Smart Metering Infrastructure for Residential Water Efficiency: Results of a Trial in a Behavioural Change Program in Perth, Western Australia

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ABSTRACT

A smart metering trial was incorporated into a residential water efficiency project in Perth, Western Australia. The *H_2ome Smart* program by the Water Corporation and its contractor ENV Australia Pty Ltd engaged 12,000 households in selected suburbs of the Perth metropolitan area. Smart meters are an informative and educational tool that allows households to instantaneously view personal real-time water use feedback. From the most apparently active *H_2ome Smart* participants nine agreed, after a selection process, to participate in the Greensense smart metering trial with the tenth participant being local television sustainable gardening celebrity Josh Byrne. It is interesting to note the patterns in water use before households could view their dashboards and after they had access their dashboard and had a few days to understand the real-time data and patterns in water use. By comparing these two separate date ranges we can see the differences that access to real-time water use data can make on water use behaviours. Now at the conclusion of the program the team has collated all water use data and feedback from the participants to complete a final analysis demonstrating the outcomes of the challenge including its advantages/ disadvantages and opportunities/ constraints for the future.

Keywords

Smart metering infrastructure, residential water use, water efficiency, Community Based Social Marketing.

1. INTRODUCTION

Western Australia is experiencing a drying climate. In the South West, where Perth the capital city of 2 million people is located with a Mediterranean climate, winter rainfall has been steadily declining since the 1970s. The Water Corporation is the State of Western Australia's principal water utility, a State Government owned enterprise, and set the following targets by 2030 to address the State's water crisis:

- reducing water use by 25%;
- increasing wastewater recycling to 60%; and
- developing new sources [10].

In Perth, the city drinking water supply, known as the Integrated Water Supply Scheme (IWSS) is sourced from a combination of surface water catchment dams (15%), groundwater (35%) and seawater desalination (50%), with typical percentages given, to provide an annual total supply of about 300 gigalitres per annum (Glpa). Most of this water supply, 70%, is used by the residential sector. Average household water use in Perth is 280 kilolitres per annum (klpa) and of this about 40% is used outdoors on garden irrigation. Reading of water meters for billing purposes is done physically twice per year. The intention of the Water Corporation is to move to reading meters and billing four times per year.

In order to achieve its goal of reducing water use by 25% the Water Corporation commenced water efficiency projects in the industrial, commercial and residential sectors served by its schemes.

There are approximately 60 licensed wastewater recycling schemes in small towns across regional Western Australia and these are typically reusing effluent from treatment lagoons for turf irrigation on sports fields at the rate of about 3 Glpa. In Perth, wastewater recycling for industry is undertaken at the Kwinana Water Reclamation Plant at the rate of 6 Glpa. In order to increase this rate of recycling, the Water Corporation will commence recharge of Perth's main groundwater source, the Gnangara Mound, with treated wastewater. Currently, Perth discharges approximately 130 Glpa of treated wastewater into the Indian Ocean from three main treatment plants. Aquifer recharge is proposed at about 40 Glpa by 2015, with a major trial currently underway. This simultaneously becomes a new source of water for the IWSS.

Smart metering that is integrated with online portals or in home displays (IHD) is fairly well established in the USA and UK, especially for the energy sector. Companies such as OPower [1], GreenWave Reality and Tendril provide sophisticated services for energy utilities, while SmartReach [6] is also undergoing smart metering trials for water utilities. These companies provide online

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or paper feedbacks founded on the same principles as Community Based Social Marketing (CBSM) behaviour change programs [4], but are generally not implemented in conjunction with any formal behaviour change program that includes one-to-one coaching or dialogue marketing. In Australia, smart metering rollout has commenced. A number of trials have been undertaken by water and energy utilities. Smart metering for water consumption has been implemented in communities such as Hervey Bay [9] and trials are recommended by research, such as those conducted for the Victorian Water Trust and Sydney Water [3, 8]. At present, smart meter technology in Australia is being implemented rapidly in the energy sector (e.g. by Department of Primary Industries in Victoria and Ausgrid in NSW) and is not integrated with a behaviour change program. The Water Corporation has successfully rolled out smart meters in Kalgoorlie and the Pilbara region of the Northwest of Western Australia and follow-up with behaviour change programs is planned.

2. METHODS

In the residential sector, a behavioural change pilot project was designed using Community Based Social Marketing (CBSM) methods to reduce residential water use for a small town in the southwest of Western Australia, Margaret River. Besides raising awareness for water conservation, the project aimed to provide 1,030 participating households with information delivery and a 10% reduction in water consumption in 2009. Starting with an adjusted gross of 1,351, 96% of the contacted households were interested in the project. With 89% requesting information, delivery to a total number of 1,157 participating households was accomplished. A continuously high participation resulted in 1,043 households being part of the project until the very end. Upon completion of the project, the participating households reduced their water consumption by 12% amounting for a saving of 35 kilolitres per household in one year. Due to a highly effective Diffusion Effect in the community, all residents in the Margaret River township reduced their water consumption by 7 to 11% summing up to savings of 72,970 kilolitres in one year for all 2,644 residential properties for which valid readings existed. The households prior to the project displayed an average water use of 296 kilolitres per annum (klpa) while after the project they reduced to 260 klpa. With 97% being satisfied with the project, a deeper understanding of their own water use and a considerable amount of water saving appliances purchased during the project, the evaluation of the participants' behavioural changes seems to indicate sustainable ongoing water savings for some time to come.

The Water Corporation then decided to apply the methods in the north of the State, on a select group of towns that were experiencing water shortages. All households in these towns could participate. The selected group of eight towns in the north of the state have an annual average household water use of 606 klpa. This is about twice that of towns and cities in the south of the state. The higher water use in the north is due to a combination of factors including year round higher temperatures, dust, free water use allowances for mining company housing tenants and the fact that fewer demand management programs have been implemented compared to those in the southern towns and cities. It was estimated that the water use in these households of the north was evenly split between indoor and outdoor use, the latter including gardens and washdown of cars and boats. Another important factor is the relatively low cost of water at approximately $AU1.90 per kilolitre at this level of consumption. This tariff is approximately the same across the State even though cost of supply in the north is much higher. This is made possible by State Government subsidy to the Water Corporation. By comparison, the residential tariff for electricity in WA is $AU0.25/kWh.

McKenzie-Mohr [5] and others [7] identified that unintegrated intensive approaches towards changing individual's behaviour, such as provision of information and economic self-interest are not successful. Instead 'community-based social marketing' (CBSM) has shown to be very effective at inducing behavioural change due to its pragmatic approach. In particular, it is important to introduce goal-setting [7], a sense of community ("your neighbours are doing it") and inspire concern for the environment [5] as better motivators for change.

Accordingly, the *H_2ome Smart* programs by Water Corporation and ENV have undertaken the following methodological development:

Firstly, a conceptual framework of CBSM has been refined with the main actions developed into an ongoing feedback loop as shown in **Figure 1**.

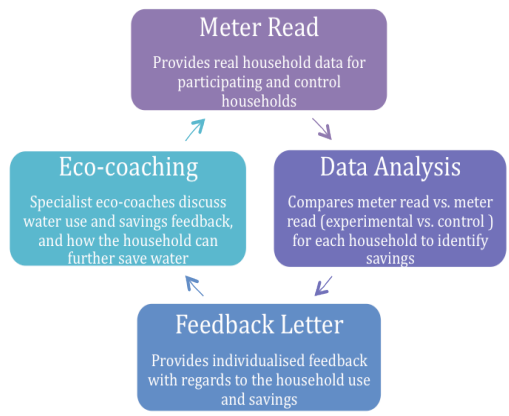

Figure 1. The CBSM eco-coaching feedback loop for residential energy & water use behaviour change programs.

Secondly, community engagement strategies have been incorporated that connect people with their community interests and raise awareness on the drying climate. After recruitment, this is followed by application of coaching with facilitative conversations that help customers set targets for themselves.

The CBSM methods deployed across these towns during 2010 and 2011 included:

a) Identifying the barriers to engaging sustainable behaviours through research prior to delivery;

b) Designing a strategic approach that integrates behaviour change tools;

c) Announcement letter and phone call;

d) Delivery of requested educational materials;

e) Three annual meter reads supplemented by five more by the contractor and self-reads by willing households;

f) Five feedback/progress letters followed by coaching phone calls each round by trained eco-coaches;

g) Final thank you letter and scorecard.

The Water Corporation coined the term "H_2ome Smart" for this program and specified a target 15% water savings from

behavioural change in 8,331 households to be recruited from 13,643 in eight selected towns in the Pilbara and Kimberley regions of the Northwest of Western Australia. Another 15% savings was targeted from retrofits to houses that provided free product upgrades including new shower roses, toilet cisterns and tap aerators. Water Corporation was the Principal in this program with methodological design, project management, community forums, training of coaches, call and mail centre operations including coaching, meter reading, website development, statistical analysis of data and evaluation by subcontractors. The targets of 15% were overly ambitious in the absence of sound information at the time of scoping. Unknown at the time was the very small number of owner-occupied households. The vast majority of tenancies were employer-owned housing (large mining companies) with free water-use allowances provided as part of the salary package thereby dis-incentivising water conservation practices and participation in the program. Despite the target of engaging 8,331 households the Water Corporation databases only held 4,413 accounts with most of these lacking in customer contact details. 1,428 of these households were eventually registered on the program. This represented only 17% of the desired registration target. Therefore the project team needed to source other databases to increase the potential number of registrations. After several months, when contact details could be augmented from other sources and a total of 4,997 households were ultimately registered, with some withdrawals along the way also, a reduced amount of time was available for engagement of the new recruits with CBSM techniques. The rounds of coaching that occurred as part of the Project Plan are shown in **Figure 2**, with not all households receiving all calls because of their late recruitment in the program. Nevertheless, final evaluation showed that as an overall average, participating households achieved a 6.9% savings from behavioural change and 9.9% overall if the results were annualised.

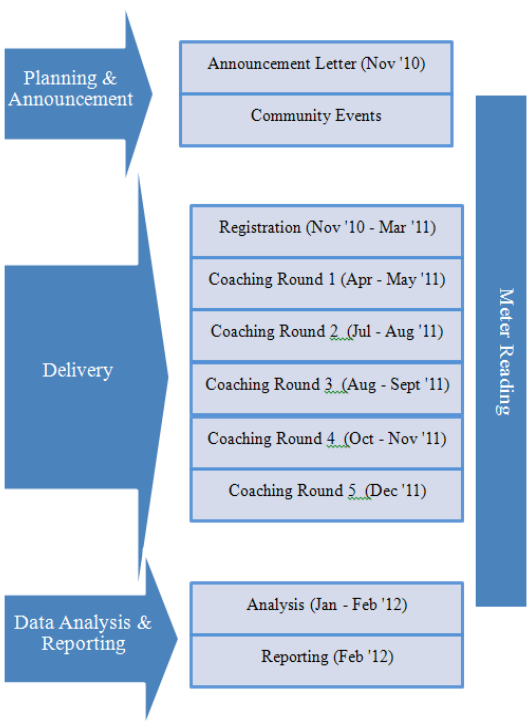

Figure 2: Summary of Northwest Project Plan

Once the North West region *H_2ome Smart* program was underway and despite the difficulties encountered with results encouraging enough, the Water Corporation decided to launch similar CBSM programs in the Great Southern and Perth regions in the South West of the State, jointly funded by the Water Corporation and Australian Government's *Water for the Future* initiative.

In Perth, the target number of households was specified as a minimum of 10,000 households participating throughout the program. The water reduction target to be achieved by the contractor with the participating households was an average of 12% in the first full year after program completion compared to non-participating households. Wastewater flows from these households were to be reduced accordingly. The program intent was to inform and empower the participating households on a one-on-one basis so they are able to formulate their own plan to put water efficiency into practice in their own homes and ensure efficient use of scheme water into the future by forming sustainable water saving habits.

The CBSM core methods of Figure 1 were again applied with five rounds of meter reading, data analysis, feedback letters and coaching calls after the initial planning and announcement phase. During this research prior to delivery baseline meter reads were taken, control households selected and appropriate communications and feedback materials developed in focus groups and surveys.

A smart metering trial was run in conjunction with the Perth *H_2ome Smart* program as a prize package. Greensense is a Western Australian company that partnered with the *H_2ome Smart* program to run the trial. Smart meters are an informative and educational tool that allows households to instantaneously view personal real-time water use feedback.

Nine participants agreed, after a selection process, to participate in the Greensense smart metering trial with the tenth participant being local television sustainable gardening celebrity Josh Byrne at his local Perth metropolitan residence. Josh Byrne was included in the trial to provide a base line dataset of efficient water use for households to compare their water use and aim to emulate. The selection of the nine households was based on the following factors:

- The budget available only allowed for this small-scale trial.
- The offer was made to participants in the southern suburbs to minimise time required for installation of the equipment.
- A short list of 30 households was compiled from those that had registered early and online to *H_2ome Smart*, had access to a computer and the internet; were clearly a keen *H_2ome Smart* participant; and willing to monitor their water use weekly and engage with the H2ome Smart team.
- The project team reviewed the selected properties and compared the data collected during the first round of phone calls, and the latest aerial imagery.
- The project team called the short listed households to collect additional data needed to determine eligibility and their enthusiasm towards the program.
- The project team conducted a site visit to assess the shortlisted properties on site and to assess the households on a variety of parameters including meter access, meter type, internet access, water consumption and participation level amongst others.

- The final nine households were confirmed by direct contact.

The Greensense product, *GreensenseView*, is provided as a hosted software service (**Figure 3**). It monitors electricity, water and gas use, displaying the results on an interactive 'dashboard' on your website or kiosk-displays within homes or buildings. Greensense brings the data to life for building users, enabling people to see – in real time – how their actions are impacting on the sustainability performance on the spaces they live and work in. The Greensense product works by providing timely and sustained feedback and evidence of performance improvements. One of the unique features of the Greensense product is its ability to aggregate information across multiple facilities to enable real-time benchmarking, comparative performance tracking, and competitions between home or office occupants.

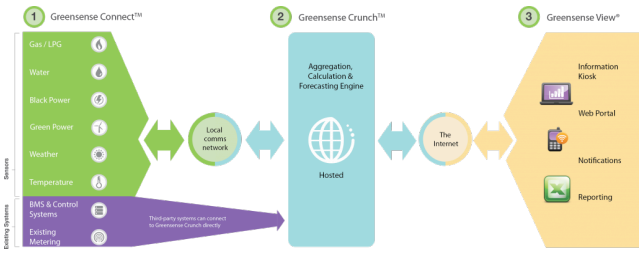

Figure 3: The Greensense Process

All nine (9) loggers were successfully installed by the end of March, 2012 (**Figures 4 & 5**). These were only temporary installations for the duration of the trial.

Figure 4: A Unidata logger and transmitter is connected to this V100 Elster water meter via a T-probe

The water use data captured and processed for each household is then displayed on their Smart Meter Challenge Dashboard. The Smart Meter Challenge dashboard has been tailored to align with Water Corporation branding, the feedback letters provided to participants and eco coaching (see **Figure 6**).

Figure 5: A Unidata logger and transmitter is connected to this Actaris water meter via a Cyble sensor

The main module shows water use in real time (within each five minute interval) and can be updated as frequently as desired, with consideration given to the battery within the data logger. Greensense data is uploaded to the dashboard every four hours. When interacting with the dashboard you can hover over each peak to clarify the volume of water used in the last five minutes. By clicking on the Select Date Range button, the household can modify the timeframe in which they view their data (e.g. yesterday, last week, last month etc).

The dashboard (**Figure 6**) underwent many edits during the establishment period. All wording on the dashboard was revised to ensure it provided softer feedback, for example the wording in right-hand side module was modified from "Worst" and "Best" to "Highest" and "Lowest". The Water Corporation has supplied a series of tips and the Water Corporation website address to be utilized in the rotating tips box.

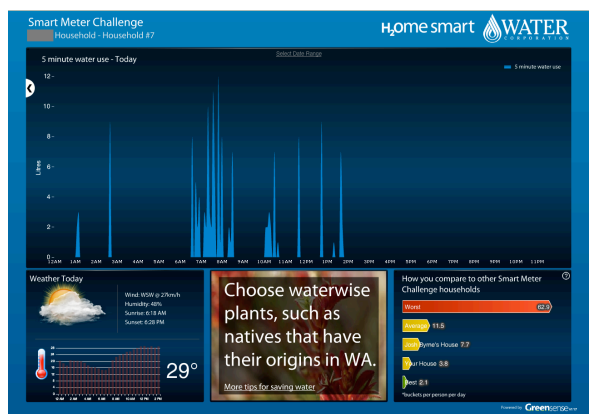

Figure 6: The Smart Meter Challenge Dashboard

Focus groups were conducted during the planning phase of the Perth *H_2ome Smart* program. From this research appropriate wording and graphics for feedback letters were developed to optimize participant experience. The main feedback graphic was a quintile pyramid, as shown in **Figure 7**. A quintile is a statistical value of a data set that represents 20% of a given population. Participant households were assigned their quintile according to their water use. The water use quintiles were re-calculated each round by ranking the control households according to their water use (highest to lowest) and allocating 20% of the control households to each water use quintile. This meant that the water

use of the household at the bottom of each 20% group (in L/person/day) was a 'breakpoint'.

During eco-coaching weeks the quintile diagram (**Figure 7**) for each household was displayed on the dashboard, and for all other weeks a general weather module took its place. The draft information pack was edited and updated to reflect all of the above changes to the dashboard. Once confirmed and approved the packs were individually tailored to each Greensense participant to include their username and password.

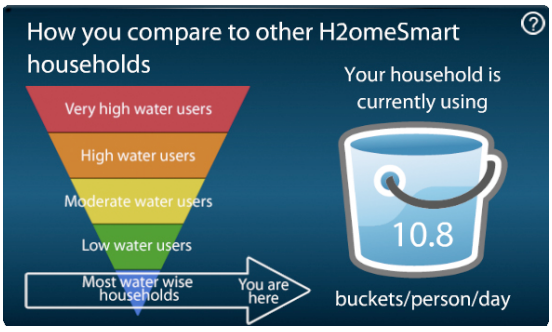

Figure 7: Quintile module

To ensure Greensense smart metering challenge households get a targeted and specific type of eco-coaching call, only two eco-coaches were identified to call the households for the remaining rounds. This approach allowed the team to technically train these two eco-coaches and allow them to become familiar with the real-time data and develop a rapport with the households.

These two eco-coaches underwent a targeted training session covering the following:

- A summary of what the participants have received (letter and information pack);
- An online run through *GreensenseView* and dashboard; and
- Discussion around the script and how important it would be for the coaches to try and tailor their eco-coaching to the available real time data.

The selected eco-coaches also had access to each household's dashboard and web-based reports to allow them to further understand the household's water use and facilitate behavioural change. In order to understand the real-time water use data received and to provide personalized feedback to Greensense participants it was essential that each individual households situation was understood.

An example of a web-based 'heat map' report is shown in **Figure 8**. This report shows the average pattern of water use in a given period. In the example shown, the report provides evidence of a household using automatic garden irrigation in winter (the large flows at 10:00pm on Thursday and Sunday) and possible evidence of a water leak (minimum night-time flows are above zero).

This report shows the average 24-hour consumption profile over each day of the week for 'Water (L)' for the period 1-Jul-2012 to 30-Sep-2012.

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
12:00 AM	4.2	0.4	5.4	2.1	2.5	3.8	1.5
01:00 AM	1.9	1.3	3.3	0.4	0.0	1.3	0.0
02:00 AM	0.0	0.4	2.5	1.7	0.0	0.4	0.8
03:00 AM	3.1	1.3	1.3	2.5	0.4	0.0	0.0
04:00 AM	1.9	1.3	11.3	1.3	0.4	0.8	0.0
05:00 AM	1.5	6.3	2.5	1.7	2.5	2.5	1.5
06:00 AM	3.8	17.9	19.6	7.1	15.0	5.8	18.1
07:00 AM	55.0	42.9	66.3	25.8	31.7	9.2	18.1
08:00 AM	83.8	83.8	90.8	92.1	88.8	31.7	61.9
09:00 AM	33.3	39.6	54.2	42.1	30.4	46.7	39.2
10:00 AM	16.3	23.8	37.1	25.0	10.4	76.7	32.7
11:00 AM	30.8	28.8	25.4	13.3	14.2	51.3	42.7
12:00 PM	24.6	26.7	36.7	12.1	14.6	40.0	37.3
01:00 PM	25.8	20.8	25.8	26.7	17.9	9.2	19.2
02:00 PM	13.3	22.5	12.9	17.9	16.3	13.3	19.6
03:00 PM	20.8	17.1	10.8	22.5	12.9	13.8	5.4
04:00 PM	26.3	20.4	12.1	17.5	11.7	23.8	8.8
05:00 PM	15.0	17.9	10.0	10.8	21.7	31.7	9.6
06:00 PM	12.1	19.2	17.9	15.4	11.7	17.1	17.3
07:00 PM	24.6	15.8	7.5	14.6	9.2	10.8	14.6
08:00 PM	15.0	18.3	9.6	9.2	19.2	5.0	8.5
09:00 PM	12.1	20.0	8.3	7.1	19.6	17.9	7.3
10:00 PM	12.9	10.0	8.3	182.1	10.8	8.3	164.2
11:00 PM	8.3	4.6	2.9	9.6	7.9	6.3	3.1

Figure 8: Heat-map report

3. RESULTS

The Perth *H_2ome Smart* program ran from July 2011 to August 2012 and 12,256 households were initially recruited from approximately 33,000 households the target suburbs. By the end of the program 11,067 were still participating. At the time of publishing this paper, the water saved as a result of this program was still being evaluated.

The Greensense smart metering trial system started to record data for all ten participating households on Wednesday 1st February 2012.

It is interesting to note the patterns in water use before households could view their dashboards and after they had access to their dashboard and had a few days to understand the real-time data and patterns in water use. By comparing these two separate date ranges ('before' corresponding to Thursday 23rd February 2012 – Wednesday 28th March 2012, and 'after' corresponding to Thursday 29th March 2012 – Wednesday 2nd May 2012) we can see the differences that access to real-time water use data can affect in water use behaviours.

The Greensense smart metering trial, or 'challenge' as it was communicated to participants, demonstrated a variable response to the real-time water use dashboards.

By utilising Heat Maps the Greensense system can retrieve hourly averages for water use in an average week and display the data using average litre figures and colour coding to help identify anomalies and patterns of water use. The Greensense system can also produce Weekly Profile Comparison Reports where the average water use and maximums can be tabulated and graphed for two periods of time.

Water use data was downloaded from *GreensenseView* to track water usage in each household. It is evident from **Figure 9** below that most households made significant water savings since the start date.

Josh Byrne, from ABC TV's Gardening Australia, and his family were consistently low water users. Their household is a great example of a waterwise household that has a highly functional (and productive) garden. Indeed, many of their water savings

come from actions taken in the garden. Some of the other households in the smart metering trial had established gardens with lower percentages of lawn, but most of the households did not have highly functional gardens. In order to create a highly productive and waterwise garden, the Byrne household has implemented the following:

- Careful design of garden considering space, sunlight, aspect etc;
- Hydrozoning of plants;
- Seasonal planting of food plants;
- Collection and treatment of greywater for drip irrigation;
- Collection of rainwater for drip irrigation, as well as supplying water to the toilet and washing machine.

As can be seen in **Figure 9**, water use is much higher generally in the months of February and March when high summer temperatures require garden irrigation. The Bodis household showed the highest water due to large areas of turf that were subsequently changed to Waterwise gardening techniques leading to substantial reduction in water use. The Byrne household water use during this same time was low, even with the lush, productive garden, because of the use of greywater for irrigation.

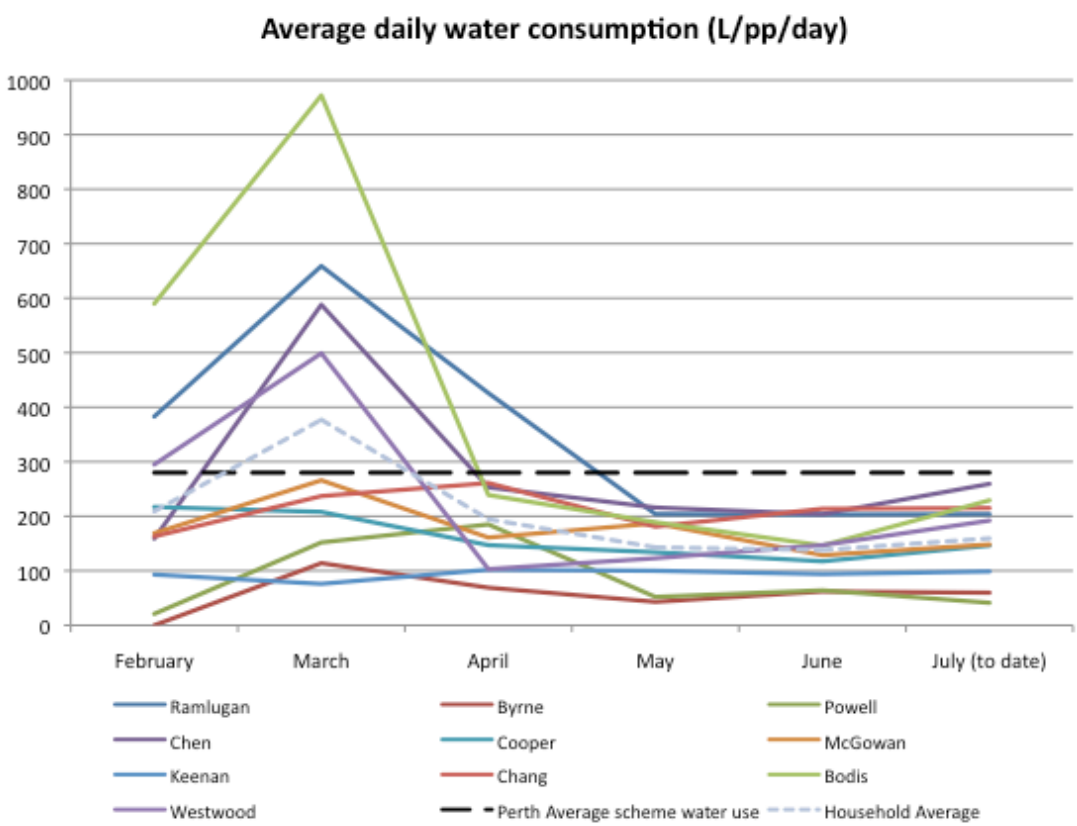

Figure 9. Average daily water use (L/p/day) of Greensense VIP households

4. FINDINGS

At the conclusion of the program the team has collated all water use data, and feedback from the participants to complete a final analysis demonstrating the outcomes of the challenge including its advantages/ disadvantages and opportunities/ constraints for the future. The following findings are important for the future:

1. The display of water use versus time can be limited by water meters that measure in 5 litre intervals; the data displayed is likely to lag behind when the water was actually used.
2. The integration of two data collection methods (real-time and manual meter reads) proved difficult. Though significant effort was expended to design meaningful modules for the dashboard, the quintile module was eventually pulled down.
3. Participants enjoyed seeing their water use in real-time, but engagement by the participants with the dashboard was lower than anticipated and decreased as the program progressed. Monitoring their own water use was not a high priority and there were no mechanisms to ensure that participants would log on.

4. Some participants stated that they would prefer an in-home display (IHD), whereas others preferred an online portal. This suggests that one solution does not fit all.

5. The eco-coach found it beneficial if they and the participant were viewing the dashboard during the coaching calls, but this would not be practical as part of a larger program where speed and efficiency is necessary to achieve cost-effectiveness.

6. To integrate the data collected into this trial, the dashboards were reviewed manually and key points summarized for the eco-coach. However, the ideal would be for the data to be analyzed automatically and then included within feedback letters and scripting.

5. RECOMMENDATIONS

The following recommendations are particularly relevant for utilities, industry practitioners and project managers of behaviour change programs:

1. Install water meters with a small logging interval (i.e. 1 litre instead of 5 litres) to improve the accuracy of real-time data and allow actions to be directly correlated to water use.

2. Smart metering should be utilized to collect baseline data for at least 1 year prior to the implementation of a BCP.

3. IHDs or online portals should be opt-in, as it is unlikely that all households will engage with these as often as desired.

4. Water use feedback should also be available as an automatic daily or weekly e-mail with embedded charts showing comparative water use to continuously re-engage participants through the duration of the program.

5. The display of data and any additional analysis for participants should be as clear and easy to understand as possible. It is recommended that water use be displayed in litres per 1 min units (though this will only be effective if the water meter logs in 1L intervals). Analysis results displayed on an IHD or portal must align with the aims of the program and provide real value.

6. Results from regular data analysis of the real-time data should be incorporated into personalized feedback letters, along with up to date results of the community effort and a reminder of their agreed actions.

7. Feedback letters should be followed by an eco-coaching call that does not require the eco-coach or the participant to see their real-time data to be effective.

6. ACKNOWLEDGMENTS

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