Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Demand-side management for supply-side efficiency: Modeling tailored strategies for reducing peak residential water demand

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ABSTRACT

Increasingly, the water sector is exploring the value of applying demand management strategies to reduce peak water use through behavioural and technical solutions. Literature suggests that using behavioural interventions may be a useful approach in changing the daily peak demand patterns to reduce the pressure on network pumping energy costs during peak use times. There is a lack of studies, however, that have investigated the role of social based marketing or behavioural intervention studies on specifically reducing and shifting residential peak diurnal daily water end-use demand. This concept is modelled in this current study through the application of longitudinal experimental end-use data to predict how reduced demand through behaviour change can impact on overall peak residential demand. Notwithstanding the acknowledged limitations of the study, results illustrate a range of potential peak hour flow savings that can be realised from reducing total demand, or shifting the peak demand in households. The study provides preliminary evidence that water businesses can use demand-side strategies to also achieve efficiencies in the distribution of urban water (e.g. reduced energy for pumping in pressurised water system, pipe augmentation deferrals, peak energy demands).

Keywords: End-use studies; Infrastructure optimisation; Smart meters; Behavioural interventions; Demand management; Peak demand

1. Introduction

Like many regions around the world, Australia's climate is dictated by drought and flood cycles, making management of climate-dependent water supplies complex, uncertain and often costly. Demand-side water management is historically associated with the onset of the drought cycle with the aim of securing drinking water supplies during low recharge periods (Arbues et al., 2003). During more plentiful water supply conditions, demand management strategies are being increasingly recognised as a useful tool to reduce short term costs associated with peak water supply and long term costs associated with infrastructure augmentation (Beal and Stewart, 2014, van Staden et al., 2011). The costs not only relate to direct economic costs of supplying water but also to the indirect costs for the energy requirements to treat, pump and maintain the water supply network. The energy sector has long recognised the value of implementing demand management strategies for the purpose of reducing peak grid energy load (Suganthi and Samuel, 2012; Nadel, 1992). Increasingly, the water sector is exploring the value of applying demand management strategies to reduce peak

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Received 16 March 2015; Received in revised form 24 October 2015; Accepted 17 November 2015; Published online 4 January 2016.

http://dx.doi.org/10.1016/j.spc.2015.11.005

water use through behavioural and technical solutions such as time-of-use tariffs (Cole and Stewart, 2012), customer feedback from smart metering systems (Beal and Flynn, 2015; Fielding et al., 2013) and options for alternative off-grid water sources (Gurung et al., 2014; Dolnicar et al., 2012). As such, the main aim of this present study was to model a range of estimated savings from the implementation of behaviourally-driven water demand management strategies.

The study will draw upon previous data from SEQ households that has shown how different behavioural approaches can reduce not only total household consumption, but targeted end-uses such as shower, clothes washer and outdoor irrigation (Fielding et al., 2013). This information will be applied to known peak demand patterns to predict how peak use can be reduced through promotion of similar behavioural approaches to the wider community. The scope of the study does not extend to testing the predicted peak water demand reductions but seeks rather to provide an indicative range of savings that may be achieved from behavioural interventions that have been shown to be successful on average water demand for SEQ households. Based on this study scope, the research aim was to determine the likely range of potential reductions to peak water demand arising from targeted water demand management strategies (e.g. behavioural interventions). Such information may assist utilities with reducing peak demand flows in pipe networks, which may subsequently accrue infrastructure or pump energy efficiencies for water utilities.

2. Background

2.1. *Demand management for water conservation*

Water demand management broadly defines any actions or strategies that aim to promote and improve water conservation or efficiency (Brooks, 2006). Following the historical Millennium drought, research into water demand management became a focal point in Queensland, Australia (e.g. Beal et al., 2013, Fielding et al., 2012, Fielding et al., 2013, Makki et al., 2015, Makki et al., 2013 and Turner et al., 2009). The chief aim of this research effort was to understand how best to reduce residential water consumption and promote water conservation in a bid to reduce demand on the exceptionally low water supplies at that time (Beal and Stewart, 2011, Walton and Hume, 2011, Turner et al., 2009). There are a wealth of studies worldwide that compellingly demonstrate the effectiveness of demand management strategies in reducing potable water demand through: technical approaches such as installation of water-efficient devices (e.g. Willis et al., 2013, Fidar et al. 2010, Millock and Nauges, 2010), voluntary and behavioural approaches such as tariff structures (Cole and Stewart, 2012, van Vugt, 2001, Nieswiadomy, 1992), social-based marketing (Fielding et al., 2012, Walton and Hume, 2011, Athanasiadis and Mitkas, 2005) and mandatory behavioural approaches such as water restrictions (e.g. Grafton and Ward, 2008 and Syme et al., 2004). The effectiveness of water restrictions, while not always a favoured demand management approach for water utilities, has been shown to be very effective at reducing residential demand (Beal et al., 2014; Syme et al., 2004). However, by understanding the factors that drive upward or downward trends in water consumption, managers can adopt a proactive approach to demand management and potentially circumvent the need for restrictions or other mandatory approaches (Giurco et al., 2011).

2.2. *The role of demand management beyond water conservation*

In the absence of drought, there can be a different focus for applying demand management strategies. For example, in post-drought south-east Queensland (SEQ), a different political landscape exists with the security of supply now much more resilient due to new climate-independent sources such as the Tugun desalination plant and the Western Corridor Recycled Water Scheme (Traves et al., 2008). Along with this infrastructure and two substantial flood events (leading to full water supply dams across the region), the promotion of urban SEQ water conservation and efficiency programmes have all but disappeared off the local and state government agendas. It could even be argued that in some cases residents have been subtly encouraged to increase their water consumption, particularly outdoor use, to assist in the cost-recovery (through additional revenue) of the many billions of dollars of capital investments in bulk water infrastructure for securing the SEQ water supply during the drought (e.g. Thompson and Solomons, 2012).

The water price cost increases to SEQ customers has been rising well above inflation in the past five years in order to service the additional debt taken on by the government-owned SEQ bulk water agency to fund such drought security infrastructure. In response to the necessity to increase water prices but at the same time respond to political pressure to reduce prices, the bulk and distribution water business of the SEQ region have shifted their focus from demand management and managing water scarcity, to system efficiency in order to reduce the future price acceleration of water. Thus, there has been a marked shift in SEQ towards investigating how changes to domestic potable water demand can assist in revenue forecasting, optimising future water network infrastructure, leak management, and reducing peak usage—rather than water conservation *per se*. Some examples include Gurung et al. (2014, 2015), who discuss the application of smart metering technology to improve our understanding of peak demand patterns and subsequent network optimisation, including non-traditional water supply systems. Cole and Stewart (2012) combined diurnal consumption patterns and their peak demands to inform system flow rates and the subsequent calibration of network distribution models. Beal and Stewart (2014) demonstrated how smart meter enabled water end-use data can identify the key indoor and outdoor end-uses that contribute to peak hour, day and month demand.

2.3. *Behavioural strategies for reducing peak demand*

In the current context where surface water supplies are secure in the SEQ region, water utilities have not been focused on reducing the current overall water consumption of its customers, but instead have focused more on reducing peak demand, which can in-turn reduce network pumping costs and defer trunk infrastructure upgrades (Gurung et al., 2015). That is, during times where peak water demand coincides with the highest energy tariff period for pumping to supply reservoirs, a reduction in residential peak demand can substantially reduce operating costs (van Staden et al., 2011). In terms of using social marketing strategies to achieve this, encouraging behaviour change in peak water use activities such as irrigation and other outdoor water uses could be promoted (Browne et al., 2013). Time of use tariffs is one