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End use water consumption in households: impact of socio-demographic factors and efficient devices

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A B S T R A C T

To assess water savings in households using efficient devices and to understand how savings vary between different socio-demographic groups in the community, high resolution end use water consumption data is required (i.e. disaggregating water use for showers, toilets, clothes washers and garden irrigation etc.). This paper reports selected findings from the *Gold Coast Residential End Use Study (Australia)*, which focussed on the relationship between a range of socio-demographic and household stock efficiency variables and water end use consumption levels. A mixed methods approach was executed using qualitative and quantitative data. The study provided evidence as to the potential savings derived from efficient appliances as well as socio-demographic clusters having higher water consumption across end uses. The payback period for some water efficient devices was also explored. The study has implications for urban water demand management planning and forecasting.

1. Introduction

1.1. Improving urban water security

The strong emphasis on ensuring a secure water supply for the population of Australia has been brought to light by the increasing frequency, severity and duration of drought events throughout the nation. Drought, coupled with growing populations has lead to numerous instances of many water supply reservoirs in South-East Queensland (SEQ) dropping below 20% over the last decade. This has forced State and Local government to implement alternative water supply schemes, along with a range of demand management interventions, in order to improve urban water security. Innovative water re-use (e.g. Willis et al., 2010a; Willis et al., 2011a) and decentralised supply solutions (e.g. Talebpour et al., 2011) are becoming increasingly viable technologies to meet city water needs but there are often many financial, behavioural and regulatory barriers to their diffusion in practice (Partzsch, 2009; Krozer et al., 2010; Giurco et al., 2011; Willis et al., 2011b). Planning studies employing holistic Integrated Water Resource Management (IWRM) models (e.g. Dvarioniene and Stasiskiene, 2007) have been applied and demonstrated that high efficiency water fixtures and appliances are a least cost planning strategy for water conservation and a good starting point for policy makers before higher cost water supply or demand solutions are commissioned (Stewart et al., 2010).

1.2. Domestic water consumption and conservation

In the Gold Coast, Australia – a city of 510,000 people – residential water consumption accounts for approximately 66% of the City's total supply (2007/2008). Residential water consumption has previously been determined to be influenced by seasonal changes and Water Demand Management (WDM) strategies such as water metering (compared with unmetered homes), water restriction levels, water efficient devices, water consumption information devices and education (Beal et al., 2010; Inman and Jeffrey, 2006; Mayer et al., 2004; Nieswaidomy, 1992; Willis et al., 2010b).

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Although prior research in these areas has occurred, it is well established that there is a requirement for specific country and location based research for a range of reasons, including differences in: (1) community attitudes and behaviours; (2) water appliance stock efficiency profiles; (3) environmental conditions; (4) water pricing structures; (5) government water restriction regimes; and (6) conservation message intensity. All such contextual factors have an influence on the effectiveness of WDM strategies (Corral-Verdugo et al., 2002; Turner et al., 2005; Stewart et al., 2011; Willis et al., 2011b; Beal et al., 2011). To evaluate the effectiveness of WDM strategies high quality data is required (Stewart et al., 2010). The development of smart metering technologies and end use analysis techniques allowed for the acquisition of such data in this study.

1.3. Advent of smart water metering, monitoring and management

The measurement, benchmarking and management of a process, product, project or system is an expected requirement in almost all industry sectors in the modern age (Stewart and Spencer, 2006; Stewart, 2008; Panuwatwanich et al., 2009). Such evaluation activities ensure the continual improvement of a business or industry sector, and are finally being applied in the water industry due to the advent of smart water metering technologies, which allow the collection of empirical evidence on *where in the home* and *how often* water is used, thereby allowing planners and conservationists to determine the relative water savings achievable from WDM strategies. Smart metering and management systems enable better measurement and management of valuable urban water supplies and the distribution systems that deliver this potable water to the household (Stewart et al., 2010). Conventional water meters in residential households in Australia only count the volume of water used and there is no facility to determine when and which water end use event is occurring (such as in showers, toilets, clothes washers, garden irrigation etc.). Water consumption is characteristically recorded quarterly, resulting in just two to four data points describing a whole year's water consumption (Britton et al., 2008). Smart metering couples a higher resolution water meter with data logging equipment which allows for continuous water consumption recording. Data resulting from smart metering applications allows water managers to investigate the effectiveness of WDM strategies and household water consumption patterns amongst different socio-demographic groups (Beal et al., 2010; Stewart et al., 2010).

1.4. Overview of Gold Coast residential end use study

The Gold Coast Residential End Use Study (GCREUS) commenced in 2007 as an Australian Research Council (ARC) funded collaborative research investigation by Griffith University, Gold Coast Water and the Institute for Sustainable Future (University of Technology, Sydney). The purpose of this study was to identify end use water consumption in Gold Coast homes and to evaluate the effectiveness of WDM strategies namely the application of water efficient devices and education as well as understanding water use differences between varying socio-demographic groups. Smart metering was implemented to ascertain end use water consumption data, to enable comparative analysis between varying household socio-demographic clusters and to understand the water saving potential of efficient devices. These aspects represent two objectives of the GCREUS study explored in this paper.

1.5. Engineered water efficiency

Engineered efficiency or the development of higher efficiency water using devices has seen effective reductions in water consumption. In Tampa, USA Mayer et al. (2004) determined that the retrofitting of water efficient devices can result in a reduction of up to 49.7% of water use per capita; a highly significant reduction. Inman and Jeffrey (2006) report that the comprehensive replacement of household appliances (such as showers, toilets and clothes washers) with highly water efficient appliances can reduce indoor water consumption by between 35 and 50%. Not only does this reduction in demand serve to preserve water supply security for future generations but reduces the life cycle cost of potable water treatment and distribution, as well as energy intensive wastewater treatment (Barrios et al., 2008; Mahgoub et al., 2010) and ultimately the ecological footprint of the city or nation (Friedrich et al., 2009; Hubacek et al., 2009).

1.6. Influences of socio-demographic factors

There are several previously reported socio-demographic factors that can influence water consumption. The result of the socio-demographic variable investigations by the ARCWIS (2002) indicated that owner occupied properties, higher income families and households with swimming pools consumed more water for irrigation. Loh and Coghlan (2003) reported a strong relationship between income level and outdoor water use. The occupancy and makeup of dwellings, lot size and the age of water using devices have also been found to influence water consumption with larger lot sizes generally consuming more water (Mayer and DeOreo, 1999).

1.7. Research objectives

The objectives of this paper are to:

a) Determine a household and per capita water consumption end use break down for a sample of Gold Coast households;
b) Explore the relationship between household stock survey efficiency rating clusters and water end use consumption levels; and,
c) Ascertain demographic information of water users and determine if socio-demographic factors influence water consumption.

The multifaceted objectives of the GCREUS study required the application of a mixed methods research design to obtain the required data types.

2. Method

To achieve the desired objectives of the study, a mixed methods data collection procedure including a stock survey of water using fixtures/appliances in households, end use water consumption study and a questionnaire survey, were concurrently undertaken with 151 households on the Gold Coast City, Australia.

2.1. Mixed method study design

The study adopts a mixed method design through collecting, analysing and mixing quantitative and qualitative research approaches and processes. This mixed methods approach allows the use of multiple methods to address research objectives (Creswell and Plano Clark, 2007). A mixed method approach was embarked upon as an array of data types are required to meet the developed research objectives. Namely, natural science data in the form of end use water consumption data, quantitative statistical survey data for demographic information, quantitative stock survey information, and, qualitative water behaviour data were required.