END-USE DEMAND FORECASTING: CONTEMPORARY INSIGHTS

Data assumptions and findings across case studies in regional Victoria and the lower Hunter region in New South Wales

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ABSTRACT

This paper reports on the application of integrated resource planning using the integrated supply demand planning tool in regional Victoria (Geelong and Colac) and New South Wales (Lower Hunter region). It discusses data assumptions and findings across the case studies. A key finding is that the uptake of efficient appliances has been decreasing total water use (e.g. in toilets and showers) despite population growth. However, this will be driven close to the maximum limits over the next 15 years or so, while customer behaviour patterns such as length and frequency of appliance use will be crucial for informing future demand side management strategies.

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INTRODUCTION

Ensuring water security is a fundamental objective of long-term urban water planning. Constantly changing projections for population, technology, usage patterns and rainfall make this an ongoing challenge. Integrated Resource Planning (IRP) is an established internationally recognised approach for considering both future supply and demand projections across 25–50 years, which assists in establishing the supply-demand balance of a specific region (Turner *et al.*, 2010). The gap between supply and demand can then be filled using a suite of least cost ($/kL) options, be they supply or demand, taking into consideration social and environmental factors.

IRP is the overarching framework used to inform the integrated supply demand planning (iSDP) model, which has recently been updated using funding from the National Water Commission (NWC). The model assists in projecting water demand for a region using a combination of end-use and sector based approaches. When supply projections are incorporated, the model assists in identifying the lowest cost way to fill the supply-demand gap.

This paper reports on the application of the iSDP model in regional Victoria (Geelong and Colac) and New South Wales (Newcastle) (Fyfe, Giurco, May and Rickwood, 2011; Fyfe, Giurco, May, Mohr *et al.*, 2011; HWC, 2012). It provides an overview of IRP and the iSDP model and summarises and contrasts data, assumptions and findings across the three case study sites, drawing on additional complementary research conducted by the Institute for Sustainable Futures (ISF) and other key researchers in this field.

It also briefly highlights some of the potential influences on end-use that we may need to keep an eye on over the coming years – they could affect demand.

The paper concludes with reflections on remaining data gaps and strategies to strengthen the use of IRP.

METHODOLOGY

Internationally, IRP is considered a best practice planning framework (Turner *et al.*, 2010). It has been used to varying extents by water utilities, councils and water resource managers across Australia since the early 1990s. In several Australian jurisdictions, IRP is embedded as a policy and/or regulatory requirement.

IRP considers both supply and demand side options and treats them equally when determining how to close the supply-demand gap. Over the last decade the Australian water industry has seen a significant shift in the number of water service providers using IRP (to a lesser or greater extent) and practitioners needing to gain new skills in detailed demand forecasting and developing, implementing and evaluating demand management options.

The iSDP model was first developed by ISF for Sydney Water Corporation in the late 1990s to conduct a detailed water planning exercise. This included both the development of a detailed end-use and sector based demand forecast and the development of a broad range of options. The tool, now known as the iSDP model, was further developed by ISF and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and recently updated with funding from the NWC; it is freely available and has been used as a planning tool by various large water service providers in Australia.

Rather than use broad trends for overall demand, the forecast module projects water demand based on a series of disaggregated sectors (e.g. residential, commercial, industrial) and end-uses (e.g. showering, toilet flushing) where feasible. These component forecasts are each based on a series of assumptions relating, for example, to future changes in the mix of housing type and the ownership, usage behaviour and efficiency of fixtures and appliances, among other variables (ISF, 2009).

Residential end-use measurement is concerned with understanding where and how water is used by the domestic customer to determine what proportion of the total water consumed by a household should be attributed to individual end-uses. Understanding where and when people use water in their homes by collecting information about the contribution of various appliances to total water use, the relative split between indoor and outdoor use and/or seasonal and geographical variations in water consumption is essential for determining likely future demands on water supply, detecting system leaks and designing demand management programs (Giurco *et al.*, 2008).

The iSDP model builds up the residential demand using a "bottom-up" approach (see Figure 1) based on the various end-uses. The structure of each of the residential end-uses in the model is similar in that they generally rely on usage frequency and stock/ownership models of appliances or fixtures, which have been refined over a number of years (Snelling *et al.*, 2007). For most end-use categories (appliances) annual sales data are estimated using data on appliance ownership in each year in combination with assumptions about the

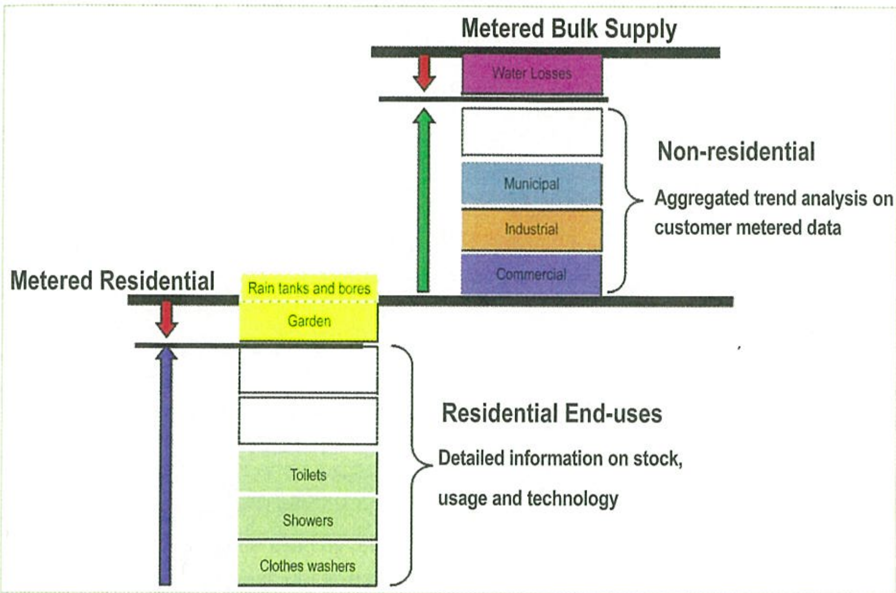

Figure 1. Bottom-up residential end-use and non-residential top-down approach (Mukheibir and Boyle, 2012).

average time that appliances remain in service prior to being replaced.

Key assumptions have been updated as more end-use data has become available. In 2008, for example, Athuraliya *et al.* (2008), on behalf of Yarra Valley Water (YVW), released updated stock profiles of water using appliances and profiled patterns of use, building upon previous work undertaken in 2003 (Roberts, 2004). The key assumptions are discussed further in the following section.

DISCUSSION AND RESULTS

Referring to Figures 2 and 3, wide variations in the disaggregated water use can be observed between different regions. For the Lower Hunter region (NSW), shower use is the leading end-use, followed by commercial and industrial consumption. In Colac (regional Victoria), on the other hand, agricultural use is by far the largest user, due mainly to dairy production, followed by industrial use. In the residential sector, garden irrigation and showers, clothes washers and toilets are the major end-users.

The extent of irrigation will vary depending on the climate, and for all end-uses on the level of efficient stock and behaviour already prevalent, due for example to newer housing stock and/or demand management programs. It should also be noted that some end-uses may not feature in some locations but be a significant user and potential saver in others. An example is evaporative air conditioners in Alice Springs, where over 90% of single residential households used such devices in the early 2000s (Turner *et al.*, 2003). This may have declined in recent years, though, with the shift to reverse cycle air conditioners. This kind of information is essential for understanding demand and planning future water efficiency programs.

Table 1 provides a comparison of modelled estimates of residential end-use consumption for the Lower Hunter region, Geelong, Colac and Wagga Wagga (ISF, 2011) against the end-use studies in Melbourne (Roberts, 2005), Toowoomba and Gold Coast (Willis *et al.*, 2009). As can be observed for indoor use, showers contribute the highest demand for all locations (50–60 L/p/d) and, hence, have the potential to make reductions in demand through the installation of efficient showerheads.

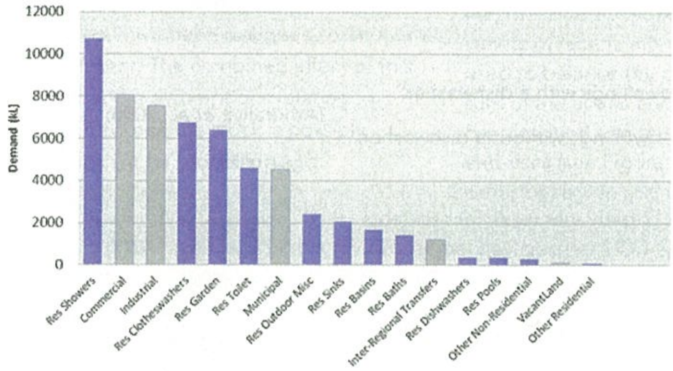

Figure 2. Breakdown of total end-use consumption for Lower Hunter, NSW.

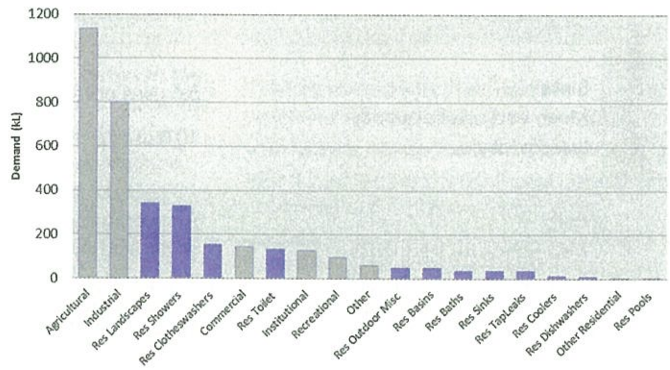

Figure 3. Breakdown of total end-use consumption for Colac, Victoria.

Table 1. Comparison of observed and estimated end-use consumption.

	Demand (L/p/d)						
End Use	HWC Modelled 2008	Barwon Modelled 2010	Colac Modelled 2010	Wagga Modelled 2010	Melbourne 2005	Gold Coast 2008	Toowoomba 2008
Clothes washers	38	28	28	38	40	30	28
Showers	60	56	59	59	49	50	53
Basins & sinks	15	15	16	16	27	27	19
Dishwashers	2	2	2	2	3	2	3
Bathtubs	8	7	7	8	3	7	3
Toilets	24	24	24	26	30	21	16
Irrigation	35	64	62	237	57	19	1

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Table 2. Key end-use assumptions.

	Parameter	Currently used assumptions	Source
Showers	Appliance lifetime	15 years, σ 0.5	
	Mean flow rate (L/min) inefficient appliances	10.1	(Athuraliya *et al.*, 2008)
	Stock of efficient appliances	55% stock efficient in 2012 80% stock in 2022-2050	(Fane *et al.*, 2009)
	Duration of use (min/use)	7.2	(Willis *et al.*, 2010)
	Mean end use frequency (uses/p/day)	0.88	(Athuraliya *et al.*, 2008)
Clothes washers	Appliance lifetime	15 years	
	Stock of efficient appliances	Front loaders – 28% in 2011	(ABS, 2011)
	Mean end use frequency (uses/p/day)	Based upon a power interpolation of per capita usage survey done in 2004 for Melbourne.	(Roberts, 2005)
Toilets	Appliance lifetime	35 years	
	Sales and stock of efficient appliances	Sales • Sales Single flush end in 1987 • Sales Dual Flush 11, 1983–1993 • Sales Dual Flush 9, 1991–2015 • Sales Dual Flush 6, 1996–2015 • Sales Dual Flush 4.5, 2007–100% of sales by 2016 Stock Dual Flush 4.5 approaching 95% in 2050	(Fane *et al.*, 2009)
	Mean end use frequency (uses/p/day)	3.5	(Roberts, 2005) (Athuraliya *et al.*, 2008)
Sinks and baths	Sinks: Water intensity	13.5 litres per use; based on average filled capacity 25L filled to an average 54% filled volume ; 10.3L/week rinsing component calibrated against a historical end-use study in Perth.	(Roberts, 2004) (MWA, 1985).
	Sinks: Mean end use frequency (uses/p/day)	5.6 uses per week for dwellings with a dishwasher; 10.0 uses per week for dwellings without a dishwasher.	(Athuraliya *et al.*, 2008)
	Bath: Mean end-use frequency (uses per person per day)	An average of 2 and 0.17 baths per week for residents under and over the age of 12, respectively, adjusted for the local age distribution.	(Athuraliya *et al.*, 2008)

However, in locations such as Sydney, Melbourne and Brisbane there have been significant demand management programs in recent years, which have assisted in pulling out hundreds of thousands of inefficient showerheads. Hence the potential savings in such locations are now likely to be less. Clothes washers are the second highest users with a wider range (28–40 L/p/d), followed by toilets (16–30 L/p/d). Garden irrigation varies considerably, depending on climate conditions and water supplies.

The end-use modelling is based on behavioural and appliance stock assumptions, discussed in more detail in the following text.

Showers

Work by Fane *et al.* (2009), based on interviews with plumbing product suppliers, and Athuraliya *et al.* (2008), suggests that the stock of efficient showers was approximately 55% in 2012 and that efficient showers will make up approximately 80% of installed showers by 2022. Figure 4 illustrates the uptake curve fitted to the reported uptake of efficient showerheads (ABS, 2007).

The amount of savings from showerhead replacements is dependent on the flow rate of inefficient showers, which is affected by the pressure in the network system. A sensitivity analysis for this key assumption may be appropriate to assess the impact of varying pressures on the flow rate.

Toilets

More efficient dual-flush models were introduced in 1989 (9/4.5L), 1995 (6/3L) and in 2005 (4.5/3L). It is expected that all three dual-flush models will remain as part of the sales mix until 2015, which is consistent with observations by the ABS (2010). Considering that other appliances could assist in meeting the required total water reduction under BASIX (mandatory water conservation for new dwellings in NSW), toilet stock does not, therefore, have to be all 4.5/3L after 2006. In addition, it can be assumed that some non-4.5/3L toilets may still be in operation post-2050.

As illustrated in Figure 5, the installation of more efficient flushing toilets results in

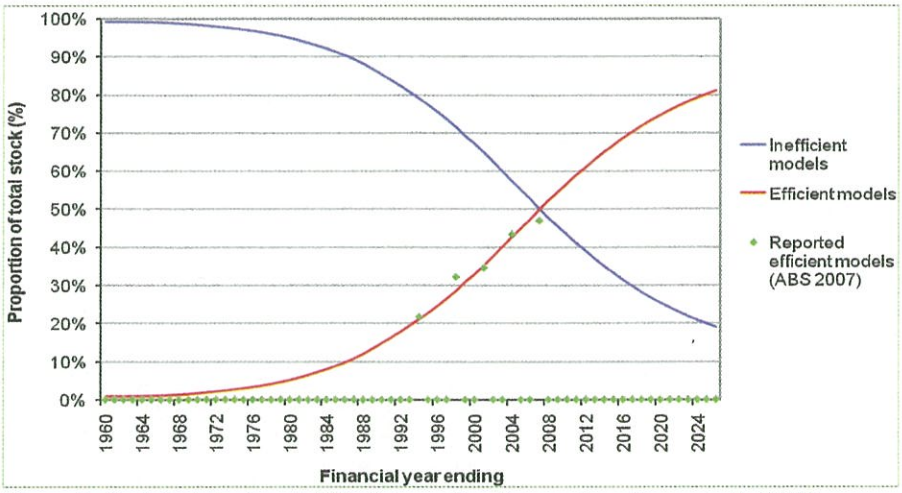

Figure 4. Modelled stock split (%) of showerheads over time (Fane *et al.*, 2009).

the reduction in total water used by toilet flushing. This trend has been observed for all growing urban locations within Australia. However, the reduction in total water demand from toilets diminishes over time (assuming even more efficient devices aren't developed and introduced) and usage is then projected to rise again in line with population growth from around 2030. A similar profile can be expected for showers.

Clothes washing machines

The trend towards front-loading washing machines has resulted in an overall decrease in the water demand from this end-use. However, more recently, front loaders have been produced with larger capacities, while top loaders have been designed to be more water efficient. The combined effect of this means that the assumptions relating to the split between the stock is possibly less significant for modelling and forecasting purposes.

Dishwashers

Dishwashers make up a small percentage of the total residential consumption, therefore small changes in ownership percentages and frequency of use parameters make little difference to the overall picture.

Basins and sinks

Basins and sinks combined make up the fifth largest end-use for residential consumption. The assumptions are based on work done by Yarra Valley Water (Roberts, 2004; Athuraliya *et al.*, 2008), and relate more to the behaviour than to the introduction of efficient appliances.

Garden irrigation

Garden use in most cases is the highest and most variable end-use due to the wide variety of factors affecting it. As such, it is used to balance the difference between the sum of the actual annual metered residential consumption and the sum of all the other end-uses (see Figure 1). Garden irrigation varies by region and climatic conditions

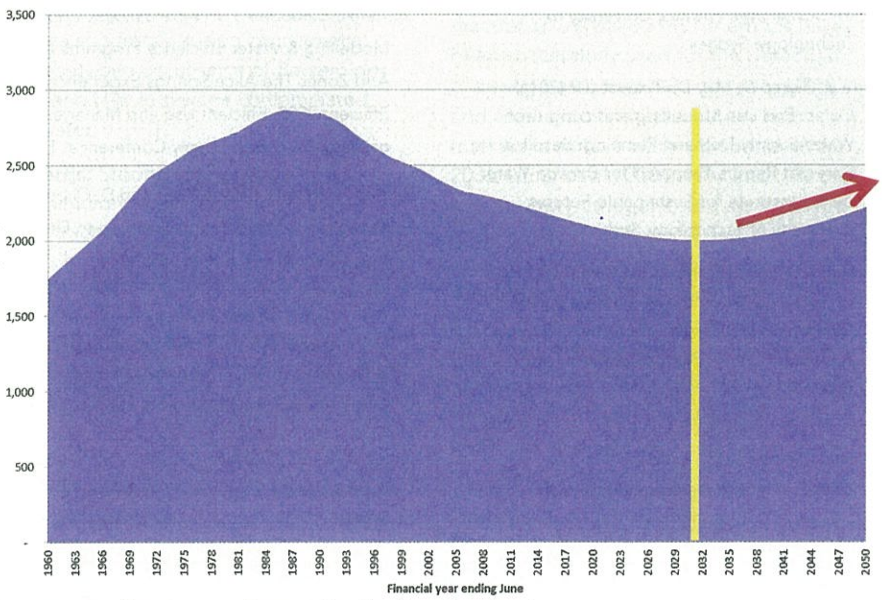

Figure 5. Total water use from toilet flushing for Geelong.

and the residential end-use data should be climate corrected, especially for outdoor use, based on soil-moisture content.

When determining the average garden end-use, alternative sources of supply, such as rainwater tanks under BASIX, should be ignored so that the true demand from gardens can be determined. The suppression of demand for potable water through alternative sources should then be deducted from the total baseline demand at the end of the analysis. This is important, since it is not easy to establish which end-use the alternative water source is offsetting – toilets, washing machines, garden irrigation or other outdoor uses.

It is recommended that a survey for the study region be undertaken to verify the model assumptions and outputs. For the Lower Hunter region, for example, the outdoor usage determined by the model was 20% of the total residential use, which is very close to the average percentage outdoor usage of 19.6% obtained by field survey measurements (Orr *et al.*, 2010).

CONCLUSION

By undertaking end-use modelling, an improved understanding of the customer uses of water and, hence, targeted demand management programs, such as rebates, appliance swaps and incentives can be implemented in order to reduce per capita demand, thereby potentially delaying large infrastructural investments over the medium term.

It has been shown that increased uptake of efficient appliances decreases with specific residential uses of water (e.g. in toilets and showers) even though population continues to rise. This is because the appliance stock is becoming progressively more efficient while usage patterns and behaviours remain similar. Without additional significant shifts in the level of efficiency of such end-uses these major savings are likely to bottom out.

These estimates differ across the various regions of Australia and can be attributed to differences in the social, environmental, economic and regulatory contexts, survey circumstances and, in the case of the modelled estimates, the assumptions used and how the iSDP model is calibrated.

It is for this reason that Stewart (2011, p 27) suggests the need for location based research to overcome the dependency on end-use estimates and to verify the assumptions on which the forecasts are based, such as stock penetration, flow rates and volumes per use, and frequency and duration of use. This data will ensure that the model is appropriately calibrated. In addition, the commercial and industrial demand forecast projections should be updated on an annual basis based on new information. While end-use studies in Melbourne, Geelong and South-East Queensland are providing a more comprehensive picture of usage, notable gaps remain – particularly with respect to outdoor water practices – and it is likely that these will be progressively filled as smart metering studies expand.

As has also been shown, the usefulness of residential appliance stock modelling will extend over the next 10–15 years, i.e. until installed household water appliance efficiency has been driven close to the maximum limits. Thereafter, improved understanding of customer behaviour patterns, such as length and frequency of showers, frequency of toilet use etc, will be crucial in designing demand side management strategies.

With the shifts in customer behaviour experienced due to the prolonged droughts in recent years, greater water availability due to desalination and higher water and energy prices, it will be important to keep a watching brief of how behaviour patterns change due to these conflicting influences. The deployment of household smart meters and the application of the collected data will vastly improve the knowledge in this space.

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