency appliances/fixtures. The estimated savings, resulting from the introduction of this array of demand management measures, amounted to approximately one third of total water consumption. While these are significant water savings, it is considered prudent for both consumers and water managers to determine monetary aspects. Additionally, whilst outside the scope of this paper, in the age of climate change mitigation, the energy implications of WDM decisions should also be investigated as water savings may come at a higher energy cost.

3.2.5. *Financial benefits of efficient appliances*

Often the understanding of relative water savings attributed to water efficient devices is not enough to encourage consumers to outlay the capital cost to upgrade fixtures. Information about the payback period associated with upgrading appliances is another way of displaying information to encourage uptake. Based on the 2008/2009 financial year water billing price (i.e. A$(AUD) 1.87/kL) the retrofitting of a low to high efficiency showerhead can potentially deliver a 2009 annual water consumption monetary saving of A$69 increasing to A$136 by 2018, for Gold Coast City residential households. Based on a A$100–160 capital cost for the supply and installation of water efficient showerheads, a 2 year payback period was determined. While not factored herein, this payback period would be considerably lower (i.e. less than 1 year) when considering the cost of the electricity saved for heating a considerable portion of the water used in the shower. This is an extremely good payback period and provides evidence to support the recent Gold Coast Water and Queensland Government strategies to retrofit appliances across SEQ in the recent drought (e.g. GCW & SEQ Home Water wise Service). Shower retrofit programs are undoubtedly a least cost water demand management option that also reduces household hot water related electricity demand and subsequently GHG emissions.

Table 2
Showerhead efficiency cluster comparisons.

Description	Showerhead efficiency clusters		
Efficiency category Weight range	Low $w \leq 2$	Medium $2 < w < 4$	High $w \geq 4$
No. of households in cluster ($n = 151$) Proportion (%)	50 (33.1%)	42 (27.8%)	59 (39.1%)
No. of people in cluster ($n = 495$) Proportion (%)	190 (38.4%)	124 (25%)	181 (36.6%)
Per capita shower consumption per day (L/p/d)	64.7	46.8	33.6
Household shower consumption per day (L/hh/d)	245.7	138.1	103.1
Per capita shower consumption per annum (kL/p/a)	23.6	17.1	12.3
Household shower consumption per annum (kL/hh/a)	89.7	50.5	37.6

Table 3
Clothes washer efficiency cluster comparisons.

Description	Clothes washer efficiency clusters		
Efficiency category	Low	Medium	High
Star rating range	1–2.5	3–3.5	4–6
Category (L/wash)	120–170	80–119	40–79
No. of households in cluster ($n = 148$) Proportion (%)	38 (25.7%)	40 (27.0%)	70 (47.3%)
No. of people in cluster ($n = 486$) Proportion (%)	148 (30.5%)	119 (24.5%)	219 (45.0%)
Per capita clothes washer consumption (L/p/d)	53.0	36.3	14.4
Household clothes washer consumption (L/hh/d)	206.4	108.0	45.2
Per capita clothes washer usage per annum (kL/p/a)	19.3	13.3	5.3
Household clothes washer usage per annum (kL/hh/a)	75.4	39.4	16.5

Table 4
Rainwater tank cluster comparison.

Description	Rainwater tank clusters	
	Households with RWT	Households without RWT
No. of households in cluster ($n = 151$) Proportion (%)	39 (25.8%)	112 (74.2%)
No. of people in cluster ($n = 495$) Proportion (%)	114 (23%)	381 (77%)
Per capita irrigation consumption per day (L/p/d)	10.1	19.6
Household irrigation consumption per day (L/hh/d)	29.6	66.6
Per capita irrigation consumption per annum (kL/p/a)	3.7	7.1
Household Irrigation consumption per annum (kL/hh/a)	10.8	24.3

Replacement of low efficiency washing machines to those with higher efficiency also has the potential to deliver annual water savings of A$86 in 2009, increasing to A$170 in 2018. This equates to a cumulative saving of A$1364 per household over this 10 year period. Hence, a 7 year payback period was calculated based on a conservative capital cost of A$600 for a water efficient washing machine. Again, this represents a reasonable 5.6 years supporting the upgrade of washing machines.

The use of RWTs could potentially deliver an annual water consumption saving of A$21 in 2009 increasing to A$115 in 2033 equating to a A$11,451 cumulative saving per household over this 25 year period. Based on a A$1200 capital cost for a 2000–4000 L RWT a 23 year payback period was determined. This payback period is high for the average homeowner and does not consider the ongoing maintenance requirements for a RWT, providing evidence to the argument that RWT installation that are not internally plumbed, is not low hanging fruit in the least cost planning framework. Understanding payback periods for the replacement of efficient water use devices provides important information to allow consumers to make economically informed decisions. These payback periods can also help support the introduction, or otherwise, of rebate schemes targeting the highest water savings at a reasonable price as part of a broader consideration of the social environmental and economic cost savings to the utility (through reduced pumping and treatment as well as lower infrastructure upgrade costs) as well as the consumer in a total resource cost approach to option evaluation (White et al., 2008).

4. Conclusion

Smart metering has enabled the collection of a registry of end use water consumption data. The mixed method acquisition of this data in association with socio-demographic and stock survey information, allowed for the relationship between these factors and individual water end uses to be revealed. As discussed, socio-demographic factors such as household income and makeup, lot size and RWT ownership, were examined in this study and had an influence on relevant end uses. End use data demonstrated that actual water savings associated with the installation of efficient water use devices was generally at the higher end of ranges reported in previous research investigations. This may be due to the extreme drought conditions experienced in SEQ in 2008 influencing water consumption habits or a range of other contributing factors. The payback period of showerheads occurs within half a year or less, while clothes washer and RWT payback periods were determined as 6.5 and 21 years respectively. These findings support the continuation of rebates particularly for showerheads and clothes washers.

As a final note, savings achieved through water demand management programs have a flow-on benefit to the entire water and wastewater system (as well as the water heating and electricity supply system) that is not often considered, but can be substantial, such as:

- Enables the deferment of expensive supply expansion options such as desalination plants;
- Reduces the peak hour potable water demand and thus can lead to deferred water supply pump and pipe infrastructure upgrade requirements;
- Reduces average and peak effluent loading to the wastewater system; and
- Lower overall requirement for heated water (i.e. lower shower volumes means less hot water from heating system) which is energy intensive and contributes significantly to GHG emissions.

Acknowledgements

The GCREUS study is conducted through a larger ARC collaboration. The Institute for Sustainable Futures, University of Technology, Sydney; Wide Bay Water and the Queensland Water Directorate are acknowledged for their involvement in the research collaboration.

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