



# RAINWATER TANK END USAGE AND ENERGY DEMAND: A PILOT STUDY

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## Abstract

High-resolution smart meters (ie, 0.014L per pulse collected every five seconds) are being increasingly utilised for end use studies underpinning water demand forecasting and management strategies. An area that has not been examined is the impact of mandated internally plumbed rainwater tanks on water end uses and verification of potable water savings targets. This is a critical area for research, given that a number of State Governments have mandated internally plumbed rain tanks to certain end uses (such as laundry, toilet and outdoor taps) for newly constructed residential dwellings, and projected savings are being included in urban water supply plans.

Annually, in excess of 50,000 detached dwellings in Australia are being constructed with some form of internally plumbed rain tank configuration, predominantly in Queensland, NSW and SA. However, the evidence to support the viability of set potable savings targets is based on non-validated modelling and lacks field-based empirical support. Accordingly, this pilot study aimed to design an experimental method to determine the reliable supply of internally plumbed rain tanks across their supplied end uses, and also to analyse pump energy intensity of individual events.

Readers should note that this pilot study was carried out on five households for the purpose of experimental design for a full study of 50 households, and should not be interpreted as a completed Rain Tank End Use Study for planning purposes.

## Pilot and Collaborative ARC Linkage Study

This pilot study examined five households with internally plumbed rain tank systems on the Gold Coast. It was designed to explore the technical challenges and procedures to instrument and analyse data as the foundation for a greater study. The most common means for achieving potable water savings is through plumbing the rainwater tank to the toilet, laundry and two external taps for garden usage. This study aimed to achieve the following objectives: (1) experimental design for end use study; (2) design for determining

the pump energy intensity for individual water use events; and (3) reliable flow trace analysis process for resolving all the mains and rain tank supplied end uses, thus paving the way for a recently commenced collaborative Australian Research Council (ARC) Linkage Project involving Griffith University, Allconnex Water, Institute for Sustainable Futures (at the University of Technology Sydney) and CSIRO, which will sample 50 households over a 12-month period (which should cover seasonal variations in garden irrigation). It will provide an empirically determined target for the potable water savings achievable from mandated internally plumbed rain tanks.

## Smart Metering for End Use Studies

The advent of smart metering has enabled the process of water end use analysis among a plethora of other urban water management benefits (Giurco *et al.* 2008; Stewart *et al.* 2010). Residential water end use studies have been completed internationally (Mayer & DeOreo 1999, Mayer *et al.* 2004 and Heinrich 2007) and nationally (Loh & Coglean 2003, Roberts 2005 and Willis *et al.* 2009). Recently, end use studies are beginning to explore the end uses for diversified water supplies such as dual reticulated recycled water schemes (Willis *et al.* 2010). Internally plumbed rain tanks are being installed in a large proportion of new residential housing stock in Australia; however, there are few examples providing experimental verification of their performance (ie, covering rainwater use and potable savings as well as energy use) and no research showing the end uses they reliably supply.

## Popular Internally Plumbed Rain Tank Configurations

Retamal *et al.* (2009) provides a comprehensive description of a range of internally plumbed rain tank configurations and their advantages and disadvantages. The majority of residential dwellings being constructed utilise fixed speed pumps with mains switch systems or tank top-up systems. The more elaborate and efficient designs, incorporating pressure vessels and variable speed pumps, are rarely considered by home builders as they are

predominantly concerned with satisfying mandated building code requirements at least capital cost. The experimental procedure presented here suits the commonly installed mains switch system, specifically the popular Davey pump with *RainBank*<sup>TM</sup> model. For this system rain from the roof is collected in-tank and used for the toilet, laundry and irrigation. When there is demand for water the switch system senses this and checks the level of water in the rain tank. If the switch system detects inadequate water in the rain tank it will automatically let the mains water flow. The system also automatically supplies mains water if there is a very low flow demand (for example, a small leak) or a power failure.

## Designing the Rain Tank End Use Study Experiment

As mentioned earlier, the primary goal of the pilot study was to design an experiment that would enable the disaggregation of water consumption from both the mains and rain tank supplies into end use events. Moreover, the study sought to design an experiment that could reveal the energy consumption of each and every end use event supplied by the rain tank pump. While studies have explored the energy intensity of rain tank pump configurations (for example, Retamal *et al.* 2009), none to date have aligned energy demand directly to individual water end use events (such as energy demand for half toilet flush). The predominant issue resolved through the following exploratory data analysis process was the accurate disaggregation of events and water balance calculations when the supply switched between the rain tank and mains supplies, even part-way through high consumption events like irrigation.

In total, five households located on the Gold Coast were included in the pilot study. Stock inventory and socio-demographic surveys were completed for each of these households. Such surveys provide an understanding of the family make-up and their likely water-using behaviours (for example, young children are typically bathed at 5pm), along with the model and star rating of every water using fixture/appliance (for example, a 75L/wash 4-star rating washing machine). A detailed assessment of the rain tank

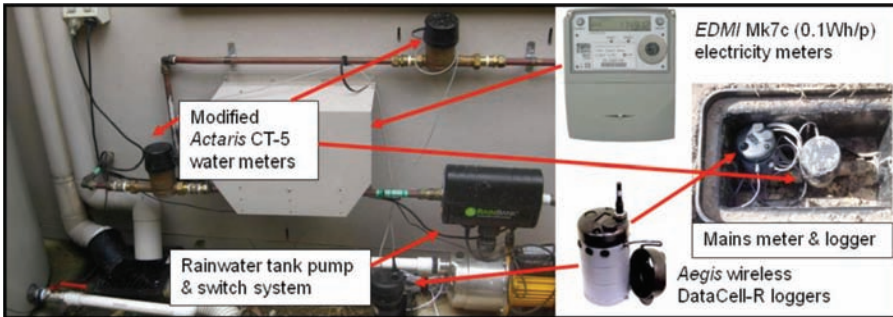


Figure 1: Rain tank end use study experimental design.

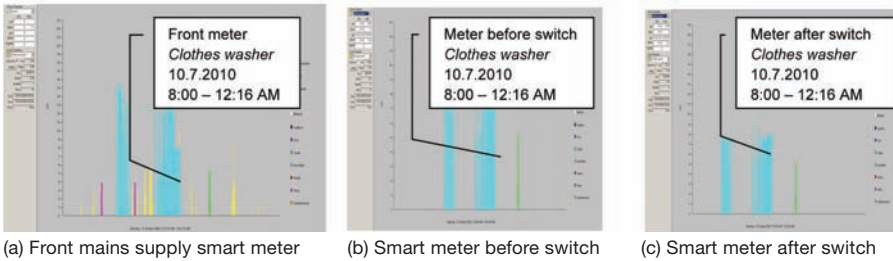


Figure 2: Trace Wizard software showing event supplied by mains water.

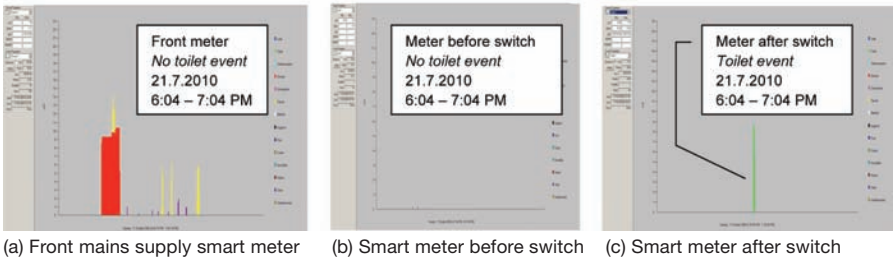


Figure 3: Trace Wizard software showing event supplied by rain tank.

system was also conducted (including pump size, switch system type, first flush size, and so on). All such information aids the analyst completing the end use analysis process (see Willis *et al.*, 2009 for an overview of the end use analysis process) and improves its accuracy.

Figure 1 details the experimental design, which includes three modified Actaris CT-5 high-resolution water meters (one at the front of the household and one on each side of the switch system), an EDMl Mk7c high resolution electricity meter (0.1 Wh/pulse), and two Aegis DataCell-R loggers (one at the front of the household, and one at the rain tank with two flows and one electricity meter input). Flow and energy data was collected at five-second intervals and transferred via mobile phone network to the data server on a weekly basis. It should be noted that the pilot study period was only a few weeks, but this was sufficient to ensure that the experiment could handle end use disaggregation of flow data when the rain tank supply switched to mains and vice versa.

As displayed in Figure 1 and discussed in detail later, the three meters enable the determination of all end use events in the household and their supply source even when the event is split between

supplies. For example, if the rain tank plumbed end use is supplied by mains water, the same flow trace will appear on both the front-of-house meter and the meters located before and after the switch system. Otherwise, a flow event pattern supplied by the rain tank only appears for the meter after the switch system.

In fact, the experiment has proven to provide even higher end use categorisation accuracy than the ongoing mains-only end use studies. This improved trace analysis comes from the additional meter after the switch system improving the deductive process when multiple mains-supplied events are occurring simultaneously (for example, when the shower and washing machine are running concurrently).

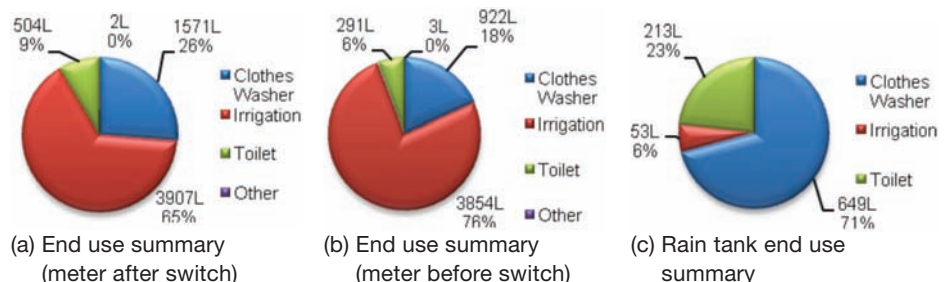


Figure 4: Resolving rain tank end uses.

### Determining Mains and Rain Tank Supplied End Uses

Each site had a 5000L rain tank with a Davey pump and associated RainBank™ switch system. The wireless loggers were set to record for a period from mid-October to early November 2009. The primary purpose of the logging period was to ensure that the supply sources switched over at least once in this period, ensuring that both the rain tank and mains supplied the three mandated end uses (toilets, outdoor taps and washing machine).

The flow trace process using Trace Wizard software has an essential role in this particular study, beyond disaggregating flow into end use events. The process also has a critical role to reveal whether individual events from the rain tank plumbed end uses have been supplied by either the tank or mains water supply sources. For mains-supplied events, the identical flow trace pattern will be clearly evident for the two smart meters each side of the switch system, and the flow pattern will also be displayed at the front meter along with all other events supplied by the mains. As an example, Figure 2 shows a clothes washer event from the mains supply. For a rain-tank supplied end use, a flow trace event will be evident only on the smart meter after the switch system (not the meter before the switch system). As an example, Figure 3 shows a toilet event which is supplied by the rain tank.

Completed end use analysis for the two smart meters each side of the switch enables the resolution of supply from the rain tank and mains supplies. Figure 4 illustrates the end use summary for the smart meter after the switch (Figure 4a), before the switch (Figure 4b) and the resolved rain tank supplied water (Figure 4c), which represents the difference between (a) and (b). For example, the water consumed by the clothes washer from the rain tank is the difference between 1571L and 922L, equating to 649L for the study period. 922L was consumed by the mains supply and will also be evident in the front mains water

supplied end use breakdown, along with all other mains-supplied end uses in the brief pilot study (Figure 5).

## Determining Water End Use Event Energy Intensity

Understanding the energy intensity of various pumping configurations across a range of end use events is essential in order to optimise the design of, and policy for, future internally plumbed rain tank installations. Retamal *et al.* (2009) indicates that an energy intensity range for an internally plumbed rain tank is in the order of 0.9 to 2.3 Wh/L. This study goes beyond total rain tank system energy intensity to reveal the energy intensity of individual end use events for a variety of system configurations. Table 1 details energy intensity sample results for the five particular end use events supplied by the pump at one of the pilot study households. The pilot study results confirmed that the experimental equipment had sufficient data resolution to match pump energy directly to each end use event.

The energy and flow rate profile for each of these events will be explained further. Half-flush events were recognised as having the highest energy intensity (ie, 1.67 Wh/L) among the end use events (Figure 6). Expectedly, these low flow and shorter events also have higher greenhouse gas (GHG) emission intensity rates. This high-energy intensity for half-flush events relates to the short period of that event and the low flow rate to refill the toilet cistern. Similarly, Figure 7 illustrates a full-flush event, which also has high pump energy intensity when compared to other end uses (ie, 1.52 Wh/L). The results indicate that fixed speed and/or high pressure pumps are not optimally configured for such low flow and short duration events.

Figure 8 illustrates the energy intensity for a particular clothes washer event (1.09 Wh/L). While some washer cycles had

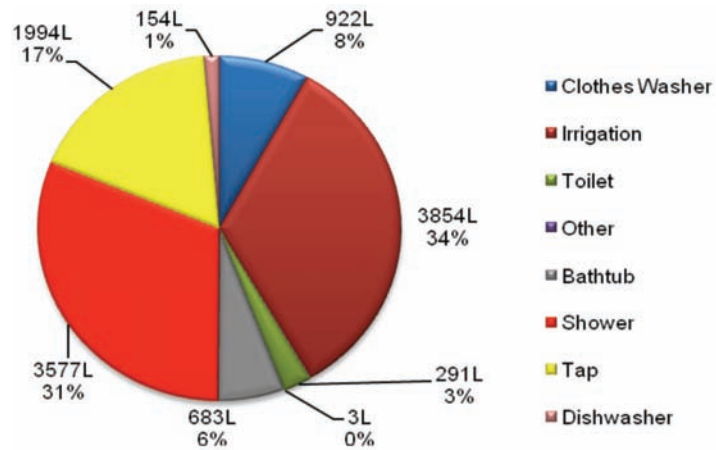


Figure 5: Mains-water-supplied end use summary.

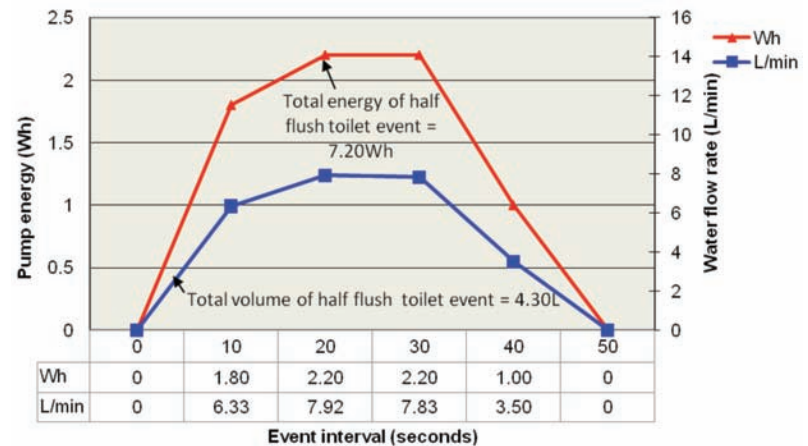


Figure 6: Half-flush toilet event energy intensity plot.

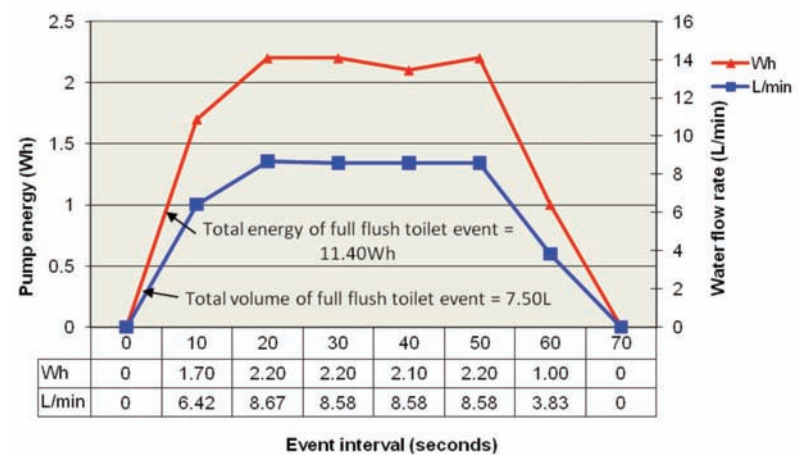


Figure 7: Full-flush toilet event energy intensity plot.

Table 1: Rain tank pump energy intensity for mandated end use events.

Individual end use event	Event volume (L)	Event energy (Wh)	Event energy intensity (Wh/L)	Event GHG intensity (kg CO <sub>2-e</sub> /L)*
Long irrigation	450.30	467.20	1.037	0.00108
Short irrigation	13.13	13.60	1.040	0.00109
Clothes washer (cold-water wash)	118.16	128.80	1.090	0.00114
Full-flush toilet	7.50	11.40	1.520	0.00159
Half-flush toilet	4.30	7.20	1.670	0.00175

\*Note: 1.046 kg CO<sub>2-e</sub> per kWh rate applied for GHG emissions (Source: Queensland Department of Environment and Resource Management.)



higher energy intensity due to the sharp fluctuation in water demand (for example, a 240- to 440-second period), overall the mean flow rate is considerably higher than those for toilet events, thereby working closer to the pump's optimal operating range.

Irrigation events were recognised as having the lowest energy intensity (ie, 1.037 to 1.040) due to the pump working at its optimal range to supply a constant flow rate for the majority of the event period. Efficiency is only reduced for a short duration at the start and end of the event. Figure 9 illustrates the energy intensity for a short irrigation event.

In summary, the above sample results demonstrate that the commenced ARC Linkage Project will be able to provide an extensive matrix showing the energy intensity for a range of pump configurations for the mandated end uses. Such a matrix will undoubtedly provide evidence to develop robust rain tank pump policy and practice guidelines for implementation.

**Pilot Study Summary**

The key points of this pilot study are listed as follows:

- An experimental method has been designed that enables high-resolution

data collection for both the mains and rain tank supplied end uses and their respective pump energy requirements.

- A reliable data analysis procedure has been developed for resolving all household end uses through one smart meter at the front of the property and two near the rain tank (ie, on each side of the switch system), enabling water balance analysis at an end use level.
- Developing a data collection and analysis procedure for aligning end use event water and energy requirements (ie, energy intensity) for the mandated rainwater tank supplied end uses, paving the way for further innovative research in this area.
- Lastly, the pilot study provides the basis for a larger, recently commenced ARC Linkage Project (12-24 months for 50 households).

**Future Work: ARC Linkage Project**

Outcomes derived from the more significant ARC Linkage Project that evolved from this pilot study include the following:

- Development of physical data sets on mains and rain tank water end usage, potable savings and energy use, linked with socio-demographic, environmental and stock efficiency factors.
- Development of an evidence-based assessment on the reliable supply of internally plumbed rain tanks across different household usage patterns, demographic groups, regional contexts, and in relation to relevant policy including potable savings estimates/targets.
- Completion of a rain tank performance improvement study outlining key

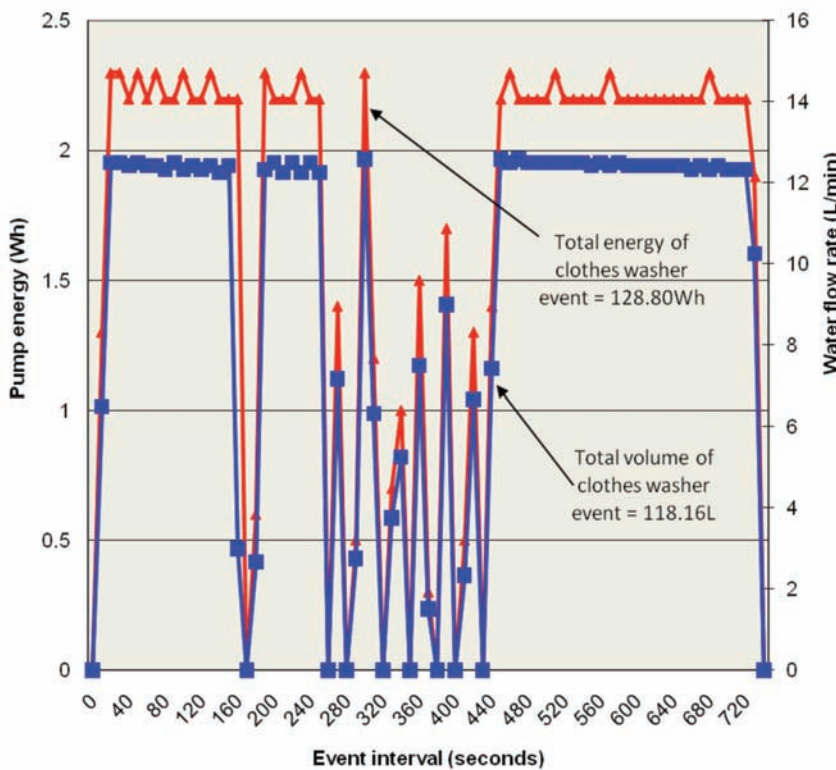


Figure 8: Clothes washer energy intensity.

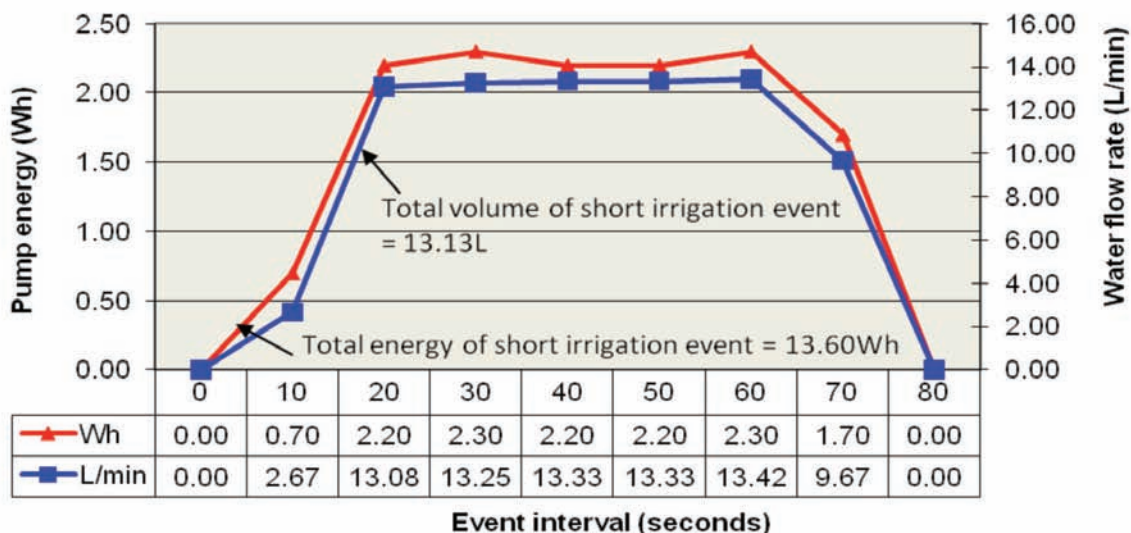


Figure 9: Short irrigation event energy intensity plot.



parameters underpinning the optimised design/configuration of internally plumbed rain tanks and providing relevant policy recommendations.

- Empirical quantification of the influence of internally plumbed rain tank schemes on diurnal patterns, peaking factors and trunk main pump and pipe infrastructure requirements.

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### References

Giurco D, Carrard N, McFallan S, Nalbantoglu M, Inman M, Thornton N & White S (2008): *Residential End Use Measurement Guidebook: A Guide to Study Design, Sampling and Technology*, prepared by UTS and CSIRO for the Victorian Smart Water Fund.

Heinrich M (2007): *Water End Use and Efficiency Project (WEEP) – Final Report. BRANZ Study Report 159*. Judgeford, New Zealand, Branz.

Loh M & Coghlan P (2003): *Domestic Water Use Study* – WA Water Corporation.

Mayer PW & DeOreo WB (1999): *Residential End Uses of Water – Boulder, CO*. Aquacraft, Inc. Water Engineering and Management.

Mayer PW, DeOreo WB, Towler E, Martien

L & Lewis D (2004): Tampa Water Department residential water conservation study: The impacts of high efficiency plumbing fixture retrofits in single-family homes – Tampa Aquacraft, Inc. *Water Engineering and Management*.

Retamal M, Glassmire J, Abeyuraya K, Turner A & White S (2009): *Investigation into the energy implications of household rainwater systems*. Final Report. CSIRO. Institute for sustainable futures, UTS 2009.

Roberts P (2005): *Yarra Valley Water 2004 Residential End Use Measurement Study*. Melbourne, Yarra Valley Water.

Stewart RA, Willis R, Giurco D, Panuwatwanich K & Capati G (2010): Web-based knowledge management system: linking smart metering to the future of urban water planning, *Australian Planner*, 47(2), 66-74.

Willis R, Stewart RA, Panuwatwanich K, Capati B & Giurco, D (2009): Gold Coast Domestic Water End Use Study, *Water*, 36(6), 84-90.

Willis R M, Stewart R A & Emmonds SC (2010): Pimpama-Coomera dual reticulation end use study: pre-commission baseline, context and post-commission end use prediction, *Water Science & Technology: Water Supply*, 10(3), 302-314.



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