MONASH University

A STRATEGY FOR A NET ZERO WATER CYCLE

Phase 1: Drivers for energy reduction in the use of water in residential households

Literature and Practice Review

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Drivers for energy reduction in the use of water in households: Literature and practice review

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"The authors have no conflicts to declare."

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INTRODUCTION

The Victorian Government has committed to legislating a long-term target of net-zero greenhouse gas emissions from Victoria by 2050. The State water plan, Water for Victoria, recognises the obligation to achieve net-zero greenhouse gas emissions by 2050. The plan commits the water corporations to (1) being a leader in both climate change mitigation and adaptation, (2) to demonstrate a pathway to net-zero emissions and (3) to pledge an interim emission reduction target to be achieved by 2025, while being cognisant of vulnerable customers.

The four metropolitan water corporations will examine an early path to achieve net-zero emissions by 2030. While the path to net-zero for water corporations is important, their potential influence on the broader water cycle represents an opportunity to go further. Of note, the emissions generated by water corporations' customers represent a significant proportion of energy used in the water cycle. Achieving greater energy savings through influencing customer water use behaviour represents an opportunity to demonstrate leadership and assist the Victorian Government achieve their net-zero ambition.

There are three key areas where water utilities can contribute. These areas align to significant components of greenhouse gas emissions in cities that are directly, or could be, influenced by the management of water system, which are:

1. The use of water in residential households
2. The use of water by business and industry
3. The use of air conditioners in households and businesses

This review is part of a research collaboration between Monash University, the University of Queensland, the Department of Environment, Land, Water and Planning and a number of water and energy retail companies in Melbourne.

To support this collaboration, BehaviourWorks Australia (BWA) undertook an evidence and practice review to identify behaviours and interventions (or programs) that have been targeted to reduce water-related energy and water-related greenhouse gas emissions. The evidence and practice review focus on the behaviours that increase or decrease water-related energy use. This includes daily behaviours, such as showering or washing clothes, and one-off behaviours, such as installing low-flow showerheads.

The rapid evidence review collates the existing literature regarding effective behavioural interventions for household water-related energy conservation, household water conservation, and household energy conservation. The rapid evidence review draws on literature reviews on these topics identified in a systematic literature search. Due to the limited available evidence the literature reviews are complemented with primary research and reports.

The practice review draws on the expertise of specialists in the field of household water and energy reduction to identify existing programs and innovative approaches to reducing water-related energy use, and challenges for implementing water-related energy conservation strategies, that may not be captured by published academic literature.

This report presents findings from the rapid evidence and practice review as a background to the next project phases of the net-zero emissions water cycle research collaboration.

WHAT DOES THE EVIDENCE SAY?

A rapid literature review was undertaken to identify, evaluate and synthesise published literature addressing the following question:

What are the behaviours that have been targeted and interventions that have been used to reduce households' water-related energy consumption?

Rapid reviews are an emerging method of efficiently synthesising evidence in policy where a broad overview of research evidence is required within a short timeframe[1]. Rapid reviews are different to systematic reviews, which aim to identify all primary studies or trials pertaining to a particular intervention and can take from nine months to two years to complete.

Rapid reviews can be completed in a short time frame because they are an "overview of reviews" – that is, they focus on identifying and summarising existing systematic reviews, reports or other consolidated information on a topic. In the absence of available systematic reviews, a rapid review can instead look for high impact, highly cited studies. Finally, rapid reviews can also gather information from the grey literature, such as industry, government reports or websites.

RAPID REVIEW APPROACH

Search terms were identified in collaboration with the project management and stakeholder working group and the key search terms combined '**energy'**, '**water'**, '**intervention'** and '**households'** (refer to **Appendix A** for a detailed description of the search protocol).

Overall, the database search produced **2,618** citations. Following screening, no systematic reviews were identified and **5** narrative reviews with a focus on water and/or energy conservation intervention were eligible for inclusion.

Five reviews:

- Berman, H., Shwom, R., & Cuite, C. (2019). Becoming FEW Conscious: A Conceptual Typology of Household Behavior Change Interventions Targeting the Food-Energy-Water (FEW) Nexus. *Sustainability, 11*(18). doi:10.3390/su11185034
- Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). The Socio-Demographic and Psychological Predictors of Residential Energy Consumption: A Comprehensive Review. *Energies, 8*(1), 573-609.
- Iweka, O., Liu, S., Shukla, A., & Yan, D. (2019). Energy and behaviour at home: A review of intervention methods and practices. *Energy Research & Social Science, 57*, 101238. doi:https://doi.org/10.1016/j.erss.2019.101238
- Jones, R. V., Fuertes, A., & Lomas, K. J. (2015). The socio-economic, dwelling and appliance related factors affecting electricity consumption in domestic buildings. *Renewable and Sustainable Energy Reviews, 43*, 901-917. doi:https://doi.org/10.1016/j.rser.2014.11.084
- Koop, S. H. A., Van Dorssen, A. J., & Brouwer, S. (2019). Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics. Journal of Environmental Management, 247, 867-876. doi:https://doi.org/10.1016/j.jenvman.2019.06.126

The reviews summarised more recent findings on the varied impact of behavioural drivers of water and/or energy consumption as well as the effectiveness of various interventions for reducing water and/or energy consumption.

[1] Khangura, Sara, Kristin Konnyu, Rob Cushman, Jeremy Grimshaw, and David Moher. 2012. "Evidence Summaries: The Evolution of a Rapid Review Approach." *Systematic Reviews* 1 (1): 10. https://doi.org/10.1186/2046-4053-1-10

We conducted quality appraisal of the reviews using the Scale for the Assessment of Narrative Review Articles (SANRA)[2]. According to the SANRA rating, the reviews were of 'high' quality (see **Appendix B**) because they provided sound scientific reasoning for their conclusions. Three of the reviews only provided a limited description of their search strategy or aims, whilst two other reviews were lacking a thorough description of their evidence. Despite this, all of the reviews scored highly in the Quality Appraisal meaning that the results of these reviews are still useful to inform practice.

Whilst rapid reviews typically focus on review papers, we have also included some primary studies and reports. These extra studies and reports were included as there were no reviews that investigated water-related energy behaviour, thus it was necessary to supplement the reviews with more specific studies. In addition to the included reviews a further **10 primary studies** and **2 industry reports** were identified by forward and backward citation screening (i.e., searches in the reference lists) and expert recommendations. The primary studies explored specific gamification and demand shifting interventions for both water and energy and the reports focused on general overviews of behaviour change interventions for water-related energy behaviour (see **Appendix C** for a short overview of the included references).

RESULTS

In this section, we summarise the academic literature on behaviour change solutions to household water-related energy consumption. Whilst there is recognition in the academic literature of the importance of investigating water-related energy consumption, until recently studies have largely focused on water or energy consumption. Thus within this review we will indicate which studies focused on water, energy or both.

Our aim for this review was to identify behaviours that are targeted to reduce water-related energy consumption and interventions that aim to increase the uptake of the target behaviour. In addition, we included factors (behavioural drivers) commonly reported to influence these target behaviours as they provide important information for intervention design. *Table 1* provides a quick reference guide of the included studies.

[2] Baethge, C., Goldbeck-Wood, S., & Mertens, S. (2019). SANRA - A scale for the quality assessment of narrative review articles. *Research Integrity and Peer Review*, *4*, (5).

Table 1. Summary reference guide of included studies and reports

Reference	Topic (Reference Type)	Target Behaviour	Contextual Factors	Socio-demographic Factors	Psycho-social Factors	Interventions
Berman (2019)	Food-Energy-Water nexus (Review)	Energy and water consumption	✓			✓
Frederiks (2015)	Energy (Review)	Energy consumption	✓	✓	✓	
Iweka (2019)	Energy (Review)	Energy consumption				✓
Jones (2015)	Energy (Review)	Energy consumption	✓	✓		
Koop (2019)	Water (Review)	Water conservation				✓
Beal (2013)	Water (Primary Study)	Showering, clothes washing, using taps		✓		✓
Csoknyai (2019)	Energy (Primary Study)	Energy consumption				✓
Currie (2020)	Energy (Primary Study)	Energy consumption				✓
Dieu-Hang (2017)	Energy and water (Primary Study)	Adoption of energy and water efficient technology		✓	✓	
Eon (2018)	Energy and water (Primary Study)	Personal showering, use of ambient cooling and heating, pool pumps				✓
House (2012)	Water (Primary Study)	Water consumption				✓
Laskari (2016)	Energy and water (Primary Study)	Energy consumption				✓
Russell (2019)	Water (Primary Study)	Water conservation		✓	✓	
Willis (2010)	Energy and water (Primary Study)	Showering, clothes washing and using taps				✓
Tiefenbeck (2018)	Water (Primary Study)	Showering				✓
Tiefenbeck (2014)	Energy and water (Report)	Showering		✓	✓	✓
Behavioural Insights Team (2018)	Energy and water (Report)	Energy and water consumption				✓

Behaviours

The majority of the papers included in this review did not target a specific behaviour, rather they focused on decreasing water and/or energy consumption in general. Household consumption can be categorised into two broad types; efficiency and curtailment behaviour. Where efficiency behaviour is a singular action to reduce resource consumption, such as installing an efficient appliance, curtailment behaviours are continuous efforts that lead to behavioural change, such as having shorter showers (Iweka, Liu, Shukla, & Yan, 2019; Koop, Van Dorssen, & Brouwer, 2019). Whilst the reviews offered overviews of energy and/or water efficiency and curtailment behaviours, the primary studies largely investigated explicit curtailment behaviours. In general, these behaviours were those that were classed as discretionary, such as showering, clothes washing, dishwashing, using taps, bathing and adopting efficiency technology. Of these behaviours, showering received the largest focus, appearing in four primary studies. This was followed by three studies investigating clothes washing and using taps in addition to showering. In terms of these behaviours, the literature focuses on curtailment i.e. decreasing the frequency and shortening the length of showers; ensuring that clothes and dish washing occurs when the respective machines are full and on 'eco' settings; and that hand washing of dishes is not performed with a running tap. Finally, only one study explored efficiency behaviour through the adoption of water and energy efficient technology. These technologies include more efficient washing machines and dishwashers or low flow showerheads and taps.

Behavioural factors

Before a behaviour occurs, there is a range of factors mediating whether an individual will engage in a behaviour. Consequently, it is necessary to understand these factors to ensure that interventions have the greatest chance of success. Within the energy and water literature, many factors that influence conservation behaviours have been identified. We characterised these drivers as contextual factors, sociodemographic factors and psychosocial factors. Where contextual and sociodemographic factors have important implications for conservation they are difficult to change in the context of an intervention. Alternatively, psychosocial factors are often the subject of interventions themselves. For example, an intervention may target creating more positive attitudes towards conservation behaviours. In this section, we largely report on review level findings, where pertinent we highlight findings from primary studies.

Contextual factors

Contextual factors refer primarily to the type and size of a building that have important water and energy conservation implications. These factors often determine how much of a resource is consumed as well as the likelihood of decreased consumption in response to an intervention. In general, *bigger dwellings* with more rooms, and total floor area have higher consumption (Frederiks, Stenner, & Hobman, 2015; Jones, Fuertes, & Lomas, 2015). However, these households tend to invest in efficiency technologies more frequently. Moreover, *homeowners* tend to consume more energy and water but are also more likely to invest in efficiency technology (Frederiks et al., 2015). In this regard, homeowners have an advantage compared to renters who are often unable to install efficiency technologies due to prohibitive cost or being unable to modify their properties.

Efficiency technology and infrastructure is an important determinant of household water and energy consumption. Efficiency technologies include those such as insulation, solar panels, energy-efficient appliances and new technologies and are the target of efficiency behaviours (Frederiks et al., 2015). Whilst these technologies can help reduce consumption, how people use these efficiency technologies is still important. For instance, rebound effects, wherein potential savings are undermined by a corresponding increase in water and energy use, frequently occur (Jones et al., 2015). An example of rebounding would be when a household buys an energy and water efficient washing machine; however, they may use it more frequently than their previous less efficient machine resulting in the household using more energy and water in total (Iweka et al., 2019; Jones et al., 2015). Some primary studies

have shown that where households are able to (i.e. can afford to buy and have the right to install new technology), they prefer to install new efficiency technology rather than change their behaviour for energy and water conservation (Currie, 2020; Eon, Liu, Morrison, & Byrne, 2018). Thus, efficiency technology and infrastructure may help reduce consumption, but it is not guaranteed to do so. This highlights the importance of both efficiency and curtailment behaviours.

In regards to energy and water conservation, dwelling and infrastructure factors are often barriers for household decision-making (Berman, Shwom, & Cuite, 2019). This is largely due to these factors operating beyond the context of behaviour and instead influencing households' ability to engage in conservation. For example, it is difficult for households to engage in a behaviour that relies on them buying energy efficiency technology, such as a dishwasher with an 'eco' setting. Thus, often dwelling and infrastructure factors need to be overcome through technological, material or regulatory changes in order to facilitate behaviour change (Berman et al., 2019).

Socio-demographic factors

Of all the factors underlying water and energy consumption behaviour, socio-demographic factors are the most consistently correlated factors with consumption. Unsurprisingly, *households with more residents* use more water and energy. Moreover, *households with children and teenagers* have both higher and more difficult-to-reduce consumption due to the needs, priorities and activities of the household (Frederiks et al., 2015). Whilst a *higher level of education* has been shown to increase the intention to conserve water and energy, this is often not translated into actions for conservation (Beal et al., 2013; Jones et al., 2015). *Household income* has been explored across reviews and primary studies and has been shown to have a differential impact on conservation. Where households with higher incomes are more able to reduce their consumption due to being able to afford the costs of efficiency technologies, they have also been found to be less willing due to being able to afford to pay for their consumption (Currie, 2020; Dieu-Hang, Grafton, Martínez-Espiñeira, & Garcia-Valiñas, 2017; Frederiks et al., 2015). Alternatively, households with lower incomes are often unable to reduce their consumption due to not being able to afford or install efficiency technologies (Beal et al., 2013; Frederiks et al., 2015). Other socio-demographic factors such as *age* and *gender* have not consistently been shown to have a significant impact on conservation.

Psychosocial factors

Many psychosocial factors have been shown to be important drivers of water and energy conservation; however, there is inconsistency in the research. We describe these factors, starting with those that have been most consistently shown to impact on conservation behaviour. *Habits* are described as relatively stable behaviour patterns, which have been reinforced in the past and are executed without deliberate consideration, and result from automatic processes, as opposed to controlled processes like consciously made decisions (Russell & Knoeri, 2019). Understanding habit is particularly important for targeting curtailment behaviours as they are frequently repeated behaviours (Russell & Knoeri, 2019). In general, the aim is often to decrease households' high consumption habits and to ingrain conservation behaviours as a habit. In practice this might look like a household changing from having two long showers a day to only one short shower (Berman et al., 2019). Changes in habits are often used as a measure of whether an intervention has been successful (Dieu-Hang et al., 2017; Iweka et al., 2019). However, changing habits can be seen as inconvenient and a sacrifice of personal comfort (Eon et al., 2018). The need for *personal comfort* has a variable but important impact on conservation behaviour. People use both energy and water to increase their personal comfort, and often are unwilling to decrease their personal comfort (Eon et al., 2018; Frederiks et al., 2015). Indeed, perceived decreases in personal comfort associated with energy or water conservation can reduce the likelihood that a household will engage in those behaviours (Frederiks et al., 2015). This pattern is not found for people who describe themselves as environmentalists; these people will often sacrifice their personal comfort if they perceive the action as having important environmental consequences (Frederiks et al., 2015).

Both social and personal norms have been shown to impact conservation behaviour. Where personal norms are an individual's value system in a given situation that contributes to the extent of moral obligation felt to engage in the behaviour, social norms are made up of the perceived expectations of relevant other people who are important to the person as well as our perceptions of what most people are doing. Personal norms have been shown to impact on the likelihood that households will pursue conservation, whereas social norms directly influence conservation behaviour (Frederiks et al., 2015). Often social norms are used to create competition between neighbours to decrease energy and/or water consumption (Koop et al., 2019). Moreover, households often perceive information from their friends as more trustworthy than that from experts (Frederiks et al., 2015; Koop et al., 2019).

Other psychosocial factors such as knowledge, attitudes, and values have been frequently explored but have had inconsistent results. Where knowledge affects a person's awareness and understanding of energy and water conservation, attitudes are understood as overall measures of the favourability of particular behaviours and values are a global, abstract and relatively enduring set of beliefs, ideals and standards that serve as guiding principles in life (Frederiks et al., 2015). Inconsistent findings relating to these factors are likely due to the intention-action gap where there is a difference between what people say and then what they actually do (Dieu-Hang et al., 2017; Frederiks et al., 2015). Whilst intentions can indicate whether a behaviour will occur they do not always directly translate into that behaviour occurring (Frederiks et al., 2015; Russell & Knoeri, 2019).

Thus, there is a range of factors that can mediate whether a household is likely to engage in water and/or energy conservation behaviours. Understanding these factors is an important first step in building an effective intervention.

Interventions

Throughout the academic literature, many different interventions have been created to decrease water and/or energy consumption. Within this report, the reviews focused on decreasing consumption in general, whereas the primary studies explored specific behaviours such as showering, clothes washing, dishwashing and using taps. Of these behaviours, the majority of studies focused on showering. Only one primary study specifically investigated the adoption of water and energy efficient equipment (Dieu-Hang et al., 2017). In the following section, we described the interventions used to target both general consumption and specific behaviours. We follow the intervention categorisation outlined by Berman et al. (2019) with categories relating to information, tailored information, gamification, action based interventions and pricing. In *Table 2* we present a more in-depth description of interventions as well as a summary of whether the interventions have been shown to be effective. Here effectiveness is described as behaviour change occurring due to the intervention, specific mention is made when behaviour change has been demonstrated to sustain for a period post intervention.

Information

Within information interventions, households often received generalised information, not specific to their own household or resources use, including information about how to engage in a behaviour, information about why they should engage in a behaviour, or visual prompts or nudges to engage in a desired behaviour (Berman et al., 2019). As shown in *Table 2*, these interventions include labelling and performance certificates. Providing information is intended to increase knowledge about the environmental impacts of resource overuse or knowledge about how households can curb usage (Iweka et al., 2019). However, these interventions often result in knowledge or intention to action gap. There is potential that labelling and providing information about conservation may be more effective for water rather than energy interventions but this is inconclusive (Berman et al., 2019; Koop et al., 2019). Recent research suggests that information approaches should be combined with other intervention strategies such as providing tailored information or feedback to affect behaviour change (Berman et al., 2019).

Tailored information

Tailored information interventions consider the specific household or individual by customising or tailoring information. Providing tailored information, helps make the intervention more meaningful and useful as it directly relates to the household (Berman et al., 2019). Within *Table 2*, these interventions include auditing, prompts, norm appeals and feedback. Audits are a particularly useful information-based intervention that are typically well received by households (Eon et al., 2018). Through these audits, households are provided with useful information that identifies the specific water and/or energy improvement opportunities in their own homes. As a result of audit processes some households report that they have the skills in order to engage with conservation (Eon et al., 2018). Enabled by smart technology such as digital monitors that continually observes consumption patterns and reports usage, real-time feedback is also becoming an increasingly popular intervention (Tiefenbeck et al., 2018). However, it is important to note that real-time feedback is only an effective intervention when feedback can be provided as close to the behaviour occurring as possible due to households being able to see the impact their behaviour is having on consumption (Beal et al., 2013). Normative appeals have typically been applied to energy conservation; however, these interventions are starting to be applied to water conservation and are gaining success (The Behavioural Insights Team, 2018). Often these interventions were more successful when households did not have to seek out the information i.e. they were more likely to act on feedback when they were emailed a monthly report rather than if they had to log into a website to check their dashboard (Eon et al., 2018). Moreover, there is evidence that behaviour change resulting from norm appeals is sustained post intervention (Berman et al., 2019; Iweka et al., 2019).

Gamification

Gamification does not have one standard definition within the literature; however, within the context of behaviour change it refers to the incorporation of game based elements into an intervention setting (Berman et al., 2019). Gaming in the sphere of resource consumption research is relatively new and expanding (Berman et al., 2019). These interventions tend to be combined with norm appeals and benchmarking (Iweka et al., 2019; The Behavioural Insights Team, 2018). Occasionally, gamification has been combined with economic incentives; however, this tends not to be an effective approach (Iweka et al., 2019).

Action

Action-based interventions require an individual or household to take part in an activity designed to teach a behaviour, form a habit, reflect on old behaviours, or strategically plan new ones (Berman et al., 2019). Within *Table 2*, these interventions include commitments, goal setting and community-based initiatives. Commitment and goal setting can be supported through providing feedback as this helps households assess whether they are meeting their goals (Iweka et al., 2019). Some studies suggest that private commitments result in greater conservation; however, other interventions using public commitments made either online or in person have also been effective (Iweka et al., 2019; Koop et al., 2019). Providing a supportive social environment through community-based initiatives provides an avenue for households to discuss the pros, cons or barriers to enacting a behaviour, potentially increasing their confidence and capacity to engage in the conservation behaviour (Iweka et al., 2019).

Economic incentives and disincentives

Economic incentives or disincentives motivate people to take actions that they would not have otherwise engaged in (Iweka et al., 2019). Within *Table 2,* these interventions include time-of-use tariffs. Time-of-use tariffs seek curtail demand as well as shift water and energy consumption from times of peak demand, when many people are using water and energy, to off-peak times (Currie, 2020). There is limited evidence for the effectiveness of these interventions. Households which do respond to these interventions tend to be large consumers of water and/or energy as well as wealthier than the average household (Currie, 2020). However, the effects of these interventions tend not to be sustained post intervention (Iweka et al., 2019).

Table 2. Summary of interventions for water and/or energy behaviour

Category	Intervention	Definition (example)	Effectiveness?	References
Information	Labelling	Seals or efficiency ratings usually found on white good and appliances (e.g. stickers on washing machines and dishwashers indicating energy and water efficiency of the appliance).	Limited evidence for effectiveness for behaviour change.	(Dieu-Hang et al., 2017; Iweka et al., 2019)
	Performance certificates	Inform prospective house tenants and owners about the performance level of a particular house and the systems within it; the certificate also offers information on how to enhance the performance of buildings (e.g. ratings provided on rental advertisement websites).	Limited evidence for effectiveness for behaviour change.	(Iweka et al., 2019)
Tailored information	Auditing	Auditing tools can be used to offer consumers in specific locations the details they need to optimize their consumption (e.g. professionals coming to the home and using tools such as infrared imaging to identify opportunities for infrastructure or behavioural efficiency improvements).	Some evidence for effectiveness, particularly when combined with feedback.	(Eon et al., 2018; Iweka et al., 2019)
	Prompts	Prompts remind people about their commitments or drives them towards indulging in a repetitive efficient behaviour (e.g. text messages or emails).	Some evidence for effectiveness, particularly when combined with feedback and goal setting.	(Eon et al., 2018; Iweka et al., 2019)
	Norm appeals	Norm appeals can be presented to users as messages, highly influential persons such as community leaders can also be recruited to promote norm appeals within their communities (e.g. providing a consumption comparison to other similar households).	A large body of evidence demonstrating effectiveness, particularly when combined with commitment and community initiatives.	(Beal et al., 2013; Berman et al., 2019; Iweka et al., 2019; Koop et al., 2019; Russell & Knoeri, 2019; Tiefenbeck et al., 2018, The Behavioural Insights Team, 2018))
	Feedback	Feedback systems provide details that a user can refer to in order to find out about their available consumption information (e.g. digital metering or online dashboards)	A large body of evidence demonstrating effectiveness, particularly when combined with norm appeals	(Beal et al., 2013; Berman et al., 2019; Iweka et al., 2019; Koop et al., 2019; Laskari, Karatasou, & Santamouris, 2016; Tiefenbeck et al., 2018; Willis, Stewart, Panuwatwanich, Jones, & Kyriakides, 2010,

				The Behavioural Insights Team, 2018)
Gamification	Gamification	Gamification provides householders with models, simulations and examples of recommended consumption behaviours with a hope that they will be adopted if meaningful, worthwhile, reasonable and appropriate (e.g. participants receive a deck of action cards, where each card has a specific efficiency action. Participants log their participation in the action on a website, gaining points for each action they participate in).	Some evidence for effectiveness, particularly when combined with norm appeals and feedback.	(Csoknyai, Legardeur, Akle, & Horváth, 2019; Iweka et al., 2019; Koop et al., 2019, The Behavioural Insights Team, 2018)
	Economic incentives and disincentives	Economic incentives and disincentives are used to motivate people to take actions they would not have otherwise engaged in, it can also prompt individuals to carry out such actions frequently (e.g. time of use tariffs charging more for resource use during peak demand).	Limited evidence for effectiveness	(Berman et al., 2019; L. W. House & House, 2012; Iweka et al., 2019; Tiefenbeck et al., 2018)
Action	Commitments	Commitments can be written or verbal, public or private, individual or group and represent being dedicated to a cause or activity (e.g. households or individuals pledging to decrease consumption or engage in a specific behaviour).	Some evidence demonstrating effectiveness	(Berman et al., 2019; Frederiks et al., 2015; Iweka et al., 2019; Koop et al., 2019; Russell & Knoeri, 2019)
	Community-based initiatives	This usually involves a group of people making unified decisions to change certain consumption habits that can lessen the impact of their lifestyle on the environment and optimize consumption (e.g. convening groups of people to come together and discuss their consumption and the actions that may or may not have worked to decrease their consumption)	Some evidence for effectiveness, particularly when combined with feedback.	(Dieu-Hang et al., 2017; Eon et al., 2018; Frederiks et al., 2015; Iweka et al., 2019)
	Goal setting	Households can decide on energy saving goals or reference points they want to achieve and commit themselves to attaining it (e.g. households setting a goal to decrease their consumption by a particular amount).	Some evidence for effectiveness, particularly when combined with feedback.	(Berman et al., 2019; Frederiks et al., 2015; Iweka et al., 2019; Koop et al., 2019; Tiefenbeck et al., 2018)
Economic Incentives and disincentives	Time of use tariffs	Households are charged more for using electricity and water during times of peak demand	Some evidence for effectiveness	(Currie, 2020; Iweka et al., 2019; The Behavioural Insights Team, 2018)

KEY INSIGHTS FROM THE LITERATURE

Whilst the papers included in this review detail a variety of behaviours, behavioural factors and interventions, there are several key conclusions on which the authors agree.

In general, studies aim to decrease water and/or energy consumption, rather than focus on specific behaviours. This may be because many studies tend to investigate multiple behavioural factors and interventions simultaneously. Whilst this approach has led to a breadth of literature being developed, there is some depth missing in terms of a thorough understanding of what works to reduce water-related energy consumption. To this end, the body of research (at both the review and primary study level) still requires some maturing to provide robust and synthesised accounts of behavioural interventions for water-related energy conservation.

In general, the energy literature has a longer and more successful engagement with behaviour change approaches when compared to the water literature. Drawing on the energy literature, the water literature is increasingly engaging with behaviour change approaches. Largely, the water literature has focussed on information-based interventions; however, it is increasingly exploring tailored information and gamification interventions. This new focus is enabled by advances in smart technology and household adoption of this technology.

The studies included in this review suggest an important approach to building an effective intervention to reduce water-related energy consumption. First, the key behaviours need to be identified, this would facilitate a better understanding of which behavioural factors are pertinent and finally interventions that align with the behaviours and factors can be selected.

Before intervention design occurs, researchers and practitioners should ensure they *understand the households' context*. The success of many of the interventions identified in this report is predicated on the context of the household. For instance, a household that rents will not be able to make the same efficiency upgrades as homeowners. Moreover, low income and/ or households with children and teenagers are often unable to respond to behaviour change interventions due to different behavioural patterns. Thus, any intervention targeting these groups should consider context and participatory intervention design techniques to ensure the greatest chance of success.

Many of the authors suggested that *interventions should be combined* to include multiple strategies and target multiple behaviours. A general format was suggested wherein an intervention should start with providing general information and then making that information useful through tailoring it. Finally, households should be provided with a hook to engage in the behaviour, this can be provided through gamification or action-based interventions. Of these interventions, community-based initiatives and norm-based appeals have been shown to be the most effective and sustained.

WHAT CAN WE LEARN FROM THE EXPERIENCES OF EXPERTS?

A practice review consists of structured one-on-one interviews with a small number of people who are actively involved in **running programs to change water-related energy behaviour.** We were particularly interested to find out **what works for whom and what are the barriers to implementation?** Practice reviews can reveal invaluable information on how best-practice recommendations from research have played out in the real world and what barriers to implementation have been faced.

PRACTICE REVIEW APPROACH

An interview guide was developed and revised over several iterations in collaboration with the project management and stakeholder working group (see **Appendix D**). The questions focused broadly on:

- **Existing programs/initiatives** that aim to reduce household water-related energy consumption
- **Innovative approaches** to support households to reduce water-related energy consumption
- Specific **challenges** and **strategies** for engaging target household types (e.g. single parents, low-income, apartment, rental)
- **Logistical and political challenges** for water authorities engaging households on water-related energy consumption.

Interviewees were sourced through a list of contacts provided by the project management and stakeholder working group. We also asked interviewees for recommendations of further contacts. The research team was introduced in most cases by members of the project management group or stakeholder working group.

In total, we completed **28** individual or small group interviews. Interviewees included:

- 12 policymakers (Victorian state government, Israeli government),
- 6 national and international academics,
- 8 national and international water industry representatives and
- 2 Australian energy company representatives.

Each interview lasted between 30-60 minutes, was conducted via videoconference (Zoom) and was recorded provided that permission was granted by the interviewees. Responses were collated and summarised in the report here.

RESULTS

In this section, we summarise the main themes that emerged from the interviews. To illustrate the themes, we often provide direct quotes from interviewees that typify the insights provided. All these quotes have been de-identified (including the removal of details that may link the quote to a specific participant) to ensure confidentiality, as interviewees were asked to provide their own opinions, not necessarily the views of the organisation they represented.

Participant profile

Table 3 provides an anonymised list of interviewees who participated in the project, including their organisations and the focus of their work.

Table 3. Profile of interviewees

PROFILE OF WATER AND ENERGY SECTOR INTERVIEWEES		
Sector	**Organisation**	**Focus Area**
Water	Alliance for Water Efficiency, California	Water efficiency, water and energy nexus
	Alliance for Water Stewardship, Australia	Water stewardship, certification of large corporations, recent foray into certification for households
	Central Highlands Water	Community rebates, holistic assistance for vulnerable households
	City West Water	Water-related technology, including digital metering
	VicWater	Peak body for water industry, recently studied water literacy across Vic
	Yarra Valley Water	Water data analysis
	Yarra Valley Water	Marketing campaigns for water conservation
	Yarra Valley Water	Strategic research- water issues
Energy	Ergon Energy	Energy saving, technical solutions and engaging with communities
	Snowy Hydro/Red Energy	Energy innovation
PROFILE OF POLICYMAKER INTERVIEWEES		
Sector	**Organisation**	**Focus Area**
Water	DELWP	Climate change adaptation and mitigation in water sector
	DELWP	Planning provisions, primarily for stormwater management
	DELWP	Climate change adaptation and mitigation in water sector
	DELWP	Water efficiency, rebates for vulnerable and hardship customers, social housing and individuals
	DELWP	Information sharing between water authorities, including digital metering
	DELWP	Water pricing
	DELWP	Urban water supply.
	Government of Israel	Water reduction, particularly conservation and education
Energy	DELWP	Retrofits, Victorian Energy Upgrades, including hot water system upgrades
	DELWP	Solar hot water
	DELWP	Residential energy efficiency including, low-income households, rental properties
	DELWP	Solar hot water
PROFILE OF ACADEMIC INTERVIEWEES		
Sector	**Organisation**	**Focus Area**
Water and energy	Griffith University, Australia	Climate change and health, with an emphasis on sociotechnical change in water use
	Griffith University, Australia	Transformational water governance
	Lund University, Sweden	Industrial automation, interaction of technology and end users in the water-energy nexus
	Massachusetts Institute of Technology, Harvard, United States	Systems approach to quantifying resource use of water, energy, food and waste
	Public Policy Institute of California, United States	Policy issue research, water environmental engineering, end users of water-energy
	University of Queensland, Australia	Environmental psychology

Defining water-related energy use behaviour

One of the first questions asked of interviewees explored how they defined water-related energy use. The term was not commonly used by participants, but most participants understood household water-related energy use as referring to the emissions caused in order for households to access water. Some participants referenced the energy required to sanitise and pump water, or to treat sewerage. Others noted that heating water is particularly energy intensive and is one of the largest sources of household emissions. Some interviewees in the water sector stated that they never considered the energy impacts of water use, their goal is only to save water. Those in the energy sector felt that householders see water-related energy savings as water savings rather than energy savings. In conversation, most participants referred to "water use", "hot water use" or "the water-energy nexus" rather than water-related energy use.

> *"You have water use embedded in your energy usage and energy use embedded in your water use. They're treated as separate by the utilities but they're really not."*
>
> *"We know that water heating can be 30 or 40 percent of your energy bill. How you're using your water and how you're heating your water are the main consideration."*

Respondents whose work focuses on technology tended to use the term "water-energy nexus". Some noted that the water-energy nexus generally involves trade-offs between saving water and saving energy. In households, this tension is removed because saving water also saves energy, particularly with respect to hot water.

We also asked interviewees to identify the behaviours that are associated with household water-related energy use. These typically fell into two categories: one-off changes to the appliances in a home (i.e., efficiency behaviours), and daily usage of those appliances (i.e., curtailment behaviours). **Showering** was the most commonly cited behaviour, followed by **washing clothes** and **dishwashing**. Use of older-style evaporative coolers and pumps on rainwater tanks were examples given that did not relate to hot water.

Existing initiatives to reduce household water-related energy use

We asked interviewees to identify programs targeting household water-related energy use in Victoria. While Australian interviewees observe that activities to encourage water saving have reduced significantly since the end of the Millennium Drought, international experts continue to name Victoria, or Australia more generally, as a leader in water saving programs. Most of the programs that address household water-related energy use are based on economic or information-based approaches to reducing hot water consumption.

In some cases, the interventions identified in the practice review differ from those identified in the rapid review. While the academic literature focused on the use of financial incentives to influence curtailment behaviours, and found them to be ineffective, the practice review identified financial incentives to encourage retrofitting, and found them to be effective. Information interventions identified in the rapid review were primarily labelling interventions, to highlight the efficiency of appliances or properties. These interventions exist as the Australian Government Water Efficiency Labelling and Standards (WELS) and Energy Rating labels. However, interviewees in the practice review mentioned those schemes as background information only. The focus of information interventions in Victoria is education and social marketing. These campaigns target daily use of appliances rather than their efficiency.

Table 4, below, provides a summary of existing programs, which are then discussed in more detail.

Table 4. Existing programs

Intervention type	Example	Organisation	Results (where available)	Target audience
Economic incentives	Volume pricing	Victorian Government	N/A	Whole population
Retrofit incentives	Showerhead exchange	Various water authorities	N/A	Initially whole population, now whole population within participating water authority catchments.
	Victorian Energy Upgrades	DELWP	4.8 million tonnes of CO2-e abated	Whole population
	Solar Victoria rebates	DELWP	Review currently underway	Whole population (with eligibility criteria)
	Community Rebate Program	DELWP, in conjunction with water authorities	Estimated savings of 330 ML per year, across 13,688 households	Low-income households
	Community Housing Retrofit Program	DELWP, in conjunction with water authorities	Estimated savings of 60 ML per year, across 583 properties	Social housing providers
	Home Energy Assist Retrofit Program	DELWP	319 items retrofitted into 88 homes	Low-income households
Information	Target 155/Target Your Water Use	DELWP, in conjunction with water authorities	N/A	Whole population
	Make Every Drop Count	Water authorities, led by Yarra Valley Water	N/A	Whole population (segmented)
	Smart Water Advice	DELWP, in conjunction with water authorities	N/A	Whole population
	Schools Water Efficiency Program	DELWP	Estimated 8.8GL saved since 2012	Children/families

Economic and retrofit incentives

Economic initiatives include incentives to install efficient appliances and pricing disincentives to high water use.

Current pricing in Victoria combines a fixed charge with **volume pricing** to provide an economic signal to use water efficiently. While interviewees did not discount the importance of volume pricing, they noted that customer demand is not very responsive to price increases, especially because water remains comparatively cheap. Interviewees who work in the water sector noted that energy costs provide a

stronger financial incentive to save water-related energy than the lower cost of water. Quarterly water billing means that there is up to a three-month delay between the times that water is used and paid for.

> *"The volumetric price of water reflects the long run marginal cost of supply so that people have that economic signal to be efficient in the use of their water. Good practice is that you don't make people's water bill all fixed charge… Price elasticity of demand is relatively low. However, if you draw attention to cost savings in conjunction with efficiency messages and programs such as showerhead exchange, you can see a reduction [in water use]."*

Various programs aim to reduce or eliminate the upfront cost of installing efficient appliances to reduce hot water consumption in households. Some water authorities have continued the long running **shower head exchange program** which provides free low-flow showerheads (<9 litres/minute) to owners or renters of residential properties. There may be opportunities to refresh the program with newer low-flow showerheads that use as little as five litres per minute.

The **Victorian Energy Upgrades** program (VEU) is a market-based mechanism, led by DELWP and the Essential Services Commission. VEU provides access to discounted energy efficient appliances, including shower heads and water heaters. Installations of showerheads and water heaters have generated 4.8 million Victorian Energy Efficiency Certificates (VEECs). Each VEEC represents one tonne of Co2-e abated.

Solar Victoria offers rebates for solar hot water or heat pump hot water installations. Fewer households have applied for water heater upgrades than for solar panels. Solar Victoria is a 10-year program in its second year. A review is currently underway that may shed light on the lower uptake of water heating rebates.

DELWP supports various retrofit programs for low-income households. The **Community Rebates** program provides rebates for low income households and are delivered by the water authorities. Rebates cover the cost of fixing leaks, installing low-flow showerheads, flow restrictors or aerators; upgrading toilets and fixing hot water systems. The **Community Housing Retrofit program** provides funding for similar improvements in properties owned by non-profit housing providers. The **Home Energy Assist retrofit program** pilot tested a cost-sharing arrangement between low-income households and DELWP to retrofit energy efficiency improvements, including efficient hot water systems. Home Energy Assist built on the findings of the Low Income Energy Efficiency Program (LIEEP[3]) that highlighted the importance of using trusted channels and existing relationships to engage low income households in water and energy efficiency. DELWP contracted Brotherhood of St Laurence to recruit households and deliver Home Energy Assist retrofits using their existing relationships with low-income households and other service providers. A difficulty for retrofit programs such as Home Energy Assist is the trade-off between breadth and depth, the number of households that can be included is in competition with the benefits that can be delivered to each household.

Information: Communications and education initiatives

Communications and education initiatives are generally websites, mass media campaigns, or classroom education. Most communications and education initiatives in Victoria are provided under the umbrella programs of **Target 155** and **Target Your Water Use**, centralised branding that allows DELWP to ensure consistency of water-saving messaging across the state, while enabling water authorities to develop messages that are relevant for households in their region. Target 155 is the umbrella campaign for Metropolitan Melbourne. Target Your Water Use is the equivalent program for regional Victoria because water use varies too much between different regions to have one target for all regional households.

Target 155 is an ongoing program that was developed to capitalise on the fact that, when water restrictions were brought in during the Millennium Drought, households reduced water use beyond what

[3] LIEEP was a federally funded program that allowed 20 organisations/partnerships to deliver energy efficiency projects to low income households across Australia.

was required by those restrictions. By providing tips for saving water such as having shorter showers, turning the tap off while brushing teeth, using half flush toilets or trigger nozzles on garden hoses, Target 155 encourages people to limit total use to 155 litres per person per day. The program also encourages people to use their water bills to learn how much water they consume. Information is delivered via an advertising campaign with supporting materials online.

Make Every Drop Count, led by Yarra Valley Water, is the most recent water-saving communications campaign under the Target 155 branding. Make Every Drop Count is designed to encourage collectivism and the cumulative effects of simple changes: if we all save a little, we save a lot. While Make Every Drop Count provides a range of tips for saving water, the priority behaviour to encourage is shorter showers.

> *"Our research has shown that where the greatest litres are to save are in the shower, which has the most discretionary use. We know that people have an emotional connection to the shower; a lot of people just love showering, so there's a fine line you've got to strike there in terms of trying to get people to get out. We typically have taken a gentle approach, saying, "Just take minute off your shower," rather than punitive. So even if you're taking a 20-minute shower, if you can drop it down to 19, we're saying job done."*

Smart Water Advice is a website (smartwatermark.org/Victoria/) with water saving advice for households and businesses. Smart Water Advice is shared by DELWP and all Victorian water authorities. Some water authorities link to Smart Water Advice, others adapt and add to that information as needed. Most water conservation education delivered is connected to the Target 155/Target Your Water Use campaigns and the permanent water saving rules. The permanent water saving rules relate only to outdoor use and have minimal impact on water-related energy use.

The **Schools Water Efficiency Program** works with 1240 Victorian schools. While the emphasis of the schools program is water saving in the school, it also provides water saving information for kids to take home. Water education is also included in the curriculum of some schools through the Resource Smart Schools and Water Learn It, Live It programs.

Key findings about existing programs to reduce household water-related energy use

- Activities to reduce household water-related energy use most commonly involve reducing hot water use by installing efficient appliances, or encouraging shorter showers.
- Economic incentive programs focus on reducing the upfront cost of installing retrofits, particularly for vulnerable households. In contrast, communications and education campaigns have a whole of population focus, and are generally mass media campaigns that deliver a range of water-saving tips.
- Water-related energy reduction is generally delivered as a water-saving message rather than an energy-saving message. Collectivism is emphasised to highlight the importance of individual actions.

Innovative approaches to reducing water-related energy use

We asked interviewees to identify innovative approaches and best-practice water-related energy use programs, anywhere in the world. Interviewees noted the difficulty in measuring the reach and effectiveness of behavioural programs, and that there are few rigorous evaluations available to draw on. Data-driven electricity reduction programs were highlighted because water authorities may be able to take a similar approach once digital metering becomes widespread, making granular water data available. *Table 5* summarises the innovative and evidence-based approaches identified by interviewees, including examples. Each approach is then discussed in more detail.

Table 5. Innovative approaches

Intervention type	Example	Organisation	Results (where available)	Target audience
Economic incentives	Durban	Local government areas, such as eThekwini Municipality, in Durban, South Africa	N/A	Whole population (aims to influence high consumers without penalising low-income households)
Tailored information and norm appeals	Digital metering trial	City West Water, Victoria, Australia	3 million litres saved (by early leak detection)	Whole population in trial zones (Richmond and Docklands)
	OPower	OPower, United States	2% average reduction in energy use	Whole population
	Water stewardship homes	Water Stewardship Alliance, Australia	N/A	Whole population
Gamification and time of use incentives	Ohm	Ohm (energy gamification company), United States, Singapore	Reduced energy load by over 100 Megawatts at a single point in peak time	Whole population
	Climate Clubs	Institute for Sustainable Futures, Sydney, Australia	5-15% reduction in energy use	Families
	Coachella	Coachella Valley Water District, California Energy Commission, United States	14% increased shift to off-peak use, compared with control group	Whole population
Comprehensive package of interventions	Israeli water conservation program	Government of Israel	N/A	Whole population (segmented)
	Power Savvy	Ergon Energy, Queensland, Australia	5% reduction in energy use	Remote communities, generally vulnerable households, many indigenous households

Economic incentives

Tiered pricing was proposed as an alternative price signal to encourage reduced water use. California and Durban were nominated as examples of international best practice in water pricing. In California, tiered pricing is coupled with **dynamic pricing**, also known as **drought pricing**. Price increases are triggered when water reserves available to the water authority fall below a certain level (Mitchell, 2017). In parts of China and Africa, extreme tiered pricing means that water consumed once households pass the highest threshold is charged at more than double the price of water below the lowest threshold. In Durban, for residents of low-cost housing, water is free until the first threshold is reached (eThekwini Municipality).

Some interviewees felt that water is too cheap to influence household behaviour using standard volume pricing. Other interviewees noted that there is not much evidence that water use is price sensitive, and that pricing disincentives to water use can disadvantage low-income households.

> *"Is there any product that would be delivered into your home at lower cost than water?"*
>
> *"There's not much evidence that people are responsive to changes in the price of water. And, the burden is felt by vulnerable households."*

Tailored information and norm appeals

Various water authorities around Australia are conducting trials using in-home **digital water metering**. Digital meters provide immediate feedback, for example daily water usage or in-home displays of real-time water usage, rather than the traditional meters that are only read to calculate water bills.

Many interviewees who did not work directly with digital metering expect that the **immediate feedback** offered by digital meters will result in a sharp decrease in water use. However, those working directly on digital metering pilots expect only modest behaviour change to result from immediate feedback, under three per cent, based on results from previous pilot projects. Some digital metering programs do not invest in portals to provide immediate feedback about consumption but only contact customers to alert them to leaks, which saves large volumes of water. For example, the City West Water pilot project found leaks in five per cent of participating properties.

> *"The hypothesis is that by giving people access to their data, they will be more aware and more conscious of their water use and therefore likely to reduce how much they consume…I've got a strong feeling that the leak alert will provide most of the savings and the portal will be a minor benefit."*

The more invasive prompts used for **in-home portals**, for example beeping to alert householders to their water or energy use, are more effective but also more annoying. It is not yet clear how to balance these aspects.

> *"A lot of thought is going into how to notify the customer. How often do they want that information, is it a leak alert or is it for them to go into the app themselves? Getting the balance right is important to keep the customer informed but not pestering them because customers do like to set and forget."*
>
> *"People habituate to these feedback mechanisms so they lose effectiveness, and people can be really annoyed by them as well…people said to me "that thing annoyed me. I just shut it down and put it in the draw."*

The superior data produced by digital metering provides an opportunity to engage householders using portals that provide water and energy information or prompts, mobile phone apps, or gamification (more information on gamification is included below).

On-bill comparisons with neighbours' water and energy use are popular in the United States. The most high-profile example of this approach to creating positive **social norms** is O-Power. The O-Power program reduced energy consumption by two percent by comparing householders' energy use with their neighbours (Allcott, 2009).

A pilot project by the Alliance for Water Stewardship Australia aims to create positive social norms by **labelling homes** that demonstrate strong water stewardship (Water Stewardship Alliance, 2020). Householders complete a survey that tests their knowledge about water, water-use behaviours, and efficiency of appliances. The Alliance's aim is to create a letterbox sticker for households to promote their water stewardship to neighbours.

Gamification and time of use incentives

Gamification is the application of game mechanics to serious issues. The introduction of digital metering should provide sufficient data to introduce gamification of hot water use. Gamification has been a popular approach in the energy sector. Gamification encourages individuals or communities, often school communities, to competitively reduce their energy or water consumption. The global leader in gamification of energy is Ohm, a specialist company that provides **energy gamification** services in North America and Singapore and has recently partnered with Origin Energy in Australia. Ohm incentivises individual households to reduce energy use at peak times that would otherwise be powered by coal (Ohm Connect).

A pilot project in Sydney worked created a **schools competition** across three different local government areas. Households that signed up had their energy use monitored. Scoring was judged by the change in household energy compared to the average use for the previous three years. In order to build positive social norms around energy use, the program used professional rugby players, local newspaper articles, in-school activities, prompts for whole families to examine their energy use, and parent champions within each school. Reduction in energy use across the three local government areas varied from approximately five to 15 percent.

If the goal is to move to a renewables-powered grid, ***when* power is used** can be as important as *how much* power is used. Hot water use is generally diurnal (morning and evening) whereas solar power is plentiful in the middle of the day. Most water heaters in Metropolitan Melbourne are currently fuelled by gas. Interviewees noted that if there is an electrification of water heating in Victoria then moving water-related energy use to the middle of the day could emerge as a behavioural goal. This may include programming storage hot water systems to heat up in the middle of the day, or washing clothes or dishes during the day.

The energy sector is addressing **time of use** by providing **incentives** for customers to reduce energy use during peak times (Powershop) or to allow remote control of appliances, particularly air conditioning. Energy customers have proven resistant to remote control, even when offered significant financial incentives and no loss of amenity. Energy providers are attempting to redesign or reframe time of use solutions as **solutions to lifestyle problems** rather than energy problems. For example, programming air conditioning to a preferred temperature before householders arrive home rather than programming air conditioning to cycle on and off to save power.

The Coachella Valley Water District in California trialled **incentives for households to move water-related energy use to off-peak times**. A one-off payment and request to use water outside of peak times resulted in a significant shift to off-peak usage (20.1% total water used during peak times for the intervention group, compared with 34% for control group). The shift to off-peak was maintained for at least the four month study period (House).

Comprehensive package of interventions

Some interviewees noted that no single intervention is effective for all households, a suite of interventions delivered together is considered the best-practice approach to delivering water-related energy use reduction programs. Israel has an **ongoing, coordinated water conservation program** that combines awareness raising and specific behavioural interventions. The program includes mass media, social media, education in schools and early learning centres, and embedding water-saving behaviours in children's television programs. The program promotes positive social norms by targeting all members of the household at the same time, and providing education about how to speak to other people about saving water.

For every iteration of the campaign, surveys are undertaken before, during and after implementation to check resonance with different language, religious, age, and education groups and campaigns are amended as needed. For example, the Israel is Drying Up campaign was effective in engaging householders who identified as environmentally friendly. In order to influence non-green households, messaging was added highlighting that everybody's actions combine to create large savings. Program

evaluation reports and materials are in Hebrew so we are unable to report specific water-saving outcomes.

> *"We have different campaigns for different age, religion, culture. As much as you can differentiate, that is the best…If one member of the family is doing the wrong thing, the others will tell them about that every time…All of us are part of a community and nobody wants to be an outsider."*

Ergon Energy's **Power Savvy program** for remote communities combined behaviour, small technology (such as showerheads), and audits of water infrastructure. Behavioural interventions included classroom education and respected community advisors, who would work one on one with each household in their community. Visits from respected community champions resulted in approximately 5% reduction in water use from behavioural changes. Behaviour change reduced after approximately 12 month unless advisors re-visited each home.

Co-design of programs with communities

Two interviewees highlighted the importance of co-designing programs with communities, particularly vulnerable communities where appliances may not be installed or in good working order. Co-design can ensure that programs and messaging are appropriate for target communities.

> *"It should be the default to work with communities around demand management strategies, not just tell them what's going to work."*
>
> *"The most obvious thing, which I think in my experience with programs all over the place and particularly ones run by government is that it's designed before the community is involved. And I think that's the completely wrong way to do it because you need to get community members involved to tell you what their stories are and what they want to hear, what they want to know. Otherwise you may just be going off on a divergent track from the very beginning and you don't even realise and then you have to adjust later on."*

Key findings about innovative approaches to reduce household water-related energy use

- Digital metering as a standalone tool is likely to produce small changes in water-related energy behaviour. However, the data generated by digital meters allows for gamification of water use, gamification was previously only possible for electricity use. Competition pairs gamification and social norms by tracking household or community data and comparing it with other households or communities.
- While digital metering and the potential to use digital meter data to create data-driven behavioural approaches such as gamification were the most commonly cited innovation, other interviewees highlighted innovative approaches to water pricing, the importance of working with communities to develop relevant programs, or bundling different approaches into a cohesive strategy.

Engaging different types of households

We asked interviewees to identify programs that target specific populations, as well as challenges and effective strategies for engaging those populations. Many interviewees highlighted the importance of engaging different households differently depending on variables such as household size, language, religion and location. However, this segmentation approach is relatively new for water-conservation programs in Australia and few interviewees were able to provide examples of targeted programs.

Segmentation

Make Every Drop Count draws on customer segmentation in order to target advertising messages to those households that have the highest discretionary water use and that are most amenable to reducing that water use. Age was identified as the key demographic; those under 35 were identified as having the highest water use that could easily be reduced.

> *"Our research which shows that the people who have the most litres to give are those under the age of 35, they were children during the Millennium Drought and so they didn't have quite the same experience as those paying bills and running households."*
>
> *"The most efficient group, probably slightly over indexes to women over the age of 65 who are of above average income, and the second most efficient group are those who are the same age group but below average income. So it's age, not income, that, in our case, has dictated experience and attitudes."*

The target of 155 litres per person per day is not appropriate for the under 35 demographic because they are more likely to live in small properties and therefore do not have the high water use associated with gardens. The Make Every Drop Count messaging is more appropriate for young households. Under 35s were too young to take on water-saving information during the Millennium Drought and therefore need to be taught why water-saving is important and that they have a role in collective action to save water. Some examples of Make Every Drop Count messaging that draw on collectivism and the importance of water saving are:

> *"Can you save seven litres of water a day? If we each save a little, we all save a lot. Melbourne needs you. Everything that makes Melbourne great, from the hallowed turf of the MCG to our world famous coffee, depends on a healthy, reliable water supply."(Make Every Drop Count)*

When customers were segmented according to their key motivators for reducing water use, environmental messaging motivated the largest group. A smaller number are motivated by cost savings, an even smaller number are primarily concerned with time or convenience. A small group of customers spread across all demographic groups are apathetic and resistant to water conservation messages.

Segmentation has been more widely used in energy conservation than in water conservation programs. Two examples of energy consumer segmentation approaches are included in *Table 6*.

Table 6. Energy consumer segmentation projects

Program	Delivery Agency	Segment delineation
Low Income Energy Efficiency Program (LIEEP) funded 20 organisations/partnerships to deliver energy efficiency projects to low income households.	Researchers from the Group of Energy Efficiency Researchers (GEER) Australia network analysed the findings of all LIEEP projects to identify segments within low income households. The resultant segments inform the Power Shift strategy now used by Energy Consumers Australia.	Segments are defined by energy-related attitudes and behaviours: New to energy, Energy without Effort, Stressed about energy (Russell-Bennett et al., 2017).
City Smart household segmentation	Queensland University of Technology, University of the Sunshine Coast	Segments based on household goals for energy use. Each segment is allocated an animal mascot (Russell-Bennett, 2017).

Other targeted programs

In addition to segmentation strategies, some policies and programs target specific populations.

For **vulnerable households,** trusted sources of information are essential. For some groups, such as survivors of family violence or widows whose husbands took care of home maintenance, there are challenges with allowing (usually male) tradespeople into the home to install or maintain appliances. Water authorities are a trusted source to introduce tradespeople into the home. Trust building is most effective with face to face communications, which also encourages word of mouth referrals to those households who are most in need. Water-saving training sessions at senior citizens groups, men's

sheds, and other clubs are a more effective recruitment tool for vulnerable households than traditional recruitment methods such as mailouts. Central Highlands Water (Victoria) have used this approach so successfully that they no longer employ other recruitment methods to the Community Rebate Program. Trust is further built by taking a holistic approach to improving water efficiency and quality of life for householders.

> *"Word of mouth was the best way. They'd refer neighbours, family members or friends. We couldn't run more than two [training sessions] a month because of the amount of work that came in to the plumbing programs… When we send a plumber out, they know that it's a recommended person, they feel safe. They have that link then, they don't need to be reliant on us, they trust that person... Removing the stress of needing to get things fixed and not being able to afford it. The health benefits of removing mould. What comes out of this is holistic wellbeing."*

Renters do not have the authority to install efficient appliances into their homes. Central Highlands Water (Victoria) provide additional assistance to renters to negotiate landlords' approval for water-efficient retrofits. DELWP are working to ease energy efficiency retrofit approvals at the policy level. Amendments to the Residential Tenancies Act will allow renters to make modifications without approval from their landlords, and will require landlords to install some energy efficient appliances, these changes have been delayed due to Covid-19 and are now scheduled for 2021. Some interviewees commented that this could provide an opportunity to engage the real estate industry to encourage other upgrades such as low-flow showerheads.

Key findings about targeting programs to specific populations

- Segmentation of advertising campaigns has been used to target messages to populations with the highest average discretionary water consumption, particularly under-35s. Vulnerable households, such as those with low-incomes, English as a second language, or single parent households, do not have high average discretionary water consumption and are not targeted by mass media campaigns.
- DELWP and water authorities target low-income households to provide financial and practical assistance for water-efficient retrofitting. Trust is important for many vulnerable households. Water authorities can build trust by using face to face engagement when possible.

Enablers and constraints for water retailers to support households to reduce water-related energy use

We asked interviewees to reflect on the positioning of water authorities to support households in water-related energy use. Where needed, interviewees were prompted to think about regulatory and policy context, water and energy targets, connections to community, and community attitudes and behaviours.

Enablers were:

Trust

Compared with energy companies, water authorities are well trusted by their customers. This can make program implementation easier. For example, opting-out of digital water metering trials has been negligible. The Central Highlands Water Authority approach to recruiting vulnerable households is an example of a program that both uses and builds the trusted status of the water authority.

Water and energy literacy and awareness

Some interviewees noted that water literacy is high in Australia compared with countries that do not have a history of water shortages, and that households engage with water saving more than energy saving, and certainly more than water-related energy saving. Others felt that water-saving behaviour would increase if water literacy could be improved.

Both water and renewable energy are more plentiful at some times than others. Interviewees from both water and energy sectors noted the difficulty in maintaining consistent messaging when the ideal

outcome for water authorities and energy companies would be for customers to increase and decrease their consumption in line with availability.

> *"Financial savings for households are often small so environmental awareness is the primary driver for saving water and energy. But, awareness can be both an enabler and a constraint."*

Partnerships

Some interviewees noted that the most effective programs are possible when water authorities partner with other organisations such as energy companies, non-government organisations or government departments.

> *"The cross agency collaboration was really important too… it's really important to engage and get other people's perspective and drivers and needs so that you are on a common goal or you can adjust your goal where possible to accommodate the needs of others... If you bundle it all together, you can have those synergies and access a bigger pool of funding."*

While saving water-related energy has benefits for health and emissions reductions, people working in the water sector report that it can be difficult to establish partnerships with people working in those areas. Water authorities are often unable to offer retrofits to vulnerable households who are in public housing because the responsibility for public housing lies with the Department of Health and Human Services (DHHS).

Constraints were:

Funding

Many interviewees, both in Australia and overseas, noted the inherent tension in water authorities working to reduce water consumption, given that water is the product that they sell. However, some Australian water authority staff felt that the long-term imperative to avert future water shortages overcomes this tension. Others noted that there is no financial incentive for water authorities to deliver conservation programs and that this could be overcome with the introduction of a payment, or a reduction in the environmental levy that water authorities pay, for water saved. Similarly, energy companies have no incentives to assist their customers to save energy, with the exception of energy consumed at peak times when wholesale energy prices are higher than retail energy prices. It is also difficult to quantify water authorities' impact on household water-related energy consumption and therefore to incentivise this work.

Both energy and water have been politicised in Australia and funding increases and decreases depending on who is in government. In the water sector, many programs were abolished at the end of the Millennium Drought and there has been a loss of specialised staff and corporate knowledge of water conservation strategies.

Approaches such as face to face engagement, and delivering targeted programs to specific groups are resource intensive. Lack of long-term funding also appears to contribute to the shortage of rigorous program evaluations.

> *"In the cycles of state or federal government resourcing, water efficiency programs get a lot more funding when there's no water around. It's not driven by the energy side of things, we work in quite siloed perspectives so we focus on it when there's a need because there's no water."*
>
> *"The evidence base for behaviour change takes longer to develop than a three year political cycle, or three year ARC [Australian Research Council] Linkage grant."*

Cultural expectations of hot water availability

Culturally, Australians have high expectations of amenity from hot water. This can lead to a low appetite for experimenting with hot water-saving technologies.

> *"It is hard to find early adopters for hot water technologies. Culturally, we have a high expectation of hot water being available when you step into the shower. People don't want to experiment because there is no tolerance for malfunction."*

Key findings about enablers and constraints for water authorities engaging households on water-related energy use

- Water authorities in Victoria are well positioned to support households to reduce water-related energy use. Water authorities are well trusted by householders and Victorian households, particularly those who remember the Millennium Drought, have a high level of water literacy.
- The most frequently identified constraint on water authorities' (and other organisations) ability to support households to reduce water-related energy use is the lack of ongoing funding dedicated to water conservation. Reliable, long-term, funding is required to establish data about effective strategies for changing household behaviour and to create a workforce of specialised practitioners to deliver household programs.

Advice for the development of the Net Zero Strategy

Finally, we asked interviewees for any additional advice to guide the development of the household behaviour element of the Net Zero Strategy. The most commonly issued advice was to commit to programs for the long-term, including ongoing evaluation. Provide different messaging in times when water is plentiful but maintain the campaign. Other advice included:

- Financial drivers are small for household water-saving programs, therefore focus on awareness. Emphasising energy costs may provide a more compelling financial driver than water costs.
- Encourage positive social norms around water-related energy use.
- Consider whether net zero is the best goal. Some environmental groups, such as WWF, are against the use of net zero because it has been associated with greenwashing.
- To maximise emissions reductions, consider ways to share the strategy with regional water authorities who are generally less well funded and less progressed in reducing water-related energy use.
- Partner with other organisations such as NGOs or local councils to maximise credibility and learning from previous programs.
- Collect good data. Pilot test interventions with large numbers of households.
- Apartment buildings may provide space for experimenting with new technology. In apartments, it may be possible to create backup systems to overcome the concern that energy efficient technology may not meet householders' high expectations of hot water on demand. In buildings where building owners provide hot water to all households, often with power generated on-site, there is a strong financial incentive for building owners to invest in energy-saving improvements.

CONCLUSIONS

The key focus of this review was to identify behaviours and behavioural interventions for reducing household water-related energy use. There is minimal research that specifically examines water-related energy behaviour so this report also draws on evidence from behavioural interventions that aim to reduce consumption of energy *or* water. In the academic literature, the most frequently targeted water-related energy behaviours are showering, clothes washing and dishwashing. These behaviours are also emphasised in existing water-saving campaigns in Victoria. Water-related energy use is also addressed through a range of retrofit programs that increase installations of efficient appliances, particularly hot water systems and low-flow showerheads.

The academic literature is not sufficiently advanced to make firm recommendations about effective interventions. Similarly, practitioners stated that there are few available examples of program evaluations that measure behaviour change, particularly long-term behaviour change. However, some broad approaches were consistently identified in both the rapid review and the practice review as being the best-practice approach to reducing household water-related energy use. These include: using social norms, providing individual feedback about water and energy use, targeting programs to specific populations, including communities in designing interventions, and delivering a coordinated suite of interventions These approaches inform the recommendations for the Net Zero Strategy that are outlined below.

Recommendation 1: Develop a strategy that combines multiple approaches but evaluate the contributions of individual interventions. While combined approaches are identified as best practice by both the academic literature and practitioners, delivering programs in combination makes it difficult to establish the contribution of individual interventions to total reductions in water-related energy use. Rigorous pilot testing of individual interventions, and staged introduction of different interventions would help to establish an evidence base to help make decisions about the most effective combination of interventions.

Recommendation 2: Select digital metering installations that allow water authorities to provide individualised feedback to households. Digital metering trials are currently underway to determine the most effective options for installation in Victorian households. In addition to the effectiveness of the meters themselves, the potential for digital meter data to develop behavioural interventions should be considered when selecting meters. Digital metering data has the potential to allow water authorities to develop interventions such as gamification of water use and comparing households with other households in their communities. These interventions may produce more behaviour change than simply providing feedback about individual households' water use.

If digital metering data does not allow analysts to differentiate the precise end uses of water, additional pilots of hot water metering may add useful data.

Recommendation 3: Establish positive social norms around water-related energy use. Positive social norms can be generated in various ways. Digital metering allows for comparing high-using households with similar, lower-using households. Trusted champions within specific communities can model behaviours that reduce water-related energy use. Gamification programs that include school or community-level competition build positive social norms by showcasing and publicly rewarding households that reduce their consumption. Water-related energy saving education programs can include education about how to encourage others to reduce their consumption.

Recommendation 4: Continue and enhance the two-pronged approach to household segmentation. The available academic literature highlights the importance of targeting high consuming households. The current approach in Victorian water conservation, employed in the Make Every Drop Count campaign, takes this approach one step further by targeting households with high *discretionary* water use, which is high use of water that is easy to reduce. The highest discretionary water use is in long showers so targeting high discretionary use also targets water-related energy use. While the global

literature focuses only on high-consuming households, Victoria also has a range of programs that provide targeted support to low-income households. This dual approach should be continued because it enables water authorities to save the largest volume of water at the least cost by targeting households with high discretionary water use, while also supporting households who have high needs rather than high use. Further segmentation could include differentiation of groups according to criteria such as culture, education, religion, or attitudes to water-related energy use.

Recommendation 5: Co-design programs with vulnerable communities. Although there are few examples of evaluated co-designed programs to draw on, the academic literature and some practitioners recommend designing interventions with community members. This is particularly relevant for close knit communities and those with households that face additional barriers to reducing their water-related energy use, such as difficulty accessing energy efficient appliances.

Recommendation 6: Emphasise the energy-saving benefits of water-related energy use reductions. Water-related energy use has generally been framed as a water-saving strategy. Emphasising energy-saving has multiple potential benefits. First, the financial benefits of reducing energy use are greater than those for reducing water use. Second, energy is not subject to the cycles of drought and rain that affect water-saving programs. Third, emphasising the energy-saving benefits of water-related energy may assist in developing partnerships with energy companies, government departments, and NGOs with an interest in energy affordability.

While water-related energy use is a new area of policy and program focus, and many practitioners noted that water conservation activity has declined in Victoria since the end of the Millennium Drought, this review found that Victoria still has strengths in engaging households on water conservation. This provides a foundation for supporting households to reduce water-related energy use. Many of the recommended actions in this report are to continue and enhance existing programs, particularly as digital metering improves the household water data that is available, rather than to develop entirely new approaches.

Water authorities are well-placed to support households to reduce water-related energy use because they are well trusted by the community. Water literacy is high here compared with countries that have not previously experienced water shortages.

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APPENDIX A

RAPID REVIEW PROTOCOL

Project title	Literature review – Net Zero Water
Research question	What are the behaviours and interventions that have been targeted to reduce households' water-related energy consumption?
First reviewer	Dominique McCollum Coy
Second reviewer	Michaela Lang
Project supervisor	Julia Meis-Harris and Liam Smith

Inclusion and Exclusion Criteria

Aspect	Include	Exclude
Study Type	**Systematic reviews** (SRs), defined as an overview of primary studies containing an explicit statement of objectives, materials and methods and that has been conducted according to explicit and reproducible methodology. Reviews of quantitative or qualitative studies will be included. **Narrative reviews:** overviews of primary studies lacking explicit and reproducible methodologies but which have had at least some form of quality assurance such as peer review for inclusion in a journal. If too few systematic reviews and narrative reviews, then inclusion of primary studies, favouring those including and comparing several interventions.	All other study designs including: Primary studies, theory / frameworks, modelling, technical research, single case studies, feasibility studies.
Population	**Residential populations** of any kind, living in permanent structures such as houses, flats and apartments.	Populations in managed institutional settings such as residential education, medical, military, tourist and similar facilities.
Study Design	**Interventional** (population-level or individual)	Descriptive, exploratory and formative designs lacking intervention relevance.
Study Setting	Studies in all geographical and jurisdictional settings practically comparable to Australia	Studies in geographical and jurisdictional settings in less-developed country with contexts less comparable to Australia.

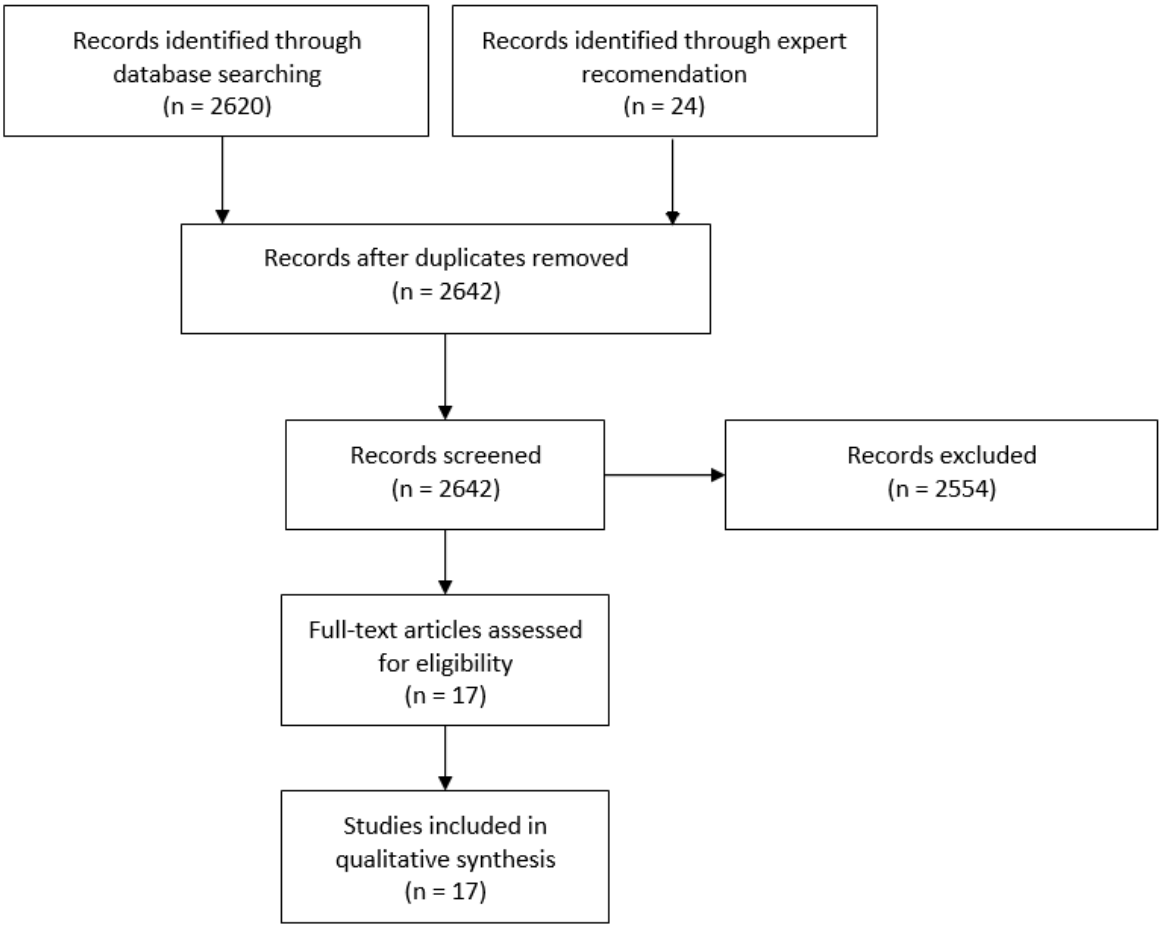
Intervention	Primary aim: **interventions that can be used to reduce water-related energy use** And/or as a secondary preference, **interventions to reduce energy use and water use**	
Outcome	**Primary outcome:** Identification of effective interventions to reduce water-related energy use **Secondary outcome:** Interventions are a means to reduce water and energy consumption - Interventions focusing on engaging specific target household types (e.g. CALD, low-income, apartment, rental)	
Publication status	**English-language** **Peer-reviewed journal** **Publications or reports** Published in the **last 10 years** i.e., 2010 onwards	Books, conference proceedings, grey literature
Database	**Scopus**	All others

Keywords

Aspect	**BWA generated**	**Additional keywords from stakeholder working group**
Outcome **energy** and **water** *(plus related terms)*	"energy efficiency*" OR "energy saving" OR "energy consumption" OR "energy demand management" OR "energy use" OR "low carbon" OR "zero carbon" OR emission* OR electricity OR gas OR heat OR "emission reduction" AND "water"	Water-related energy
Intervention *(*plus related terms)*	intervention OR program OR behaviour* OR evaluation OR innovation* OR training* OR education* OR campaign OR coercion OR practice OR policy OR regulation OR strategy	
Population *(*plus related terms)*	household* OR apartment* OR renter* OR flats OR residential* OR citi	Rental OR term OR tenant* OR rental OR energy consumer OR energy user

	zen* OR neighborhood OR neighbourhood OR community OR home OR "end*user"	
Excluding studies focusing on *(*plus related terms)*	AND NOT insulation OR commercial OR office OR leed OR bio*	

PRISMA DIAGRAM DEMONSTRATING THE FLOW OF STUDIES THROUGH THE REVIEW



APPENDIX B

QUALITY APPRAISAL

SANRA—a scale for the quality assessment of narrative review articles

	0	1	2	Berman (2019)	Frederiks (2015)	Iweka (2019)	Jones (2015)	Koop (2019)
Justification of the article importance for the readership	Importance not justified	Importance alluded to, but not explicitly justified	Importance is explicitly justified	2	2	2	2	2
Statement of concrete aims or formulation of questions	No aims or questions formulated	Aims formulated generally but not concretely or in clear questions	One or more concrete aims of questions formulated	2	2	0	2	2
Description of the literature search	Search strategy not presented	Literature search described briefly	Literature search described in detail, incl search terms & incl criteria	2	2	1	0	2
Referencing	Key statement not supported by references	Referencing of key statements inconsistent	Key statements supported by references	2	2	2	2	2
Scientific reasoning (e.g including appropriate evidence like RCTs in clinical med)	Article's point not based on appropriate arguments	Appropriate evidence used selectively	Appropriate evidence generally present	1	1	2	2	2
Appropriate presentation of data (e.g. absolute vs relative risk, effect sizes, confidence intervals)	Data are presented inadequately	Data are often not presented adequately	Relevant outcomes are generally presented adequately	2	2	2	2	2
			SCORE	**11**	**11**	**9**	**10**	**12**

APPENDIX C

SHORT STUDY DESCRIPTION

Papers	Study Type	Title and Abstract
Berman (2019)	Review	**Becoming FEW conscious: A conceptual typology of household behavior change interventions targeting the food-energy-water (FEW) nexus** The food-energy-water (FEW) nexus presents an opportunity to rethink predominant approaches to household behavior change science. We linked emerging FEW nexus research with existing literature examining household consumption and pro-environmental behaviors. While a large body of work examines the environmental impacts of household life and explores pathways to behavior change for sustainability, the literature lacks studies that test interventions in multiple FEW resource categories, leaving researchers unable to identify tensions and tradeoffs in the household system. To guide this developing field and accumulate findings on household behavior across disciplines, we proposed a conceptual typology that synthesizes interdisciplinary analytic traditions to classify behavioral interventions targeting the household FEW nexus. The typology synthesizes behavioral interventions as active, passive, or structural, and household-specific or non-specific, illustrating six distinct categories: information, tailored information, action, gamification, policy/price change, and material/technology provision. A review of 40 studies that guided the typology identifies four significant lessons for future intervention research: household non-specific information and tailored information work better together, feedback is more effective when it is persistent, price-based interventions (information or incentives) are often incective, and material/technology provision is very effective but utilized in few household studies. To push forward household resource consumption science, we advocated for a holistic nexus focus that is rooted in interdisciplinarity, coalition building with stakeholders, and data reporting that facilitates knowledge accumulation.
Frederiks (2015)	Review	**The socio-demographic and psychological predictors of residential energy consumption: A comprehensive review** This article provides a comprehensive review of theory and research on the individual-level predictors of household energy usage. Drawing on literature from across the social sciences, we examine two broad categories of variables that have been identified as potentially important for explaining variability in energy consumption and conservation: socio-demographic factors (e.g., income, employment status, dwelling type/size, home ownership, household size, stage of family life cycle) and psychological factors (e.g., beliefs and attitudes, motives and intentions, perceived behavioral control, cost-benefit appraisals, personal and social norms). Despite an expanding literature, we find that empirical evidence of the impact of these variables has been far from consistent and conclusive to date. Such inconsistency poses challenges for drawing generalizable conclusions, and underscores the complexity of consumer behavior in this domain. In this article, we propose that a multitude of factors-whether directly, indirectly, or in interaction-influence how householders consume and conserve energy. Theory, research and practice can be greatly advanced by understanding what these factors are, and how, when, where, why and for whom they operate. We conclude by outlining some important practical implications for policymakers and directions for future research.

Iweka (2019)	Review	**Energy and behaviour at home: A review of intervention methods and practices** The transition of householders towards optimal energy use in the residential sector has proved to be challenging, with human energy-use behaviour been identified as one of the factors behind the setback. Social interventions geared towards engaging and making energy end users aware of their energy consumption and its footprint on the environment have been conducted in the past. Forty-six papers on the outcome of these social intervention were reviewed and categorized in this article based on the major strategies applied in anticipation of behaviour change. This paper shares information on the techniques used for the interventions, to what degree each intervention was successful or not and why it was adjudged successful or otherwise. It further explores some of the problems associated with the interventions and their reporting, followed by suggestions on how study practices can be improved. The techniques discussed include the use energy labels, energy performance certificates, energy auditing, prompts, norm appeals, commitments, economic incentives and disincentives, feedbacks, community-based initiatives, benchmarking, goal setting and gamification. Feedbacks, gamification, goal setting and community-based initiatives proved to be the most effective as they all recorded average energy savings of above 20%. Interventions practices can be performed individually, though a combination of complementary intervention tools have been observed to be effective.
Jones (2015)	Review	**The socio-economic, dwelling and appliance related factors affecting electricity consumption in domestic buildings** This paper aims to investigate the socio-economic, dwelling and appliance related factors that have significant or non-significant effects on domestic electricity consumption. To achieve this aim, a comprehensive literature review of international research investigating these factors was undertaken. Although papers examining the factors affecting electricity demand are numerous, to the authors' knowledge, a comprehensive analysis taking stock of all previous findings has not previously been undertaken. The review establishes that no less than 62 factors potentially have an effect on domestic electricity use. This includes 13 socio-economic factors, 12 dwelling factors and 37 appliance factors. Of the 62 factors, four of the socio-economic factors, seven of the dwelling factors, and nine of the appliance related factors were found to unambiguously have a significant positive effect on electricity use. This paper contributes to a better understanding of those factors that certainly affect electricity consumption and those for which effects are unclear and require further research. Understanding the effects of factors can support both the implementation of effective energy policy and aid prediction of future electricity consumption in the domestic sector.
Koop (2019)	Review	**Enhancing domestic water conservation behaviour: A review of empirical studies on influencing tactics** The world faces imminent drought-related challenges that, from a tap-water supply perspective, require increasingly expensive infrastructure enhancement and energy expansion to maintain sufficient service levels. This paper argues that enhancing domestic water conservation provides a promising alternative or necessary addition to reduce costs and to stimulate pro-environmental behaviour. Although the number of field experiments on how people's behaviour can be changed with respect to their daily water consumption is growing, to date, most studies in this field have focussed either on explanatory socio-economic factors (e.g. water pricing, income, or family composition) or behavioural intentions and personal characteristics related to behavioural change. Accordingly, there is limited empirically validated knowledge about the use and effectiveness of different influencing tactics to change behaviour. This paper provides a review of the empirically oriented literature in this field and aims to provide an up-to-date assessment that identifies eight different Behavioural Influencing Tactics (BITs) that target long-term water conservation behaviour within households. Our analysis is structured around three information processing routes: the reflective route, the semi-reflective route, and the automatic

		route. We conclude that the current body of literature is promising and provides a useful body of evidence on the range and effectiveness of individual water conservation mechanisms, but that needs further development to deepen our understanding of how to effectively prolong and reinforce newly formed water conservation routines.
Beal (2013)	Primary Study	**MIND OR MACHINE? Examining the drivers of residential water end-use efficiency** Essentially, there are two overarching demand management strategies employed to achieve efficient water consumption in the residential sector. These are: targeting water use behaviour change ("mind") and promoting the use of water-efficient technologies ("machine"). Using detailed water end-use data and qualitative methods, this paper describes the role that each of these strategies has played over the last few years, using data from 250 residential properties located in the south-east corner of Queensland. The role of water-efficient technology (e.g. low-flow shower heads, 4-star-rated clothes-washers) in reducing potable demand will be compared with the importance of attitudes and behaviours to water conservation. Results indicate that how we value water (psycho-social variables) and interact with water-efficient fixtures is at least as important in reducing water consumption in the home as the quality and quantity of water-efficient stock. The paper concludes with some suggestions on how such study outcomes can be relevant to future demand management approaches.
Csoknyai (2019)	Primary Study	**Analysis of energy consumption profiles in residential buildings and impact assessment of a serious game on occupants' behaviour** The paper has a focus on energy consumption habits, trends and intervention strategies in residential buildings, mainly through the serious game approach with a combination of direct consumer feedback through smart metering. More than 150 homes in France and Spain have been involved in the research experiment and the consumption habits of approximately 50 homes were deeply analyzed. The applied methods, processes, results and findings of the monitoring data analysis are presented in the paper with two aims. First, consumption profiles and trends were determined for apartment homes with regard to heating, domestic hot water and electric consumption. Second, the impact of a serious game experiment was assessed comparing energy consumption, indoor air temperature and users' habits (based on questionnaires) before and after launching the experiment.
Currie (2020)	Primary Study	**ToU Tariff Effect on Domestic Electricity Patterns- Australian Case Study** This article shows an evaluation of a ToU network tariff test on Australian domestic electricity customers. The test was with 444 domestic electricity customers in Tasmania, Australia. This Australian case has international implications for energy policy and regulation. Australia has the world's highest domestic PV (photovoltaic system) adoption and combining this with high air-conditioning and water heating load leads to high diurnal variation and an emerging issue globally. Related issues include over-voltage. Thermal overload, frequency instability and voltage instability. The method was a statistical analysis of the energy use patterns using k-means clustering, and then stepwise regression to find drivers of energy reduction behaviour. There were also tests on the effect of weather and seasonal effect. The conclusions are that there was strong response from 4% of customers, and moderate response from 15%. There was a stronger response in households that were drawing more electricity and were wealthier than the average households.
Dieu-Hang (2017)	Primary Study	**Household adoption of energy and water-efficient appliances: An analysis of attitudes, labelling and complementary green behaviours in selected OECD countries** Using a household-based data set of more than 12,000 households from 11 OECD countries, we analyse the factors underlying the decision by households to adopt energy-efficient and water-efficient equipment. We evaluate the roles of

		both attitudes and labelling schemes on the adoption of energy and water-efficient equipment, and also the interaction and complementarity between energy and water conservation behaviours. Our findings show: one, 'green' social norms and favourable attitudes towards the environment are associated with an increased likelihood of households' adoption of energy and water-efficient appliances; two, households' purchase decisions are positively affected by their awareness, understanding, and trust of labelling schemes; and three, there is evidence of complementarity between energy conservation and water conservation behaviours.
Eon (2018)	Primary Study	**Influencing energy and water use within a home system of practice** Approaches that attempt to influence resource use in the home often consider the building system alone, without due consideration of occupants and their practices. However, occupants interact with technology and ultimately affect energy and water metabolism in the home. This research used an explanatory design mixed method approach to investigate the energy and water use in eight homes over a two-year period, before and after an intervention based on persuasive behaviour change. Each home was considered as a system of practice and results were analysed in terms of overall resource reduction, changes in practice and changes made to the building systems. It was revealed that five of the homes succeeded in reducing their resource use through the two years. Most changes were achieved through affecting technology as an element of practice. Automation was shown to enable the dis-interlocking of practices from aligned and interlocked routines and can be considered an effective solution to influence resource use in the home.
House (2012)	Primary Study	**Shifting the timing of customer water consumption** This project assessed how a combination of time-of-use water meters and information affected consumption patterns for representative members of customer classes during peak summer electricity demand periods. The project also assessed the resultant change in water agency electrical demands. Compared with the control group, residential intervention customers reduced their peak period water use by more than 50% (significant at the 0.05 level) and their total use by an average of 17% during the study. These reductions in peak and total water use for this group persisted after the study was completed. Business and irrigation groups did not demonstrate statistically significant water consumption changes. The project also determined the water embedded energy of the water agency and the effect of reducing on-peak water deliveries on system electricity consumption. Results of this study demonstrated that changes in customer consumption patterns may represent a viable electricity demand response opportunity and cost reduction mechanism for the utility.
Laskari (2016)	Primary Study	**The design of an energy and water advice programme for low-income households** Occupants of residential buildings are not always fully aware of the potential to save energy or water in their homes since they do not know much about their consumption profiles neither do they know all the measures they could apply and behaviours they could adopt for this purpose. Numerous behaviour change programmes have been developed in the past years, that help occupants exploit their home's saving potential by providing feedback, information and advice. Many of these programmes rely on Information and Communications Technology (ICT) as an enabling technology for energy and water efficiency. This paper presents an energy and water advice programme designed specifically for social housing. Advice is provided as part of an ICT service providing feedback and information to social housing occupants aiming to improve behaviour-based energy and water efficiency. Provision of advice supplements direct feedback with the aim of achieving the maximum savings possible. The service was developed based on a commonly followed methodology that included collection of requirements for the service design and user evaluation of the service

		after it had been used. Utilities were monitored along with indoor environmental parameters to ensure that health and comfort of the occupants is not compromised in favour of saving.
Russell (2019)	Primary Study	**Exploring the psychosocial and behavioural determinants of household water conservation and intention** Securing urban freshwater supplies is a major challenge for policy makers globally. This study investigated the determinants of household water conservation to identify the relative contribution of psychosocial and behavioural determinants. Using a survey of 1196 households across the UK, we found that attitudes, norms and habits play an important role in determining intention to conserve water, and that habits were the single most important predictor of water conservation intentions and self-reported water bills. Changing ingrained water conservation habits is therefore an important component of managing urban water demand.
Tiefenbeck (2018)	Primary Study	**Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation** Inattention and imperfect information bias behavior toward the salient and immediately visible. This distortion creates costs for individuals, the organizations in which they work, and society at large. We show that an effective way to overcome this bias is by making the implications of one's behavior salient in real time, while individuals can directly adapt. In a large-scale field experiment, we gave participants real-time feedback on the resource consumption of a daily, energy-intensive activity (showering). We find that real-time feedback reduced resource consumption for the target behavior by 22%. At the household level, this led to much larger conservation gains in absolute terms than conventional policy interventions that provide aggregate feedback on resource use. High baseline users displayed a larger conservation effect, in line with the notion that realtime feedback helps eliminate "slack" in resource use. The approach is cost effective, is technically applicable to the vast majority of households, and generated savings of 1.2 kWh per day and household, which exceeds the average energy use for lighting. The intervention also shows how digitalization in our everyday lives makes information available that can help individuals overcome salience bias and act more in line with their preferences.
Willis (2010)	Primary Study	**Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households** Sustainable urban water consumption has become a critical issue in Australian built environments due to the country's dry climate and increasingly variable rainfall. Residential households have the potential to conserve water, especially across discretionary end uses such as showering. The advent of high resolution smart meters and data loggers allows for the disaggregation of water flow recordings into a registry of water end use events (e.g. showers, washing machine and taps). This study firstly reports on a water consumption end use study sample of 151 households conducted in the Gold Coast, Australia, with a focus on daily per capita shower end use distributions. A sub-sample of 44 households within the greater sample was recruited for the installation of an alarming visual display monitor locked at 40 L consumption for bathroom showers. All sub-sample shower end use event durations, volumes and flow rates were then analysed and compared utilising independent sample t-tests pre- and post-intervention. The installation of the shower monitor instigated a statistically significant mean reduction of 15.40 L (27%) in shower event volumes. Monetary savings resulting from modelled water and energy conservation resulted in a 1.65-year payback period for the device. Furthermore, conservative modelling indicated that the citywide implementation of the device could yield 3% and 2.4% savings in total water and energy consumption, respectively. Moreover, a range of non-monetary benefits were identified, including the deferment of water and energy supply infrastructure, reduced resource inflationary pressures,

		and climate change mitigation, to name a few. Resource consumption awareness devices like the one evaluated in this study assist resource consumers to take ownership of their usage and individually tackle individualistic and/or society driven conservation goals, ultimately helping to reduce the ecological footprint of built environments.
Tiefenbeck et al., (2014)	Report	**On the Effectiveness of Real-Time Feedback: The Influence of Demographics, Attitudes, and Personality Traits** Feedback interventions that indicate personal energy consumption have received much attention among scholars and practitioners alike. Due to their cost-effectiveness, political feasibility, and scalability, such programs have been rolled out to millions of households. Recent studies that lasted between 6 months and 5 years have documented reductions in the range of 1-6%. While it has been shown that feedback is more effective when provided on a specific behavior and right at the point and time of use, a demonstration of the impact and cost-effectiveness of feedback in such favorable conditions on a larger scale is still missing. This study investigates the impact of behavior-specific real-time feedback (here: on hot water consumption in the shower) and evaluates factors and mechanisms facilitating its effectiveness in a randomized controlled trial with 697 households. Overall, participants who received real-time feedback reduced both their energy and their water consumption by 23% compared to the control group. The effects are sustained throughout the study period of two months. Projected to one year and assuming persistence of the effect, this results in yearly savings of 443 kWh, 8,500 liters of drinking water, 94 kg of CO2, and CHF 110, making the device cost-effective within 6-9 months. Individuals with high baseline consumption show a stronger behavioral response to the intervention, as do participants with a general tendency to monitor progress towards goals. While environmental attitudes drive the effect behind the scenes, they do not significantly affect the overall net treatment effect, as they are strongly negatively correlated with baseline consumption. The intervention also substantially increases knowledge about resource consumption. Conversely, the results do not support any evidence that negative psychological pressure might drive the treatment effect. The baseline data also indicate that the amount of energy and water used is negatively correlated with age, with 20-29 year-olds using 72% more resources per shower than participants over 65. Yet given their higher baseline consumption, young people respond stronger to the feedback, making them a valuable target for feedback campaigns. The study shows that behavior-specific feedback can prompt substantial behavior change. Moreover, profiling, e.g., targeting households with an above-average baseline consumption, can even further raise program cost-effectiveness. The findings also suggest that positive mechanisms drive the conservation effect, not negative psychological pressure. Altogether, the results indicate that behavior-specific real-time feedback is highly cost-effective and scalable.
Behavioural Insights Team (2018)	Report	**Aquarevo Behavioural Change Research** This review summarises some of the key behavioural insights solutions used to reduce water consumption. Due to substantial overlap with the consumer energy sector, this review draws on evidence from both energy and the water sectors to identify effective techniques to reduce consumption.

APPENDIX D

INTERVIEW PROTOCOL

About you

I'd like to start by asking some questions to understand your background and provide some context to your responses.

1. What is your current position or role? What does it involve?
2. What is your experience with engaging households to reduce water or energy use?

Water-related energy use

3. We know that the term "**water-related energy use**" means different things to different people. How do you define water-related energy use and what type of behaviours do you think of when using this term.

For the rest of the interview, please consider the following definition of the term "water-related energy use" *(To be defined)*

Programs and initiatives the interviewee engaged in

4. Tell me about a **policy/program** that you/your organisation has implemented to support households to reduce water-related energy use?
    a. What outcomes has this achieved?
    b. Was the program successful in achieving its purpose?

5. How was this policy/program **developed**? PROMPTS:
    a. Was it focused on technology or behavioural change?
    b. What evidence did inform the policy/program design?
    c. Was it based on any underlying theory?
    d. Were there any regulatory drivers in place that you consider important for this specific program e.g. incentives?

6. Who was the **target audience** for the policy/program? PROMPT
    a. What challenges are associated with engaging that group?
    b. What strategies are effective for engaging that group?
    c. Are behaviour or technological changes more appropriate for that group?
    d. What are the measures of success for engaging that group?

7. What would you **do differently** if you were designing this program again?

Knowledge of other programs and initiatives

8. Can you tell me about an **innovative program or initiative**, anywhere in the world, that aims to reduce water-related energy use by encouraging energy efficient technology or by changing household behaviour? PROMPT:

a. What outcomes has the program achieved? What outcomes have not been achieved and why?

b. Who did the program target?

Recommendations for Net Zero Strategy and policy context

9. What **recommendations** or advice would you give for the development of the Net Zero Strategy for water retailers to encourage households to reduce water-related energy use?

Regulatory and policy context: enablers and constraints, documents

10. Thinking about the **regulatory and policy context** surrounding your organisation. What **enables** and **constrains** your organisations ability to support households to reduce water-related energy use? PROMPT

    a. Regulatory or policy context (incl. funding and resourcing, scope of responsibilities)

    b. Water/energy targets

    c. Connections to community

    d. Community attitudes and behaviours (e.g. water literacy)

11. Are policy/program **documents**, or evaluation results, available for the policy/program(s) you have talked about? Would you be able to share them with me?

Final remarks

12. Do you have any thoughts about water-related energy use that you haven't had the chance to share with me?

13. Is there **anyone** else that you would recommend interviewing about how to support different types of households to reduce their water-related energy use?

Thank you for participating.