Please cite: Beal, C.D., Stewart, RA., Giurco, D., Panuwatwanich, K., (2014). Intelligent Metering for Urban Water Planning and Management. In K. Adeyeye (Ed.), *Water Efficiency in Buildings: Theory and Practice* (pp. 129-145): John Wiley & Sons Ltd, UK.

BD01. Intelligent metering for urban water planning and management

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Introduction

Prosperous cities must be able to respond to future pressures from increasing populations, climate variability and climate change while maintaining adequate water services for residents and businesses. Based on dwindling water supplies (due to droughts and changing rainfall patterns) and projected increasing demands, the management of water resources has become a major concern for residential consumers, industry and all levels of government. Many water constrained cities have recently embraced a combination of initiatives to reduce demand (e.g. installing efficient appliances and undertaking water recycling) and have begun increasing sources of supply through the installation of rainwater tanks and the construction of desalination plants. Such changes to water supply sources and patterns of demand mean smarter approaches to urban water management are required to achieve a sustainable water future; the era of urban water planning that is highly focussed on how to build and supply water has passed. The ever-changing water supply system demands adaptive and innovative management fed by robust information.

Currently, governments and public utilities are investing significant funds in the development and implementation of water strategies in order to ensure future water demands are met. Demand management strategies include water restrictions, rebate programs for water efficient devices, water efficiency labelling, water conservation or education programs and pressure and leakage management (Inman & Jeffrey 2006). Source substitution or 'fit-for-use' water involves replacing specified potable end-uses, such as toilet flushing and irrigation, with recycled, grey or storm water. Water savings achievable from such programs are calculated through a variety of assumptions but, once in place, limited consideration is given to determining the actual water savings associated with these strategies.

The potential of the aforementioned diversified demand management strategies depends on their scale of implementation (Figure 1). The size of the 'bubble' in Figure 1 represents a measure of relative savings potential at the relevant scale (either smaller or larger), with more than half of these measures depending on intelligent metering technology to achieve or effectively monitor their potential. For example, to implement time-of-use or drought pricing, a real-time signal on water use is needed for consumers and utilities. Intelligent meters, which can discern end-uses, can also play an important role in detecting leaks in existing dwellings (Britton *et al.* 2008).

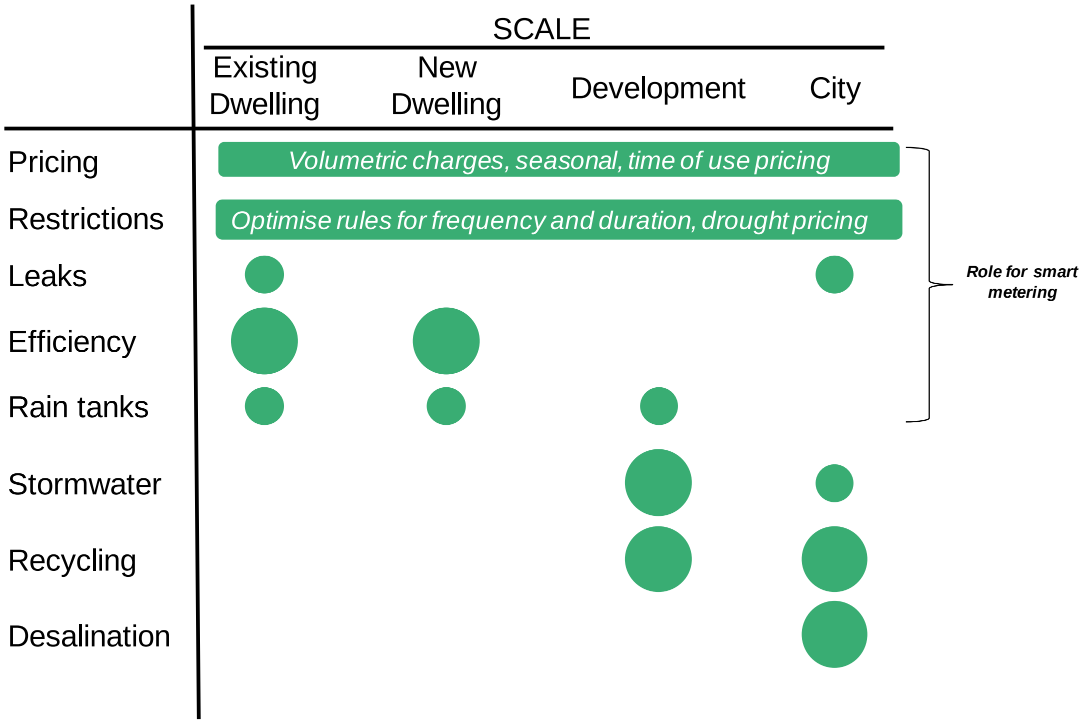


Figure 1: Potential for demand reduction and alternative supply options across scales (Stewart *et al.*, 2010)

The advent of advanced water metering, logging and wireless communication technologies has enabled the dynamic accurate measurement and data transfer of useful end-use (i.e. shower end-use) water consumption information (e.g. Beal & Stewart 2011; Willis *et al.* 2009). Furthermore, real-time data of this nature would help planners and developers to understand everyday water use and consumer behaviour, and their spatio-temporal variability. In order to improve long term forecasting, more data, and information, is needed on the effectiveness and sustainability of demand management techniques (Chambers *et al.* 2005). Although, intelligent metering technologies is increasingly prevalent and are being implemented in an improvised manner, no water organisation on the international stage have developed a robust system which can assist and empower both water users (i.e. households) and managers (i.e. water businesses, architects, planners and state authorities) through with comprehensive, and instantly available reports or comparisons (e.g. comparable household shower use), on water consumption patterns . Moreover, researchers have, to date, failed to proactively provide a roadmap for the coherent adaptation of this wide range of available technologies. Nor have they provided the architecture of a suitable web-based information transfer platform. Both of which could be used to rapidly advance current, outdated urban water resource management practices.

The primary purpose of this chapter is to explore a paradigm shift to sustainable urban water planning and management by outlining the role and implications of intelligent water metering. This is based on the argument that intelligent metering can facilitate a wide range of planning functions including citywide urban planning, infrastructure planning and management, water demand management, and customer satisfaction. Figure 2 illustrates the role of intelligent metering in management and planning across scales.

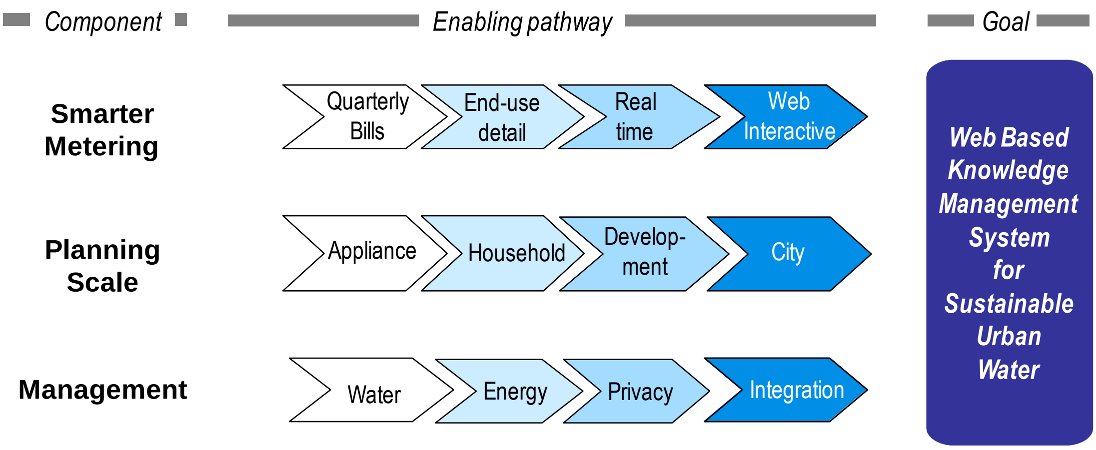


Figure 2: Role of intelligent metering in management and planning across scales

Role of intelligent water metering and big data

This section describes how intelligent metering can be applied across a range of urban settings (e.g. residential, commercial and public sectors) to facilitate sustainable urban planning.

Defining intelligent water metering

Intelligent metering when used in the context of urban water has a range of definitions (Boyle, 2012). Intelligent meters differ from standard meters by improving one or more of the following aspects:

- the information which is recorded (and stored) with respect to water use, for example:
  - more frequent recording of water use (daily, hourly, seconds);
  - higher resolution recording of water use (5-10L intervals to 1-2mL intervals);
  - recording of use via multiple sub-meters (indoor, outdoor, per end-use);
- recording additional information in addition to water flows (this is currently less common in households, but is present for industrial and commercial uses):
  - temperature of shower water;
  - energy use in rain-tank pumps;
  - quality or turbidity of water;
- automated reading / transmission of collected data, for example:
  - drive-by or Automated Meter Reading;
  - via radio, wireless or mobile telephone network;
- ability to access and interact with collected data:
  - from a customer perspective, via a web-based customer portal;
  - from a utility perspective;
  - from a developer perspective in a block of apartments or units.

Whilst some may call an Automated Metering System (AMR) enabling a drive-by read of a standard meter an “intelligent meter”, in fact this is just *intelligent communications*. Intelligent water meters essentially perform three functions; they automatically and electronically capture, collect and communicate up-to-date water usage readings on a real-time (or nearly real time) basis (Idris, 2006). The information is available as an electronic signal, which can be captured, logged and processed like any other signal (Britton *et al.* 2008). Figure 3 provides a schematic of an intelligent metering system.

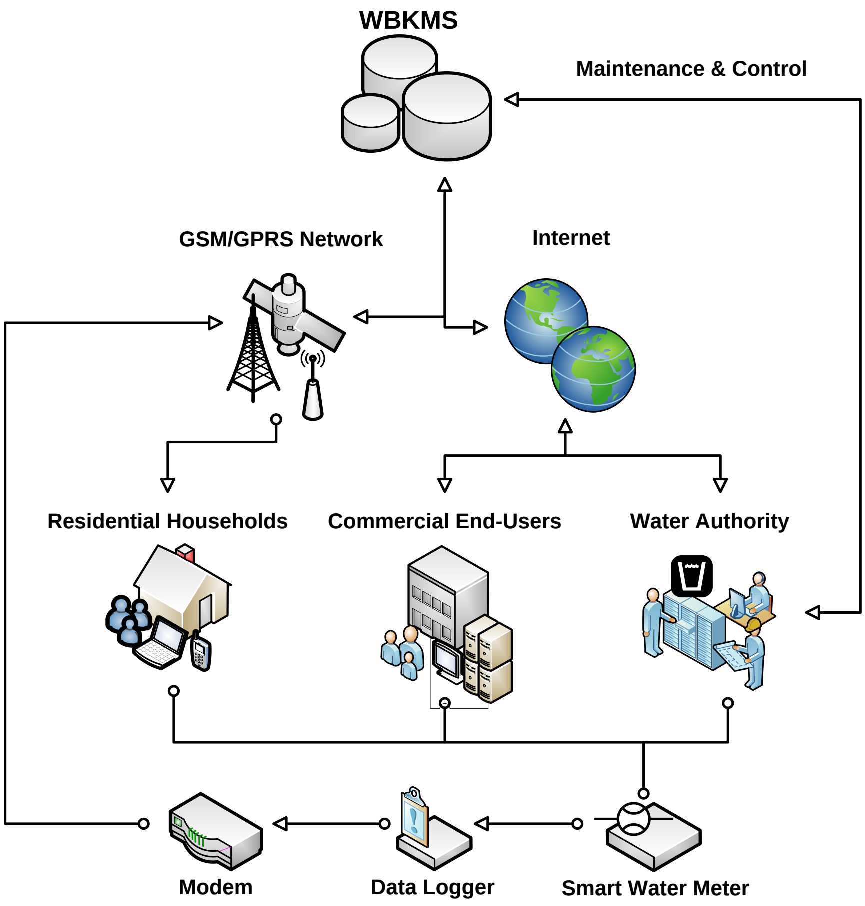


Figure 3: Schematic of intelligent water meter data flow

Drivers of intelligent water metering

The diffusion of intelligent water metering into the urban setting has been slower than that of electricity. However, costs for intelligent water meters (i.e. meter and data logging and transfer) have reduced from several hundred USD to below USD 100, thereby opening up opportunities for much wider deployment. Internationally, large scale deployments are rare. There are a few major rollouts in the USA; New York has 875,000 intelligent water meters, Global Water in Arizona has many thousands. In total more than 10 million are installed in the USA. In Australia, there is a citywide implementation of 20,000 AMR meters in the small city of Hervey Bay, Queensland. Consequently, the multiple dimensions and drivers for intelligent water metering are not yet fully articulated, and nor is the cost-benefit ratio for intelligent water metering understood. To date, drivers for deployment include:

- better understanding of time-of-day residential and commercial consumption
- increasing water end-use (micro-component) insights in residential homes

- identifying leaks
- exploring the potential for time-of-use or scarcity pricing
- seeking behaviour change (more efficient consumption practices) in consumers through in-home displays; and
- raising awareness about own water use in customers.

Barriers to intelligent water metering

To ensure that intelligent metering makes a positive contribution towards sustainable urban water management, a number of factors must be considered. Handling big volumes of data generated by intelligent metering is a critical challenge, and could potentially revolutionise the way utilities operate. Further work to understand the implications of this change are needed. Additionally, more focus ought to be directed to customer needs. While many utilities in developed countries have privatised their telecommunications and energy sectors for several years, urban water still largely remains in a government or quasi-government domain and enjoys monopoly status. Therefore, the focus on customer satisfaction by water businesses is been poor when compared with other privatised utility sectors such as telecommunications.

Over the last ten years, one of the biggest changes in the utility-customer relationship has been the introduction of a website. However, customer access to their own data online; via smart phone or computer, could further change (improve) this relationship (Darby 2010). Poor understanding of customer needs has the potential for customer backlash, which occurred in the electricity industry in Australia (Robins 2012) and overseas (Costello 2012). This was prompted by several factors, including; poorly explained changes to pricing structures, concerns over health impacts of transmissions, service interruptions, physical explosion of metering infrastructure, and concerns over privacy and security.

Security and privacy concerns are also barriers to the uptake of intelligent systems by water businesses, especially securing personalised customer access to their records. Giurco *et al.* (2010) discussed in detail the impact of collecting, collecting and communicating detailed water-use information on householder privacy . Ultimately, more research is required to ensure that utilities can strike a balance between the benefits of data access and potential privacy risks (Giurco *et al*. 2010).

Issues with the management of data will arise if knowledge from intelligent systems is not properly and effectively managed by the utility. Thus, new skill sets for utility employees, including meta-data handling, information management and customer engagement is required when implementing intelligent systems. Utilities that choose not to acquire such skill sets, and outsource associated IT tasks, can incur the risk of technology vendors that propose off-the-shelf solutions that are ill-suited. The outsourcing option could also result in telecommunication companies or internet providers, already proficient in managing data and customer needs, to take on the management of water utility data, or even the utilities. Therefore there is a very real need for utilities to adapt to the intelligent meter and 'big data' age, and lead the implementation task based on theirs and their customers' needs. The future of the water utility will be data rich, hence water utilities need to adapt.

Intelligent metering applications and benefits

Intelligent metering, especially if it enables end-use data disaggregation, can generate a wide spectrum of datasets, of which can form the buildings blocks for a range of citywide urban water planning applications (Figure 4). The benefits related to the key water business functions of citywide urban water planning, infrastructure planning and management, water demand management and customer satisfaction, are discussed in the following sections.

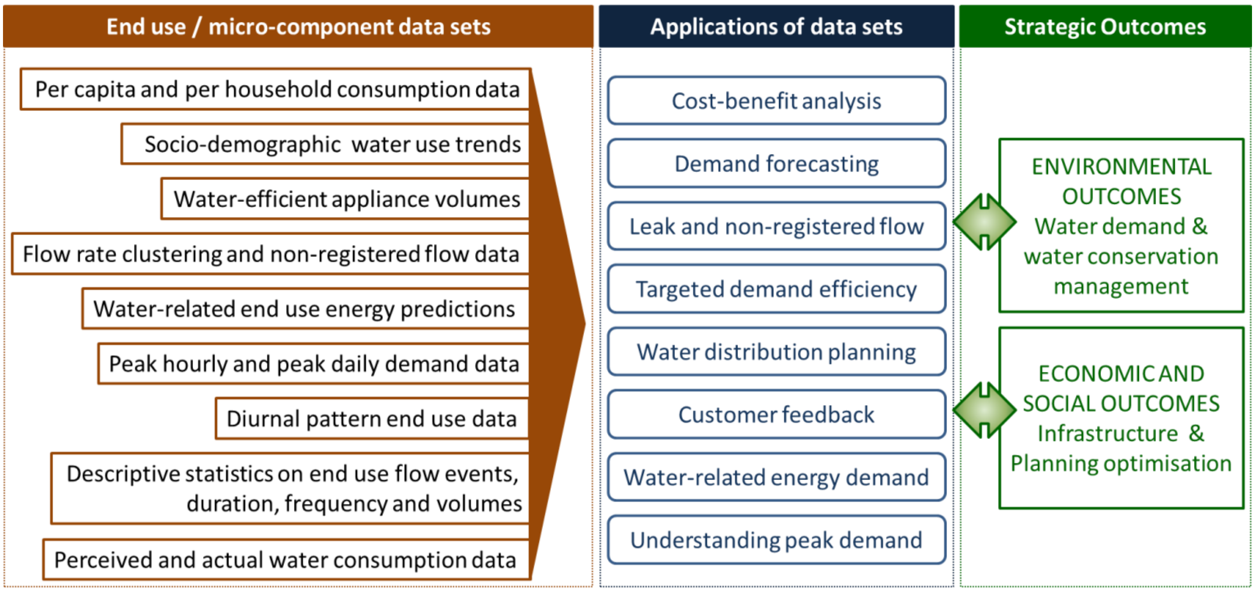


Figure 4: Applications of intelligent water metering and end-use (micro-component) data

Citywide urban water planning

The use of intelligent metering to better understand the water consumption patterns of a city's various residential, commercial and industrial customers will undoubtedly help city and urban water planners to better understand consumption trends and to exploit opportunities to extract greater efficiencies from the present system. Best practice planning for a city's urban water needs is usefully undertaken using Integrated Resources Planning (Turner *et al.* 2010; White *et al.* 2008; Stewart 2011). This concept considers both the changes to future demand, and the available supply. It then identifies options to ensure a supply-demand balance based on a least-cost approach (dollar per kilolitre $/kL). Key determinants of future demand include: changes in population, changes in housing stock (larger or smaller gardens to irrigate, increasing number of water using appliances), changes to the type of water using appliances (more efficient showers, clothes washers) and finally, changes to water use practices (shorter or longer showers, shorter or longer periods of garden irrigation).

As outlined in Figure 1, intelligent metering plays a unique role in informing planning across scales, from better understanding the potential for efficiency (and leaks) in existing dwellings, to understanding the real-time water use practices likely to apply in new dwellings. Uniquely, this system will support the build up of utility-wide databases over time which is based not only on the installed water using devices, but also the variability of expected behaviours and number of residents in households. At the development scale, tens or hundreds of co-located households, increased information about peak demands can inform detailed planning for a plethora of applications from small bore vacuum sewers (saving piping costs), to the patterns of appliance usage (typically toilets, irrigation and washing machines) which could be supplied via recycled water or rainwater.

There are many small sample, short period studies that provide data on appliance stocks and usage patterns in cities (e.g. Beal & Stewart 2011). The advantage of intelligent metering is that large volumes of accurate data could be collected on variables such as the average shower flow rate and, importantly, average shower duration. This data can also be collected instantaneously, thereby enabling immediate understanding on a range of government or water business strategies to shift water consumption levels, particularly in water scarcity periods. The ability to better understand the potential for water savings in times of scarcity – either from restrictions or approaches such as scarcity pricing – could save billions of dollars by avoiding the premature deployment of capital infrastructure such as desalination plants, which have been built around Australia to pre-emptively secure supply. As shown in a study for Sydney (White *et al.* 2006), changes to the form of restrictions and the reliability criteria could considerably increase system yield - without upgrading capital infrastructure. However, in the absence of intelligent metering data, the areas in which customers might save water under modified restriction regimes, and their willingness to tolerate a change in system reliability (e.g. from 97% to 96%), is poorly characterised. System reliability, relates to the number of months (on average) a customer is in restrictions. A 97% reliability criteria means customers will not be in restrictions 97/100 months (or restrictions will not last longer than 3% of the time). In summary, any city planning and management function requires reliable and up-to-date information to inform good decision making. Intelligent metering will enable citywide urban water planning to be far more efficient and effective.

Infrastructure planning and management

Not only does intelligent water metering benefit the planning of urban water supply, it also has far-reaching benefits on the planning and management of an entire water and wastewater infrastructure system. This approach will enable the development of intelligent information systems that can be used to improve urban water practices and achieve a seamlessly integrated infrastructure planning and management system.

Essentially, water and wastewater infrastructure planning and management are focused on long-term strategic planning, which includes: holistic strategies catchment water management;

assessment and conditioning; priority infrastructure planning; infrastructure charges, policy and schedules; growth management; process assessment; research and development; regional planning; and, most importantly, system-wide modelling. By capitalising on a developed intelligent metering system, the provision of readily available demand and supply data from water and wastewater systems as well as household consumption data can serve as a powerful tool that will assist enhanced system-wide modelling through the following capabilities:

- identifying leakage within households, as well as in the distribution system and network;
- providing real-time diurnal pattern data of water demands at a household level that will enable a better understanding of required supply quantities, storage needs, excess supply available for resale or distribution, and discharge volumes; and

providing more accurate and reliable predictive models on wastewater system requirements (e.g. treatment processes, estuarine, marine and river impacts, etc.) through real-time end-use data related to prior knowledge on the typical waste constitute materials associated with such uses.

Successful implementation of the above capabilities can improve infrastructure planning and policy-making for:

- a more effective priority infrastructure planning and regional planning
- a comprehensive understanding of the expandability of a particular region (with existing infrastructure) and management of growth based on water demands; and
- better modelling of water and wastewater systems and improved identification of upgrade requirements for stressed infrastructure (e.g. by linking service capacity to predicted demands).

A couple of demonstration projects on the potential benefits for intelligent metering for infrastructure planning and management have been completed by the authors and are detailed in the following sections.

Influence of stock efficiency on diurnal demand patterns

A recent study conducted by Carragher *et al.* (2012) demonstrates how real-time data collected using intelligent metering approach can provide an insight into a better understanding of water supply infrastructure management. Based on the clustered sets of 191 households participating in an Australian intelligent metering study, the authors identified statistically significant reduction in average day (AD) peak hour water consumption in homes with higher composite fixture/appliance star ratings. They highlighted that the use of efficient water appliances and fixtures contributes to reduced use of potable water supplies and lowers the AD peak hour demand from which water supply infrastructure is designed. The lower peak demand flow rates results in a reduction in pressure on existing network infrastructure, which in turn provides the following add-on benefits:

- lowered demand placed on current pump and pipe infrastructure thus offsetting the need for imminent upgrades and hence large capital cost savings;

- energy and further running costs savings due to the smaller sized pumps remaining in use for a longer period of time; and
- longer draw-down periods of storage reservoirs through decreased demand offsetting the need for necessary upgrades.

The data from any intelligent water metering system also provides significant insight into the development and effectiveness of water demand management strategies at the development scale as discussed in the following section.

Water distribution planning and peak demand analysis

A reduction in the degree and frequency of peak demand days is likely due to the high penetration of residential water stock efficient measures, water consumer behavioural changes, higher dwelling density, and anticipated changes to future climate patterns. Accurate and up-to-date peak demand data is essential to ensure that future mains water supply networks reflect current usage patterns and are designed efficiently from an engineering, environmental and economic perspective. Example of how intelligent metering data can be used to identify peak demand, peaking factors (PD/AD) for infrastructure modelling, and the end-uses driving high demand is shown in Figure 5. Tracking the changes (reductions) in peak hourly and daily flows can offer vital insight into the future peak flows from homes. The implications of knowing the reduction in peak demand potential includes deferral of infrastructure costs and greater ‘optioneering’ for distribution network design (Beal & Stewart 2012).

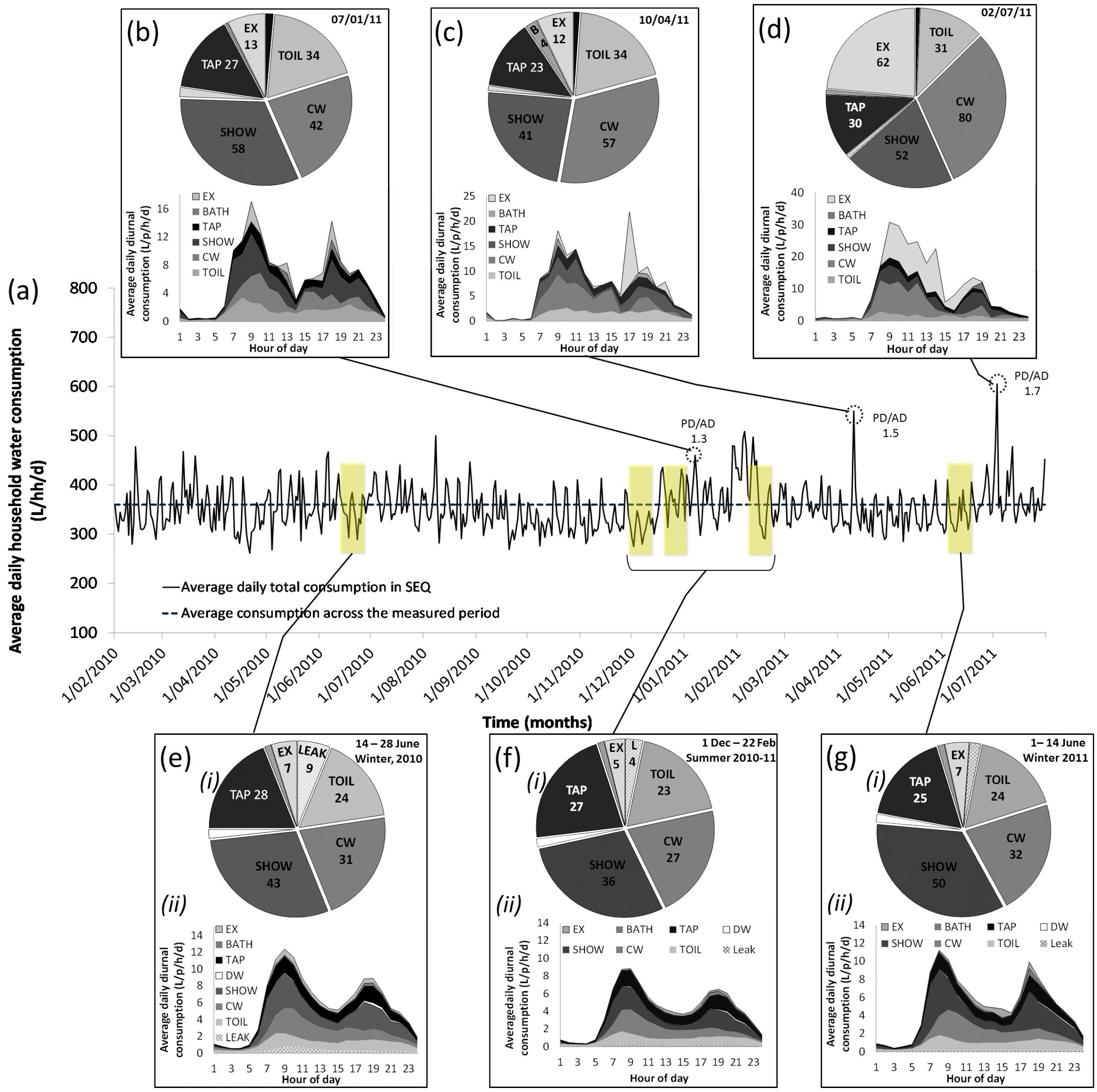


Figure 5: Example of how intelligent metering data can aid better understanding of daily diurnal demand patterns and peak demand (Beal and Stewart 2011)

Water demand management

A shift in public perception towards water requires renewed understanding of the relationships between the end-use *and* the end-users of residential water. Hence, water demand management (WDM) is a term used to define the practical development and implementation of strategies aimed at reducing demand (Savenije & van der Zaag 2002). WDM may be categorised into five key areas: (1) engineering, i.e. installing efficient showerheads or washing machines; (2) economics, i.e. water pricing; (3) enforcement, i.e. water restrictions; (4) encouragement, i.e. rebate programs for water efficient clothes washers; and (5) and education, i.e. promoting water saving practices such as shorter showers (Gold Coast City Council 2005).

Despite successful demand management outcomes, approaches by many regulating authorities to reduce water consumption are often reactionary rather than proactive (Farrelly &

Brown 2011; Kennedy 2010; Rendwick & Archibald 1998). Although there are many examples of proactive water demand management approaches emerging (e.g. Domènech & Saurí 2011; Farrelly & Brown 2011; Inman & Jeffrey 2006), the often reactionary policies to reduce water demand in times of potential supply crisis highlights the need for more detailed information at the "coalface". The use of intelligent metering and subsequent datasets could significantly improve decision making in relation to WDM strategies (Figure 4). In addition, empirical verification on achieved water savings from already implemented programs can be achieved. The application of real-time end-use data, by both water authorities and consumers, will undoubtedly revolutionise the often ad-hoc approach to WDM.

Current demand management functions can be enhanced by intelligent metering-enabled end-use datasets in a number of ways. Some key applications are shown in the middle column of Figure 4. Examples of each of these applications are provided below.

Demand forecasting

Descriptive statistics such as end-use event frequencies, flow rates, mean volumes and durations can provide the fundamental input parameters for demand forecasting models. Total and disaggregated water consumption data will also allow water businesses to monitor the effect of enforcement or restriction levels on water consumption, and also monitor rebound trends following the removal of enforcement strategies. An example of how intelligent metering water use data can be tracked against restrictions and advertised water saving targets is shown in Figure 6.

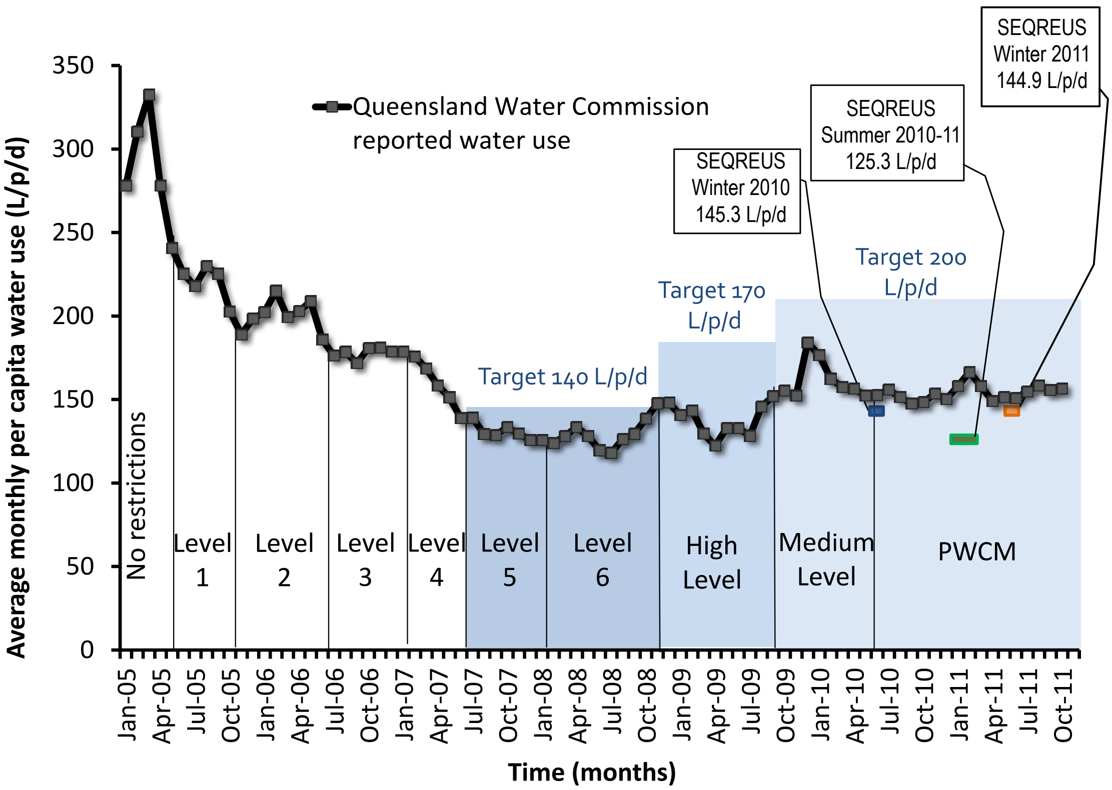


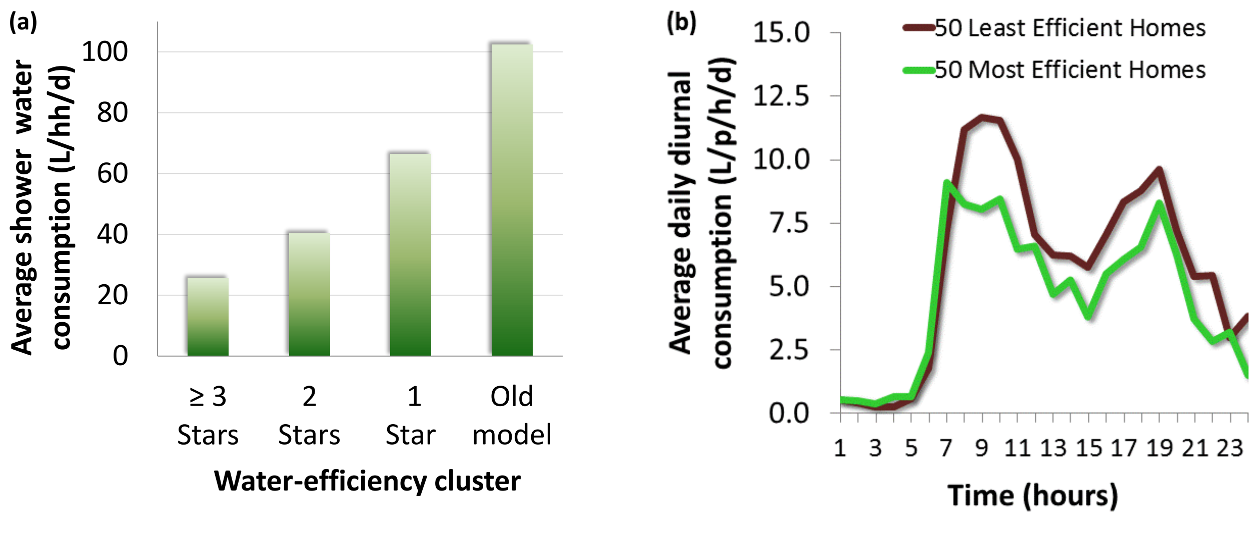
Figure 6: Example of how intelligent metering data can be used to track rebound and compare with regional-wide consumption (Beal and Stewart 2011)

Leak and non-registered flow

Leak and non-registered flow can be identified and managed through high resolution intelligent meters, resulting in the minimisation of undetected leaks and non-registered flow. A real-time monitoring system would also enable water utilities to intervene as soon as an exception alarm is raised for end-uses such as major water leaks (e.g. service breaks). Intelligent meter data can be categorised into flow rate categories (L/hr), which has implications for water meter management and replacement programs.

Targeted demand efficiency

Regular monitoring of end-use consumption data provides the ability to immediately quantify the effect of targeted education programs (e.g. for particular demographics, shower time, rebate program, etc.) on their intended water end-use(s). Therefore, there is a capacity to establish the water savings resulting from implemented engineering applications such as efficient water appliances (e.g. washing machines, shower roses, etc.) as shown in Figure 7, and pressure and leakage management. The analytical report generated by intelligent meters will also be able to help utilities to identify the water consumption patterns of different types of consumers to support education campaigns relating to conservation and water use.



(a) Daily household shower fixture comparisons (b) Average day diurnal patterns

Figure 7: Application of stock appliance efficiency cluster data

Water-related energy demand

The conflict between water use and associated energy consumption is often referred to as the water/energy nexus. Managing water demand through water efficient technology and behavioural changes has strong implications for reducing greenhouse gas emissions as well as conserving potable water supplies. Water-related energy demand can be predicted from analysing the energy requirements and resultant greenhouse gas emissions from measured residential water usage.

Beal *et al.* (2012) recently completed a study demonstrating that intelligent water metering and resultant end-use data, combined with datasets on household appliance water and energy specifications, enabled greater understanding on this water-energy nexus.

Cost-benefit analysis of water efficiency strategies

Intelligent metering and water end-use data provides opportunities for informed and detailed cost-benefit analyses, where financial analysis of the cost and water saving benefits of implemented WDM programs, can ultimately drive a least cost planning agenda. By evaluating the performance of state or citywide rebate programs (e.g. showerhead replacement program), it will be possible to provide firm performance evidence and how it compares against other proposed water supply and demand schemes by the government or water business.

Enabler for urban water tariff reform

The analytical report generated by intelligent meters will also inform the development of different tariff systems to influence consumption behaviour. Time-of-use or other alternative tariff structures can be applied if intelligent water metering is implemented citywide. While there are many fears related to tariff reform, it has potentially strong advantages for reducing consumption in water scarcity periods, peak network periods, etc. Cole *et al.* (2012) explored an hourly block tariff structure and demonstrated that it has the potential to target only those residential customers consuming significant volumes of water for irrigation purposes. Following major tariff reforms instigated by intelligent metering in the electricity sector, a similar policy trajectory will likely ensue in the coming years.

Customer satisfaction

The current metering and billing system only provides a single water consumption data figure to customers on their water bill or rates notice. An intelligent metering system provides a platform for extensive knowledge transfer of water consumption data, directly to consumers. Such a system will offer an easily accessible platform which allows users to log on and see where and when they are consuming water; how they are consuming on a per capita basis; how their consumption compares with others of a similar demographic or sector (e.g. type of commercial customer) makeup, information on current water restriction levels and allocations (i.e. regulated water target split to end-uses), and tips on how to reduce water consumption in areas and periods of high use. Users will be directed to pay their water bill through the system thus providing the need for people to use the system which instigates an understanding of how consumption behaviour translates into charges on their water bill. The functionality requirements for customers of the proposed intelligent metering system include, but are not limited to, the following:

- User log-into the water company's website with their specific login and password for their property (water account). The screen will then take them to a Welcome Page that provides a water use summary for their water connection
- The summary of water use to include water used over the last seven days, the month, year to date and associated costs. A summary of developed water end-use reports for these periods could also be available
- Users can compare their use with the 'average' or 'usual' consumption in their region, suburb, demographic cluster or industry sector. Potentially, this can be achieved at the end-use level for residential customers
- In events where the customer is exceeding normal consumption levels for their category, they may be informed through an alert system. Once an alert is triggered, they could be provided with downloadable fact sheets on ways to reduce consumption in that area (i.e. "leak – how to check" or "high in shower – use efficient shower rose"; etc.)
- The current water restriction levels set by local water business or state authority, and any other relevant information that can be conveyed to them (e.g. water supply level); and
- The reports and recommendations could also provide cost implications over a particular timeframe for reducing water in their home.

The provision of such an intelligent system will help consumers take a higher degree of ownership of their water use instead of the water business or government. Ultimately, the proposed system will be a valuable tool for knowledge and awareness transfer to users, allowing for the heightened levels of government scrutiny of water use, and the associated regulation and enforcement to be considerably reduced over time. Figure 9 provides an illustrative example of a web-based platform that could be viewed on computers, tablets or mobiles, and can be used by customers to better engage with their water consumption, thereby making them more empowered to undertake targeted actions towards water conservation in scarcity periods.

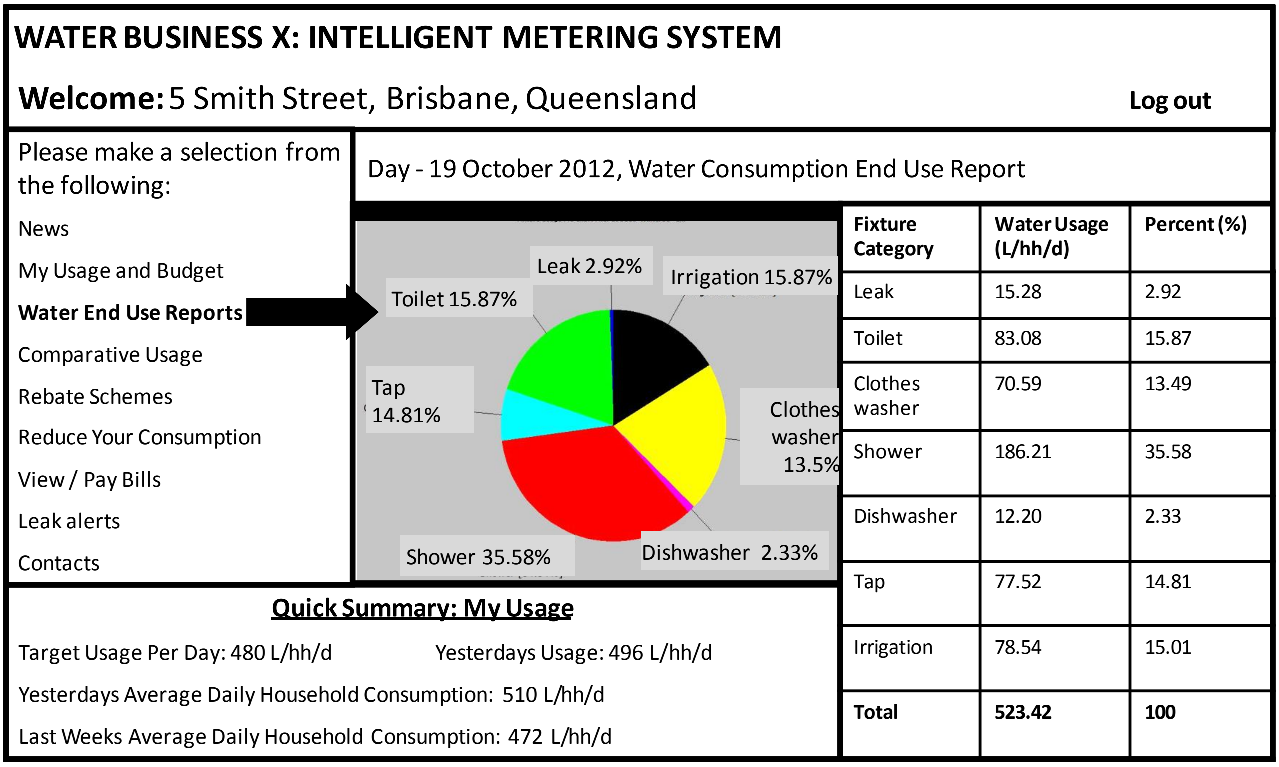


Figure 9: Intelligent water system customer interface illustrative example

Conclusion and recommendations

This chapter has shown how the widespread deployment of intelligent water metering has a range of benefits for the urban water industry and society at large. Introducing intelligent water metering on a wide-scale necessitates the development of extensive databases and a range of autonomous and intelligent data processing modules which can interface with both the customer and water business. If this can be achieved, the valuable information reported from this intelligent system will significantly enhance current urban water planning and management functions.

Current research in the intelligent metering and end-use fields demonstrates the need for the development of such a system, since its creation poses significant benefits for city planners, infrastructure planners, water demand analysts, as well as architects and developers who seek to better understand water consumption patterns in order to design highly water efficient new developments. The system also provides comprehensive information to users which will vastly improve their current level of knowledge and understanding of their water consumption, thus enabling them to proactively address and control their consumption levels. Customers empowered by instant water use information will also likely have a much higher degree of satisfaction with their water supplier. The development of an intelligent system could ultimately lead towards more informed infrastructure planning, strategically developed and monitored demand management strategies and a significant improvement in awareness of where, when and how water is being used, by both water utilities and consumers.

In order to achieve a more rapid diffusion of intelligent water metering systems, a number of barriers need to be addressed, including: (1) current high cost of intelligent meters; (2) poor understanding on the benefits of intelligent metering data; (3) reliability, security and affordability of data communication systems; and (4) monopoly water supply businesses are often slow to engage innovation and less inclined to view high customer satisfaction as a key performance indicator of business. To overcome these barriers, it is recommended that further research and trial implementation studies, such as those presented herein, demonstrating the benefits of intelligent metering be conducted, government incentives for transforming water businesses are introduced, technology investment and large scale production of intelligent meters is completed, and that water industry professionals receive training on intelligent metering technologies, functionality and outputs. If such strategies are effectively implemented, the current rate of successful intelligent metering diffusion could accelerate.

Summary

The key points presented in this chapter on intelligent metering for sustainable urban water planning and management are summarised below.

1. Intelligent metering systems, facilitating the capture, storage and communication of (nearly) real-time water usage, will be a vital strategy for government and public utilities to sustainably manage water supply and demand in the future.

2. Adoption of intelligent metering systems will require not a only a paradigm shift in urban water planning, infrastructure management, and customer relations, but will necessitate a new staff skill set to ensure successful roll out and application of such systems.

3. Applications of intelligent metering in optimising integrated urban water management in the built environment are wide ranging, from: individual end-uses (e.g. usage of specific appliances and fixtures), sectors (e.g. residential, commercial, industry), and spatial scales (e.g. household, sub-division, city).

4. Benefits of intelligent metering include: improving demand management approaches (e.g. tracking the impact of water restrictions, media campaigns, water-efficient technologies), optimising infrastructure planning (e.g. longitudinal peak demand data/peaking factors, more accurate modelling of water and wastewater systems and improved identification of upgrade requirements for stressed infrastructure), and enhanced customer-business relations (e.g. extensive knowledge transfer of individual water bills, leak alerts and improved billing systems).

5. Current barriers to acceptance and adoption of intelligent systems, such as cost, poor knowledge of benefits, and reluctance of utilities to adopt, can be overcome by government incentives, leading to increased research, and importantly, widespread dissemination of successful outcomes of trial implementation studies.

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