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Promoting water conservation: where to from here?

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Academic Editor: Magnus Moglia and Stephen Cook
Received: date; Accepted: date; Published: date

Abstract:

This paper reports on a review of international water conservation efforts, but with a particular focus on the Australian context. The aim is to take stock of the current understanding of water conservation, what influences people's decision to conserve water, what influences whether people persist with water conservation behaviour and what contributes to awareness and familiarity of water conservation behaviours. We also explore how all these factors jointly can achieve water savings over time, what has worked in the past. Subsequently, this is used to identify where the current frontier of water conservation is, and we argue that there is a growing potential for changing the public awareness campaigns with more personalised messages; especially if based on smart metering information and behavioural science insights. To support this type of water conservation efforts, we need more longitudinal studies of water conservation behaviour, a greater focus on behavioural science, as well as the development of modelling tools that embed insights and lessons of this research into decision support capability. This is particularly important in the context of staff who are often new in their roles and for whom behavioural science is not very familiar.

Keywords: Water conservation; Sustainable Urban Water Management; Smart metering; Behavioural science

1. Introduction

Over the last decade a number of global regions have experienced severe droughts that have impacted on regional water supply security. Furthermore, it is expected that anthropogenic climate change will increase drought risk in many areas around the world (Diffenbaugh et al., 2015). Water stressed regions have included California in the United States where a severe drought limited the water available to support a large population (Mann and Gleick, 2015). In Cape Town, South Africa an extended drought caused dwindling reservoirs and the possibility of a "day zero" when water supplies run-out for a modern city of 3.7 million people (Wolski, 2018) but whether this is due to drought or mismanagement is still unclear. The water security of cities is often negatively influenced by population growth, competition with other demands (e.g. agriculture and environment), droughts, over extraction, and pollution of fresh water sources (Pahl-Wostl, 2007, Maggioni, 2015, Postel, 2000). Typically, however, it is when a drought strikes that underlying vulnerabilities become apparent, sometimes not allowing planners the time to respond. For example, (Muller, 2018) argued that the water supply crisis in Cape Town was mostly a product of poor management and planning where decisions were made based on political popularity rather than scientific assessment of drought risks. Ziervogel and colleagues (2010) argued that water demand-side interventions, i.e. water conservation, is an essential climate adaptation priority for Cape Town. In particular, water conservation measures are able to be rapidly implemented in response to a drought event, while interventions to augment supply have a much longer lead time to reduce water security stress. With the benefit of hindsight, few would now argue it was not prudent to implement water conservation measures. In Australia, the location of the authors, the Millennium Drought was an extended period (1996-2010) of below average rainfall that meant water storages for Australia's most populous cities reached critically low levels (Low et al., 2015). The response to the drought transformed how cities in Australia both source their water and how they use it (Grant et al., 2013). In fact, due to the length of the drought, many would argue that it changed the culture of water management in the country (Lindsay et al., 2017, Neal et al., 2014).

Generally, the responses to water supply deficits are of three types:

A. Conserve water,
B. Substitute potable water with alternatives sources
C. Augment existing supplies.

Strategy B (substitute supply) and C (augment supply) usually come at considerable costs and require time to implement. Conversely, water conservation efforts support more responsive governance and can be implemented quickly and is not associated with large infrastructure investment costs. Therefore, pressures on water supply security highlight the importance of demand-side measures, where the focus of water services is not only on meeting growing demand through augmentation of supply infrastructure but also on shaping future demand to ensure that water services are reliable, cost-effective and environmentally sustainable (Sharma and Vairavamoorthy, 2009). Reduced water use is also associated with reduced energy use and greenhouse gas emissions (da Costa Silva, 2014, Nair et al., 2014, Novotny, 2011, Siddiqi and De Weck, 2013). Another important advantage of water conservation is that it has the potential to protect environmental water flows, especially at times of drought (Anderson, 2005, Meng et al., 2015) and can, if using stormwater as a supply source, even reduce environmental damage caused by urban runoff (Walsh et al., 2012). As such, water conservation is often considered to be an important tool in the toolbox to support Sustainable Urban Water Management (SUWM) (Marlow et al., 2013, Larsen and Gujer, 1997, Hellström et al., 2000, Wong and Brown, 2009).

This paper provides a review of water conservation experiences over the last couple of decades, with a specific focus on Australia, to identify any key lessons, and subsequently provides a discussion about where the key opportunities are for water conservation going forward. As such, the paper is primarily a review paper, but it is framed around a theoretical understanding of how water conservation is implemented through the practice of promotion, and therefore focusing on the behavioural aspects of water conservation. We do this in recognition that the primary driver for water conservation is the adoption of water-efficient practices by households. In particular, we structure the discussion around how to promote water conservation based on the notion of the 'consumer decision journey' (Court et al., 2009) translated into the context of water conservation behaviour:

- ***Awareness and familiarity***: how can you make people be aware of and familiar with water conservation practices? To what extent does this translate into *consideration* of water conservation behaviours? The consideration here is the active choice whether or not to undertake a particular behaviour.
- ***Adoption***: once water conservation practices are 'on the radar', what makes people consider and adopt them?
- ***Persisting***: once people have adopted water conservation practices, to what extent will they persist with this behaviour?

Finally, with this in mind, we ask: what approaches are available for planners to initiate water conservation behaviour in response to future water security challenges?

2. Awareness and familiarity of water conservation behaviours

There is a reason why many of the water conservation programs are essentially programs to raise awareness, rather than focusing on providing incentives or restrictions. In fact, there is huge potential in voluntary water conservation (Syme et al., 2000). This is because the first step towards a household deciding to conserve water is that they understand the importance of water conservation and that they know what to do in order to reduce water demand. Based on experiences of water conservation awareness media campaigns in Barcelona, March and colleagues (2013) report survey results which indicate that campaigns over several years can achieve a near complete awareness (92% in the case of Barcelona) of the impacts of severe drought and the associated need for water conservation. Furthermore, nearly two thirds of the population reported to have adopted measures to reduce their water consumption, although the majority of actions were behavioural, such as having shorter showers (74%), turning off the tap whilst brushing the teeth (67%) and only using the washing machine when full (49%). They do however note that there are concerns about how the media campaigns were implemented, in the sense that there needs to be a greater focus on how to reduce water demand, and providing targeted information suitable to particular household segments. For example, it was noted there was a need for a greater focus on those households with outdoor water use, and what they could do to reduce water demand. This echoes research from the 1980s that found that whilst the awareness of the need for water conservation could be generated, given underlying circumstances, the increased understanding of specific of water conservation actions is harder to achieve (Syme et al., 2000). The authors also noted that there needs to be a rigorous and numeric approach to the evaluation of the effectiveness of awareness campaigns, an issue that still appears to be largely unaddressed. Particular focus needs to be given to the influence of the credibility of the information source, the narrative style of the message, the information channel, and how the message is targeted to the individual (Syme et al., 2000).

3. Influences on the choice to conserve water

The choice to conserve water depends on contextual factors, the price of water, household characteristics, the level of inconvenience and practicality of practices, as well as the attitudes and social norms of the household (Fielding et al., 2012, Inman and Jeffrey, 2006).

3.1 Contextual factors

There are contextual factors that influence both water demand as well as the potential to conserve water (Gilbertson et al., 2011). For example, in the context of Sydney, it has been shown that changes in temperature, rainfall patterns, and evaporation, has a moderate impact on water demand (Moglia et al., 2009, Campbell et al., 2004). We also know that the urban design, soil and urban greenery has an impact on urban heat as well as on water demand (Cleugh et al., 2005, Connellan and Symes, 2015, Symes and Connellan, 2013). It has also been observed in the Californian context, not surprisingly, that the potential for water savings are greatest during summer months (Mayer et al., 2004)

3.2 Price and restrictions

The elasticity of water demand to the price of water has been the topic of many studies, e.g. Kenney et al (2008); Campbell et al. (2004); Iglesias and Blanco (2008). This is a typical approach by economists and an example of such a study is that by Arbués et al (2003). Arbués and colleagues explored an econometric model derived of the form Qd = f(P,Z), which relates water consumption to some measure of price (P) and other factors (Z) such as income, household type, or household composition. However, there is no general consensus on the methodology to analyse water demand. Variables affecting demand include price, household income, weather, housing characteristics (number of bedrooms and bathrooms, garden size, metering), the frequency of billing and tariff design, indoor versus outdoor use (seasonal demand and peak-load pricing.). Furthermore, water companies and/or governments often put in place water restrictions at times of drought and this fairly heavy-handed approach clearly helps to reduce demand (Kenney et al., 2008, Worthington and Hoffman, 2008). We note, however, that water restrictions tend to come at a cost in terms of externalities put onto the community so this approach should ideally be used sparingly as a last resort (Brennan et al., 2007, Mansur and Olmstead, 2012).

3.3 Household characteristics

Household characteristics influence water demand and the potential for water conservation, such as:

- Higher income is generally found to be associated with a higher water demand (Yu et al., 2015, Fielding et al., 2012).
- Larger household size uses more water and similarly (Fielding et al., 2012).
- An older household tends to use more water (Fielding et al., 2012).

Along these lines, Pullinger and colleagues (2013) explored the influence of demographic factors on water conservation behaviour and their analysis was also performed in part to test the validity of existing standard approaches to modelling overall household water use within the water industry. Current approaches to household segmentation, for example, categorise 'households of water users' based on socio-demographic or other household characteristics. These approaches assume that these household level variables can 'predict' the water using behaviour of particular types of households, as well as other environmental behaviours (e.g., Collier et al., 2010; DEFRA, 2008a; Ipsos Mori, 2007; Waterwise, 2011).

Another important goal of market segmentation is finding out which groups that could best be targeted in order to achieve water savings, and for example Turner et al. (2004) has suggested that one particular group for which it would be useful to promote water conservation within low-income groups because of the high relative savings as well as benefits to these groups. However, it has also been argued that there is 'average water user' because there are so many context-specific factors associated with different sites and different homes (kitchen sink, shower, toilet, outdoor tap, etc.) that vary so greatly that prediction becomes almost impossible (Medd and Shove, 2006). In fact, it has been shown that even with segmentation based on attitudes, values, and socio-geo-demographic variables, current approaches provide relatively poor predictions of individual water use (Waterwise, 2011).

3.4 Inconvenience and impracticality

Dolnicar and Hurlimann (2010) collected empirical data, through a survey study of 1495 people, about Australian attitudes towards water conservation and their water conservation behaviours. This market research provides a knowledge basis for the development of public policy measures and social marketing campaigns aimed at increasing water conservation among Australian residents. The results from this survey indicate that Australians generally had, at the time of the study, very positive attitudes towards water conservation and water saving appliances, however, these positive attitudes did not consistently translate into reported water conservation behaviour. It is therefore believed that important barriers to adoption of water conservation behaviours are the perception of inconvenience and impracticality, as well as costs associated with water saving appliances. Note that costs in this instance is not just the financial cost of the appliance, but it includes the perceived time and effort it takes to acquire the appliance i.e. the opportunity cost of time and the perceived amount of space the appliance will require as well (Tapsuwan et al., 2017).

3.5 Attitudes and social norms

Fielding and colleagues (2012) aimed to identify the key determinants of household water use, with a view to identifying those factors that could be targeted in water demand management campaigns. Objective water use data and surveys were collected from 1008 households in four local government areas of southeast Queensland, Australia. Results showed that demographic, psychosocial, behavioural, and infrastructure variables all have a role to play in determining household water use. Consistent with past research, household occupancy was the most important predictor of water use. Households in regions recently exposed to drought conditions and higher-level restrictions also used less water than those who had less experience with drought. The effect of water efficient technology was mixed: some water efficient appliances were associated with less water use, while others were associated with more water use. Results also demonstrated the importance of considering water use as a collective behaviour that is influenced by household dynamics. Households who reported a stronger culture of water conservation used less water. These findings, along with evidence that good water-saving habits are linked to water conservation, highlight the value of policies that support long-term cultural shifts in the way people think about and use water.

4. Persisting with water conservation behaviours

Ideally, households persist with water conservation behaviours at the end of water conservation campaigns. Indeed in most countries around the world, the per-capita water use is in decline. As an example, per-capita residential water use in Australian cities declined during the drought 5% in Perth, 11% in Sydney, 26% in Melbourne, and 48% in Brisbane over the time period of 2004-2009 (Rutherfurd and Finlayson, 2011). Similar declines during drought have been reported in other jurisdictions (Brelsford and Abbott, 2017, Renwick and Green, 2000, Wolski, 2018). However, this saving occurred during the Millennium Drought, and when the drought broke, this low level of water use did not persist, as shown in the graph in Figure 1 from Melbourne (2000-2016). Notable, however, and this appears to be typical, some of the reductions in water savings have persisted, and some have not. Similar results were observed in California which revealed that in the first year of a campaign to reduce water demand, there was a 19% reduction in residential water demand, but only a 9% reduction after two years (Maddaus, 2001). This indicates that water demand bounced back after the initial efforts. The challenge for water planners is to create water savings that do not bounce back.

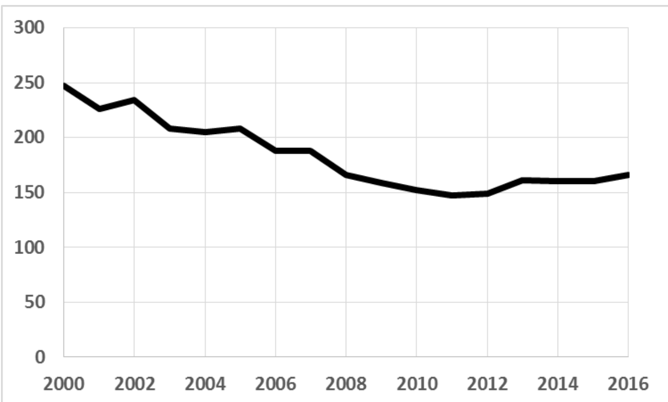

Figure 1: Residential water use in Melbourne, 2000-2016. X-axis: years. Y-axis: Per capita residential water use in litres per person per day. Sourced from Melbourne Water (2016).

So what types of water conservation behaviours are more 'sticky' and which are likely to bounce back over time? There is no extensive studies on this topic, but we may glean some insights from exploring which behaviours have persisted in cities that have been through drought, which have water demand data that includes the period post water conservation efforts. For this purpose, we explore the case of Sydney, as shown in Table **1**. Whilst there is not enough data to draw too many conclusions, we note a few implications of the data:

- There is a close correlation between stated intention in 2005 and the self-reported behaviour in 2017, beyond what we would have expected. We interpret this to mean that stated intentions take time to be realised due to limits on resources - time, effort, knowledge and capacity etc. However, over time, if motivational drivers remain, the stated intentions will largely be translated into behaviour through a process of diffusion.
- We do however also note that two types of behaviour where there appears to have been a bounce-back effect, i.e. only using washing machines when they are full, and turning the tap off whilst brushing teeth. We interpret this to mean that when opting out is easy, and when there is an effort and/or cost involved with persisting with the behaviour, some of the households will opt out over time.
- We also note that the appliance stock has changed significantly over the time period, with front-loading washing machines (often considered a proxy for water-efficient appliances in Australia) increasing their proportion of the stock from 16% to 37%. This uptake of more water efficient appliance stock will definitely lead to reduced water demand

All considered the data in Table **1** is quite consistent with the per-capita water demand over time. The majority of households will persist with most of the behaviours even after motivational drivers are removed, except in some cases when the effort and/or cost triggers householders to opt out of the behaviours. This shows that further longitudinal research is required in order to explore the persistence of water conserving behaviours, as well as changes in appliance stocks, in reducing water demand.

Table 1: Rates of self-reported water conservation behaviours in Sydney 2005 and 2017. First two data columns are from Randolph and Troy (Randolph and Troy, 2008). The last data column is based on a survey of 406 households in Sydney by the authors in 2017.

	Self-reported behaviour 2005	Stated intention 2005	Self-reported behaviour 2017
Use half flush button on the toilet	13%	62%	62%
Use the washing machine only when full	21%	86%	56%
Take shorter showers	29%	58%	57%
Reduce garden watering	13%	44%	50%
Turn the tap off whilst brushing teeth	18%	92%	72%
Front loading washing machine (a proxy for water efficient appliance)	16%	N/A	37%

5. What has worked in the past?

Inman and Jeffrey (2006) provided a review of types of water conservation programs, which is still very much valid, even if water demands may have changed since 2006. They note a range of residential urban water demand in the range of 123 – 503 l/c/d; and then focus on an array of policy instruments by which reduced residential water demand can be achieved noting five categories of interventions: technological, financial, legislative, operation and maintenance, and educational. What we are interested in is, to what extent do the respective programs achieve water savings? This question is explored in Table **2**.

Table 2: Water savings from different types of water conservation programs

Type of program	**The estimated range of savings**
Public awareness / media campaigns (mean=13%, stdev=6%)	
Public awareness campaigns, e.g., media broadcasts (Baumann et al., 1998)	2-5%
Public awareness and media campaign during a drought in Barcelona (March et al., 2013)	21%
Media attention during drought, i.e. ~100 articles bimonthly (Quesnel and Ajami, 2017).	11-18%
Information and media campaign during drought (Tortajada and Joshi, 2013)	11%
Implementation of water use restrictions, and reductions in the household and network leakage in the UK (Ofwat, 2002)	14%
Metering linked with pricing mechanism (mean=28%, stdev=7%)	
Metering residential water use and charging on a per unit basis, excl. limited metering (Inman and Jeffrey, 2006)	10-56%
Metering residential water use and moving from flat rate to volumetric pricing (Tanverakul and Lee, 2015)	15-31%
Smart Metering feedback of information to householders (mean=6%, stdev=2%)	
Real-time feedback on water use, via meters (Petersen et al., 2007)	3%
Smart metering intervention providing detailed feedback on household water use, in the context of Australia (Liu et al., 2016)	8%
Smart metering feedback of information to households (Erickson et al., 2012)	7%
Synthesis of a range of smart metering feedback studies (Liu and Mukheibir, 2018)	6%
Water saving / efficient devices (12-80% depending on type)	
Residential retrofit program in Sydney (Turner et al., 2005)	12%
Adoption of rainwater harvesting, in the context of Australia (Khastagir and Jayasuriya, 2010)	Up to 80%
Retrofitting water efficient devices (Mayer et al., 2004)	50%

Public awareness and media campaigns have been shown to be quite effective, although the exact mechanisms of shifting water use behaviour are largely unexplored. An issue with these public awareness campaigns promoting water conservation practices is that they are often tied to a drought episode, and once that drought threat recedes often the public awareness efforts are also wound back. While public awareness campaigns have been effective in reducing water demand (Nieswiadomy, 1992, Gilbertson et al., 2011), there can be considerable variability. Therefore, it would be worthwhile to explore how the effectiveness can be maximised.

Moving from fixed pricing to volumetric pricing has a very considerable potential for impact in terms of water savings. But this is clearly not an available option for most cities who already have implemented volumetric pricing schedules. Another option may be to introduce more complex tariff structures, based on time of use to reduce peak demand (Cole and Stewart, 2013); or to use increasing block tariffs whereby consumers that use larger volumes pay a higher price per kL (Sibly and Tooth, 2014), although this has been noted as problematic from a fairness perspective.

Promoting water saving devices is another high impact option, but does typically require some rebates or investments in infrastructure (Tapsuwan et al., 2014). For example, rainwater tanks may help reduce water demand by up to 80% but comes at a significant infrastructure investment cost, and also requires ongoing maintenance and operation by households (Moglia et al., 2016a, Moglia et al., 2016b, Moglia et al., 2015). A key benefit of these investments is that to a greater extent, the water demand does not bounce back after a drought.

System-wide adoption of smart metering technology seems to be low-hanging fruit for water planners, where the cost of the metering equipment is to a large extent offset by the average reductions in water use of approximately 6%. The key advantages of smart meters, however, may not be the immediate savings, but the increased understanding of water use (Willis et al., 2013), the potential for leakage management (Britton et al., 2013); as well as the possibility to provide targeted messaging to households (yet to be fully explored).

6. What may work in the future?

Here we draw on previous experiences to discuss the potential to improve water conservation practices into the future, with a focus on personalised messages, smart metering, and nudging; plus what this means in terms of research needs.

6.1 Personalised messages

Already in 2004, Campbell et al. (2004) suggest that 'personalised communication can enhance the water saving potential of implementation and decrease the effect of offsetting behaviour'. This points to the important of targeted communication, which is quite feasible with current information technology and recent potential changes in how customers interact with their water suppliers, such as for example through social media. Personalised messages can either be based on contextual factors (demographics, age, type of dwelling, location, climate zone, etc.), or based on surveys that indicate individual preferences and practical limitations; or indeed based on real-time monitoring of water use through smart meters. There is also the opportunity now to provide individualised practical information to households on what types of water conservation actions that they can carry out.

6.2 Smart metering as a tool

There needs to be further research on testing how to use smart meters as a catalyst for greater water conservation, including through the types of creative uses identified by researchers already:

- Understanding individual end-use profiles, including the potential for water savings in changed behaviour, changed appliances and fixing leaks (Willis et al., 2013). This has the potential to be the basis for individual messages to households, providing advice which is specific to circumstances.

- Using smart meters to enable more nuanced pricing structures, although this has already been explored by various agencies and researchers (Ofwat, 2002, Maddaus, 2001, Worthington and Hoffman, 2008) there is a need for further exploring how price structures, individual commitments to water conservation and information feedback can increase the effectiveness of policies in a fair manner.

6.3 Nudging

The behavioural science perspective is mostly absent in the research papers on water conservation, expect for in a smaller number of papers (Athanasiadis et al., 2005, Fielding et al., 2013, Koutiva and Makropoulos, 2016, Rixon et al., 2007, Fraternali et al., 2015). There is a potential to use behavioural science in the way that Thaler describes (Thaler and Sunstein, 2008, Thaler et al., 2013). For example, by understanding the choice architecture of water conservation we may move our attention to:

- How the decision to conserve water is being presented to community members.
- The cognitive effort of making choices, i.e. make choices easier to understand.
- The consumer funnel, which dictates that you may only make a decision if you are aware of a choice and if you are triggered into action by some event.
- Focusing on defaults, i.e. people are more likely to choose a pre-selected option.
- Understanding the broader set of attributes that people may consider when making a decision to conserve water, especially in relation to factors such as effort and social norms.
- Rebound effects, i.e. what makes people choose to opt-out of water conservation behaviours. In consumer and marketing theory, this loyalty aspect of purchases is critically important, and it should also be important for water conservation theory.

Modelling tools may also provide a better understanding of how all these effects interact to provide desirable outcomes. These tools can help visualise and communicate complex feedback from water conservation interventions in a consistent manner to a broad audience that might have different levels of experience and training backgrounds.

7 Research needs

We note three key areas of research which are not yet well understood:

- There is a need for longitudinal studies of water conservation behaviours in order to better understand the impacts of enablers (such as awareness and motivational drivers) and barriers (effort and costs). Well-designed longitudinal studies will finally allow researchers to distinguish causality from correlation. This also needs to be done with a control sample in order to understand relative savings (Turner et al., 2004) because absolute savings in any one year will not prove useful as they do not account for other contextual factors such as climate or imposed restrictions which can vary significantly.
- The research around how to best promote water conservation is still not well developed including on which communication tools to use, how to frame and target messages, and how

the success is influenced by trust in the information source, etc. These issues and questions were raised already by Syme in 2000 but remain largely unaddressed (Syme et al., 2000).

- To enable the capacity for nudging significant change in water conservation behaviour through identifying strategic interventions and triggers, there is a need to further understanding of how state of the art behavioural science in the planning and evaluation of water conservation programs, along the lines of that by Moglia and colleagues (2018).

8. Conclusions

Decades of research in water conservation has provided us significant insights on the key factors that have an effect on water conservation behaviour. This has helped us to a degree, improve prediction of water conservation behavioural responses to intervention programs, such as water restrictions and price increases. However, we still have a long way to go to accurately predict water use change within the context of water stress events, such as droughts, and individual customer values and motivations. Given the possibility of another drought, coupled with persistently increasing water demand driven by population increase, water decision-makers are still faced with the challenging task of ensuring that demand does not outstrip supply in the future. Supply augmentation is expensive and should only be used as a last resort if per capita demand cannot be further reduced. There is a great need for an accurate and reliable water use model that could help water planners decide on which short and long-term measures to implement to achieve long-term behaviour change. However, there are still many gaps in our understanding of water conservation behaviour, particularly around how we can make water conservation behaviour stick when the threat of water scarcity is no longer preeminent in people's minds. We argue the importance of longitudinal studies, as the key research method to develop further. Only by using longitudinal observations, can we have a clear understanding of key causalities of water conservation behaviour, and test the key influencing factors that will cause water conservation behaviour to persist in the long term. In addition to better modelling, we also advocate the use of new techniques employed in the behavioural sciences to 'nudge' people towards better water use behaviour through strategic, targeted interventions.

Acknowledgements: This research is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative. It is also co-funded by CSIRO and Sydney Water. We acknowledge those in CSIRO, and Sydney Water who have contributed to this research. This includes Stephen White and Luke Reedman of CSIRO, and from Sydney Water: Marcia Dawson, Bronwyn Cameron, Jonathan Dixon and Andre Boerema

Conflicts of Interest: The authors declare no conflict of interest.

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