Smart Metering

water e-journal
Online Journal of the Australian Water Association
ISSN 2206-1991
Volume 5 No 1 2020
https://doi.org/10.21139/wej.2020.006

Smart Meter Technology

A Ten-Year Study on Urban Water Consumption

K Davies, C Doolan, A Northam, R Shi

ABSTRACT

There is increasing pressure being placed on water resources globally, arising from external factors such as climate change impacts, changing community values, population growth and urbanisation. In response, there is an urgent need for utilities and communities to adapt to this scenario. One of the ways to achieve this is through the use of technology to support sustainable consumption. This study investigates the effect of smart metering technology on the water consumption of an urban community.

From 2008-2010, Sydney Water, the primary water utility in Sydney then serving a population of over 4.2 million, conducted a comprehensive smart metering study in residential homes in the suburb of Westleigh. This study initially involved 1,201 participants residing in 630 households. A key finding was that households with an in-home display (participant group) reduced their consumption by an average of almost 7% over the study period when compared to the control group. The continued accumulation of data up to 2018 has allowed the longer-term effects of smart meters to be investigated.

To ensure that the behaviour of a consistent set of households was being measured over time, properties that did not meet certain conditions such as a change in ownership, were removed from the study. This resulted in a reduction from 218 to 88 households (44 pairs of matched participant and controls), with 264 participants residing in these households. The average change in household consumption by the 44 matched pairs of households increased in both the participant and control groups in the 2010-2018 period. However, this increase was much greater in the control group (2.21 kL or 14.2% per month) than in the participant group (0.53 kL or 3.3% per month) compared to the pre-study period.

An examination of the average change in consumption from the pre-study to the post-study period shows that the water savings of the participant group is significantly greater than that of the control group. The paper highlights the potential for smart metering technology to change water-use behaviour over the long term, demonstrating the value of this technology in a residential setting.

Keywords: Smart meter, water, urban, water consumption, behaviour, whole-of community engagement, climate change, technology.

INTRODUCTION

Globally, there is increasing pressure being placed on the provision of all-natural resources, including water resources, to sustain the livelihoods of current and future generations. These pressures are expected to increase due to influential variables such as the impacts of climate change, changing community values, population growth and urbanisation. The 2018 Intergovernmental Panel on Climate Change (IPCC) report supported this prediction when it stated (IPCC 2018, p.1):

Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C.

To add further levels of pressure to this scenario, changing values in developed nations have led to an increase in the consumption of natural resources, together with a growing population, and unprecedented rate of urbanisation. Population growth is predicted to grow globally by 42% over the coming century, from 7.7 billion in 2019 to 10.9 billion in 2100 (UN 2019). Additionally, 55% of the global population now resides in urban areas; by 2050, this percentage is predicted to increase to 68% (UN 2018).

In response to the growing pressures placed on the provision of natural resources, there have been many global initiatives developed to protect the sustainability of the planet, including the UN establishing the Sustainable Development Goals (SDG) in 2015. Of relevance to this paper are SDG 6, 'Clean Water and Sanitation' and SDG 11, 'Sustainable Cities and Communities' (UN 2015).

One of the ways to address these challenges is to reduce the consumption and waste of natural resources by communities. Technology can be utilised to support behavioural change in communities, with the aim of reducing their consumption patterns.

This study investigated the long-term influence of smart metering technology on urban residential water consumption in Westleigh, a suburb of Sydney (Australia), over a ten-year period (July 2008-June 2018). Smart metering is a term used to describe several different technologies that provide a more comprehensive record of consumption than standard mechanical residential meters.

For the purpose of this paper, smart metering is defined as the provision of near real-time information enabling customers to understand and monitor their water use (Davies et al., 2014), and to assist Sydney Water, Sydney's primary water utility, in managing its network and providing better customer service. This research is based on a study that was conducted by Sydney Water.

The first phase of the study involved measuring quarterly consumption data for the pre-study period (July 2008-June 2009) followed by the study period (July 2009-June 2010). Findings from the initial study period were published in 2014 (Davies et al., 2014). This paper reports on the post-study period (July 2010-June 2018) when water consumption was measured to evaluate the long-term effects of the smart metering technology that had been removed at the end of the first study period.

SMART METERS AND BEHAVIOUR

Studies on systems which measure energy consumption that feedback directly to households and businesses have been ongoing since the 1970s. These studies established that feedback can have measurable effects on behaviour, at least in the short term. These studies have been typically funded by energy utilities, regulators or government authorities, rather than the water sector. It should be noted, that while these studies offer relevant observations that can be useful for the water sector, there are differentiating variables that should be considered, as these will be influential in terms of resident's consumption behaviour. One example, in Australia, is the lower cost of water (per household per day) when compared to energy.

The energy sector

Burchell et al. (2016) identified that it was possible to achieve a 3-19% reduction in energy consumption by modifying occupants' behaviour. Gölz and Hahnel (2016) explored the motives for using energy feedback systems and found that there were many influences that contributed to the commitment to informed decision-making to reduce energy consumption.

Ehrhardt-Martinez et al. (2010) also identified that consumers were more receptive to reducing their energy consumption when receiving frequent and disaggregated information, which assists short-term understanding that sustains motivation and commitment to the overall goal.

Hargreaves (2013) found that after the initial study, usage of the direct feedback systems declined after the 'honeymoon period', although awareness of energy consumption was incorporated into everyday life. Participants were also aware if there were any abnormalities or spikes in usage, and were more responsive to excessive or increasing energy expenditures.

The research of Rausser et al. (2018) finds that the benefits of smart meters largely depend on the willingness of the consumer and regardless of the method, it is dependent on their personal commitment.

El-Hawary (2014) found that electronic feedback indicators resulted in environmental and socio-economics benefits to society. The results of a study conducted by Buchanan et al. (2014) found that participants welcomed the idea of instantaneous or rapid feedback on their daily electricity use. However, they cautioned that it should not be assumed that feedback would automatically lead to reductions in energy consumption.

The water sector

The paper *Smart Metering for Urban Water: A Review* (Boyle et al. 2013) highlighted the need for further consideration of the potential of smart metering "to promote individual responsibility [...], access to timely, relevant and comprehendible information that can assist with daily decision-making processes around resource use" (p. 1053).

Giurco et al. (2010) warned that these potential benefits "…are contrasted with the real risk of consumer privacy breaches which requires further input and discussion from all stakeholders [highlighting] the need to include social factors into any technology futures assessment..." (p.466).

Metering, as described in Maggioni (2015), aims to reduce the consumption of urban water in Southern California by 20%, statewide by 2020, through conservation measures. In the *Californian Water Conservation 2010 Report* (Californian and US Government agencies, 2010), the plan's third target is to 'Reduce water waste' while prioritising the accelerated "…installation of water meters" and the establishment of "a state standard for water meter accuracy" (p. xii).

THE STUDY

The research was conducted in Westleigh, a suburb located within the greater Sydney area. Distinctive characteristics of the suburb's profile at the time of the study included: the large number of established families with adolescent, or grown children; the majority of properties were owned, or in the process of being purchased by residents; the ethnic heritage of residents was largely of Anglo-Celtic origins; and those who practiced a religion predominantly followed Christian denominations (ABS 2006, ABS 2006a).

The population density was relatively low due to the medium to large area occupied by each property, mostly comprising of single dwellings and expansive gardens, planted with a mix of exotic and native species. The environment of Westleigh is noted for the surrounding areas of natural bushland, flora and fauna.

At the commencement of this research in July 2008, and for the duration of the pre-study period, Sydney was experiencing drought conditions and Level 3 water restrictions were in place. During the study period, the drought ended, the restrictions were lifted, and water wise rules were introduced [1]. Water wise rules were in place for the whole post-study period.

METHODOLOGY

Summary of initial study (2008 – 2010)

The study was designed as a quantitative and qualitative study that examined the effects of smart metering technology on the water consumption of a participant group compared with that of two control groups, both of which were in different geographical locations within the suburb of Westleigh.

The recruitment process for the participant group involved encouraging one member of each household to complete a household survey. A survey form, together with a letter, was distributed to 468 residents in the study area and to 398 residents in the proposed lower control group in October 2008. The letter introduced the project and advised residents that an automatic meter reading (AMR) unit would be installed on their water meter in early 2009.

The initial phase of project recruitment did not produce the required number of participants. To attract further households a follow-up letter was sent to residents offering a $10 voucher for the local Franklins supermarket as an incentive to participate. This action resulted in the recruitment of a further 190 properties. This process was completed in May 2009 concluding with a total of 381 participant households.

The participant group was provided with an in-home display (IHD) and AMR units on their water meter. One control group had AMR units installed on their water meters and the other control group had no intervention. To assist ease of interpretation in this paper, the two control groups have been grouped together and are referred to as `the control group'.

A unique approach to this study was the inclusion of a whole-of-community engagement method, known as Intergenerational Democracy (Davies 2012). The application of this age-based method involved capturing the views of children to the elderly (12 to 70+ years of age) and their responses to the smart metering technology. The demographic profile of the studies participants was representative of the profiles of the population of the area (see Table 1, Davies et al., 2014).

	Male		Female		Total Persons	
Age (years)	**Study Group**	**Westleigh**	**Study Group**	**Westleigh**	**Study Group**	**Westleigh**
0-11	94 (15.7%)	367 (16.5%)	75 (12.5%)	340 (14.8%)	169 (14.1%)	707 (15.6%)
12-17	53 (8.8%)	212 (9.5%)	57 (9.5%)	220 (9.6%)	110 (9.2%)	432 (9.6%)
18-29	88 (14.7%)	310 (13.9%)	87 (14.5%)	271 (11.8%)	175 (14.6%)	581 (12.8%)
30-49	129 (21.5%)	572 (25.7%)	148 (24.6%)	677 (29.4%)	277 (23.1%)	1,249 (27.6%)
50-69	184 (30.7%)	627 (28.2%)	201 (33.4%)	647 (28.1%)	385 (32.1%)	1,274 (28.2%)
70+	51 (8.5%)	135 (6.1%)	34 (5.6%)	144 (6.3%)	85 (7.1%)	279 (6.2%)
Total	**599 (100.0%)**	**2,223 (100.0%)**	**602 (100.0%)**	**2,299 (100.0%)**	**1,201 (100.0%)**	**4,522 (100.0%)**

Table 1: Age, gender and number of participants from the 381 households provided with an AMR unit compared to Westleigh (SLA) (ABS 2006)

[1] Water Wise Rules are common-sense actions outlining the way water should be used outside the house. They include activities such as watering gardens using either hoses fitted with a trigger nozzle, sprinklers or irrigation systems, before 10am and after 4pm only.

During the study period, households in the participant group were each matched with a similar household in the control group. Participant and control properties were paired according to their recent consumption patterns and were then matched on the area size of the property, the presence or absence of a swimming pool, and the household size (number of occupants) for the 12 months preceding IHD installation. The matching resulted in 109 pairs.

Quantitative methods of initial study

Consumption data was collected from two sources, the existing mechanical or billing meters, and the AMR units. Metered data was removed if the property had been sold, as data relating only to the current occupant was required. During the study, data was collected for 468 properties over 16 months, amounting to 683,280 data records or 9 million data points (Davies et al., 2014).

Qualitative methods of initial study

Three surveys and two face-to-face interviews, designed to recruit participants, capture household demographics and aspects of householders' attitudes towards water conservation and smart metering technology, were collected throughout the duration of the pre-study and study period.

Longitudinal quantitative methods

The study presented an opportunity to examine the impacts of the presence (or absence) of the IHD technology over a period of ten years (June 2008 to July 2018). There have been no interventions with the participant or control groups since the original study concluded in 2010.

To ensure that the behaviour of a consistent set of households was being measured over time, some properties were removed from the study. These had one or more of the following characteristics:

- changed ownership during the post-study period from July 2010 to July 2018
- rented from owners
- identified meter reading errors
- abnormal readings (leakage detected) or zero readings during the post-study period

This reduced the initial 109 pairs (July 2009) of properties to 44 pairs (June 2018), which were analysed to detect changes in household consumption habits.

Longitudinal qualitative methods

A fourth survey was distributed via post to the 44 pairs of properties in October 2018, requesting information regarding household demographics, appliances and fixtures, and water use behaviour. A gift voucher was offered as an incentive in exchange for a completed survey. Participants could return the completed survey via email, online via a Survey Monkey link, or by standard post.

Households were given two and a half weeks to complete and return the survey. After this period, participants were reminded to complete their survey via phone or email. Lastly, the remaining properties that had not returned their survey were door-knocked to collect as many responses as possible.

Limitations

The IHD's were removed from each property upon completion of this first phase of the study. Since this time (2010), the community has not had any further interventions. This has limited the study's capacity to examine the influence of educational and incentive programs, coupled with the technology. Analysis of the economic influences driving behavioural change were not included in the later phase of the study.

The cost of water to consumers in Sydney remains lower than the cost of energy. In Sydney, the average cost of drinking water supply and service for the 2018/19 financial year was $538 (based on average 220 KL water usage) (Sydney Water 2020). Comparatively, in New South Wales, the average market offer of electricity was $1,294 for the same period (based on average 4,215 kWh electricity usage) (Australian Energy Market Commission 2020). Therefore, this variable needs to be considered when comparing studies pertaining to the influence of smart metering technology on consumption behaviour in the energy sector to that in the water sector.

Concern surrounding residents' privacy and this technology was expressed by some members of the participant group in the first 'intervention' phase of this study. However, it was outside the scope of the fourth survey to consider this issue, particularly given the length of time since the intervention.

In the later study phase, the demographics of householders in the remaining household cohort will have changed, such as ageing residents and/or additional, or less, members residing in each household. These changes will have influenced water consumption behaviour positively and negatively. As such, current household demographics were captured during this phase but not applied extensively in the analysis of the data.

RESULTS

Qualitative longitudinal results

The qualitative results for the first phase of this study (2008 -2010) have been previously reported by Davies et al. (2014). A summary of key findings is provided as background information to inform the longitudinal results:

- Before the installation of the IHD, many participants believed that the technology had the capacity to raise awareness and knowledge of their water use.
- The IHD had minimal, if any, influence on households which were actively conserving water prior to the study.
- Lifting restrictions on water use did not have a discernible effect on consumption patterns of the participant group over the period of the study.
- At the end of the study, 62% of survey respondents believed that once the IHD had been removed they would maintain their changes in household water conservation behaviour.

At the time of the initial study, all age groups were represented in the suburb's demographic profile. However, in 2018, the demographic information captured for 59 of the 88 households exhibited a shift in this profile, revealing an ageing demographic which is indicative of the suburb's profile (ABS 2016).

The survey found that 39.5% of the sample population were aged 50-69, whereas only 2.3% were aged under 12 years. The 59 households consisted of 177 people, split into 89 males, 85 females and three people identifying as other. Demographic information was not captured for the 22 properties from the control group and the seven properties from the participant group.

Based on the Australian Bureau of Statistics (ABS), occupancy in these households was calculated to be approximately 87 people, resulting in an overall group of 264 people, comprising the participant and control groups (ABS 2016). A summary of responses from the 2018 survey is outlined below.

There were mixed responses regarding the IHD's role in facilitating long-term water use behavioural change. 43% of participant group survey respondents (n=37) indicated that their involvement in the study was still shaping their water use behaviour in 2018. One person said that it has made his family "very aware of water use, particularly gardens and lawns" (Male, 50-69 years). Another respondent (Male, 50-69 years) highlighted that it had made him look more closely at his quarterly bill to check his usage, with other comments suggesting that it had likely "reminded us/made us more aware of what amounts we were using on a day-to-day basis which tends to make you a bit more careful with water use".

Of this 43%, eight of the 16 households increased their average water use from the pre-study to the post-study period (average increase of 2.61 kL per month), which is likely a result of the increased number of occupants residing in these households, as reported in the survey responses.

Conversely 57% of the participant group survey respondents indicated that their involvement in the study in 2009-2010 was not influencing their water use behaviour in 2018. Many residents said that they have always tried to use water wisely, and their participation in the study did not change this. For example, one resident said, "…prior to the survey we had a water tank and tried to use water wisely and that has continued" (Female, 30-49 years).

Some residents simply forgot about the study. With responses like "cannot remember" (Male, 50-69 years) and "…we had forgotten all about the study" (Female, 50-69 years), too much time may have passed for some residents to still be aware of the possible influence of the study on their water consumption. Another resident shared his negative views on the study and technology noting that his priorities lay in different areas, as "the issue of climate change is more worrying!" (Male, 50-69 years).

One resident suggested that continual use of the IHDs would have helped target water saving potential, "…as we can no longer see water usage data until the bill arrives it is hard to understand where the water usage is to make any adjustments" (Male, 50-69).

The technology was found to have little influence on those households which were actively conserving water prior to the study. When asked to evaluate the impact of the IHD technology on the household's water consumption in 2018, one respondent (Female, 50-69 years) answered "I don't think we have ever been excessive users of water", and another (Male, 50-69 years) said "…I tried to be water conscious [before the study] and that hasn't really changed…".

Quantitative longitudinal results

An examination of the average change in consumption from the pre-study to the post-study period shows that the ***water savings of the participant group was significantly greater than that of the control group*** ($t=2.5279$, $df=43$, $p<0.0076$) (see Table 2).[2]

[2] Further details of the Smart Meter Trial quantitative results have been previously published in Davies et al. 2014.

Paired 44 Households (Data from Sydney Water)				
	Pre-Study Period July 08 - June 09	**Post-Study Period July 10 - June 18**	**Difference**	**Change**
Water Consumption	**Average kL/Month**			**%**
Sydney Water Single Dwelling	17.63	18.42	+0.79	+4.5%
Participant Group	16.23	16.76	+0.53	+3.3%
Control Group	15.8	18.01	+2.21	+14.2%

Table 2: Comparison of water consumption pre- and post-study periods (2008-2018)

The participant household group thus consumed only slightly more water on average during the post-study period (when water wise rules were operational) than during the pre-study period (water restrictions), whereas the control group consumed much more on average over the same period.

Water consumption for the participant and control groups were compared with Sydney's average trends. All three groups followed a reasonably clear cyclical trend, aligned to mean maximum monthly temperature patterns. Rainfall patterns in Sydney over this period were effectively random. Fluctuations in consumption patterns in Figure 1 also represent the three groups' changes in water consumption in response to the introduction of water wise rules which became operational in 2009.

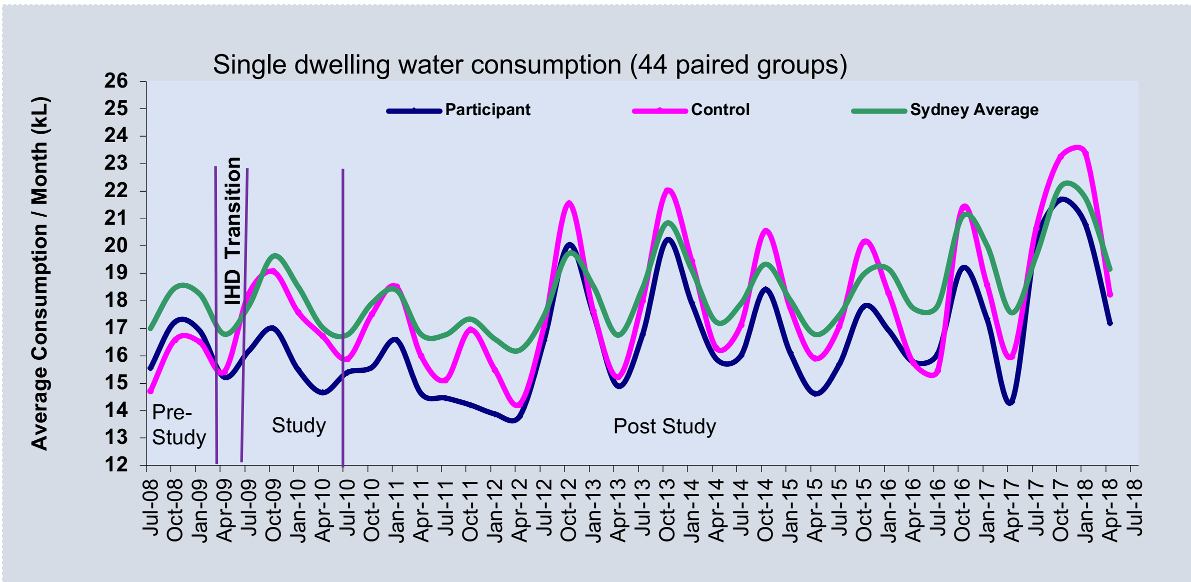

Figure 1. Water consumption trends Jul 2008 - Jun 2018 (Westleigh participant and control group, and average greater Sydney single dwelling)

QUALITATIVE AND QUANTITATIVE LONGITUDINAL ANALYSIS

The results of the 2018 data are in line with the previous medium-term study on both groups dating from June 2008 to September 2013, which found that the participant and control groups consumed 6.4% less water, and 1.3% more water per month respectively, when compared to the pre-study period (Davies et al., 2014). When the quantitative and qualitative longitudinal results are combined, it could be suggested that although residents may not still be consciously influenced by the technology, it probably influenced their awareness and reduced water consumption, which has been sustained over ten years.

When comparing studies focused on the energy sector, smart metering has resulted in savings in the range of 3-19% (Burchell et al. 2016; Berry et al. 2017; Stromback et al. 2011; Ehrardt-Martinez et al. 2010; McKerracher and Torriti 2013). Water savings from the Westleigh study, over a ten-year period, fell within this range. Interestingly, Maggioni (2015) noted the objective of a 20% state-wide reduction in the consumption of urban water by 2020 in Southern California, to be achieved in part by the installation of smart metering technology.

Lifting restrictions on water usage did not have a discernible effect on consumption patterns of the participant group over the period of the study that was large enough to indicate a bounce back to pre-restriction (and pre-millennium drought) levels. This was also consistent with the greater Sydney population. Many of the interviewees had commented that they did not understand why the restrictions had been lifted as the required behaviour had now become a habit.

When surveyed during the initial study period, 62% of respondents believed that once the IHD had been removed, they would maintain the changes they had made to their household water conservation behaviour (Davies et al., 2014). After the IHDs were removed, the average household water consumption of the participant group remained below that of the control group for most months of the post-study period (July 2010-June 2018) (Figure 2), indicating the learning impact of the IHD.

It was found that 45% of households from the participant group, and 37% from the control group, reduced their average water consumption in the post-study period (2010-2018). This finding supports the participant group's predictions that their behavioural change would be sustained over the long-term as a result of participating in this study and the influence of the technology (Davies et al. 2014). Rausser et al. (2018) noted that the success of smart metering is dependent on consumer attitudes.

Conversely, other studies (Buchannan et al., 2015; Vine et al. 2013) concluded that other methods of encouraging energy saving behaviour have a greater impact on consumption than smart metering. Additionally, the literature (Giurco et al. 2010) highlighted customer concern surrounding the technology and potential privacy breaches. These concerns were identified by some participants of the Westleigh study and reported in the previous paper (Davies et al. 2014).

In the Westleigh study, the IHD proved to be an influential tool in reducing water consumption and bringing about long-term behavioural change by providing the householders with real time feedback, knowledge, and a level of awareness of their water consumption.

By providing near real-time water consumption information the participant group could better understand and manage their water consumption. This finding concurred with studies focused on the urban water sector, (Boyle et al. 2013) which found that smart metering promoted individual responsibility by providing access to information that assisted daily decision-making.

In the case of the Westleigh study, given the long-term water savings of the participant group compared to the control group, it was concluded that IHDs provide households with the opportunity to learn new water-saving behaviour. These can quickly become the new 'normal' for the household, being sustained over the long term, as they became embedded in resident's behaviour.

CONCLUSION

The main objective of this study was to understand if smart metering could assist in reducing residential water consumption in the long term. This study has highlighted that the technology (IHDs) was of most value to households with medium to high consumption, having little impact on low consumption households, which includes residents who are already practicing water saving behaviour, and possess a high level of awareness. Therefore, future access to smart metering technology would best benefit households with higher consumption patterns.

This study has found that long term behavioural change can result from a short-term intervention. Thus, utilities and residents wanting to reduce consumption could plan for short-term installations of smart technology, which may benefit the economic viability of future interventions and/or more general adoption of smart technology.

Since completion of the study in 2010, the community has not had any further interventions. This was an important aspect of this study as it aimed to ascertain the influence of the technology. However, it is hypothesised that if there were ongoing education and incentive programs accompanying the technology use, and following the removal of the technology, the water savings of the participant group may have been greater.

Sydney Water is continuing to conduct studies on smart metering using digital meters and exploring opportunities with the Internet of Things (IoT) to realise their vision of becoming a digitally hyper-connected utility. While IoT is still immature, it is a fast-emerging technology which has the potential to transform the water industry through better visibility of the physical environment, enabling improved decision making, automated processes and the ability to provide real-time data for predicting future events. This will lead to enhanced experiences for the customers of Sydney Water, keeping them informed of their consumption, whilst delivering significant operational efficiencies and improved asset performance.

As confidence in technology performance, reliability and benefits increase, the future of IoT, including smart metering technology, will be more readily used and accepted by water utilities and customers across the globe.

As natural resources, such as water, continue to diminish, and urban populations grow, this study has demonstrated the value of smart metering technology. It is a tool with the capacity to change the consumption behaviour of communities, in both the short- and long-term, as we work together to conserve water.

REFERENCES

ABS - see Australian Bureau of Statistics.

Australian Energy Market Commission 2020, *Trends in NSW supply chain components*, https://www.aemc.gov.au/data/price-trends-2019/trends-nsw-supply-chain-components (Accessed 25 March 2020).

Australian Bureau of Statistics 2006, *2006 Census Community Profile Series: Westleigh*, Australian Bureau of Statistics, Canberra, Cat. No. 2001.0 – 2006 Community Profile Series, online. Available: http://www.censusdata.abs.gov.au/ABSNavigation/prenav/ViewData?action=404&documentproductno=SSC12043&documenttype=Details&order=1&tabname=Details&areacode=SSC12043&issue=2006&producttype=Community%20Profiles&&producttype=Community Profiles&javascript=true&textversion=false&navmapdisplayed=true&breadcrumb=LPD&&collection=Census&period=2006&producttype=Community Profiles& (Accessed 9 September 2010).

Australian Bureau of Statistics 2006, *2006 Census of Population and Housing*, Australian Bureau of Statistics, Canberra, Cat. No. 2068.0 – 2006 Census Tables, online. Available: http://www.censusdata.abs.gov.au/ABSNavigation/prenav/ViewData?action=404&documentproductno=RA10&documenttype=Details&order=1&tabname=Details&areacode=RA10&issue=2006&producttype=Census Tables&javascript=true&textversion=false&navmapdisplayed=true&breadcrumb=TLPD&&collection=Census&period=2006&productlabel=Gross Household Income (weekly) by Household Composition&producttype=Census Tables&method=Place of Usual Residence&topic=Income (Personal - Family & Household)& (Accessed 25 October 2010).

Australian Bureau of Statistics 2016, *2016 Census Community Profile Series: Westleigh*, Australian Bureau of Statistics, Canberra, Cat. No. Code SSC 14260 (SSC) 2016 Census Community Profiles, online. Available: https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/communityprofile/SSC14260?opendocument (Accessed 14 January 2019).

Berry, S., Whaley, D., Saman, W. & Davidson, K. 2017, 'Finding faults and influencing consumption: the role of in-home energy feedback displays in managing high-tech homes', *Energy Efficiency*, vol. 10, pp. 787-807.

Boyle, K., Giurco, D., Mukeibir, P., Liu, A., Moy, C., White, S. & Stewart, R. 2013, 'Intelligent Metering for Urban Water: A Review', *Water*, vol. 5, pp. 1052-1081.

Buchanan, K., Russo, R. & Anderson, B. 2015, 'The question of energy reduction: The problem(s) with feedback', *Energy Policy*, vol. 77, pp. 89-96.

Buchannan, K., Russo, R. & Anderson, B. 2014, 'Feeding back about eco-feedback: How do consumers use and respond to energy monitors?', *Energy Policy*, vol.73, pp. 138-146.

Burchell, K., Rettie, R. & Roberts, T. 2016, 'Householder engagement with energy consumption feedback: the role of community action and communications', *Energy Policy*, vol. 88, pp. 178-186.

Californian and US Government agencies, 2010, *20x2020 Water Conservation Plan*,

http://www.swrcb.ca.gov/water_issues/hot_topics/20x2020/docs/20x2020plan.pdf (Accessed 01 July 2018).

Davies, K., 2012, *Intergenerational Democracy: Rethinking Sustainable Development*. Illinois:

Common Ground Publishing.

Davies, K., Doolan,C., van den Honert,R., and Shi,R., 2014, “Water-saving impacts of Smart Meter technology: An empirical 5 year, whole-of-community study in Sydney, Australia”, Water Resour. Res., 50, DOI: 10.1002/2014WR015812.

Ehrhardt-Martinez, K., Donnelly, K. & Laitner, S, 2010, *Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities*, https://www.smartgrid.gov/files/ami_initiatives_aceee.pdf

(Accessed 01 July 2018).

El-Hawary, M. 2014, ‘The Smart Grid – State-of-the-art and Future Trends’, *Electric Power Components and Systems*, vol. 42, pp. 239-250.

Giurco, D., White, S., Stewart, R., 2010, ‘Smart Metering and Water End-Use Data:

Conservation Benefits and Privacy Risks’, Water 2010, 2, 461-467; doi:10.3390/w2030461.

Gölz, S. & Hahnel, U. 2016, ‘What motivates people to use energy feedback systems? A multiple goal approach to predict long-term usage behaviour in daily life’, *Energy Research & Social Science*, vol. 21, pp. 155-166.

Hargreaves, T., Nye, M. & Burgess, J. 2013, ‘Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term’, *Energy Policy*, vol. 52, pp. 126-134.

IPCC see Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change, 2018, *Global Warming of 1.5º C, Summary for Policymakers, Special Report, Intergovernmental Panel on Climate Change* (Accessed 07 July 2019).

Maggioni, E. 2015, ‘Water demand management in times of drought: what matters for water conservation’, *Water Resources Research*, vol. 51, pp. 125-139.

McKerracher, C. & Torriti, J. 2013, ‘Energy consumption feedback in perspective: integrating Australian data to meta-analyses on in-home displays’, *Energy Efficiency*, vol. 6, pp. 387-405.

Rausser, G., Strielkowski, W. & Štreimikinė, D. 2018, ‘Smart meters and household electricity consumption: A case study in Ireland’, *Energy & Environment*, vol.29, pp. 131-146.

Stromback, J., Dromacque, C. & Yassin, M.H. 2011, ‘The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison Short name: Empower Demand’, Vaasa ETT: Helsinki, Finland.

Sydney Water 2020, Customer Metering & Accounts Division, unpublished data.

UN *see* United Nations.

United Nations, 2019, Department of Economic and Social Affairs, *World Population Prospects 2019: Highlights* https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf (Accessed 07 July 2019).

United Nations, 2018, Department of Economic and Social Affairs, *2018 Revision of World Urbanization Prospects* https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html (Accessed 07 July 2019).

United Nations, 2015, Sustainable Development Goals.

https://www.un.org/sustainabledevelopment/sustainable-development-goals/ (Accessed 07 July 2019).

Vine, D., Buys, L. & Morris, P. 2013, ‘The Effectiveness of Energy Feedback for Conservation and Peak Demand: A Literature Review’, *Open Journal of Energy Efficiency*, vol. 2, pp. 7-15.

ACKNOWLEDGEMENT

Thank you to the community of Westleigh for their investment in this research. Data was provided by Sydney Water for this paper.

THE AUTHORS

Kirsten Davies

Kirsten holds a Master's Degree (USyd) ,PhD (USyd) in Sustainable Management and a PhD in Environmental Law (MQU) . She is an academic at Macquarie University's Law School (Sydney Australia). At the centre of her work is the engagement of communities and their connections with nature.

Rose Shi

Rose joined Sydney Water in 2009 as an Analyst. She presented the first Smart Meter paper at the UNESCO conference 'Water, Megacities and Global Change' in Paris, 2015. Previous positions were with the Department of Defence, as Senior Network Engineer at Optus Telecommunications, and as Avionics Engineer in the Aviation Industry.

Alexandra Northam

Alexandra Northam graduated with an Honours degree in Environmental Science from the University of Wollongong. Since joining Sydney Water, Alexandra has worked in Science Research and Innovation, and process optimisation at Cronulla Wastewater Treatment Plant. Her current role is to improve the environmental performance of the organisation.

Corinna Doolan

Corinna has been with Sydney Water for over 30 years', with extensive experience in drinking water quality management, operational strategies and project management, including planning and managing outcome driven research. Corinna's research focussed on smart metering, end use studies, behavioural change, leakage management and intelligent network optimisation.