REVEALING THE IMPACT OF SOCIO-DEMOGRAPHIC FACTORS AND EFFICIENT DEVICES ON END USE WATER CONSUMPTION: CASE OF GOLD COAST, AUSTRALIA

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ABSTRACT

Comprehension of the differences in water consumption within communities and the actual water savings attributed to engineered efficient devices requires high accuracy data generally of the end use water consumption form. Provided is an outline of a component of the *Gold Coast Watersaver End Use Study*, which focussed on the relationship between a range of socio-demographic and household stock survey variables and water end use consumption levels. A mixed methods approach was executed. 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.

INTRODUCTION

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 SEQ water supply reservoirs dropping below 20% over the last decade. This has forced State and Local government to implement alternative water supply schemes in order to improve urban water security.

Domestic Water Consumption and Conservation
In the case at the Gold Coast, Australia residential water consumption accounts for approximately 66% of the City's total supply (07/08). In Brisbane total residential consumption is 57%. 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 (Inman and Jeffrey, 2006; Mayer et al., 2004; Nieswaidomy, 1992). Although prior research in these areas has occurred it is well established that there is a requirement for specific country and location based research due to different community attitudes and behaviours which can influence the effectiveness of WDM strategies (Corral-Verdugo et al., 2002; Turner et al., 2005). To grasp the effectiveness of WDM strategies high quality data is required. The development of smart metering technologies and end use analysis techniques allowed for the acquisition of such data.

Advent of Smart Water Metering
Understanding and collecting empirical evidence of where and how water is used allows planners and conservationists to determine the relative water saving of WDM strategies. Smart metering and management stemmed from the need to obtain such data. Conventional water meters in residential households only count the volume of water used and there is no facility to determine when and which water use event is occurring. 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. Figure 1 illustrates a typical smart metering set-up for residential households.
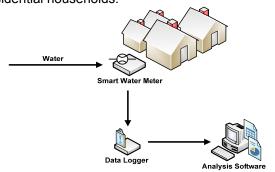

Figure 1 Typical smart meter set-up

Data resulting from smart metering applications allows water managers to investigate the effectiveness of WDM strategies and household water consumption patterns.

Overview of Gold Coast End Use Study
The Gold Coast Watersaver End Use study (GCWSEU) commenced in 2007 as an ARC funded collaborative research investigation by Griffith University, Gold Coast Water and the Institute for Sustainable Future, UTS. The purpose of this study is 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 GCWSEU study explored in this paper.

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 with highly water efficient appliances can reduce indoor water consumption by between 35-50%.

Influence 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 & Coghlan (2003) reported a strong relationship between income level and outdoor water use. The occupancy and make up 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).

RESEARCH OBJECTIVES

The objectives of the GCWSEU related to the herein mentioned study include:

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 GCWSEU study required the application of a mixed methods research design to obtain the required data types.

RESEARCH METHOD

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

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.

Sample
A sample of 151 homes was recruited across the Gold Coast in the Pimpama Coomera and Mudgeeraba regions. As noted by Willis et al. (2009), regions were selected according to differing socio-demographic makeup. Comparative investigation of demographic factors including household makeup 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).

Water Consumption End Use Study
The collection of end use water consumption data requires the application of a smart metering set-up. The GCWSEU study smart metering set-up includes high resolution Actaris CTS-5 water meters, 72 pulses/L or a pulse every 0.014L of water used, connected to Aegis Data Cell D-CZ21020 data loggers which are set to collect pulse counts every ten seconds. End use data is collected manually

through the Aegis 'Command' software and analysed by Aquacraft's Trace Wizard© software. Data was collected over a two week period in winter 2008 at a time of no residential water restrictions.

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).

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

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). Figure 2 displays the end use water consumption across the 151 households. Showering accounted for the highest use being 33% or almost 50L/p/d with clothes washing being the next highest end use at 19% or 30L/pc/d. Irrigation was much lower than previously conducted end use studies being only 18.6L/p/d or 12% of total per capita consumption, this may have been due to higher rainfall over the monitoring period.
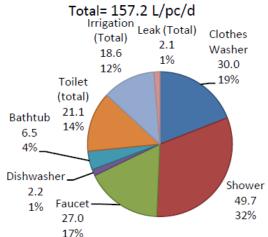

Figure 2 Average Daily Per Capita Consumption (L/p/d): Combined Sample (n=151)

An overview of water end use for the GCWSEU 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.

Water End Use Analysis and Comparison

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)	
	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	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 (total)	33.0	10%	30.4	13%	31.3	19%	21.1	13%
Irrigation (total)	180[†]	54%	57.4[†]	25%	13.9	8%	18.6	12%
Leak (total)	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%**

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

DATA ANALYSIS AND RESULTS

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 characterisation. Some of these relationships are explored in this paper and are presented succinctly below.

Socio-demographic 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 GCWSEU study, four socio-demographic 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). Figure 3 displays the end use water consumption for these four socio-demographic 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). Such findings were not substantiated in this study. Figure 3 demonstrates that generally lower socio-demographic groups tended to use slightly more water than those in higher socio-demographic groups across most end use categories. One outlying variable to this trend is irrigation. Coomera Water residents, the highest of the recorded socio-demographic regions, were the highest consumers per capita for irrigation, using 27.84L/p/d with Cassia Park, the lowest socio-demographic group consuming the lowest irrigation volume of 12.07L/p/d. This opposing trend of higher socio-demographic region translating to higher irrigation end use consumption could be attributed to lot size or higher concern for garden aesthetics.

Lot size and rainwater tank ownership
The effect of lot size and rainwater tank (RWT) ownership on outdoor irrigation was examined (n=121). Figure 4 illustrates increased irrigation with increasing lot size for households without RWTs (n=86). This result is consistent with that found by Loh & Coghlan (2003). Interestingly, houses with RWTs (n=35) actually decreased irrigation consumption 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.
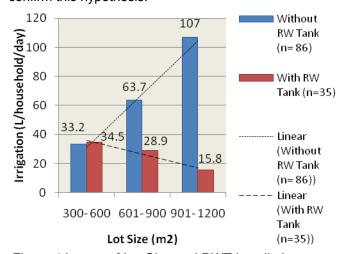

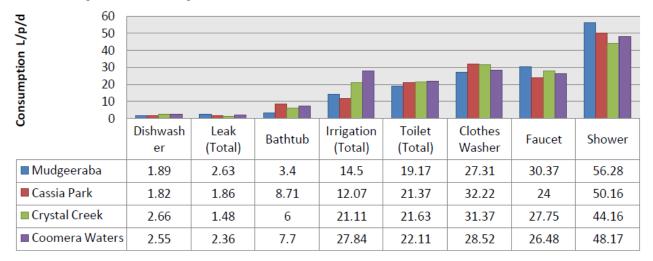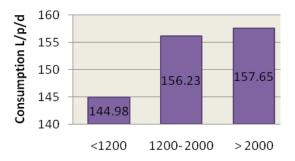*Figure 4 Impact of Lot Size and RWT Installation on Irrigation End Use*

	Dishwasher	Leak (Total)	Bathtub	Irrigation (Total)	Toilet (Total)	Clothes Washer	Faucet	Shower
Mudgeeraba	1.89	2.63	3.4	14.5	19.17	27.31	30.37	56.28
Cassia Park	1.82	1.86	8.71	12.07	21.37	32.22	24	50.16
Crystal Creek	2.66	1.48	6	21.11	21.63	31.37	27.75	44.16
Coomera Waters	2.55	2.36	7.7	27.84	22.11	28.52	26.48	48.17

Figure 3 Impact of Socio-demographic Area on End Use Water Consumption

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 $1200 per week (n=31); (b) between $1200 and $2000 per week (n=45); and (c) more than $2000 per week (n=36). Figure 5 indicates that as income increased, so does water consumption. Interestingly, the water consumption of the middle to upper household income 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 sample (i.e. 157.2L/p/d as per Table 1). This trend between water consumption and household income was also determined by Loh & Coghlan (2003)

Figure 5 Impact of Family Income on Water Consumption

Household Resident Typology
The impact of household typology (i.e. resident 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 211.4L/p/day, 183.5L/p/d, 140.6L/p/d and 135.6L/p/d for household typologies a, b, c and d, respectively. Figure 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.

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.

Influence of Showerhead Efficiency
Sample average per capita shower end use was 49.7L/p/d or 33% of total water use (160.1L/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). 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 four star rated water efficient showerheads (AAA) use as little as 6-7L/min, medium efficient showerheads (AA) consume between 9-15L/min and the standard non-efficient showerheads (A) can use as much as 15-25L/min. Different dwellings have a high variation in the efficiency of their showerheads and often showerheads differ within households. Due to the
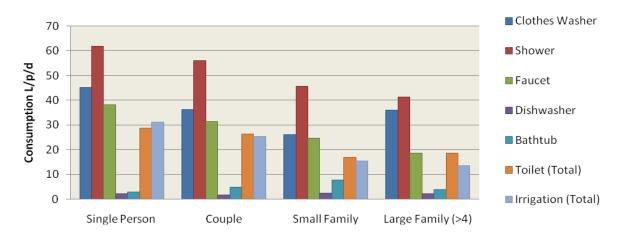

Figure 6 Relationships between Household Resident Typologies and Water End Use Consumption

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 shower heads 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 ratings, namely Low, Medium and High efficiency, Table 2 demonstrates the results.

Table 2 Showerhead Efficiency Cluster Comparisons

Description	Showerhead Efficiency Clusters		
Efficiency category	Low	Medium	High
Weight range	5 ≤ w ≤ 4	4 ≤ w ≤ 3	3 ≤ w ≤ 1
No. of households in cluster (n=151)	59 (39%)	42 (27.8%)	50 (33.2%)
No. of people in cluster (n=495)	181 (36.6%)	124 (25%)	190 (38.4%)
Per capita shower consumption per day (L/p/d)	64.7 (1.93)	46.8 (1.39)	33.6 (1)
Household shower consumption per day (L/hh/d)	245.7 (2.38)	138.1 (1.34)	103.1 (1)
Per capita shower consumption per annum (kL/p/a)	23.6 (1.93)	17.1 (1.39)	12.3 (1)
Household shower consumption per annum (kL/hh/a)	89.7 (2.38)	50.5 (1.34)	37.6 (1)

Table 2 provides evidence that by changing low efficient showerheads (A) to high efficient showerheads (AAA) in each household in the Gold Coast could result in annual per capita water savings of 11.3kL or 48%. Annual household savings were slightly higher being 52.1kL or 58%. The ratio of savings between the High and Medium categories (1.34-1.39) and High to Low categories indicates that a changeover to AAA rated showerheads yields far 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 South-east 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.

Influence of Clothes Washer Efficiency
The end use water consumption for clothes washing for the Gold Coast sample was determined as 30L/p/d or 19% of total use (101.5L/hh/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 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 Clothes Washer Efficiency 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)	38 (26%)	40 (27%)	70 (47%)
No. of people in cluster (n=486)	148 (30%)	119 (25%)	219 (45%)
Per capita clothes washer consumption per day (L/p/d)	53.0 (3.68)	36.3 (2.52)	14.4 (1)
Household clothes washer consumption per day (L/hh/d)	206.4 (4.57)	108.0 (2.51)	45.2 (1)
Per capita clothes washer consumption per annum (kL/p/a)	19.4 (3.66)	13.3 (2.52)	5.3 (1)
Household clothes washer consumption per annum (kL/hh/a)	75.3 (4.57)	39.4 (2.51)	16.5 (1)

Table 3 demonstrates that replacing a low efficiency clothes washer with a high efficiency model can save a staggering 14.1L/p/a or 73%. Annual household savings are also equally significant at 58.8kL or 78.1%. It should be noted that these savings are higher than those listed on the WELS web site and are slightly higher than those previously identified in Melbourne at 51% and SEQ, at 60%. Replacing traditional washing machines with those with a high star rating is a highly recommended water demand management activity.

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 Gold Coast end use study 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 a RWT (Table 4).

Table 4 Rain Water Tank Cluster Comparisons

Description	Rainwater Tank Clusters	
Category	Households **with** RWT	Households **without** RWT
No. of households in cluster (n=151)	39 (25.8%)	112 (74.2%)
No. of people in cluster (n=495)	114 (23%)	381 (77%)
Per capita irrigation consumption per day (L/p/d)	10.1 (1)	19.6 (1.94)
Household irrigation consumption per day (L/hh/d)	29.6 (1)	66.6 (2.25)
Per capita irrigation consumption per annum (kL/p/a)	3.7 (1)	7.2 (1.94)
Household Irrigation consumption per annum (kL/hh/a)	10.8 (1)	24.3 (2.25)

Table 4 provides evidence that the introduction of a RWT can significantly impact on irrigation water end use consumption. The installation of a RWT can result in an annual household saving of 13.5kL which equates to a 55% saving in potable water. Seasonal variations need to be explored in future research to examine whether this saving could be higher. 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 potentially more expensive than other options capital payback periods need to be explored.

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 an average annual household water consumption reduction of 38.6% or from 512.2L/hh/d to 322.1L/hh/d. 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.

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$1.87/kL) the retrofitting of a low to high efficiency showerhead can potentially deliver an annual water consumption saving of $97.2 for Gold Coast residential households. This increases to $175.7 by 2018 which equates to a $1331 cumulative saving per household over this period ($1.87/KL, 10% annual increase, 3% discount factor, N=10 years). Based on a $60 capital cost for the supply and installation of water efficient showerheads, a six (6) month payback period was determined. 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 Waterwise Service*).
Replacement of low efficiency washing machines to those with higher efficiency also has the potential to deliver annual water savings of $110 in 2009, increasing to $199 in 2018. This equates to a cumulative saving of $1510 per household over this period. Hence, a 6.5 year payback period was calculated based on a conservative capital cost of $900 for a water efficient washing machine. Again, this represents a reasonable payback period supporting the upgrade of washing machines.
The use of RWTs could potentially deliver an annual water consumption saving of $25.2 in 2009 increasing to $134.5 in 2033 equating to a $1660 cumulative saving per household over this period ($1.87/KL, 10% annual increase, 3% discount factor, N=25 years). Based on a $1200 capital cost for a 2000-4000L RWT a 21 year payback period was determined. This payback period is high for the average homeowner, providing evidence to the argument that RWT installations 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.

CONCLUSION

Smart metering has enabled the collection of highly accurate 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, household resident typologies, 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.

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