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URBAN WATER FUTURES: TRENDS AND POTENTIAL DISRUPTIONS

DISCUSSION PAPER

2017

ABOUT THE AUTHORS

The Institute for Sustainable Futures (ISF) was established by the University of Technology, Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human wellbeing and social equity. For further information visit: ***www.isf.uts.edu.au***

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The Water Services Association of Australia (WSAA) is the peak industry body that connects the Australian urban water industry, representing over 70 public and privately owned water or water related organisations. Its members provide water and wastewater services to over 20 million customers in Australia and New Zealand. For further information visit ***www.wsaa.asn.au***

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EXECUTIVE SUMMARY

The urban water industry in Australia has undergone significant changes over the last 30 years, especially due to the Millennium Drought. They have included changes to the physical water supply system, reductions in per capita water demand, and changes to decision-making processes and management practices. Not all the decisions made during the Millennium Drought were the best possible, and there are lessons to be learnt and opportunities for improvement. Nevertheless, as a result of the changes made during the drought, Australia now has significant capacity and diversity in supply, including a range of scales of supply and greater integration of decentralised and distributed systems and demand management initiatives. It also now has a mature and innovative water industry with exceptional world leading knowledge, and a new generation of water practitioners with expertise that spans across multiple disciplines (e.g. engineering, technology, customer engagement and economics).

In the future, aging water infrastructure will need to be upgraded and replaced, urban density will increase in our major cities, and disruptions will occur. Due to these changes the water industry will be presented with significant challenges but also many opportunities. The strengths developed during the Millennium Drought will need to be leveraged for another major step change in the water industry. The trends and disruptions will include increases in water use efficiency, new configurations of the water and sewerage systems, increased recognition of the water–energy nexus, reconfiguration of institutional arrangements and better engagement with the community. They will also include major transformation due to the rise of the digital era, which will revolutionise the water industry in ways not yet imagined.

The drought is over, and this is now an ideal time to reflect, to take stock of where the industry is at, to scan the trends, disruptions and innovation opportunities that lie ahead, to imagine what the water industry could look like in the next 20 to 30 years, and to work out what it would take to realise that vision. As the weight of history, the push of the present and the pull of the future unfold, there is a need to take control, innovate, advocate and consciously head in the desired direction to ensure that the collective vision of the future water industry is fulfilled.

This change, or evolution, will need to go beyond sustainability. The water industry, and associated systems, will need to embrace what are now termed “restorative”, “regenerative” or “net positive” principles so that the industry operates within its means and begins to repair the world in which we live. This transition towards “fourth generation” infrastructure will encompass improved water efficiency, improved source control and more effective separation of pollutants and recovery of resources. It will also encompass improved management and control of flows in the system. This will require a greater investment in treatment and reuse compared to investment in the transport of water, sewage and stormwater, and it will require the recovery of energy, carbon and nutrients.

Some key initial steps to take to create such a future will include:

- Australia recognising its place in the ***global context*** in terms of how it is contributing to climate change, nutrient use and other adverse environmental impacts, and how it must help to address these impacts through national and international climate change policy, the UN Sustainable Development Goals and actions that engage the water industry. This will mean creating an enabling landscape for the transition to a regenerative future.

- Having a ***national conversation*** about what the aspirations are for the water industry, and what the industry wants to look like in the next 20 to 30 years. This will involve being cognisant of the "weight" of the past (i.e. how to deal with aging infrastructure), the "push" of the present (i.e. population rise and densification), the "pull" of the future (i.e. desire for green space and liveability), and potential pathways to achieving our goals. This conversation needs to include a broad spectrum of water industry representatives plus other representatives of interlinked sectors such as energy and waste, and it needs to go beyond short-sighted political decisions and engage the community to obtain a broad level of support.

- Creating a ***pool of knowledge***. Organisations such as the Water Services Association of Australia, the Australian Water Association, the Water Directorates, government agencies and the research community need to create this pool of knowledge with broad water industry access to help retain and increase the invaluable knowledge gained during the drought.

- Creating effective ***knowledge sharing mechanisms and pathways*** to help embrace the digital era and the opportunities it offers.

- Obtaining a national view of ***knowledge gaps*** to assist in highlighting core areas in which ***pilot studies*** and other forms of ***research*** are required, together with necessary funding through, for example, a ***research levy*** based on the volume of water extracted or used.

- Undertaking research and pilot studies that stretch boundaries, link with international examples and share ***learning outcomes*** nationally. It will also be necessary to gather associated learning outcomes through the ***evaluation*** of water efficiency, recycling and distributed systems at various scales.

- Through universities and TAFE colleges, ***teaching*** the new generation of water industry practitioners to cross traditional boundaries and become ***innovative problem solvers*** who are at ease with various forms of digital technology, and who can span the disciplines of engineering, technology, customer engagement, policy and economics.

- Expanding and modifying the ***policies and regulations*** developed so far, such as the Water Efficiency Labelling Standards (WELS) scheme, the Water Industry Competition Act (WICA) and the Building Sustainability Index (BASIX), to assist the water industry to more easily implement innovative solutions. This will also involve scanning ***institutional arrangements*** to help break institutional barriers that limit the opportunities to tap into the co-benefits within cities of aligning water, waste and energy systems.

- Developing new ***cross sectoral databases, models and tools*** to identify and tap into opportunities that involve the sharing of multiple forms of data.

These are some of the actions that could aid progress in the water industry. The industry is currently at a critical juncture and is going through a rapid transition phase. It is therefore essential that the industry looks to the future and takes the necessary actions now to deal with the various challenges, opportunities and knowledge gaps unfolding, including embracing the rapidly evolving digital era.

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1. INTRODUCTION

The Institute for Sustainable Futures (ISF) at the University of Technology Sydney has developed this discussion paper for the Water Services Association of Australia (WSAA). The paper discusses recent changes in the water industry as well as trends and potential disruptions in water demand, the water system itself and changes due to the rise of the digital era.

The paper stems from a report developed by ISF and the US-based Alliance for Water Efficiency and Pacific Institute. The report, "*Managing drought: learning from Australia*" (Turner et al. 2016) was written for water planners in the state of California, which at the time faced one of its worst droughts on record. The planners were seeking a single overview of key events and initiatives implemented in Australia during the protracted Millennium Drought from which Australia had just emerged. This would enable them to learn from the Australian experience in demand management and water planning, including some of the key areas in which Australia could have responded more effectively.

The report prompted WSAA to ask ISF to write this short discussion paper that reflects on:

- how the industry has changed in recent years, due predominantly to the Millennium Drought
- what is on the horizon as tools for planning urban water infrastructure change with the rise of the digital era
- what we might need to do in the water industry to embrace and shape the future.

The water industry is a broad sector. This paper focuses predominantly on the demand side of the industry, the response to drought and the customer experience. It deals primarily with how new systems, technology, policy tools and processes will impact on utilities and customers into the future. It does not aim to be exhaustive but merely to outline some of these issues. The paper aims to provide a broad view of the complex urban water system, how it might evolve and how it might be influenced. It aims to be the beginning of a conversation.

The paper has been split into the following sections:

- Reflection and the current situation
- Transitioning the water industry
- Trends and disruptions
- Challenges, opportunities and knowledge gaps
- A vision for the future of the urban water industry.

The paper has been developed using available knowledge, coupled with a scan of innovative demand-side technology through a desktop review and a small number of discussions with utility efficiency experts.

2. REFLECTION & THE CURRENT SITUATION

The Australian water industry has undergone great change over the last 30 years, particularly since the Millennium Drought. The changes have occurred in the water supply system itself, in water demand and in decision-making processes. What follows is a short reflection on some of these changes.

2.1 WATER DEMAND

Water demand in many parts of the country increased in direct proportion to population growth until around the 1980s, when per capita bulk water demand appears to have reached its peak. After this point, the direct relationship between demand and population began to break down, with a move to lower per capita demand in many locations.

For example, in the late 1970s volume-based water pricing and restrictions were introduced in Perth, resulting in a dramatic drop in bulk water demand from a high of over 630 litres/capita/day (lcd) to 342 lcd with a gradual bounceback to around 500 lcd by the mid-1980s (Turner et al. 2005). In Sydney in the early 1980s, bulk water demand was over 500 lcd. By the late 1990s, pre-restrictions per capita bulk water demand dropped to 420 lcd (White et al. 2004). This reduction in demand was due to a number of factors, including a gradual shift to smaller lot sizes and the introduction of the dual flush toilet.

Then the Millennium Drought led to a further downward step change in water demand in most major cities, a reduction that has largely been retained. The reasons for this major recent shift in demand are multifaceted. A key reason is the significant increase in the efficiency of water-using appliances, due to changes in standards and regulations, and to the uptake of those appliances in response to a broad range of incentivised demand management programs. This shift in the level of efficiency and the prevalence of efficient appliances, combined with changes in behaviour and practices, has reduced demand across the board in the residential, non-residential and non-revenue water sectors. Figure 2.1 illustrates this for each sector in South East Queensland (SEQ).

Table 2.1 provides a summary of some of the key initiatives implemented during the drought that assisted in reducing demand, along with examples, drawn from Turner et al. (2016).

Figure 2.1 – Fall in demand in the SEQ region (QWC 2010)

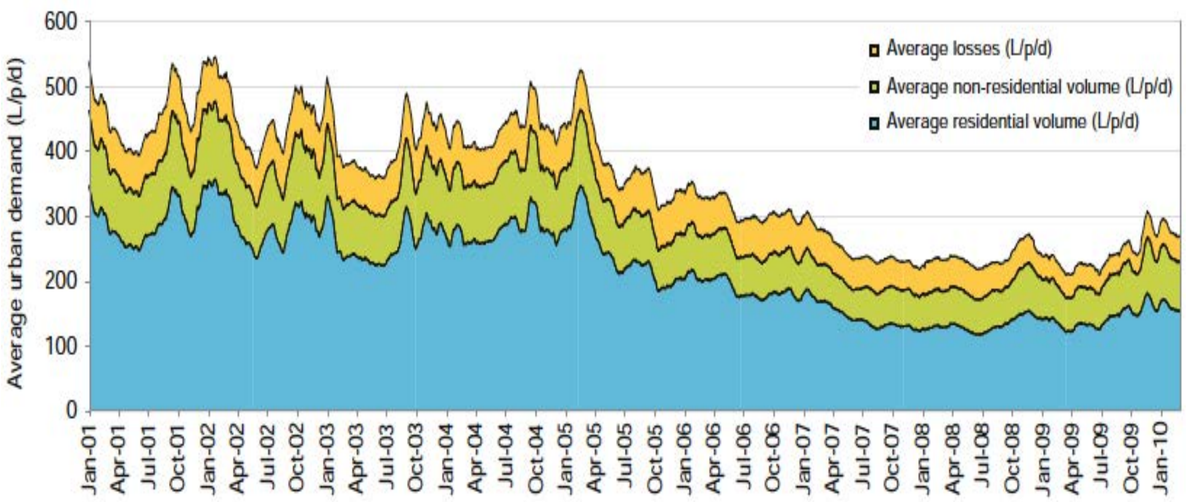


Table 2.1 – Summary of key demand-side initiatives during the drought

Types of programs	Examples
Regulations	
Standards/labelling	National (Water Efficiency Labelling and Standards – the WELS scheme)
Regulations on buildings	Sydney/NSW (Building Sustainability Index – BASIX)
Water use restrictions	Most major capital cities and many regional towns
Voluntary measures	
Standards/labelling	National (Smart Approved WaterMark – SAWM)
Water efficiency programs	
Residential home audits	Sydney Water (Every Drop Counts WaterFix – 485,000 homes) SEQ (Home WaterWise Service – 228,000 homes)
DIY water saving kits	Sydney Water (over 211,000 kits)
Showerhead swap	Melbourne retailers (>460,000 showerheads) Perth (124,000 showerheads)
Toilet replacement programs	Sydney Water (28,000 toilets) Melbourne (27,600 toilets)
Washing machine rebate programs	Sydney Water (186,000 washing machines) Perth (210,000 washing machines)
Garden programs	Sydney Water (Love Your Garden program – 23,500 home garden visits)
Rainwater tank rebates	Sydney (59,000) and many others
Targeting high residential water users	SEQ High Water Users and One to One program (70,000 homes involved in detailed survey and follow-up personalised plan)

Types of programs	Examples
Target 140/155 (residential lcd)	SEQ (Target 140) Melbourne (Target 155)
Waterless woks	Sydney and Melbourne
Business water efficiency management plans/water saving action plans	All major capital cities
Communication and promotion	All major capital cities and many regional towns
Pressure and leakage management	All major capital cities

2.2 SUPPLY

Demand for potable water has also been reduced through major water recycling initiatives and source substitution initiatives. Table 2.2 provides a summary of some of the key supply initiatives implemented during the drought along with examples (Turner et al. 2016).

Table 2.2 – Summary of key supply-side initiatives during the drought

Initiatives	Examples
Large storage projects	SEQ (Raising of Hinze Dam & Wyaralong Dam)
Major water recycling	Sydney (Wollongong Recycled Water Scheme) SEQ (Western Corridor Purified Recycled Water Plant) Perth (Kwinana Water Reclamation Plant)
Access to dead storage	Sydney (Nepean and Warragamba)
Groundwater	Sydney and Perth
Inter-catchment transfers	SEQ (Northern, Southern and Eastern pipelines) Melbourne (North-South pipeline)
Desalination	Sydney (Kurnell) SEQ (Tugun) Melbourne (Wonthaggi) Perth (Kwinana & Binningup) Adelaide (Port Stanvac)
Readiness or contingency (real options)	Sydney – desalination and groundwater (2006-2007)

2.3 DECISION-MAKING

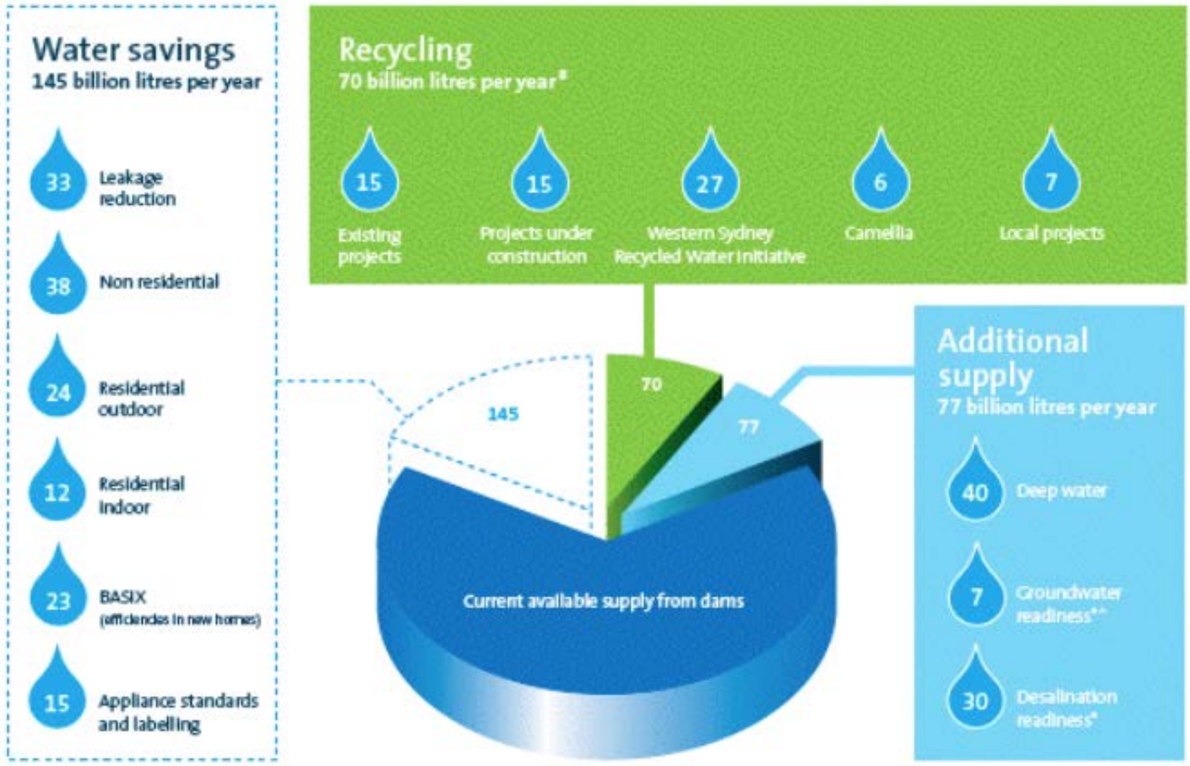
Before the drought the Australian water industry saw the emergence of new methods of urban water planning. These methods, variously referred to as integrated resource planning or integrated supply–demand planning, recognise the importance of diversification of supply sources, and of demand-side measures. That is, they recognise that in efforts to match supply and demand, reducing demand through improved water efficiency is just as important as building new supply infrastructure. Integrated resource planning (IRP), an internationally recognised best practice approach to urban water planning and management, was initially developed in the US in the electricity industry (Swisher et al., 1997; Tellus Institute 2000; Turner et al. 2010a). This approach, along with end use analysis and modelling, was employed by several water agencies, including Sydney Water Corporation, in the late 1990s. This assisted in determining how to achieve water demand reduction targets and in deferring the development of additional water supplies. Also, in Perth and Melbourne in the early 2000s, detailed studies were being conducted on how water was being used in the home to assist in determining how to reduce consumption (Lou and Coghlan 2003; Roberts 2004). These studies also followed the principles of IRP. IRP was subsequently used to assist in water forecasting, in the development of demand-side options, and in options analysis in most major cities in Australia during the Millennium Drought (Turner et al. 2010a).

However, the scale and depth of the drought forced a step change in how water planning and management were undertaken. This presented planners and decision-makers with a crisis, but also with an opportunity to innovate and think differently. Key lessons included:

- Solutions need a mix of demand-side options and supply-side options (that utilise a mix of fit-for-purpose sources) and where possible implementation of the lowest cost options first.
- Demand-side options can deliver significant short- and long-term savings, and when implemented at scale and across the breadth of water use sectors and subsectors (residential, businesses, industries, government and utility non-revenue water), they can maximise potential savings and create a sense of fairness and collaboration.
- Effective supply-side strategies use modular, scalable, diverse and innovative options that take into consideration risk and uncertainty of demand and supply.
- Clear, credible transparent communication about water planning and management is essential for public engagement, participation and support.
- Good data measurement and robust and timely monitoring and evaluation are critical to understanding how water is used and how it can be saved, and to maximising the effectiveness of demand management measures.

An example in which these elements came together during the drought was the formation of the Metropolitan Water Plan in Sydney – a whole of government approach to water planning which instigated significant investment in demand- and supply-side options. This plan also featured, for the first time in the Australian water industry, the application of a “real options” approach based on the principle of “readiness to construct” desalination or groundwater supply capacity (White et al. 2006). See Figure 2.2 for the spectrum of options included in the 2006 Metropolitan Water Plan.

Figure 2.2 - The contribution of various initiatives in the 2006 Sydney Metropolitan Water Plan (White et al. 2006)



Another example is the response to the drought in SEQ, which achieved the most rapid mobilisation of demand-side approaches of any of the major cities (e.g. incentives for efficient appliances, business programs and leakage and pressure reduction) coupled with a major communications and engagement program in the form of “Target 140”, a campaign which used a winning combination of humour and urgency.

However, responses to the drought in many of the major cities in Australia also provide cautionary lessons in terms of planning and management. To avoid the risk of stranded assets from large single investments, for example, a real options approach could have been employed more widely (Productivity Commission 2011). Real options approaches involve the use of smaller staged units and a readiness to construct strategy. The planning and implementation of high cost capital works are staged to allow maximum flexibility during times when the climate and dam levels are uncertain. The real options approach involves selecting the lowest-cost option, as doing so reduces the overall life cycle cost, taking into account the statistical risk associated with rainfall predictions. The real options approach was accepted and implemented in the planning for the Sydney desalination plant for at least 12 months, prior to the decision in February 2007 to proceed to construction (White et al. 2006; Giurco et al. 2014).

Another lesson, which applies to the construction of large-scale water recycling schemes is that individual schemes need to have a strong business case to enable them to provide value both within and outside drought conditions. Many lessons became evident from the water recycling schemes implemented during the drought, and they have been explored in a key Australian Water Recycling Centre of Excellence project, “*Making better recycling water investments”* (ISF 2013a).

Finally, knowledge sharing, strong partnerships and coordination between government organisations were developed during the drought. However, many of these have been, and are being, lost. This represents a significant erosion of water industry knowledge and intellectual capital, creating a risk that the water and financial savings, and the knowledge gained during the drought, may be lost.

2.4 THE CURRENT SITUATION

Whilst there were lessons and opportunities for improvement in some of the decisions made during the drought, Australia now has world leading knowledge in water supply–demand planning, management and decision-making. This knowledge needs to be retained in this time of uncertainty as the impacts of climate change, land use change and the emergence of the digital era become clearer.

As indicated in Section 2.1, Australia now uses far less water on a per capita basis in the urban sector than before the turn of the century. There is significant diversity and capacity in supply in the form of dams, desalination plants, inter-catchment transfers, major water recycling, aquifer recharge and groundwater reserves – depending on the sources available in each region. Australia also has a mature and innovative water industry with exceptional world leading knowledge, and a new generation of water practitioners that span the fields of engineering, technology, customer engagement and economics.

As aging water infrastructure needs to be upgraded and replaced, and as our major cities grow and their population density increases, these strengths need to be leveraged for another major step change in the water industry. This change, or evolution, will need to go beyond sustainability. The water industry, and associated systems, will need to embrace what is now termed “restorative”, “regenerative” or “net positive” principles if we are to live within our means and find a way to repair the world we live in (Australian Water Association 2014; ATSE 2014).

For example, to move from “doing less harm” in terms of resources, energy use, environmental impact and waste generation, to “doing more good”, the water industry is likely to move further towards a circular economy. Much of the nutrient, energy and carbon content, and the value of the freshwater inputs to our water system, is currently not recovered. A restorative approach would mean redesigning systems, not only to reduce resource and energy use and waste generation, but also to ensure that these systems move towards net positive outcomes (Mitchell 2014).

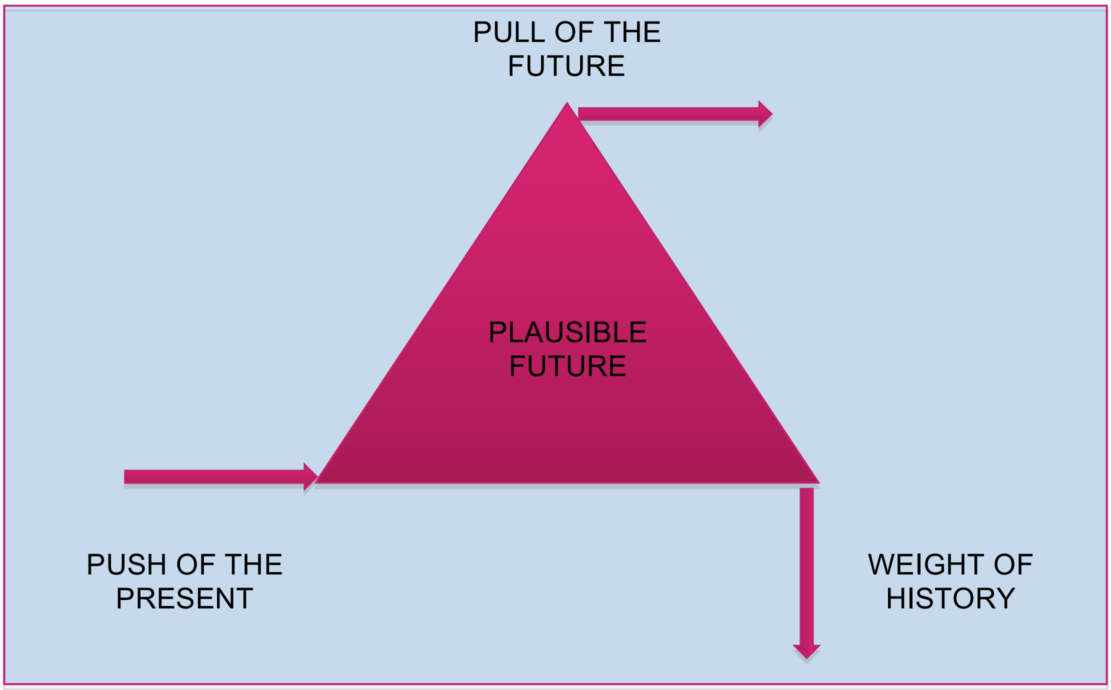
3. TRANSITIONING THE WATER INDUSTRY

3.1 FUTURES THINKING

These are exciting times. There is now an opportunity to stand back and observe the world around us and how it is changing. Instead of allowing the current trends and disruptions in the water and related industries to take us to an unknown destiny, the water industry can take control, innovate, advocate and drive us in the desired direction.

The transition to a plausible water future is characterised by three dimensions, as illustrated by the futures triangle in Figure 3.1. For example, the "push" of the present in this model would include the constraints on network infrastructure and treatment facilities under the current rate of population growth and densification, together with the associated upgrade costs and public disruption. The "pull" of the future highlights drivers such as the demand for green urban spaces that enhance liveability and the promise of the digital revolution and the availability of large data sets. The "weight" of the past reflects the historically siloed approach to water management and regulation which has meant that novel approaches such as decentralised water services and regenerative infrastructure are not fully explored (Mukheibir et al. 2014).

Figure 3.1 – Futures triangle (adapted from Inayatullah 2008)



As part of considering the desired future, and of the barriers and opportunities that might restrain or enable the pathways to that future, it is useful to look at the water system and the trends and disruptions currently being observed or anticipated. These are discussed in Section 4.

3.2 TRANSITION

There are currently significant changes occurring for the Australian water system, in terms of the physical water system, the size and shape of Australian cities, the types of technology emerging in the digital era, and the ways in which people and utilities interact with that technology. The people managing the system are also changing. For example, the workforce is ageing, the industry is smaller than it was during the boom of the drought era, new diverse skills sets are needed, and there is a greater focus on the customer. Institutional arrangements are also changing. This includes the emergence of private retailers providing water, sewerage and energy services embedded in the network.

The traditional urban physical water "system" that has been relied upon in Australia for decades has already undergone a significant shift over the first part of this century due to the Millennium Drought. For decades, large dams were the main source of supply, supplemented in some cities by groundwater. Now, there is reliance on a diverse mix of more rain-independent supply-side sources (e.g. desalination and large-scale water recycling systems). There are now larger contributions from localised source substitution (e.g. water recycling and stormwater/rainwater capture at the estate scale through to the building scale). In addition a diverse range of demand-side measures have been implemented, which have been very important in helping to maintain the supply–demand balance.

Hence, the traditional "managed" physical infrastructure of the system encompassing

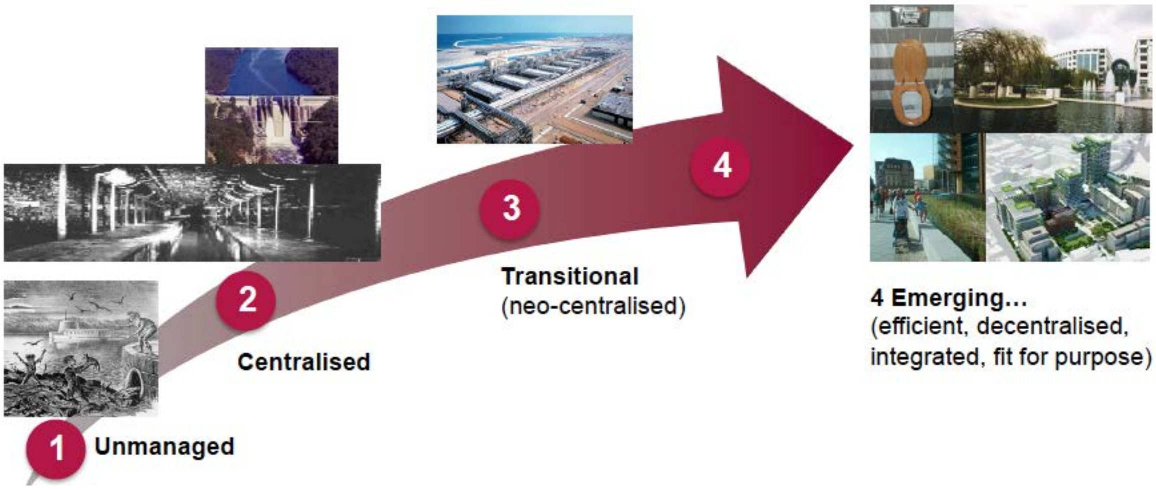
- water supply, treatment and distribution
- wastewater collection, treatment and disposal or water recycling
- stormwater collection, treatment and disposal or water recycling

has become far more complex.

In addition, the critical importance of the customer – the water user on the other side of the water meter, is now also recognised. The water system now encompasses large-scale physical infrastructure, mostly managed by public utilities, with localised water recycling (sometimes managed by the private sector) and property scale infrastructure (e.g. rainwater tanks, stormwater collection) as well as water-using equipment and appliances, and the practices of customers.

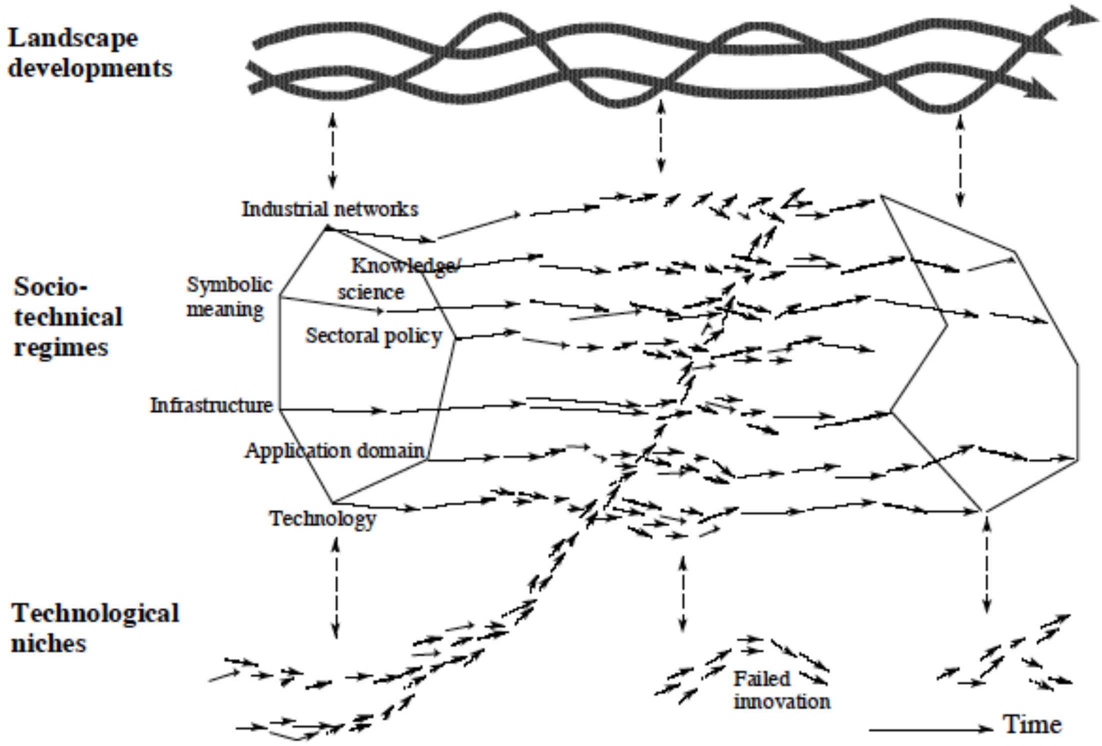
This evolution, from unmanaged systems prior to the industrial revolution (first generation systems) through to large-scale networks, to a more varied system integrating different scales, and utilising the range of water sources, is illustrated in Figure 3.2. In this framework, many cities are transitioning towards a "fourth generation" of water infrastructure. This is characterised by: improved water efficiency; source control; separation of resources and pollutants at source; improved management and control of flows in the system (including a greater investment in treatment compared to transport of water, sewage and stormwater); and resource recovery of energy, carbon and nutrients (White 2010).

Figure 3.2 – Emerging fourth generation water infrastructure (White 2010)



These transitions can be a lengthy process or they may happen quite quickly depending on the “landscape” in which the transition occurs. The Millennium Drought provided a window of opportunity (Kingdon 1995) to make significant changes in some areas, allowing innovation and a wide spectrum of specific technologies to quickly become the norm (e.g. desalination plants, widespread deployment of rainwater tanks and large scale investment in customer water efficiency). These changes were facilitated by “socio-technical regimes” such as specific policies (e.g. national regulations such as WELS, utility efficiency targets and government grants for rainwater tanks and large-scale water recycling) and knowledge transfer (e.g. multiple industry conferences on desalination, rainwater and efficiency, and the fostering of practitioner networks and communities of practice). Figure 3.3 illustrates how these windows of opportunity can occur with respect to the landscape, socio-technical regimes and technological niches. These technological niches come to the fore and have an impact as windows of opportunity occur.

Figure 3.3 – Depiction of socio-technical transition (Geels 2001)



As we look to the future, in the absence of a crisis such as a drought to drive change, we may need to create a favourable landscape and associated socio-technical regimes (e.g. policies and knowledge networks) to support and expedite new emerging technologies and innovative systems enabled by the digital era.

4. TRENDS & DISRUPTIONS

It is now clear that the water industry is in a state of transition, triggered firstly by the decade-long Millennium Drought, followed immediately by the rapid rise of the digital era.

The water system now includes a much larger range of component parts and is far more complex, with many more facets and additional dimensions beginning to emerge, and with customers and their use of water becoming a focal point, in line with the principles of liveable cities.

Within this more complex extended system there are many trends and disruptions, all occurring at different rates and with numerous different stakeholders involved. These trends and disruptions need to be actively managed and further observed in terms of barriers and opportunities in order to realise the desired vision for the future water industry.

Some of those trends and disruptions are discussed below using the following perspectives:

- ***Efficiency – pushing the limits*** – the opportunity to further reduce water demand in individual end uses in the residential and non-residential sectors through ultra-efficiency and even waterless technology.
- ***Systems – going beyond the limits*** – the opportunity to improve systems and close the loop locally with efficient smart technology currently not prevalent, such as vacuum and building-scale water recycling systems.
- ***The water energy nexus – knowing the linkages and trade-offs*** – embedding more efficient and local closed loop systems with a full understanding of the linkages and trade-offs between the water and energy systems.
- ***The digital revolution – harnessing the opportunities*** – appreciating the multiple new facets of the digital era and how these will help revolutionise the water industry in ways we haven't yet imagined.
- ***Institutional arrangements – breaking the chains*** – breaking through the traditional siloed ways of managing our systems and enabling a more holistic view to harness opportunities.
- ***Community engagement – working together*** – listening and engaging with the community so that we create the desired future together.

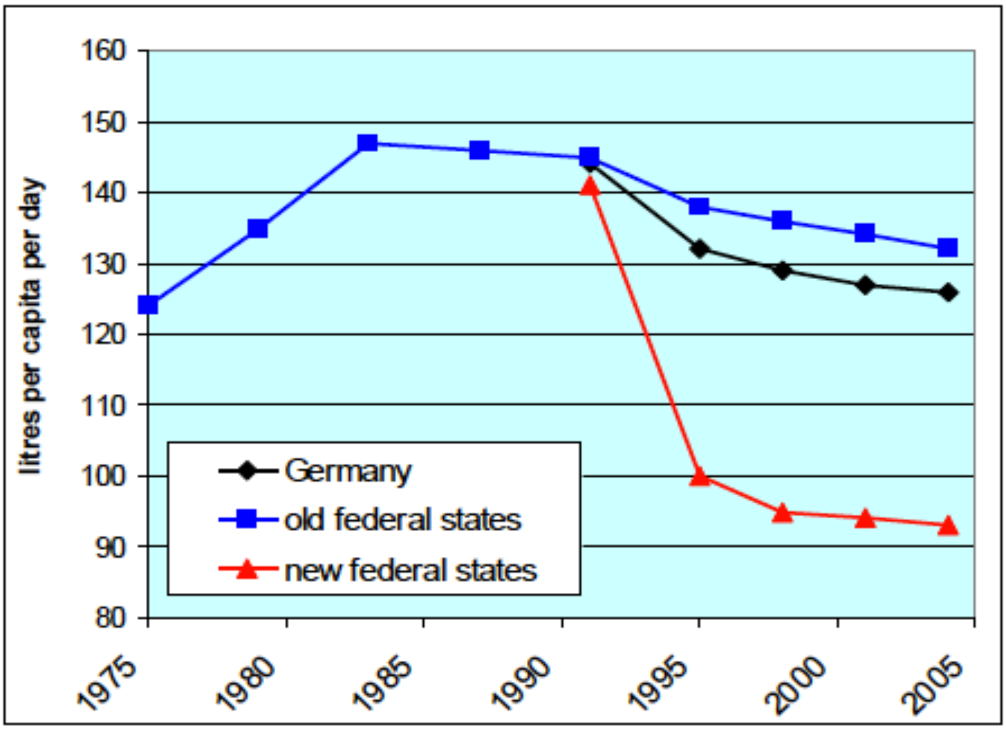
4.1 WATER EFFICIENCY – PUSHING THE LIMITS

The demand for water, like the demand for energy, is generally a derived demand; that is, people use the "services" that water provides (e.g. clean clothes, sanitation) rather than the water itself. Therefore, it is possible to provide those services with a range of levels of efficiency, with different quality sources of water (i.e. fit for purpose), and in some cases without using water at all.

As indicated in Section 2.1, per capita urban water use in Australia dropped significantly around the 1980s. It then dropped again due to the Millennium Drought, with savings largely retained since that time.

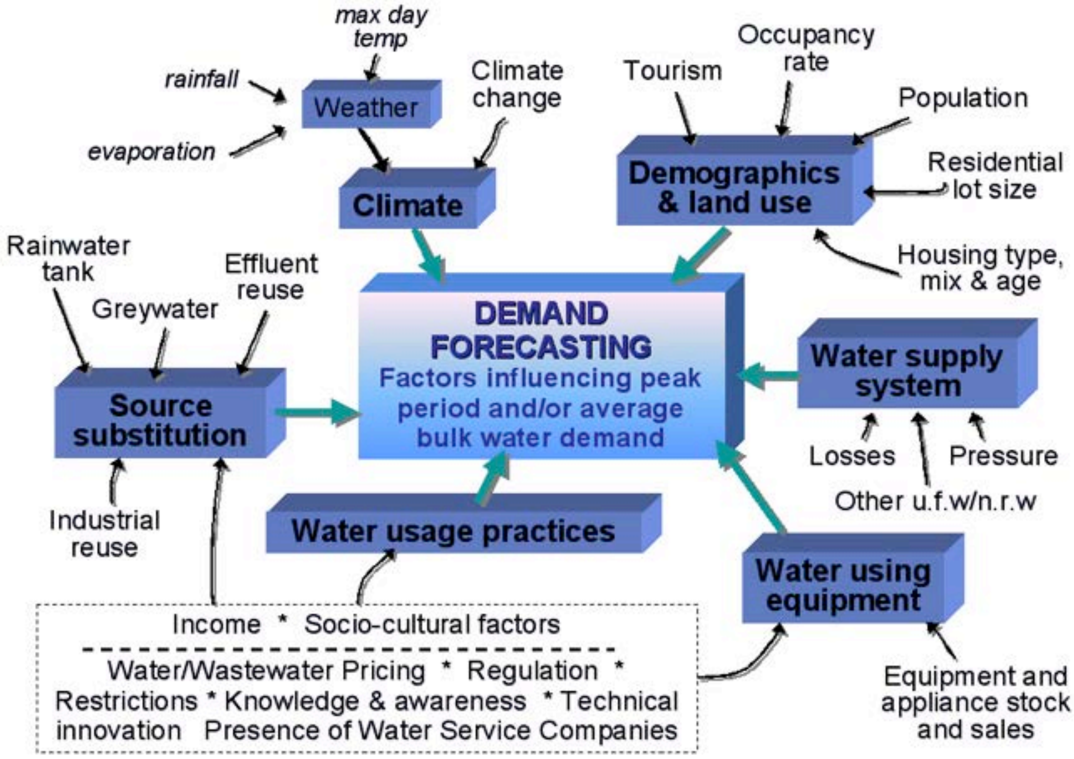
This increase in efficiency is reflected in other high income countries such as Germany, where residential water demand per person peaked, levelled and then began to decline in the 1980s and 1990s as shown in Figure 4.1. Note that in the former East Germany, the improvement was even greater, due to housing renewal leading to more efficient appliances and fixtures being installed, with the residential water demand dropping to just over 90 lcd by the mid-2000s (significantly less than Australian demand even in the peak of the drought).

Figure 4.1 – Changes in water demand in Germany 1975–2005 (Schleich and Hillenbrand 2007)



There are a range of factors that affect urban water demand including: climate; demographics and land use; the water supply system and associated losses and pressure; the amount of source substitution from other sources like rainwater tanks; the level of efficiency of water-using equipment like washing machines; and the associated water usage practices of people. These factors are illustrated in Figure 4.2. For all of these factors (except climate) we have the opportunity to further reduce water demand.

Figure 4.2 – Factors that affect urban water demand (White et al. 2003)



As indicated in Section 2.1, a major factor in the reduction of water demand in Australia has been the improvement in the efficiency of appliances and fixtures over the last 20–30 years and the associated removal of inefficient appliances from the market with the assistance of regulations such as WELS and programs such as the Melbourne-designed showerhead exchange program. This has led to savings of over 50% in the case of toilets, washing machines, showers, dishwashers, cooling towers, urinals and evaporative air conditioners. For example, it has been possible to bring clothes washing water usage down from an average of 140 litres/wash for top loading machines to under 75 litres/wash for front loading machines. However, as an example, only a third of homes have the more efficient washing machines (ABS 2013), so the “conservation potential” which still exists in cities and towns, and which can enable even greater reductions in demand, is significant.

The major potential for further reductions in water demand will therefore come from ensuring that all houses, shops, offices and factories have best practice equipment, and that new or renovated buildings have the latest equipment. There are also the potential additional benefits that can come from improving practices and using processes and systems that further increase efficiency through changes to water users’ behaviour. There was a major shift in the behaviour of water users following the drought, with the success of campaigns to change water use, and the formal adoption of water saving rules, which “locked in" level one restrictions in many states around Australia. For example in SEQ, the water efficiency programs providing rebates for efficient showers and other appliances, combined with the “Target 140” campaign. While a large proportion of the savings made were due to structural changes, changes in behaviour were also responsible for significant savings. There will be a major opportunity for further changes in behaviour through digital services and feedback to water users in the near future, as discussed in Section 4.4.

So what is the future for water demand reduction from improved efficiency in Australia?

Technical efficiency improvements will continue. A technology scan to assess the level of efficiency attainable in new appliances in various sectors indicates that there is still plenty of potential. Whilst some of the new appliances on the market and in development may appear futuristic, and some may need further development, many provide significant opportunities to push water efficiency further. This can be done slowly at a relatively low cost through regulations such as WELS and BASIX, or more quickly through rebates, as seen during the drought. The opportunities apply to both new and existing properties.

Importantly, the trade-offs or mutual benefits between water and energy use must be taken into account to ensure that water use is not decreased at the cost of an increase in energy use or vice versa, as discussed in Section 4.3.

Box 1 provides examples of some innovative new efficient products currently on the market across a range of end uses.

Box 1 – Water efficiency

Showers

Inspired by research at NASA, the Swedish “Orbital Systems” (Orbital n.d.) can save up to 90% of water and 80% of energy. Based on a closed purification system developed by NASA that recycles water without producing waste, purification capsules in the shower base enable used water to be purified, reheated and reused to maximise savings. “Hamwells e-shower” (Hamwells n.d.) from the Netherlands has similar savings. For this device users can use the conventional water efficient showerhead or a recycling system with a reservoir in the shower base to minimise water and energy use. In Australia, “Quench” (Quench n.d.) provides a similar product with a short conventional shower followed by the use of a recycling system with filter and reheating but no purification, using a 4 litre reservoir.

Other efficient shower devices rely on pre-selecting a duration with a countdown display which reduces the flow after the set time (Davinda n.d.). CSIRO has focused on creating a device that can be fitted to an existing conventional showerhead. The Oxijet, a collaboration between NZ-based company Felton and CSIRO, draws air into the water flow, making the droplets hollow. The experience is reported to be of a shower where you feel just as wet as you do in a conventional shower, and the flow is just as strong but the Oxijet saves up to 50% of the water and provides significant energy savings (CSIRO 2013).

Box 1 – Efficiency (continued)

Washing machines

Washing machine efficiency in the residential sector has gradually improved over the last decade. Historically, washing machines typically top-loaders used 140 litres/wash, whereas now with the dominance of front-loading machines they typically use 75 litres/wash. The range of machines available has shown a move to lower water consumption but this has been predominantly in the mid to high-end consumption range. In 2006, 60% of washing machines on the market used 100 litres/wash or less. By 2013 this increased to 90%. However, the share of machines available using 60 litres/wash or less has hardly changed (Fyfe et al. 2015). There are now several highly efficient 5 star machines available that often integrate intelligent sensors to weigh the washing and adjust water consumption. According to the WELS database, ASKO currently provides one of the most efficient machines at only 50 litres/wash based on a 7 kg load capacity (7.14 l/kg). Hoover sell a 10 kg capacity machine that uses 67 litres/wash (6.7 l/kg) (Australian Government n.d.).

In commercial properties (e.g. hotels, laundries, sports facilities) an ultra efficient machine, the Xeros, was released in the UK in 2013. Its development was based on research at the University of Leeds. It uses polymer beads to augment the cleaning process and reduce the water needed per cycle. The beads are removed from the clean washing during an extraction cycle, cleaned and used again for 500 to 1000 washes. This enables the machine to not only save water but also reduce wastewater, energy and detergent use (Xeros n.d.; Hickey 2014). In a year-long trial in the US, it used approximately 5.34 l/kg. It reduced water use by 60% and energy usage by 87%, mainly due to reduced hot water requirements. The manufacturer claims reductions of 72% in water use and 47% in energy use compared to a standard laundry washer (WCEC 2015a). In Australia a "good" washer extractor uses 17-22 l/kg and 12-15 l/kg if a reuse function is installed (Western Water 2009). 5 l/kg is considered best practice (AIG 2013). The Xeros machine is set to hit the US market as a domestic product in 2017.

Other noteworthy technical developments include the LG styler, a steaming wardrobe/cupboard that freshens clothes, reducing the need for washing or dry cleaning, effectively extending the period clothes can be worn between washes by steaming and deodorizing them (LG 2016).

Dishwashers

Whilst residential dishwashers are relatively efficient already, there has been a marked shift in efficiency over the last decade. In 2006, only about 25% of machines available used 14 l/wash or less. By 2013 this was up to 90% (Fyfe et al. 2015). A number of 6 star machines are currently on the market. Blanco and Smeg machines have 15 place settings that use approximately 9.7 l/wash and Neff machines have 13 place settings that use 6.5 l/wash (Australian Government n.d.).

In the commercial sector, wash and dump glass and dishwasher machines typically use 15 l/wash. Research initiated by Sydney Water during the drought showed significant savings could be made in this sector. The new certified recirculating units use less than 3 l/wash, with less than 2 l/wash feasible. Trials have shown that savings in water, energy and chemicals can be in the order of $1,000 per year (NPC 2009).

4.2 SYSTEMS – GOING BEYOND THE LIMITS

Whilst technically, the limits of water efficiency can be pushed without compromising levels of service and without significant increases to costs and energy usage, there are other issues that need to be considered. These include taking account of reduced water flows in sewerage and water systems, and therefore less reliance on water as a transportation mechanism, as well as the integration of technologies that help to close the loop locally.

Incorporating new systems that rely less on water

Most urban wastewater system are based on a century-old hydraulic system with low gradients to take advantage of gravity flow and minimise the depth of excavation. However, the greater the water efficiency of each end use, the more the flows deviate from those the systems were designed for, and difficulties begin to arise due to stranded faecal matter and anaerobic conditions in pipes that cause a build-up of hydrogen sulphide and associated pipe corrosion.

On the other hand, in other areas, where there may be reduced water demand per person, capacity issues can arise in the existing systems. In major cities urban infill and densification places immense constraints on the existing aged water, wastewater and stormwater system, and if conventional system configurations are used, there arises a need for major upgrades with associated disruptions and costs.

Hence, there comes a tipping point, after which there is a need to shift from a conventional system to, for example, a system that relies less on water as a transportation mechanism. Such systems include vacuum systems, which use different toilets and transport mechanisms and significantly less water than conventional systems. These systems also have many other benefits, such as opportunities for retrofitting and changing the interior design configurations of existing buildings, combining organics such as food waste from kitchens to reduce waste disposal, and creating new distributed forms of energy generation through co-digestion. Box 2 provides examples of modern vacuum systems.

Box 2 – Systems

Vacuum systems

Vacuum systems have been used in aeronautical and marine environments since the 1960s, in correctional facilities since the 1990s, and in areas with difficult topography and high water tables for decades (Felix J 2016). However, there has been limited application in mainstream residential and commercial sectors. This is now beginning to change with a hub of activity occurring in Melbourne in the Pixel Building first opened to the public in 2010 through to the more recent Melbourne Water Headquarters and the Victoria Gardens Shopping Centre. In Sydney vacuum technology has been used in the conversion of a heritage listed property, Legion House (Vacuum Toilets Australia n.d).

The Pixel Building is located on the site of a former brewery in Carlton, Melbourne. It was developed by Grocon and completed in mid-2010. At that time it represented a new era in office buildings and achieved a perfect score under the Green Star rating system, being carbon neutral, and one of the most sustainable office blocks in the world. The building has a set of 9 vacuum toilets that use 1 l/flush. The toilets use water sourced from a sophisticated reuse system (Vacuum Toilets Australia n.d.; Sustainability Victoria, 2012). In 2011 the nine-storey Melbourne Water Headquarters in the Docklands was opened with 72 vacuum toilets, using only 0.8 l/flush, servicing 1,100 people (Vacuum Toilets Australia n.d).

Legion House in Sydney is another development by Grocon with 6 star status. Vacuum toilets were used for the refurbishment of this heritage-listed building. Two additional office floors were added to the top of the building with minimal impact being a key requirement. Hence, twelve 1 l/flush vacuum toilets were installed together with small diameter vacuum piping that enabled the pipework to run above, under and around obstacles. The minimal toilet water used is sourced from rainwater tanks (Grocon).

Modern vacuum toilets are part of relatively simple low energy systems. They are connected to small diameter pipes that connect to in-line vacuum pumps. The toilets look very similar to conventional toilets but hold a small amount of water at the bottom of the bowl. When flushed, a vacuum is created in the system that pulls a small amount of water, typically 0.8 l to 1 l/flush, and the waste, out of the toilet. The waste passes along the small diameter pipe using air rather than relying on water. The waste passes through the pump and is discharged to a collection or treatment system. Some systems rely on vacuum on demand and others on a constant vacuum system (typically larger systems with more than four toilets) (Vacuum Toilets Australia n.d.).

Closing the loop

In terms of urban densification, and indeed the development of new growth areas to accommodate Australia's growing population, distributed systems are a glimpse of the future. They rely less on transporting wastewater vast distances to treatment centres and instead concentrate on harnessing, treating and reusing water and wastewater closer to the original source, thereby closing the loop.

There are now many examples of distributed systems of various scales where water demand is reduced through a combination of efficiency and source substitution with rainwater and/or local wastewater recycling for various end uses. The experience of implementing and operating these systems, and of dealing with the challenges involved, has been explored in *Making better recycling water investments,* a research project conducted for the Australian Water Recycling Centre of Excellence (ISF 2013a).

New examples are now emerging in denser city centres where rainwater capture and recycled water use are becoming mainstream, and indeed sought after by tenants, for large commercial and residential-commercial precincts. Box 3 provides details of Central Park in Sydney.

Box 3 – Systems

Central Park

Central Park, a 5.8 hectare residential-commercial precinct, is part of the new gateway to Sydney's central business district. Central Park demonstrates how sustainability can be incorporated into the regeneration of our cities, and it has become a symbol of renewal. The $2 billion precinct, built on the former Carlton United Brewery site, comprises 11 new buildings, 33 heritage items, a 6,400 m^2 public park, 1,200 m^2 of green walls consisting of 35,000 plants from 350 different species, and 2,500 residents and 5,400 workers over a gross floor area of 255,500 m^2. In 2014, shortly after it opened, One Central Park was declared Best Tall Building in the World by the Council on Tall Buildings and Urban Habitat.

This 5 star Green Star award-winning building has:

- incorporated water efficiency and rainwater (ten 200 kL tanks) and stormwater capture which, together with the on-site water recycling plant, mean the site is virtually a net zero mains water consumer
- a Central Thermal and Electric Plant (CTEP), the first of its kind in a precinct setting, which just after it became operational, was awarded Best Cogeneration or District Energy Project by the Australian Energy Efficiency Council in 2014.

The $13 million, 1 Ml/d on-site water recycling system, managed by private utility FlowSystems, will, when fully operational, save 1 Ml/d of potable water and reduce the discharge of wastewater to sewers by an equivalent amount. The $80 million CTEP is run by Brookfield, a private retailer. It will provide low carbon thermal energy to all buildings and electricity to some, resulting in 136,000 tonnes of GHG savings over the life of the plant (equivalent to 62,000 cars) (White et al. forthcoming).

Eastern seaboard areas such as Sydney have a forgiving climate and seasonality, and so they accommodate more easily the water balance required for such distributed systems. Whilst developing such systems is potentially challenging in less forgiving climates in other regions, these examples demonstrate how such systems can be used in the future.

4.3 WATER-ENERGY NEXUS – KNOWING THE LINKAGES AND TRADE-OFFS

The increase in large-scale water supply infrastructure built during the drought to provide diversified sources (i.e. desalination, water recycling and inter-catchment transfers), has significantly increased the energy intensity of centralised water service provision in many cities across Australia (Kenway et al 2008; Cook et al. 2012; Kenway and Lant 2016).

However, it is also the case that the water-related energy demand in cities, which includes energy used in the provision, consumption and disposal of water, is dominated by water use within homes, businesses and government. Only approximately 10% is direct energy use by utilities (Cook et al. 2012; Kenway and Lant 2016).

It is therefore critical that as water demand is reduced through the introduction of water efficiency and distributed and decentralised systems, energy usage and associated greenhouse gases (GHG) are not increased, in the same way that the introduction of new large-scale water infrastructure increased GHG emissions. If this happens, it will create a vicious circle in terms of climate change (Retamal et al. 2010). It is necessary to ensure that reduced water usage also results in reduced energy usage and GHG emissions.

For example, hot water use in homes is a large contributor to overall energy usage (Cook et al. 2012; Kenway and Lant 2016). Hence, an increase in the adoption of efficient showerheads, which have been demonstrated to reduce both hot water and energy usage (Turner et al. 2014), provides a win-win situation. With the new generation of shower systems highlighted in Box 1, these savings could be pushed further.

In the non-residential sector, many of the water efficiency programs implemented during the drought focused not only on water savings but also on energy savings, as the energy savings attained often provided significantly reduced payback periods and an incentive for businesses to take part in the programs offered. With the slow down of demand management programs after the drought ended, large water and energy savings opportunities still exist for many end uses such as cooling towers in the non-residential sector (WSAA 2013).

However, in striving to reduce water usage, and as we begin to combine products to create better utilisation of space in contracting urban living environments due to urban densification, it will be necessary to take care that “sleepers” are not created in terms of energy usage. This is highlighted in Box 4.

Box 4 – Water-energy nexus

Clothes dryers

In Europe, combination washer/dryers are common as they assist in saving space in the home. However, the dryer component of the machine typically uses a condenser system, which, if it is not a vented system, will likely use water as a coolant. Although combination washer/dryers are currently a relatively small component of the market in Australia, as space becomes an issue in households due to urban densification, an increase in the numbers of such “space saving” machines may lead to an increase in both water and energy usage for this end use, which will need to be carefully assessed and monitored. Such machines are currently assessed under WELS (Australian Government 2008).

New research into ultrasonic technology, for potential application in the residential and non-residential sectors, could provide a solution to energy usage in clothes dryers. New research from the US has found that instead of using heat to remove water from clothing, high-frequency vibrations (ultrasonic waves) produced by piezoelectric transducers driven by a custom amplifier could reduce drying times to just 20 minutes, resulting in energy savings of as much as 70% per load. Currently testing a prototype, the research aims to progress to commercialisation in 2017 (Markham D 2016). This kind of technology could potentially replace condenser style water-using clothes dryers.

It is also important to acknowledge where trade-offs between water and energy may be necessary, as illustrated in Box 5.

Box 5 – Water-energy nexus

Cooling

In Australia evaporative air conditioners (EACs) are used in the residential and light commercial sectors. They are used extensively in the drier coastal and inland regions of Australia where they work best due to lower humidity. They use a combination of water and electricity. There is limited data on their water and energy usage, especially the non-residential sector. However, there is strong evidence that excessive amounts of water are being used in EACs and there is significant scope to reduce their water requirements. A study conducted in Victoria indicated that 2.5 Gl (17% of EAC residential water usage) could be saved each year through improved efficiency. Another study for the non-residential sector in Victoria estimated that 1.8 Gl (35% of non-residential EAC water usage) could be saved each year through best practice operation. There are significant opportunities for improvements in the technical and behavioural practices of such units that could significantly reduce both water and energy demand (Murta et al. 2012).

Although such units are high water users, they typically use less than one-fifth of the energy of refrigerative systems to provide the same level of cooling, and around 80% lower peak electricity demand. Hence, there is a trade-off between the water and energy usage of cooling systems (Murta et al. 2012).

In recent years there has been a surge in the installation of split reverse cycle systems that do not use water. This has contributed to peak electricity demand issues. Reverse cycle systems now dominate the market and they are now being used more in areas where EACs would have once dominated. As EAC usage is in decline in these areas, this is reducing water demand but increasing energy usage (Murta et al., 2012).

Recent research in indirect EACs has shown significant potential to increase the range of geographical areas in Australia where EACs can function optimally, creating the opportunity to reduce both water and energy demand. Whilst products such as the Seeley Climate Wizard have won awards for such units (Seeley), further research is needed to determine the extent of the opportunity for their use in the residential and non-residential sectors, as the results of field trials have been mixed, in part due to the operation of the technology (SSE 2012; SWC 2012; WCEC, 2015b). Seeley Residential Climate Wizard Indirect EACs are currently in the field testing stage and are expected to be launched within the next one to two years (Seeley).

Finally, it has been difficult to obtain information on the energy intensity of distributed systems such as rainwater tanks and on-site recycled water systems compared to conventional systems. Several studies have indicated that without careful consideration of system components and configuration, rainwater tanks can be energy intensive and somewhat prone to failure (Retamal & Turner 2010; Ferguson 2011). In addition, many of the recycled water plants currently in place have not gone through a process of system optimisation and/or those implementing such systems do not openly share details on their operational energy intensity. In some cases the operators of such plants are choosing to run them with additional control barriers, with duplication of treatment and/or by treating all lines of water quality through a higher-grade treatment process than required, often to ensure regulatory compliance during the initial operational phase.

Hence, it should not be assumed that such plants cannot be made to operate more efficiently in terms of energy intensity, or that they cannot incorporate energy-saving or energy generation technology, such as solar pumping, tri-generation or co-digestion, depending on the nature of the site. It does mean that work is required to concentrate on operational efficiency and it is necessary to remain vigilant to ensure that as such systems become more prevalent, the water-energy nexus is controlled.

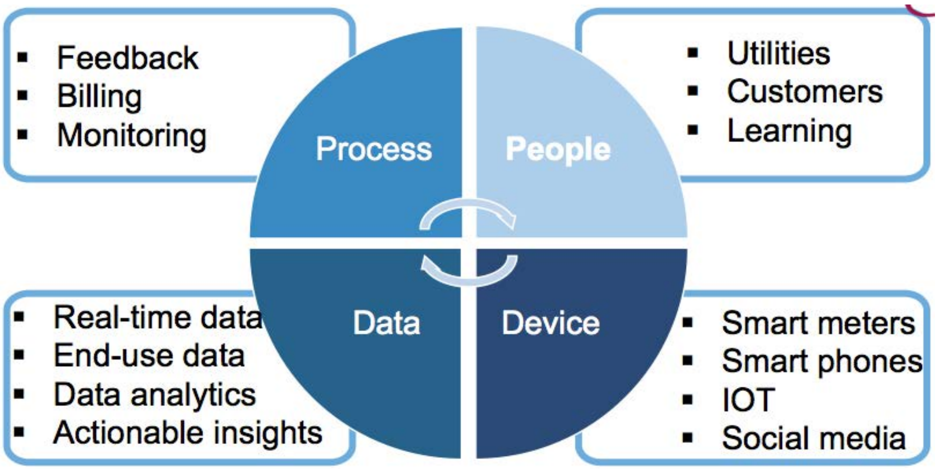
It is also important to consider the embodied energy of the new generation of systems used. During the transition phase, there may be some duplication of infrastructure while new systems are trialled and embedded and existing centralised systems are phased out because they have reached the end of their planned life expectancy. Also, many of the new systems will use dual pipe reticulation. However, in the longer term, as these distributed systems become more stand alone and inter-linkages are optimised, the principles of fourth generation infrastructure are likely to become more evident. That is, there will be more closed loop systems that rely more on smaller localised treatment and reuse, with less reliance on large embodied energy piped transport systems. Consideration of the embodied energy of new emerging systems is less well documented and requires further investigation.

4.4 DIGITAL REVOLUTION – HARNESSING THE OPPORTUNITIES

The digital revolution is here and will permeate every facet of the water industry in the future. Some elements of the digital age have already been integrated, but in many areas the industry has been slow to respond or integrate digital technology. In the future, the kinds of devices, processes and data now emerging will help revolutionise the water industry in ways not yet imagined.

Figure 4.3 illustrates some of the devices, data, people and processes that can be expected to change the industry as the digital era progresses.

Figure 4.3 – Framework for a digitally enabled urban water sector (White 2016).



Smart meters

Smart metering is a prime example of an area where we started to integrate this new technology back in the mid-2000s when Wide Bay Water was the first jurisdiction to install automatic meter reading (AMR) for their entire residential customer base and a number of their non-residential customers, over 20,000 properties. Whilst the metering system showed promise there were many teething problems (Turner et al. 2010b). The system has subsequently been replaced with a more reliable one.

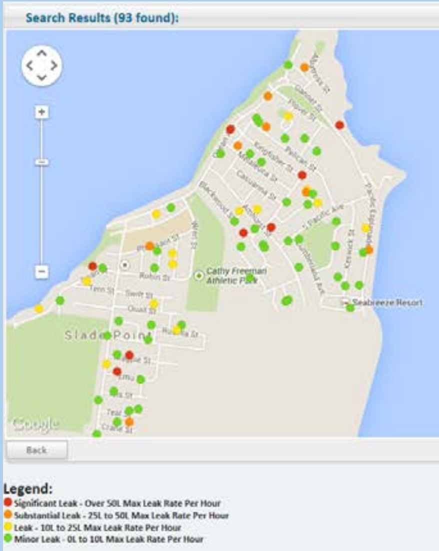
In 2013, 26 water utilities were investigating or planning to use smart metering. By 2014, this had grown to 48 utilities (Beal and Flynn 2013; Beal and Flynn 2014). Hence, this is a rapidly emerging area of innovation. As shown in Figure 4.4, there are now currently over a quarter of a million smart meters installed or planned, but with limited water use data (feedback) provision to customers or the utility, limited knowledge sharing and lack of best practice examples. Box 6 provides some of the best-in-class examples available.

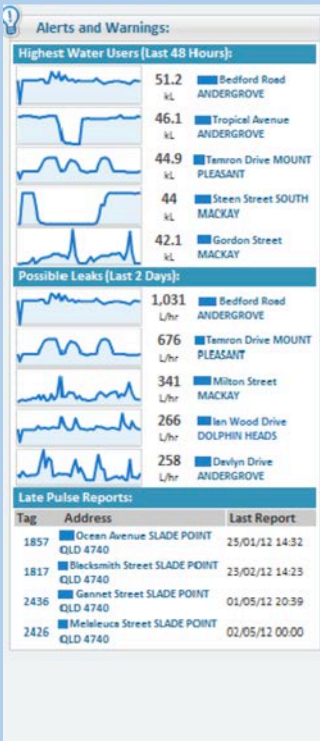
Figure 4.4 – Location of smart meter trials in Australia (White 2016).

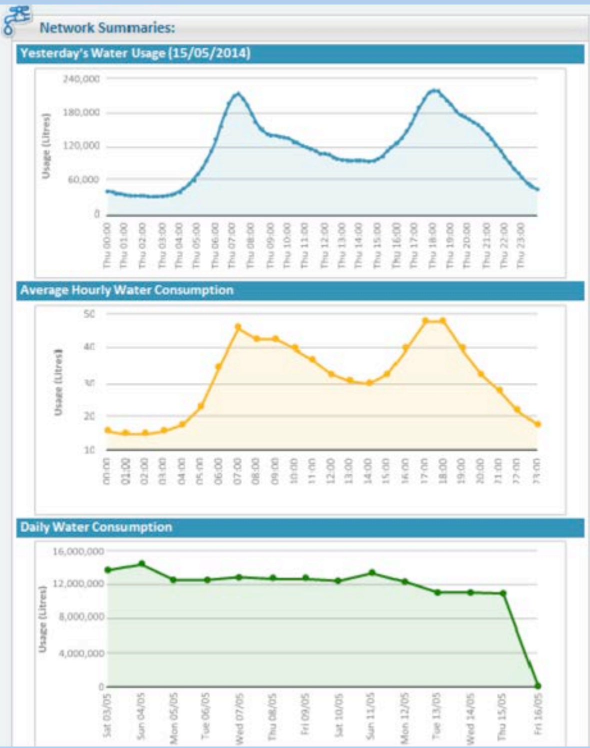
Box 6 – Digital revolution

Mackay Regional Council – smart meters

Mackay Regional Council installed an AMR/AMI smart metering system (Elster meters plus Taggle system), worth $2.5m in their residential sector (100,000 population, 36,000 properties) between 2012 and 2015. The system aimed to aid reduction in monthly peaks to help defer the construction of a water treatment plant and an infrastructure upgrade (set to cost $100m), improve customer knowledge and relations, and improve utility knowledge and network operations. Council has more than achieved these objectives by: cutting peak monthly demand by more than 10%; reducing customer leaks which were found in 5% of properties at any one time; achieving significant customer awareness and engagement through a social marketing and leak alert campaign; further engagement through a customer MiWeb portal released in 2015; and significantly increased Council knowledge of the water network through a sophisticated management system (Turner 2015).

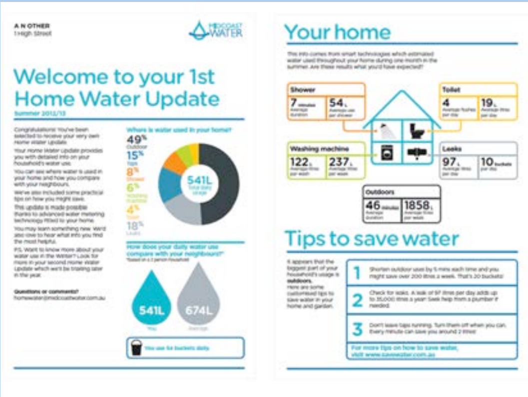






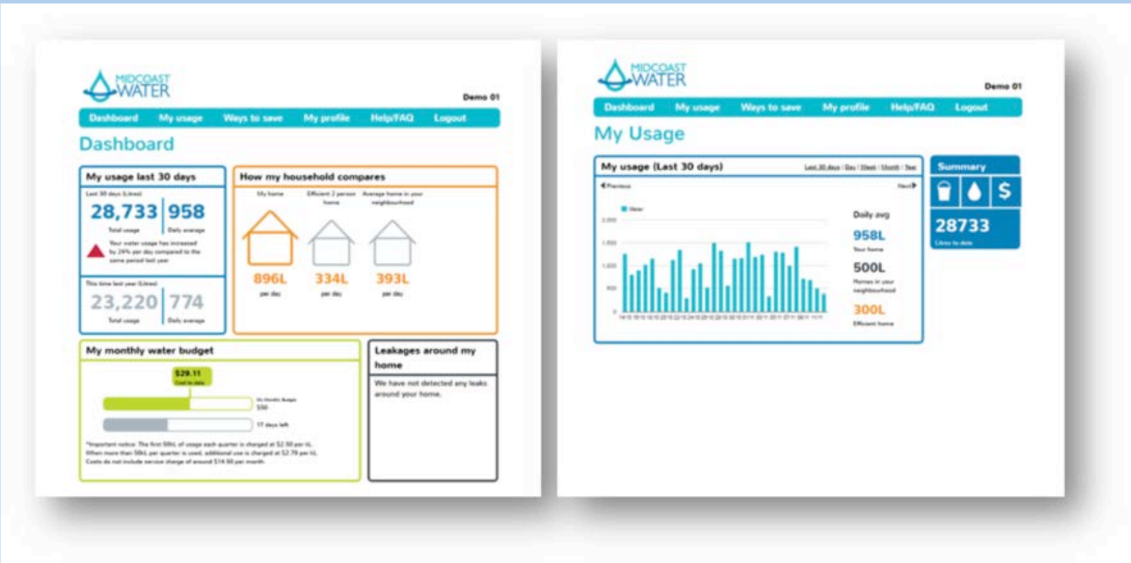
Mid Coast Water – smart meters

MidCoast Water, which similarly provides water and wastewater services to 40,000 households, installed 150 data loggers in 2009 (Datamatic Firefly data loggers attached to Elster meters to record usage at 1 min intervals with a resolution of 0.5 L per pulse). The logger were installed to help collect and compare detailed consumption data for selected summer and winter periods, initially for a pressure management study, and more recently to test smart metering communication methods on local residents.



The 'Home Water Update' study used these smart meters to provide selected households with paper-based reports which included detailed feedback down to an end use level, (i.e. a breakdown between shower, toilet, washing machine, taps, leaks, outdoors consumption), comparisons with others, and customised end use water savings tips (Liu, Giurco & Mukheibir 2015; 2016).

The "My Home Our Water" online portal study component involved the installation of additional smart meters (Outpost WASP loggers) to 120 households in 2012 and the development of a web portal for householder access. The web portal provided detailed customer usage information in near real-time, including comparisons with others, leak alerts, a monthly water budget function, and interactive tips to save water via a pledge facility (Liu, Giurco & Mukheibir in press). Both trials were used to facilitate subsequent evaluation of the mediums used and the savings achieved from the detailed consumption feedback and advice provided.



Household leak detection

In-house leak detection systems that can be bought by individual home owners are now available on the market. In Australia, Aquatrip, a low-cost product that doesn't use sensors, is a device that can be fitted close to the property meter, continuously tracking the flows of the entire plumbing system. It can be programed to suit different usage patterns, can detect very low flows and shut off the water system if a leak is detected (Aquatrip).

As smart metering systems and associated data transmission and analytics are refined, improved and combined with additional data sets, this will revolutionise how we manage water systems. The information can be used holistically to assist in, for example:

- understanding how water is used (leaks, sectors, subsectors, seasonal, diurnal, peaks, indoor/outdoor, end uses)
- detailed demand forecasting at far greater granularity, down to end use, enabling continuous adjustment of short- and long-term demand forecasts
- understanding of how and where water is used to better inform the design and costing of demand management options (leaks, subsectors, peak shifting, restrictions violations, outdoor use, residential high water users)
- finding new ways to inform more nuanced demand management programs for various sectors, subsectors and specific customer groups with the aim of average demand reduction and/or peak reduction or peak demand shifting in specific zones as desired
- virtually instantaneous measurement of savings from individual programs, a significant improvement on current evaluation techniques, enabling continuous improvement of demand management programs and optimisation of water systems to help defer capital investment and reduce operating costs.

Internet of Things

The Internet of Things (IoT) is a much discussed phenomenon. What it will mean in practice is contested and unclear. However, the widespread deployment of sensors, and the aggregation and analysis of the data from those sensors, has the potential to have a profound impact on utility services, including water. One of the main barriers has been the cost of sensors, and especially the cost of deployment and interconnection – and battery replacement when the sensors are battery powered, which in the case of ubiquitous sensors, including for water meters and soil moisture, irrigation control, equipment monitoring and control, is often the case.

Two recent developments could change this situation rapidly. The first is the deployment of low power wide area network systems (e.g. LoRaWAN) (LoRa n.d.) for the interconnection of sensors. This technology, operating on the Industrial, Scientific and Medical (ISM) band (915 MHz) allows long range low bandwidth connection (2-15 km depending on obstructions) including good reach into buildings. The low power usage means that batteries can last for years rather than weeks or months depending on data transmission frequency. These networks also allow two-way communication, allowing for actuation based on sensor conditions, for example the operation of water valves and alarms.

The second development is the deployment of community-based IoT platforms, using LoRaWAN, that allow for free connection and provide a public platform for connecting sensors and publishing data. This has been rolled out across Amsterdam by The Things Network (n.d.), and in Sydney it has been deployed at the University of Technology Sydney (2016) as the first gateway for The Things Network in Australia.

Such a network, and technology, can enable a rapid increase in sensor deployment, for uses that have not yet been imagined. Certainly, sensors could be used in water meters, soil moisture measurement, irrigation controllers, and flood level monitoring. The ability to monitor water demand in real time, and to correlate this data with weather conditions, energy consumption and appliance use, becomes straightforward and less costly, removing barriers to such functions as monitoring, feedback, system control and operation and pricing.

4.5 INSTITUTIONAL ARRANGEMENTS – BREAKING THE CHAINS

Institutional arrangements – that is, the policies, systems and processes used to regulate, plan and manage water at the federal, state and local levels, have evolved over time. This evolution has been affected by the landscape. For example, the drought forced the water industry to begin to think differently, to become more efficient and to spread risk by moving away from rain-fed sources towards a diverse portfolio.

Federal level

At a federal level, regulations such as the Water Efficiency Labelling Standards (WELS) scheme, which started in 2005, helped to provide a platform and language upon which efficiency programs could be built. The WELS scheme enabled individual utilities to run water efficiency programs and clearly advocate to customers the kinds of products they should install (showers, toilets, urinals, taps, washing machines and dishwashers). During its evolution additional products such as flow controllers have been brought on board, and now there are minimum water efficiency standards for toilets and washing machines. Similarly, Smart Approved WaterMark (SAWM), which was launched in 2006, provides standards and a simple labelling scheme predominantly for outdoor products. During the drought the scheme gained momentum and additional products were gradually added, including products for the non-residential sector, such as commercial glass washers (SAWM 2011). Both of these national schemes have been highly successful and provide an excellent foundation to progress efficiency. Various countries (for example China) are seeking advice from WELS experts on how the scheme can be implemented, and in 2015 SAWM set up a partnership in Europe with Waterwise UK under which products approved by SAWM can now use the same label in Europe. SAWM is currently the only international water efficiency label (SAWM).

State level

At a state level building regulations help drive efficiency on multiple fronts. For example, BASIX in NSW came into effect during the drought in 2004. Again, this regulation has evolved over time. It initially concentrated on water and GHG reduction targets for new single and dual occupancy dwellings. Since then it has evolved several times and now includes all of NSW, additions and alterations and a range of targets depending on climate. BASIX requires that both water and energy efficiency be considered. The targets have assisted in driving the proliferation of rainwater tanks in NSW, particularly in new builds, which in combination with rainwater tank rebate programs in existing homes, has resulted in a shift from around 5% of homes having rainwater tanks in 2004 to 16% in 2013 (ABS 2004; ABS 2013). This shift is far more pronounced in Brisbane where rainwater tanks have increased from 5% to 43% (ABS 2004; ABS 2013). Such shifts have resulted in some unexpected implications in terms of energy use as discussed in Section 4.3. In Queensland the requirement to install tanks in new homes has been repealed, predominantly for cost reasons (Turner et al. 2016). BASIX is currently again being reviewed to consider how it can be improved.

Regional level

At a regional level the Water Industry Competition Act (WICA) and associated regulations came into effect in New South Wales in 2007/08. WICA aims to harness the innovation and investment potential of the private sector in the water and wastewater industry. It also provides a licencing regime for private third parties which aims to ensure the continued protection of public health, consumers and the environment (IPART). Several innovative water recycling schemes in Sydney have had to apply for licenses through WICA. Many of these have had some difficulty, for example Darling Quarter (ISF 2013b), and this has been a factor in the delay of reuse becoming more mainstream, as have interpretations of the water recycling provisions under the Local Government Act and the Australian Guidelines for Water Recycling. Due to some of the difficulties experienced, WICA is currently under review.

Local level

The Millennium Drought also sparked a series of demand management and water recycling targets around the country. Many of these targets have now been disregarded or are being reconsidered. Sydney provides an example of the current evolution of targets (see Box 7).

Box 7 – Institutional arrangements

The Sydney Water operating licence, which originally came into force in the 1990s, has required Sydney Water to pursue aggressive water efficiency targets in the residential, non-residential and non-revenue water sectors, as well as aim for achieving a specified increase in water recycling. As part of the ongoing review of Sydney Water's licence the Independent Pricing and Regulatory Tribunal (IPART) set a new requirement, after consultation, that requires Sydney Water to move away from prescriptive targets and towards a water conservation assessment methodology. The methodology, the Economic Level of Water Conservation (ELWC), aims to help Sydney Water work out the most effective water conservation projects and the most appropriate levels of investment in water efficiency, recycling and leak reduction programs. The methodology is set to be reviewed and approved by IPART by the end of 2016. This will then allow Sydney Water to develop a new five-year water conservation program in 2017 (SWC).

An area that needs further investigation is the linkage between different institutional sectors such as planning and infrastructure and water, energy and waste services. More holistic planning and integration of services to make use of opportunities and optimise systems will be essential as urban densification intensifies. By breaking the institutional barriers between sectors and utilising the new emerging rich data sets, analytics and visualisation systems that are now available, it will be possible to view cities in a new way that will assist in fundamentally changing the ways in which we manage our cities.

4.6 COMMUNITY ENGAGEMENT – WORKING TOGETHER

Community engagement can take several different forms.

Firstly, it can mean water utilities or water planning agencies informing citizens about initiatives including restrictions, or broadcasting information on drought management measures or investment decisions. This is the “one to many” approach to community engagement.

Secondly, it can refer to utilities or planning agencies engaging with key stakeholders, such as peak body representatives and community leaders regarding decisions and initiatives, or implementing processes for generating feedback and submissions on proposals. This is sometimes known as community consultation, and it engages those with an interest or expertise, or pre-existing views on the issues.

However, the more innovative and effective approach to community engagement involves a combination of three characteristics (White 2008):

- Representativeness – a process of random selection to invite citizens who would not normally engage in these processes to have an opportunity to express their preferences in an informed way.
- Deliberation – engaged citizens are able to obtain information and increase their level of knowledge on the issues through questioning stakeholders and experts and through discussion and deliberation of the issues.
- Influence – the results of the engagement process are meaningful and directly linked to decision-making processes.

The processes that fit these criteria are varied and multiple, and include citizen assemblies, citizens’ juries, deliberative polls and similar processes (Plant et al. 2007).

These are the kinds of processes that should be used to determine appropriate levels of service by utilities, including the depth and frequency of restrictions, trade-offs between environmental flow releases, costs and reliability, and large-scale investment in capital works to increase water supply system capacity.

It is likely that in the future we will see an increase in demand for these measures, rather than these decisions being made by utilities and water planning agencies themselves, as citizens become more concerned about the level of expenditure and the environmental outcomes associated with water supply and sewerage programs.

5. CHALLENGES, OPPORTUNITIES & KNOWLEDGE GAPS

It is clear that the water industry has changed significantly since the start of the century. The drought assisted in a shift towards the fourth generation of water infrastructure, but the water system is still in transition. As the digital era unfolds the combined effects of the changes currently taking place are providing significant challenges but also enormous opportunities to create a very different water system and associated industry. There are also interesting times ahead, with anticipated population increases, urban densification, constraints on resources and the uncertainty of climate change. Again, these changes will bring significant challenges but also major opportunities to change the way water is used and managed, the shape and scale of the water system, and how it interacts with complementary systems such as energy, waste and nutrient use and recovery. The processes of observing and tapping into these interactions are still in their infancy but they are essential.

Some of the key challenges the industry faces centre around the "weight" of our past. They include, for example:

- the extensive existing large-scale centralised water and wastewater network already in place and the perceived "safety" in perpetuating engineering and policy practices that do not adequately provide an opportunity for innovation or new system configurations
- the long lead times often needed for developing infrastructure, which make it difficult to provide the agility to shift to new system configurations as new technologies and practices emerge
- concerns about the regulation and management of more complex systems during the transition phase
- the difficulty of adequately accounting for the value of avoided costs associated with new system configurations and non-structural solutions
- the entrenched disciplinary boundaries of professionals that lock out new paradigms, including those with non-structural solutions
- current policies and regulations that encourage structural solutions, including those that perpetuate an inability to capitalise on water efficiency solutions, and those that create significant barriers to the entry of third party service providers
- the volatility of funding for research into innovative technology and solutions which has seen a marked decrease in research since the drought ended, and the loss of vast teams in the water industry and the loss of their associated knowledge
- the influence of politics that can make or break good decision-making and innovation.

On the other hand, there are significant opportunities that centre around the “push” and “pull” of the future. They include, for example:

- Melbourne is the fastest growing capital city in Australia (ABS 2016). The population is expected to exceed 7 million by 2050, as is that of Sydney. This will be associated with urban densification, which means city and infrastructure planners will have to work together on how to provide services differently.
- Cross utility initiatives that integrate water, wastewater, waste and energy opportunities will be required to move towards a circular economy and break through the cost barriers associated with providing new services.
- Due to the drought, which lasted for over a decade, community engagement in water efficiency and service provision is strong, and with the new digital era and the aid of smart appliances, this community support can be leveraged further.
- The digital revolution will enable new ways of collecting, analysing and engaging with data in ways that are currently hard to imagine.

Key knowledge gaps that will need to be filled to assist in moving towards a desired future will include, for example, gaps in what we know about:

- how water is used at an end use level in the residential sector and especially the non-residential sector
- the limits of water efficiency and waterless technology and how far it is possible to push these without an unacceptable increase in energy use
- the limits of behaviour changes in the community and how digital technology can aid or even obviate the need for human involvement in water uses such as watering gardens or sports ovals
- how to manage more complex systems with multiple sources, qualities, usage, generation and waste points in a manner that ensures efficiency, quality and safety
- how best to engage the community in more complex systems and qualities of fit-for-purpose water to protect public health in more localised on-site systems
- the limits of existing utility service provision and the incorporation of third party service providers
- the best ways to take advantage of linkages between water, wastewater, waste and energy usage and generation linkages
- how best to assist the water industry to more efficiently engage and embrace new technology such as smart metering, big data analytics and management practices that help rather than hinder transition.

6. A VISION FOR THE FUTURE OF THE URBAN WATER INDUSTRY

The vision in outlined in Box 8 below is one perspective on what can be expected in a fourth generation water system in the next 20 years. Much of the technology identified already exists, and some individuals may already experience parts of the reality portrayed. Yet, to make it mainstream and to advance further in the water industry over the next 20 to 30 years, it will be essential to take active steps to envisage and create the desired future.

Box 8 – Mai's story

On 15 February 2036, Mai woke up excited and ready for work. All last week, she had been researching and collecting material for the first big job she'd been given in her new role at the IWA. The next IWA Congress was to be held in Brisbane, and she had been asked to develop a holographic game which compared the present day to life 20 years ago, the last time the Congress had come to the city.

She stood at the window of her sixth-floor apartment, looking at the streetscape below. She knew from 20-year-old photos and movies she had found, that the city had not always been so green and quiet. Down on the street there were swathes of vegetation, including edible fruit trees, vegetables and gardens maintained by the staff of the local food co-op. But the green was not just confined to ground level – all around her, offices and retail outlets were overflowing with vertical gardens. These gardens, and the ones she could see on balconies and in rooftop cafes, were irrigated by the recycled water from the precinct treatment plant.

The streets were quiet. All she could hear was the occasional hum of the light rail and the subway system, and the occasional electric delivery van. She marvelled at how, 20 years ago, so much space had been dedicated to vehicles. "We need all this green now," she thought. Heat waves, extreme storms and cyclones were now more frequent – Brisbane today was like the Cairns of 20 years ago. When she had been a child, there had been real winters; now you needed the greenery and shade all year round.

She used the sleek vacuum toilet, with low (<1 litre) flush and built-in urine diversion, and stepped into the ultra-efficient shower. It used rainwater which had been collected and treated on site. The used water from the shower flowed to the treatment system at the base of the building, where the heat was recovered and the water was treated and then stored in a holding tank, with the latest sensors to check all water quality parameters before it entered a multi-precinct system.

After breakfast, Mai stacked the dishes in the dishwasher and put her food scraps in the vacuum outlet on the kitchen bench. She pressed a button and with a faint whoosh it was taken away and combined with the vacuum toilet waste in an anaerobic co-digestion system in the basement, which digested carbon-rich material from all the buildings in the precinct. The residuals were used for nutrient rich soil conditioner for

Box 8 – continued

the highly efficient vertical pocket gardens in the city. The biogas generated from the system supplied the network with gas for cooking. This helped her building and the others in the precinct to be net carbon positive.

As she walked downstairs, Mai dropped a bag of laundry down a chute. She had a small mini efficient washing machine in her apartment, but today she had a big load of laundry, so she had decided to use the laundry service in the basement which had machines (based on the same principles as the Xeros machine) that used a fraction of the water, energy and detergents of 2016. She would pick her clothes up on the way home. As she walked across the foyer on the ground floor, she told her super Siri app to set her dishwasher (< 5 litres per wash) to start during non-peak water and energy usage times. “You are one of the only things that hasn’t changed” she told Siri as she checked her remote smart meter for data on the water, hot water and energy she had used the day before. She also looked at the current price for each service, and felt very pleased with herself when she saw that she had used less power and water than her friends in her energy and water users’ club.

Outside, Mai walked through an urban forest, smiling at the kids who were playing hide and seek among the trees. She knew that the forest was watered remotely with treated recycled water, using precision engineering based on local soil and surface moisture sensors connected to the LoRaWAN. As Mai caught the light rail and then walked to her office, she reflected on how she had benefitted from the advances made in the water industry over the last decade, and the new form of teaching at university that had enabled her to think differently and make best use of the digital era.

Mai’s office building incorporated all the latest technology and was net carbon and water positive. She remembered that two years ago, she had worked at the local water utility, and one of her tasks had been to optimise the water system in one of the sectors of the city. This was now a relatively easy task due to the fleet of smart meters that had been installed. They enabled her to understand with a swipe of the computer screen the potable rainwater, hot water and recycled water usage for individual homes and office buildings from an end use perspective for any minute of the day. Each day her smart metering system let her know if the water usage profile in a particular large building was outside anticipated parameters and needed checking. With sensors strategically placed within the building, a leak could be found and, working with the building manager, a repair could be completed within hours.

Another task she had been assigned at the water utility was to check for any pending constraints in the water and wastewater system, and design ways to relieve those constraints. Using a knowledge database, she had been able to check the age and characteristics of the existing buildings in the vicinity of the constraint, and any planned developments. Having this information at her fingertips, she had been able to design a tailor-made efficiency program which considered potential business cases and symbiotic opportunities with the waste and energy systems, including potential assistance from third party utility suppliers.

The kind of future described in Box 8 embraces “restorative”, “regenerative” or “net positive” principles (ISF 2015). It would involve going beyond a system that merely functions, beyond the principles of sustainability and liveable cities and towards a water system that improves the world we live in rather than just minimising the impacts of human activities. It would be a system that minimised the extraction of water from the environment and recovered as much as possible for reuse. It would be a system that valued and recovered the inputs to the water system, including the carbon content, the phosphorus and nitrogen content, and the energy content. It would be a system that was designed to enhance the stock of resources and energy, and improve the social, economic and environmental common good.

So how might we start to progress to that future?

Firstly, as a nation, Australia needs to recognise its place in the ***global context*** in terms of how it is contributing to climate change and how it must help in turning that around through national and international climate change policy and actions that engage the water industry. Positioning ourselves in this broad policy setting will assist in creating an enabling landscape for the transition to a regenerative future.

Within the Australian water industry, significant steps have been taken to reduce water demand and better manage our water systems in the face of climate uncertainty, stimulated primarily by the drought. Although mistakes were made along the way in terms of large, costly and energy intensive infrastructure, Australia now has the ability to use world leading knowledge from the experiences of the Millennium Drought. This is in the form of water efficiency, distributed systems and water supply–demand planning, management and decision-making. This knowledge will enable us to advance further and more quickly into the fourth generation of water infrastructure, as urban growth and the digital revolution continue. In doing so, we will create a step change in our carbon emissions and water consumption.

With the backdrop of investment in diversified non-rain dependent supply, and an excellent foundation of water efficiency and water recycling policies and regulations, technological ingenuity and world leading best practice knowledge, it is time to focus on the “pull” of the future and the goals to which the water industry could aspire. Common themes in the industry centre around “the circular economy”, “resource efficiency”, “distributed systems”, “linkages” between utilities and systems, “restorative” infrastructure and “harnessing” digital opportunities. ***A national conversation*** on what the water industry aspirations could be, and what the industry wants to look like in the next 20 to 30 years, is now essential. So too is dialogue on the “push” (i.e. population increases and densification), on the “weight” (i.e. how we deal with our aging infrastructure), and on our agreed vision and potential pathways to achieve it.

Such a conversation should include a broad spectrum of water industry representatives such as WSAA, AWA, the Water Directorates, research organisations and consultants plus other interlinked sectors such as energy and waste. Due to the timescale of the required vision, the conversation needs to go beyond short-sighted political decisions and engage the community to obtain a broad level of support.

Organisations such as WSAA, AWA and the Water Directorates need to work together to create a ***pool of knowledge*** which the water industry can access. Significant knowledge worth millions of dollars was acquired during the drought. This knowledge must be retained. WSAA has recently developed the Water Research Access Portal (WRAP n.d.) that will go some way to retaining this knowledge from some of the many websites that have closed due to the reduced focus on water efficiency and planning since the end of the drought. However, this is just the start, and a concerted effort now needs to be made across the industry to consolidate that knowledge and make it more accessible.

Engagement with industry on effective ***knowledge sharing mechanisms and pathways*** should be conducted (i.e. web portals, conferences, communities of practice, webinars, industry shadowing and the use of learning journeys) which embrace the digital era and the opportunities it unlocks.

A national view of ***knowledge gaps*** needs to be identified to assist in highlighting core ***research*** and ***pilot studies*** required, together with necessary ***funding*** that could be raised through a ***research levy,*** for example on the volume of water extracted or used. Such research and pilot studies then need to be undertaken and the ***learning outcomes shared*** nationally. Such research will need to push boundaries and link with international advances. There are also many examples of water efficiency, recycling and distributed systems at various scales already in place, and thus there are significant opportunities to gather associated learning outcomes through ***evaluation***.

Universities and TAFE colleges ***teaching*** the new generation of water industry practitioners will need to cross traditional boundaries and create ***innovative problem solvers*** who are at ease with various forms of digital technology and who can span engineering, technology, customer engagement, policy and economics.

The ***policies and regulations*** developed so far, such as WELS, WICA and BASIX, need to be further developed, modified and expanded to assist the water industry to more easily implement innovative solutions. A scan across ***institutional arrangements*** also needs to be conducted to help break the institutional barriers that inhibit the opportunities for tapping into the co-benefits of aligning water, waste and energy systems within cities.

To understand and tap into such opportunities, new ***cross sectoral databases, models and tools*** will need to be developed that share multiple forms of data.

These are some of the actions that could aid progress in the water industry.

The industry is currently at a critical juncture and is going through a rapid transition phase. It is essential that as an industry we look to the future and take the necessary actions now to deal with the challenges, opportunities and knowledge gaps we face, and that we embrace the digital era so that we create the water industry we want.

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