Advancing household water-use feedback to inform customer behaviour for sustainable urban water

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ABSTRACT

Sustainable water management is becoming increasingly essential in an age characterised by rapid population and urban growth, industrial development and climate change. Opportunities to promote conservation and water-use efficiencies remain attractive in directly reducing water demand. Smart water metering and the provision of detailed water-use feedback to consumers present exciting new opportunities for improved urban water management. This paper explores two smart water metering trials in New South Wales, Australia, which provided household water consumption feedback via (i) paper end-use reports and (ii) an online portal. This combination enabled a deeper exploration of the various impacts of detailed feedback enabled via smart water metering. The positive effects uncovered by the research present an important opportunity for smart water metering feedback to contribute towards more sustainable urban water management. Their summary contributes empirical evidence on the impacts for water utilities considering embarking on the smart water metering journey with their customers. The identification of future research and policy needs sets an agenda for smart water metering to promote a sustainable digital urban water future. Larger scale trials are now required and utilities should integrate the design and plans for scalable advanced feedback programs at the outset of smart meter implementations.

KEY WORDS

Feedback; Household Water Consumption; Smart Water Metering; Sustainable Water Management; Water Efficiency; Water Policy.

INTRODUCTION

Sustainable water management is becoming increasingly essential in an age characterised by rapid population and urban growth, industrial development and climate change (Kayaga et al., 2007). While various new technologies and methods (e.g. water treatment and re-use) can help to improve the supply of water, new opportunities to promote conservation and water-use efficiencies remain attractive in directly reducing the demands on water supplies (Butler & Memon 2006).

Smart water metering and the advanced information and communication technologies afforded by the digital age present exciting new opportunities for improved urban water management both for water utilities and consumers. The extension of smart water metering to the provision of household water consumption feedback can particularly inform customers on their uses of water and specific opportunities to save (Liu et al. 2015). This can facilitate the adoption of greater water-use efficiency measures in terms of new practices and/or more water-efficient appliances and infrastructure and therefore contribute towards a more sustainable consumption of water resources.

In Australia and internationally, implementations of smart water meters have been advancing rapidly over the past few years (Beal & Flynn 2015). Many water utilities are interested in extending systems to include consumption feedback to end-customers. However, to date, relatively few have actually implemented advanced feedback programs in conjunction with their adoption of smart water meters. Water utilities remain largely hesitant due to the lack of practical experience and quality research studies which leaves many uncertainties in terms of the impacts of detailed customer water-use feedback provision.

There are certainly important benefits from smart water metering without an extension to customer feedback (Boyle et al. 2013). However, to make a greater contribution towards a goal of sustainability, the involvement of all actors in the economy is implicated. This vision for sustainability includes the active participation of household water consumers. The provision of advanced and detailed water use feedback is a critical step in this direction and requires detailed investigation. A number of recent small-scale trials have signalled positive impacts of feedback enabled via smart water meters on household water consumption, including in Australia (Fielding et al. 2013; Britton et al. 2013), the US (Erickson et al. 2012) and South Korea (Joo et al. 2014). However, the possibilities and issues relating to advanced feedback implementations at scale have not been discussed in detail.

From 2012-2015, the Institute for Sustainable Futures at the University of Technology Sydney collaborated with MidCoast Water in New South Wales (NSW) on an Australian Research Council Linkage Project to explore the role for smart water metering in a digital urban water future. The mixed methods research project involved the practical implementation and analysis of two household water-use feedback trials. The combination of the studies was used to explore various facets of the impacts of more detailed feedback enabled via smart water metering and extend experience of the practical issues, challenges and opportunities.

This paper presents an overview of the impacts of the two distinct smart water meter feedback studies and discusses the results and issues in relation to the pursuit of more sustainable urban water management. Lastly, a research agenda is presented in the context of the current state of smart water metering and detailed feedback in Australia. The research paper offers valuable insights to water utilities, researchers and policy makers to progress the smart water metering opportunity together with water consumers, particularly at scale, towards sustainability.

METHODS

The mixed methods research project involved the practical implementation and analysis of two household water-use feedback trials. The 'Home Water Update' (HWU) study (N=68) involved the provision of detailed end-use feedback via paper-based reports to half the matched sample and was undertaken in Tea Gardens and Hawks Nest, two coastal towns in NSW, Australia. An example of the intervention medium is shown in Figure 1. A summary of the HWU study methods is included in Table 1, with more detailed methods and results of the study reported in Liu et al. (2016; 2015).

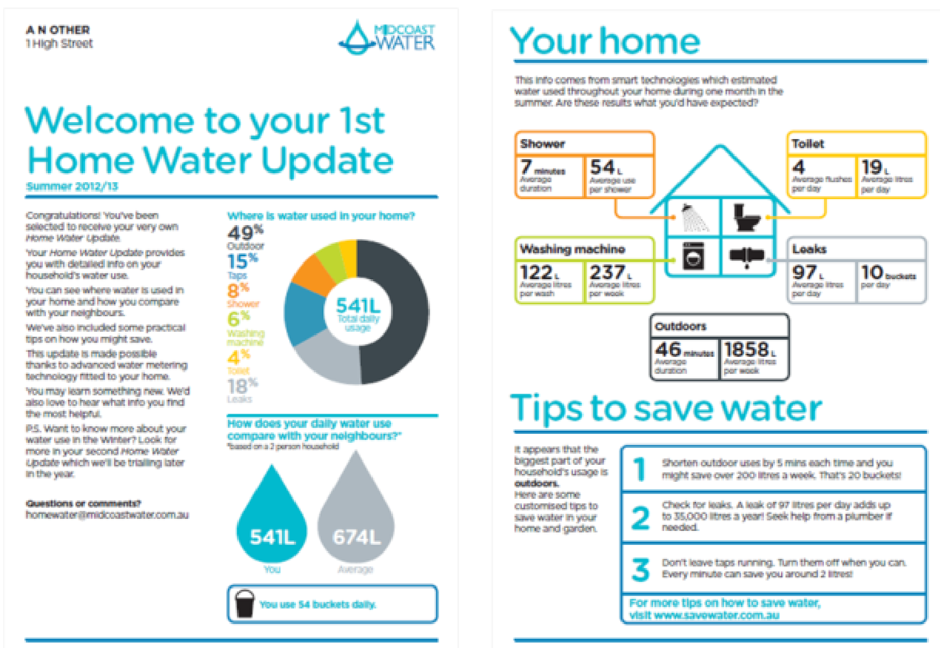

Figure 1 An example 'Home Water Update', customised paper reports, which included detailed household end-use water consumption information (Liu et al. 2015).

The 'My Home Our Water' (MHOW) study (N=120) involved providing access to a custom-built online water portal communicating household water consumption feedback in near real-time in Greater Taree, a council consisting of a number of towns and localities. A selection of screenshots of the portal is shown in Figure 2. Further details of the methods of the MHOW study are also included in Table 1.

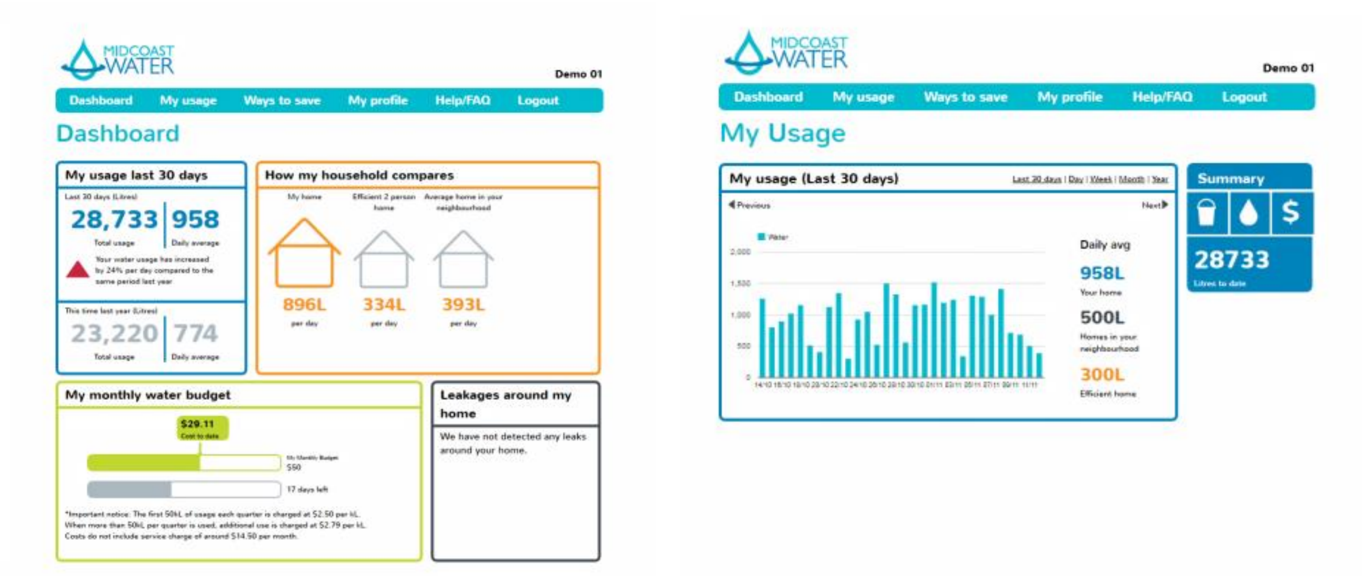

Figure 2 Screenshots of 'My Home Our Water' online water consumption feedback portal, which provided aggregated water consumption feedback in near real-time.

Table 1. Overview of study methods

	HWU study	MHOW study
Study location	Tea Gardens and Hawks Nest, NSW, Australia	Greater Taree, NSW, Australia
Sample sizes	68 households (34 intervention and 34 control group households)	120 households (60 intervention and 60 control group households)
Sample socio-economic data:		
• Average occupancy	2	2
• Median household income in Australian Dollars (AUD)	30,000 – 59,999 AUD	30,000 – 59,999 AUD
• Median age	65+	44-64
• Employment / Unemployed / Retired	64% / 3% / 33%	51% / 2% / 41%
Sampling method	Recruitment from 141 households with an existing smart water meter.	Recruitment from households within the second highest quartile of consumers to be fitted with a smart water meter.

Smart meter data collection	1 min data collected at baseline and post-intervention during a few weeks each summer and winter.	1 to 5 min data collected continuously during one-year baseline and one-year post-intervention
Additional data collection	Householder baseline survey; Evaluation survey; Interviews.	Householder baseline survey; Evaluation survey; Portal login data.
Intervention timescale	Two instances of feedback (May and Sep 2013) providing feedback based on summer and winter data collection.	Continuous feedback made available from Jan – Dec 2014, updated daily.
Methodological limitations	The time taken to disaggregate consumption data resulted in delayed feedback and measurement, creating a challenge for evaluation.	Technical issues resulted in data not always being uploaded initially and a need for replacement loggers.

In this paper, the impacts of the HWU and MHOW feedback trials are presented together for the first time. The combination of the two studies was used for a wider exploration of various dimensions of the impacts of different approaches to more detailed feedback enabled via smart water metering and simultaneously extend experience of the practical issues and challenges involved with respect to sustainable water. A greater range of impacts is presented than in other studies, covering program reach, awareness, behaviour change, infrastructure changes, appeal, willingness to pay, and water consumption savings. It should be noted that the results are indicative of the impacts of the distinct interventions, but are not always directly comparable with one another due to the differences in the interventions (including in terms of timing, frequency, duration and content). In addition, the designs of both studies were limited by budget constraints.

The data for this paper draws from the analysis of the householder evaluation surveys which were conducted post-intervention. The HWU study was evaluated via a postal survey, whereas the MHOW study was evaluated via an online survey administered using Survey Monkey ™. Both surveys used rating scales and multiple choice questions in order to measure the various impacts of the interventions.

RESULTS AND DISCUSSION

Results of the HWU and MHOW studies

The two feedback studies explored the role for smart water metering technology in providing access to detailed water-use information to household consumers. Both trials reported water consumption saving effects, concrete behaviour changes, changes in household water-using appliances and improvements in awareness of water use. Detailed results from both trials are presented in Table 2. The results demonstrate that smart water metering has a positive impact to play in term of water conservation, corroborating other results (Fielding et al. 2013; Erickson et al. 2012), and suggesting that advanced feedback can yield a variety of benefits that can contribute towards a more sustainable consumption of water resources.

Table 2 Impact evaluation

Impact	**HWU – paper-based end-use breakdown**	**MHOW – online total water use (near) real-time**
Program reach (i.e. % receiving the HWUs; or % that logged on to the MHOW portal, respectively)	100%	30 %
Reported awareness (i.e. % agreeing or strongly agreeing to having:		
• Awareness of their household's water use	86%	73%
• Awareness of their household's end-uses of water	82%	82%
• Awareness of their household's highest use of water	100%	91%
• The feeling of being informed about their water use	91%	91%
Behaviour change (% reporting changes)	38%	50%
Water-using infrastructure changes (% reporting changes in terms of):	10%	33%
• Efficient shower heads	1	3
• Water-efficient toilets	1	1
• Water-efficient washing machines	0	2
• Leak repairs	3	7
Appeal (i.e. % that found the information interesting)	80-90%	90%
Water consumption savings (intervention group relative to the control group)	8%*	4.2%†
Willingness to pay in Australian Dollars (AUD) (per HWU report; or for one years' access to the MHOW portal, respectively)		
• Average	AUD 2.50	AUD 5.75
• Range	AUD 0.50 – AUD 10.00	AUD 1.00 – AUD 20.00

Table notes:

Water consumption savings for both studies and MHOW portal logins are based on the entire study samples. All other HWU study impacts are based on the 22/34 recipient households who responded to the evaluation survey (i.e. a 65% response rate); and all other MHOW study impacts are based on the 12/30 user households who responded to the evaluation survey (i.e. a 40% response rate).

* HWU study savings are measured relative to the previous winter. The savings are not statistically significant, possibly due to the moderate sample size.

† MHOW study savings are measured over the course of one year.

Implications of the research in the current context of smart water metering

Despite recent progress, most Australian water utilities still have reservations about the business case for smart water metering, although there is at the same time a general expectation that smart water meters will come down in cost and become the norm in the future. In calculation of the return on investment, there is a reported tendency towards a reliance on tangibles (e.g. meter reading cost savings or leak detection etc.). In this way, additional benefits on the customer-side (i.e. feedback or customer engagement etc.), which are widely considered intangible, are not receiving quantification in the cost-benefit analysis and investment decision. Moreover, information and feedback services are considered as optional add-ons, whereby the decision to invest in smart water metering is generally considered a precursor to feedback but evaluated somewhat independently of the feedback opportunity. Although a few recent implementations have involved feedback, they are not always accompanied by quality research, which represents a lost opportunity to deeply understand the fuller contribution and to expand the existing knowledge base. There is also a risk of analyses largely duplicating existing results.

The HWU and MHOW studies demonstrated that there are important intangible benefits through customised feedback enabled via smart water metering. Seen in the current context in which the roll-out of smart meters within the water industry is expected to gather momentum, this means the opportunity to extend access to the newly created data resources to household water consumers will progressively increase. However, inaction will mean these fuller benefits risk being postponed, so that understanding best approaches will become increasingly urgent.

Opportunities for coordinated research regarding the design, implementation and evaluation of impacts exist. If exploited now, such an approach will help facilitate a smoother and faster implementation of feedback when smart water metering becomes more mainstream. Collaborations between research and industry can also make an important contribution. Many projects to date in Australia and overseas have notably involved small scale trials (Fielding et al. 2013; Erickson et al. 2012; Britton et al. 2013; Joo et al. 2014). However, larger and more widespread implementations will carry overall greater amounts of engagement and water-saving impacts due to the increased scale of customer coverage. This will offer greater conservation and sustainability impacts relating to the scale of roll-outs. What is now required is more in the way of a best-in-class type model implementation which can be used as an industry benchmark. In this way, utilities will be able to integrate the design and plans for advanced feedback programs at the outset of smart meter implementations.

This research project focused on the opportunities on the customer side in terms of the potential impacts on customers and their consumption of water via detailed water-use information. The two pilot feedback studies particularly demonstrated how smart water metering is enabling more detailed household water consumption feedback and its impacts. However, the detailed research was conducted with moderate sample sizes and limitations in terms of how the study samples were selected. Similar research is recommended which builds on the approaches adopted, using both larger, as well as representative samples to truly understand the role and scope of the opportunity.

Moreover, since the moderate sample sizes showed messages of variety in a number of regards, including water consumption and savings; water-use information preferences; interest in more detailed water-use feedback; motivations for accessing information; responsiveness to the information; engagement; and behaviour change; this heterogeneity suggested a variety of approaches to the provision of feedback need to be taken in order to attain improved engagement and contributions towards greater sustainability. There is a need for further research in this area, which investigates the relationships between different types of information, different population segments (e.g. according to various socio-demographics; preferences) and impacts (e.g. on household water consumption and other variables of interest). Again, larger sample sizes are required. Once impacts on a larger scale are established, this will help prepare the way for more widespread and guided adoption.

To achieve a greater contribution towards sustainable urban water, the role of feedback via smart water metering needs to be raised from pilot, independent or secondary implementations to expedite overall progress by water utilities with smart water metering. At the same time, engagement and uptake by householder water consumers in new feedback opportunities need to be maximised through varying approaches.

A robust scaled trial

Having highlighted the need for larger scale research into the impacts of detailed water-use feedback enabled by SWM, this section closes with a discussion of how to design a robust scaled study. While little assistance is directly available from water sector literature, important guiding principles can be found from other fields, including energy and health sciences.

In Milat et al. (2012), the concept of scalability is defined as "the ability of an…intervention to be expanded under real world conditions to reach a greater proportion of the eligible population, while retaining effectiveness". Across many scientific fields, randomised controlled trials (RCT) are considered the "gold standard" of intervention studies. *Randomisation* means participants are randomly assigned to the intervention or control groups, thereby helping to control for selection bias by comparing two or more similar study subgroups. How study participants are initially selected is also important, since this will also affect the *representativeness* (or external validity) of the results, even if an RCT design is implemented. For example, in the MHOW study, participant households were recruited from among the second highest quartile of water consumers, so the results might not have been generalisable to other consumption quartiles. In-situ trials have also been advocated in order to experiment with representative populations (Allcott & Mullainathan 2010). Considering the HWU study, it is noted that participant households were selected from two towns, such that the results may not have been generalisable to other localities.

To test for the scalability of an intervention, participant recruitment also needs to avoid engaging only those who are *interested* in a program, otherwise the intervention risks being trialled with more motivated and engaged subjects, producing different treatment effects than if representative samples are used (Allcott & Mullainathan 2010). This is an issue that voluntary recruitment in previous water-use feedback research (Fielding et al. 2013; Erickson et al. 2012) and in the HWU and MHOW studies would need to address differently for scalable studies. That is, "uninterested households should not automatically be excluded from studies.

The *duration* of detailed water-use feedback trials is also important, since the effects of interventions were shown to differ between the short and long term in the HWU study (Liu et al 2016). The use of a *baseline* period, as in both the HWU and MHOW studies, further offers the advantage of being able to compare water consumption pre- and post-intervention.

Milat et al. (2012) also identify intervention and research design factors which may increase the potential for interventions to be implemented more widely. Relevant factors not previously discussed within the detailed water-use feedback literature include a consideration of the *resources* required to implement at scale, including workforce, technical and organisational resources (Milat et al. 2012). For scalable water-use feedback trials, the resources deployed in a trial need to be carefully considered to avoid the risk that the 'best' resources are used for a small-scale intervention that would not be practical or available at a larger scale. Reflecting on experiences from the HWU and MHOW studies, it is noted that industry-research partnerships offer expertise (for example, in research design and evaluation), however, water utilities should ideally develop in-house 'know-how' during a smaller scale trial to later be equipped to scale up interventions.

Cost considerations were discussed in Milat et al. (2012) as the information that was most commonly missing from reports of interventions in health research, together with the suggestion that their availability would facilitate decisions to scale up interventions. This issue is also noted to be of relevance to detailed water-use feedback research.

With the principles of scalability in mind, our suggestion that future research take a more *customised* approach to advanced water-use feedback is now briefly revisited on a practical level. On the one hand, customisation is possible along a number of dimensions (e.g. using different feedback mediums, content and frequencies); and on the other hand, it may be directed by the water utility or the customer.

Some cities in Australia have recently opted for large scale implementations of smart water metering. An opportunity therefore exists to make use of this infrastructure to trial alternative approaches to detailed water-use feedback provision. By selecting households from across the service areas and deploying the principles of scalability discussed above, alternative approaches to customer segmentation for feedback provision and their impacts can be investigated and progressively enhanced to draw lessons for full scale feedback provision.

CONCLUSION

The research project contributed evidence of impacts of smart water meter feedback and discussed the opportunity for sustainable water. The identification of future research and policy needs sets an agenda for smart water metering to promote a sustainable digital urban water future. A more coordinated approach to the design, implementation and analysis of impacts of feedback programs is called for between the water industry and research organisations to ensure very clear business and sustainability objectives are met. Multiple trials which duplicate results without significantly improving understanding should also be avoided. Rather, robust scaled research trials are required so that benefits and implementations can be introduced at scale. In this respect, water utilities should aim to integrate the design and plans for scalable advanced feedback programs at the outset of smart meter implementations.

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