The role of local recycled water systems for sustainable urban water servicing

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student: ________________________ (Rachel Watson)

Date:

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List of publications

This thesis is a hybrid thesis which includes both traditional thesis chapters, as well as a mix of peer-reviewed journal papers, peer-reviewed conference papers, industry conference papers and papers under peer review presented as stand-alone chapters. The thesis includes the following papers:

I. **Watson, R.** (2011). 'Wastewater systems: Decentralised or distributed? A review of terms used in the water industry.' *AWA Water Journal* 38(8): 69-73.

II. **Watson, R.**, C. Mitchell, S. Fane (2012). 'How sustainability assessments using multi-criteria analysis can bias against small systems.' *AWA Water Journal* 39(8): 69-73.

III. **Watson, R.,** Fane, S., Mukheibir P, C. Mitchell (unpublished) Review and synthesis of the diverse impacts of local recycled water systems

IV. **Watson, R.**, C. Mitchell, S. Fane (2013). Local recycled water decisions - ensuring continued private investment. *OzWater 2013*. AWA. Perth, Australian Water Association.

V. **Watson, R**., Mukheibir P, C. Mitchell (unpublished) Local recycled water investment in Sydney: who, when and why

VI. **Watson, R**., Mukheibir P, C. Mitchell (2016) Local recycled water investment in Sydney: a policy and regulatory tug-of-war, *Journal of Cleaner Production* 148: 583-594

VII. **Watson, R.**, C. Mitchell, S. Fane (2013). Local recycled water systems – hard to justify in Sydney, but it's a great place to learn. Asia Pacific Water Recycling Conference. Brisbane, AWA, WSSA, WateReuse Australia.

VIII. **Watson, R.**, Fane, S., C. Mitchell (2016) Impact distribution for local recycled water systems: why it matters *International Journal of Water Governance* 4(12): 5-21

IX. **Watson, R.** (2014). What do building occupants think of onsite recycled water? Small Water and Wastewater Systems Conference. AWA. Newcastle, Australia.

X. **Watson, R.,** P. Mukheibir and C. Mitchell (2017). Recycled water investment in Sydney - what's happening and why. OzWater 17. AWA. Sydney, Australia, AWA.

Contributions to the papers

Rachel Watson was the lead author for all papers. She was responsible for developing the ideas, methods, data collection and analysis. Rachel wrote all the papers and completed revisions in response to peer reviewers' comments. The papers and their concepts were discussed with Cynthia Mitchell, Simon Fane and Pierre Mukheibir in their roles as supervisors. Sue Jenkins of Sydney Water customer research assisted with reviewing the research design of Paper IX.

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Abstract

Local recycled water systems are emerging as an option to meet many of the opportunities and challenges facing the urban water industry, and as a result they are being planned, delivered and operated. Although Sydney has seen an increase in the installation of these systems, their uptake is still limited and there is a lack of agreement about their overall value.

The insights revealed in this research, gained through a literature review, in-depth interviews, and analysis of an extensive database of existing recycled water sites, will:

- guide industry to make more robust investment decisions for local recycled water
- assist regulators and policy makers to revise institutional structures that have had unintended consequences, so that they encourage investment that will support a resilient and adaptable water industry into the future.

It does this by articulating the full range of impacts (costs and benefits) of local recycled water systems. The impacts identified are appropriate for inclusion in a wide range of decision-making frameworks. When compared to more conventional options, the variance in scale and distribution of impacts (as well as uncertainty regarding their measurement and timing) make the consideration of the full range of impacts challenging, contentious and potentially costly. Therefore, identifying, valuing and including impacts in the decision-making process is only one part of the puzzle.

By using Sydney as a case study, this thesis demonstrates that the interactions between impacts and the context (environment, social, regulatory and institutional setting) are critical components of explaining what investment occurs and what role local recycled water systems (or any alternative) can have in urban water servicing. It is critical to consider this complex interplay to assess whether current policies and regulatory and institutional settings are appropriately designed to drive investment that meets the broad objectives of the water industry for the future.

For local recycled water to become a mainstream strategy, a number of changes are likely to be required. An important first step is to clearly identify the objectives of the urban water industry, and then agree on how local recycled water contributes to these objectives. In addition, clearer and more equitable price signals, and simple and predictable benefit transfer mechanisms, are areas for change. To assist with developing more robust signals for efficient investment, broader dissemination of the current capacity of centralised infrastructure and investment triggers is required to provide an opportunity for the market to respond with solutions that meet market demands and assist with managing centralised system constraints.

Abbreviations

AWA	Australian Water Association
COAG	Council of Australian Governments
IPART	Independent Pricing and Regulatory Tribunal
kL	kilolitre (1,000 litres)
LRMC	long run marginal cost
LRW	local recycled water
ML	megalitre (1,000,000 litres)
MBR	membrane bioreactor
SEPP	State Environmental Planning Policy
STP	sewage treatment plant
SWARD	Sustainable Water Industry Asset Resource Decisions
NSW	New South Wales
WSAP	Water Savings Action Plan

Glossary

BASIX – a NSW Government initiative which sets sustainability targets for water and energy for new buildings.

Blackwater –wastewater that contains wastes from humans, animals or food, such as discharges from toilets.

Centralised urban water services – water services that are provided through a single (usually public) utility. This usually involves collecting water far outside the urban area, and transporting it through a large pipe network to where it is used. Used water (wastewater) is then transported out of the urban area before being treated and discharged.

Decentralised water services – localised collection, treatment and disposal/reuse of water and wastewater at an individual home, cluster of homes/ facilities, or an isolated community.

Distributed water services – decentralised or local water services (that is smaller than centralised services) that have a connection to the centralised network (i.e. they are not isolated or remote from the centralised system as decentralised services are).

Greater Sydney Region – the case study in this research covers the Greater Sydney Region. The study area matches Sydney Water's area of operations, and covers nearly 13,000 km^2 and includes Sydney, the Blue Mountains and the Illawarra.

Grey water – the less contaminated parts of domestic wastewater, such as discharges from laundry, cooking and bathing.

Local recycled water – a colloquial term for local recycled water.

On-site treatment – wastewater treatment on a single site level, that is, a household, an industrial site or a multi-storey building.

Sewer mining – extracting sewage from the sewer (before or after a sewage treatment plant) for treatment and reuse as recycled water.

Stormwater – rainwater that has run off urban surfaces such as roads, pavements, car parks, gardens or vegetated open space.

Recycled water – sewage, grey water, stormwater or roof water that is treated to a standard appropriate for reuse.

Urban water services – a term that in this thesis covers the whole range urban water services, including water capture, treatment and distribution; wastewater conveyance, treatment and disposal; and stormwater capture and removal.

Chapter 1 Introduction

This chapter starts by discussing the motivation for undertaking this thesis. It then sets out the thesis structure. Next, a literature review confirms the need for the research, defines the scope of the theisis and identifies gaps that are then used to frame the resereach questions that are answered by the remainder of the thesis.

1.1 Drivers and motivation for the research

The urban water industry is experiencing increasingly diverse and challenging shifts in every aspect of its service provision. The increasing use of sustainability principles has meant planners seek options that mimic the natural water cycle, rather than separating water, wastewater and stormwater services. Recent droughts and a better understanding of the impacts of climate change and population growth have led us to consider distinctly different additional, reliable supply sources. Many major cities have extensive but ageing and capacity-constrained networks. Expanding these networks to meet the demands of population growth is challenging financially, technically and logistically. In addition, there has been increasing support for different forms of competition within the water sector. In the residential sector, planning legislation that drives potable water reduction targets for new developments can often require alternative water sources, such as rainwater tanks or recycled water. If we view these drivers in the context of rapid advances in the acceptability, capability and cost of small scale treatment systems and an active ‘green’ market, we can see that there are many reasons to consider alternatives to the conventional approach of providing centralised services.

Distributed (or local) recycled water systems are one of a range of options that can help the urban water industry adapt during this period of challenge and change. Individual studies have shown local recycled water systems can help meet sustainability aspirations by providing an integrated solution that contributes to water supply and reliability by providing a climate independent supply; by managing the impacts of growth on existing infrastructure; by improving waterway quality by reducing wastewater disposal, nutrient loadings and water extractions; and by supporting liveability options.

In recognition of their potential, local recycled water systems are currently being planned, delivered and operated in Sydney, throughout Australia and indeed across the world. However, their uptake is limited, indicating a lack of agreement about their overall value, despite, as least in Sydney, the development of a conducive policy and regulatory context. In addition, urban water utilities are unsure about what role they should play in planning for, investing in and supporting private investment in local recycled water systems. In fact, Sydney Water, in conjunction with a cross-industry working group, defined the scope of this PhD. Consequently, its aim is to better understand the full range of costs and benefits of local recycled water systems, how these systems could be fairly assessed, and the influence of the regulatory environment on efficient and effective investment.

My interest in this area stems from my experience within the urban water industry. For a long time I have been interested in how to embed environmental and social issues in engineering decisions. This interest originally led me to complete an environmental engineering degree. Following my undergraduate degree I worked in the water and waste industries in environmental planning and environmental compliance capabilities. More recently I spent seven years at Sydney Water, Sydney's public water utility, in economic and strategic planning roles. My experience heightened my interest in localised infrastructure, particularly in relation to how it can be efficiently integrated into an urban environment.

With the current rapid changes in technical feasibility and regulatory environments, this is a stimulating and increasingly significant area of study. Local recycled water systems are an emerging application and present a new and relatively unstudied area, where large and small systems are used together to maximise the benefits of each. Therefore, this research explores, makes explicit and evaluates the depth and breadth of the role local recycled water systems can play in sustainable urban water servicing. It then investigates and reveals why assessment, valuation and implementation have been problematic to date.

1.2 Thesis structure

The thesis is presented as a 'hybrid thesis' which includes both traditional thesis chapters, and a mix of peer-reviewed journal papers, peer-reviewed conference papers, industry conference papers and papers under peer review presented as stand-alone chapters. The production of these research papers has assisted with the targeted dissemination of the research findings, and particularly with keeping close ties with industry partners. Directly preceding each paper that is a standalone chapter is a description of the status of the paper, the author's contribution, and an explanation of why the publication has been included and how it contributes to the argument of the thesis, in accordance with the UTS and ISF guidelines. A more detailed discussion justifying the selection of papers included in this thesis, and their roles in answering the research questions, is provided in Chapter 2.

In broad terms, the research insights and outcomes are presented in two parts (B and C in Figure 1 below). The first part (Chapters 4 and 5) provides the foundation, and is based substantially on a critical analysis of grey and white literature. It defines local recycled water systems, the role they can play in providing sustainable urban water services, and identifies and categorises the full range of costs and benefits.

The second substantive part, Part C (Chapters 6–10), represents the outcomes of in-depth case study research that investigates local recycled water investment in Sydney. This part provides an analysis of how local recycled water systems are being implemented and why. It examines how the 'rules' (the institutional, legal, regulatory, and policy framework), within a specific environmental and social context influence who invests, and when and why they do so. It also demonstrates the critical role that rules have in influencing not only the direct costs and benefits of local recycled water, but also their comparative costs, benefits and risks in relation to more traditional services.

The industry support for this PhD, combined with my interest in influencing what happens in practice, directed the approach I took to knowledge sharing. Presenting research findings and insights in a way that facilitated industry adoption has been a priority throughout the doctoral process. Early insights were presented as papers at national and international industry conferences as a way of meeting industry expectations and providing ongoing industry dissemination of the research, and as a way of gaining rapid feedback from a practice perspective.

The details of the thesis structure are shown in Figure 1 and discussed in more detail below.

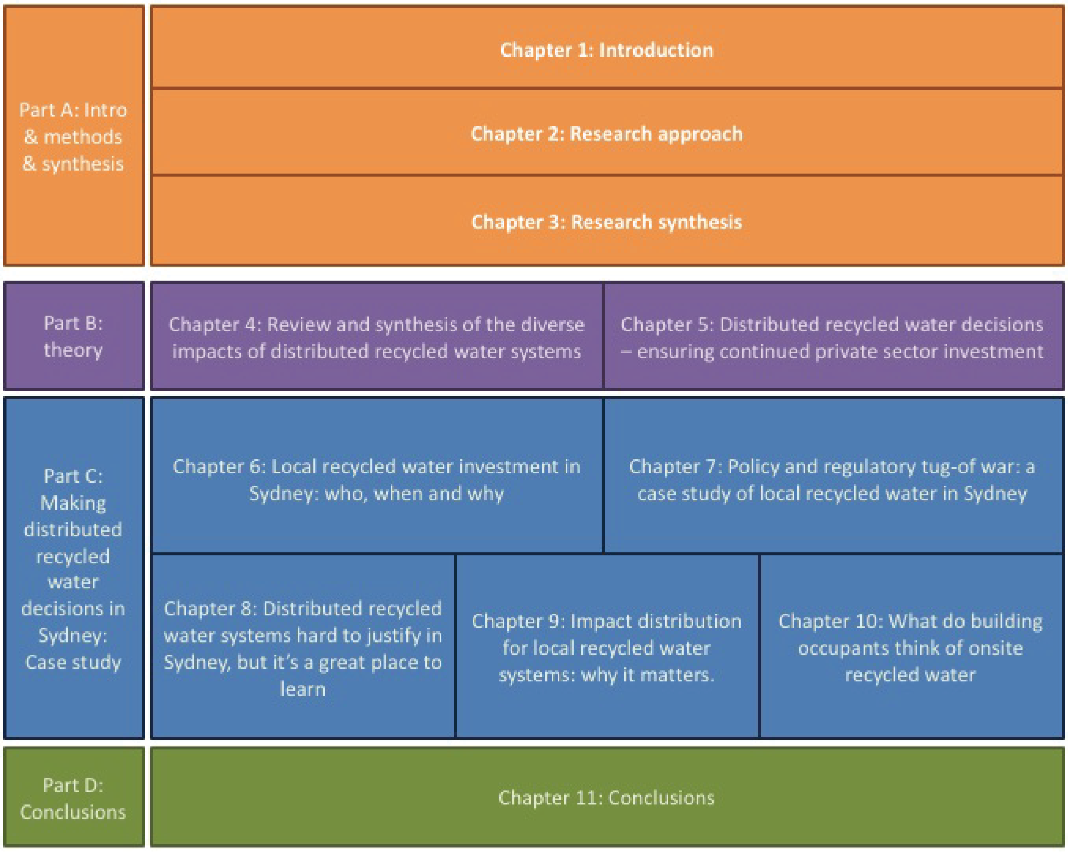

Figure 1: Thesis structure and layout

Part A: Introduction, methods and synthesis

Chapter 1: Context and literature review. The remainder of this chapter reviews the existing urban water industry and the challenges it faces. It confirms the need to examine alternatives to extending and augmenting conventional centralised water and wastewater systems. The chapter then goes on to define local recycled water systems and to explain why they are significant area of study. Next, it provides an overview of the state of knowledge for local recycled water systems. As Chapters 4–10 of this thesis are papers with their own detailed and specific literature reviews, the literature review presented in Chapter 1 is deliberately concise. Finally, the research gaps are summarised and the research questions are presented.

Chapter 2: Research approach. This chapter justifies the research approach and outlines the data collection and analysis processes. As this thesis also contains a selection of stand-alone papers, this chapter focuses on the broader research methodology and design. Further details on the methods of data collection and analysis are provided in each paper. Finally, this chapter sets out how each publication fits in with the research questions.

Chapter 3: Research Synthesis. This chapter provides a synthesis of the research to orient and guide the reader through the remainder of the thesis.

Part B: Theory

Chapter 4: This chapter consists of a stand-alone paper: ‘Review and synthesis of the diverse impacts of local recycled water systems’, which is unpublished. This paper provides a comprehensive catalogue of the full range of impacts for local recycled water systems and how can they be measured. To do this, the paper systematically defines the characteristics of local recycled water systems, and compares and contrasts them to other systems with similar characteristics. The paper goes on to analyse and characterise the impacts, revealing why assessments of local recycled water systems have been problematic to date, particularly in comparison to centralised augmentations and extensions. By distinguishing how the impacts vary from the impacts of centralised schemes, this paper not only helps to explain the lack of agreement on the long term sustainability and viability of local recycled water systems, but also provides an exceptional resource to inform and shift future research and practice.

Chapter 5: This chapter consists of the paper, 'Local recycled water decisions – ensuring continued private investment' which was peer-reviewed and presented in Perth Australia at the 2013 OzWater[1] conference. This paper reviews who invests in local recycled water and why. It then identifies regulatory and institutional barriers for both public and private investment, and compares and contrasts the factors influencing public and private sector investment.

Part C: Case study 'Local recycled water investment in the Greater Sydney region'

Chapter 6: This chapter consists of the paper 'Local recycled water investment in Sydney: who, when and why' which is unpublished but was adapted for OzWater 2017. This paper provides an extensive review of actual local recycled water investment in Sydney, using data from over 270 recycled water sites. It goes on to provide a multi-faceted analysis of the investment which examines their scale, source, end use and ownership, and it analyses key trends for recycled water investment. In doing so it reveals and explains the complex interactions between environmental conditions and the social, political and institutional contexts.

Chapter 7: This chapter consists of the paper 'Local recycled water in Sydney: a policy and regulatory tug-of-war'. It has been revised following review comments and is awaiting publication in the *Journal of Cleaner Production*. This paper focuses on how the wider context influences decisions. In this instance the focus is on the policy and regulatory environment. The paper identifies the broad range of policy, institutional and regulatory arrangements that influence investment in and use of local recycled water, highlighting the complexity that is driven by the range of drivers that influence water sector policy. Finally, it discusses the contradictory nature of the policy, institutional and regulatory arrangements.

Chapter 8: This chapter consists of the paper 'Local recycled water systems – hard to justify in Sydney, but it's a great place to learn' which was presented in 2013 at the Asia Pacific Water Recycling Conference in Brisbane. This paper focuses on who makes

[1] OzWater is the pre-eminent national industry conference in Australia.

decisions, how impacts of local recycled water systems are used and the influence of the wider context. This paper identifies barriers to local recycled water investment in Sydney, particularly those which arise due to the planning process, pricing regulation, regulatory complexity and existing geographical and system design features. It reveals the ways in which these barriers discourage recycled water based on variations in investment size and investor type.

Chapter 9: This chapter consists of the paper ‘Impact distribution for local recycled water systems: why it matters’ which has been revised for, and is awaiting publication in, the *International Journal of Water Governance*. This paper focuses on who makes decisions regarding local recycled water systems and how that influences the impacts that they consider in the decision-making process. Using the Australian regulatory and institutional context as an example, it then identifies why the use of traditional sustainability assessments is inadequate, particularly for private investment in local systems – because these assessments miss the significant changes created by local recycled water on the distribution of the impacts of water systems particularly for water users, the wider community and the public utility.

Chapter 10: This chapter consists of the paper ‘What do building occupants think of onsite recycled water?’. It was presented in 2014 at the Small Water and Wastewater Systems Conference in Newcastle. This paper addresses all of the research questions from the perspective of the users of local recycled water in a commercial ‘Green Star’ building.

Part D: Conclusions

Chapter 11: Conclusions. This chapter provides a summary of the research, integrates the conclusions from the papers in Parts B and C to address the research questions, provides recommendations for future work, and clearly sets out the contributions to knowledge.

The appendices contain: papers that have contributed to this thesis but do not form stand-alone chapters; supplementary information, including additional papers prepared during the course of this thesis but not used directly, interview questions and on-line surveys. It also includes the tables that are the appendix to Chapter 4 and supplementary material for Chapter 7.

1.3 Literature overview

This section reviews the general literature for local recycled water systems with a view to providing a justification for the research. Each subsection ends with a clear statement of the gaps identified in the literature that informed the research questions.

The section starts by reviewing the urban water context (Section 1.3.1.1) and identifying a need to diverge from the existing centralised urban water paradigm (Section 1.3.1.1). Section 1.3.1 concludes that alternatives to conventional centralised systems are critical to meeting the future demands of urban water systems. Section 1.3.2 then provides a rationale for the study's focus on local recycled water systems. Firstly, it reveals that local recycled water is an emerging method for providing local water. It then compares and contrasts the benefits of local recycled water with the benefits of using conventional sources. This analysis confirms that local recycled water has the potential to provide a valuable addition to conventional urban water services. However, the literature reveals that despite the potential value of local recycled water, its uptake is limited and justifying investment for individual projects is challenging. Section 1.3.3 provides an overview of the limits to local recycled water investment. Each subsection of Section 1.3.3 concludes with a clear statement of the gaps identified in the literature. The gaps are then used to develop and define the research questions presented in Section 1.4.

Figure 2: Word cloud of literature overview

1.3.1 Research background: the urban industry context and new directions

1.3.1.1 The urban water industry: built on a long history of separation and centralisation

Since the mid-19th century best practice in water and wastewater management has been to centralise services (Gikas & Tchobanoglous 2009). Decentralised services are often perceived as inferior to centralised solutions and as temporary measures to be used until centralised services can be installed (Pinkham et al. 2004).

Centralised servicing collects water, usually far outside the urban area, and transports it through a large network of pipes to where it is used. Wastewater is transported out of the urban area, treated and usually discharged into a receiving water body. While centralisation has produced well documented and essential public health benefits (Gikas & Tchobanoglous 2009; Harremoës 1998) and (arguably) environmental (Tchobanoglous & Leverenz 2008) benefits[2], it has also resulted in significant capital

[2] Advocates of decentralised solutions would argue that centralisation often just concentrates and moves environmental impacts.

investment and large complex systems.[3] Generally, urban centralised water services have systematically separated water, wastewater and storm water services, and have often managed them using different planning, management and regulatory structures.

1.3.1.2 An era of challenge for centralised urban water services

Over the past several decades a wide range of challenges have confronted the urban water industry. Recent severe and prolonged droughts across Australia, and a better understanding of the impacts of climate change and population growth, have led the industry to consider additional, reliable supply sources (Infrastructure Partnerships Australia & Water Services Association of Australia 2015; New South Wales Department of Infrastructure Planning and Natural Resources 2004; Warner 2009). Many major cities have extensive but ageing and capacity-constrained networks, and continuing to maintain and expand these networks to meet the demands of population growth is challenging financially, technically and logistically (American Water Works Association 2001; Infrastructure Partnerships Australia & Water Services Association of Australia 2015; Marlow et al. 2013; National Water Commission 2011b; The Institution of Engineers Australia 2010; Water Services Association of Australia 2009). These challenges are set to increase with climate uncertainty, prompting the call for more resilient and adaptive approaches (Werbeloff & Brown 2011).

1.3.2 Local recycled water an emerging alternative option

Although centralised servicing continues to dominate urban water service provision, a growing body of professionals advocate alternative approaches (Etnier et al. 2007a; Ferguson et al. 2013; Marlow et al. 2013; Mitchell, C et al. 2010; Mitchell, C et al. 2008; Nelson 2008; Pinkham et al. 2004; Willets, Fane & Mitchell, C 2007). The increasing use of sustainability principles has meant that the industry is considering options that mimic the natural water cycle rather than separating water, wastewater and storm water services (Anderson & Iyaduri 2003; Brown & Farrelly 2009; Fane, Blackburn & Chong 2010; Tjandraatmadja et al. 2008). In addition, rather than favouring

[3] For example: In Sydney Water's area of operation there are seven major dams and a desalination plant, 269 reservoirs, 177 pumping stations and approximately 21,000 km of water pipes (Sydney Water 2013d). The wastewater network has about 24,000 km of pipe and around another 20,000 km of pipe on private land. The wastewater goes to one of 16 wastewater treatment plants or 14 water recycling plants, assisted by 680 sewage pumping stations (Sydney Water 2012b, 2013b, 2013c).

approaches that are either exclusively centralised or exclusively decentralised, practitioners are now recognising the potential of hybrid approaches (Ferguson et al. 2013; Marlow et al. 2013; Poustie et al. 2015; WERF 2006d) and the need to use a wide range of initiatives, selecting which best suit the local context (Biggs et al. 2009; Werbeloff & Brown 2011).

While many studies both in Australia and internationally have shown the potential benefits of alternative decentralised options over more conventional centralised systems (see for example Marsden Jacob Associates & Brisbane City Council (2011); Sharma et al. (2009); Willets, Fane & Mitchell, C (2007)), research on how to choose between local and centralised options within an existing centralised system is limited (see for example (Mitchell, C et al. 2007)). Integrating distributed systems can either use the local system as an alternative to expansions and replacement, or as an alternative service meeting discretionary market demands for water and wastewater services. In America there has been a substantial body of work particularly reviewing the benefits of decentralised wastewater services (see for example (Pinkham et al. 2004; WERF 2006d)).

1.3.2.1 What are local (or distributed) recycled water systems?

Decentralised systems encompass a very broad range of options. To narrow the scope, the definition of decentralised systems was reviewed (see Appendix 1). Watson (2011) identified many different definitions of decentralised water and wastewater. The term decentralised water systems has been used to describe a vastly diverse set of applications across the entire range of water services, including:

- smaller water sources such as rainwater tanks and local groundwater extraction
- local wastewater treatment including onsite septic tanks and a range of different small wastewater treatment technologies
- non-potable water supplies including greywater diversion or treatment, stormwater recycling, wastewater recycling and groundwater recharge.

The key parameters of decentralised systems vary with the purposes, origins and applications of particular systems. This variation makes it difficult to compare, discuss and analyse the performance and acceptance of decentralised systems with any level of rigour or depth. The review of the literature identified the following key parameters for defining a decentralised recycled wastewater system:

- close proximity of treatment to source
- smaller scale than centralised
- perception of improved sustainability
- alternative management and ownership models
- perception of inferior performance and higher risk
- alternative form of treatment, sewer type or discharge location
- a relationship between centralised and decentralised treatment.

The relationship between centralised and decentralised treatment systems is particularly important for this research. Some definitions of decentralised systems exclude any connection to the centralised network, either explicitly (for example Sydney Water (2001)) or implicitly by using isolation as a requirement or an assumed reason for the systems (see the definition in WERF (2010)).

The assumption that decentralised systems are isolated and remote from centralised networks reflects their historical role. Until recently, most decentralised systems were in hard-to-service or remote places and used septic tanks and ground leaching trenches for disposal. More recent literature recognises the potential for decentralised systems to integrate with centralised networks (see Cook (2009) for example).

Some of the benefits, concerns and issues associated with decentralised systems on, or close to, a centralised network are very different from those associated with remote schemes. To try and differentiate between these schemes, some authors use alternative terms. For example Gikas and Tchobanoglous (2009) define satellite treatment plants as being within the network and decentralised treatment plants being off the network.

Since about 2008, the term distributed system has been used in Australian water industry literature (for example see Mitchell, C et al. (2008)). This is a term also used in the electricity industry (see Ackermann, Andersson & Söder (2001) and Pepermans et al. (2005) use it for distributed electricity definitions).

In recent literature, the terms ‘distributed wastewater’ and ‘recycled water’ have been used to describe small local schemes within or near a centralised network. Chung (2008) considers a distributed wastewater scheme in which multiple satellite wastewater treatment plants are located throughout a community with the ability to treat reclaimed water and distribute it to nearby users. Water Services Association of Australia (WSAA) guidelines for distributed systems (WSAA 2010), CSIRO documents (see for example CSIRO (2008, 2009); Tjandraatmadja et al. (2008)), and Mitchell, C et al. (2008)) all use the term distributed to refer to small/ local wastewater treatment plants within or close to a centralised network.

The term distributed is useful as it clearly refers to schemes which have the ability to connect to a centralised network, and schemes which are located within the centralised service area. Managing these schemes is likely to involve different considerations to those which apply when managing isolated schemes.

Distributed recycled water systems are still very diverse in their sources, treatment methods, discharge locations, end uses and management models (Gikas & Tchobanoglous 2009; Water Services Association of Australia 2010; Watson 2011). Sources can include industrial water, sewer mining, blackwater, greywater and stormwater. Distributed systems can discharge to the environment or back to the sewer. Distributed systems can be owned by the centralised utility or privately owned.

This research focuses on distributed (or local) recycled water, an emerging approach which combines large and small systems to maximise the benefits of each.

Distributed recycled water is a relatively unstudied area of research. However, the term distributed recycled water is not commonly used in the water industry, and has not received wide uptake. Inconsistent terminology use within the water industry is common (as discussed in Watson 2011). In addition different words are used to delineate minor variations. For example, wastewater is any water that has been altered due to human use. Greywater is sometimes used to refer to the less contaminated parts of domestic wastewater, such as discharges from laundry, cooking and bathing. Blackwater is sometimes used to refer to wastewater that contains wastes from humans, animals or food, such as discharges from toilets. It is therefore challenging to be accurate, clear and consistent throughout a detailed discourse on the various aspects that are covered in this thesis. To make the contents of this thesis as useful as possible to the water industry the term **local recycled water** has been used. Section 1.4.2 provides a greater detail on what local (or distributed) recycled water means (and does not mean) in the context of this thesis.

1.3.2.2Enablers for local recycled water

While there are a range of options that can help address the challenges faced by the urban water industry, local recycled water is a particularly good option because it has the potential to addresses the challenges and opportunities facing urban water. This significant claim is validated by the range of case studies that have demonstrated local recycled water can be a viable alternative, either as a stand-alone option, or as part of an overall urban water strategy (see for example Anderson 2006; Chanan & Ghetti 2006; Chen & Wang 2009; City of Sydney 2012; Friedler & Hadari 2006; Giurco et al. 2010; Liang & van Dijk 2010; Mediterranean Wastewater Reuse Working Group 2007b; Mukheibir & Mitchell, C 2014; WERF 2006a; Yamagata et al. 2003). These studies, and others, have shown that local recycled water can, inter alia, help meet sustainability aspirations by providing an integrated solution that benefits water supply and reliability by providing a climate-independent supply; by managing the impacts of growth on existing infrastructure; by improving waterway quality by reducing wastewater disposal, nutrient loadings and water extractions; and by helping support liveability options (Libralato, Volpi Ghirardini & Avezzù 2012).

The extensive challenges facing the conventional urban water service paradigm, and a call for alternative approaches, combined with technical and social changes further increase the potential viability of local recycled water. Over the past few decades, there have been rapid advances in the capability, and decreases in the costs, of small scale treatment technology (Mitchell, C, Abeysuriya & Willetts 2008; Pinkham et al. 2004), particularly for membrane bioreactors (DeCarolis, Hirani & Adham 2009; Libralato, Volpi Ghirardini & Avezzù 2012; Melin et al. 2006, p. 275; Santos & Judd 2010; Santos, Ma & Judd 2011). Community attitudes towards non-potable recycled water use generally have also shifted significantly since recycled water use was first introduced, and for some uses recycled water is even preferred over other options (Dolnicar & Schäfer 2009; Metropolitan Water Directorate 2014a).

In addition, political and policy decisions that aim to promote recycled water options have further increased the interest in local recycled water options. Recycled water targets established at national, state, regional and local levels have created a stimulus for recycled water investment (City of Sydney 2012; New South Wales Government 2006; Whiteoak, Boyle & Wiedemann 2008). Potable water reduction targets in planning legislation[4] and green building ratings[5] can often require or reward the development of alternative water supplies (Mitchell, C et al. 2010). In response to these multiple drivers, there has been an increase in interest and investment in recycled water systems generally.

Finally, competition reforms have also created the potential for previously unimagined private participation in the urban water sector. In particular, NSW implemented the *Water Industry Competition Act 2006,* creating certainty of entry, which has been instrumental in stimulating private sector investment (City of Sydney 2013; NSW Independent Pricing and Regulatory Tribunal 2013; Water Factory 2013).

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[4]For example in NSW the BASIX (Building Sustainability Index) scheme - State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004 (the BASIX SEPP) requires all new homes to implement measures that would reduce their water consumption by 40% compared to a similar sized home. For single dwellings meeting this target requires water efficient fixtures and an internally connected alternate water supply.

[5] For example the Green Building Council of Australia’s Green Star Rating system allocates points for onsite recycling and reuse (Green Building Council of Australia 2008a, 2011).

1.3.3 Limits to alternative infrastructure (local recycled water) adoption

Despite acknowledgment that alternative approaches are required to meet the challenges facing the water industry, there has been limited adoption (Brown & Farrelly 2009; Marlow et al. 2013). In addtion, government investment tends to prefer conventional solutions. This was perhaps most noticeably demonstrated during the recent drought where governments across Australia tended to revert to large conventional centralised solutions (National Water Commission 2011b). Limited adoption of local recycled water has occurred in niche markets, particularly in the form of private systems designed to meet non-potable demand in order to gain green building credentials and retain the value of green space in the wake of severe water restrictions. Often, these systems have emerged despite a lack of institutional and regulatory support (Mitchell, C et al. 2010). Despite increasing interest and investment in local recycled water, it is still often difficult to justify investment in individual projects (Marsden Jacob Associates 2013). In the literature a range of reasons has been put forward for the limited adoption of local recycled water, including: data and measurement limitations, limitations of institutional and regulatory regimes, and poor community acceptance, as discussed below.

1.3.3.1 The quest for better assessment techniques

Decisions in the water industry are often complex and require decision-makers to consider a wide range of perspectives and alternatives. In the context of already complex decisions, the range of viable options and the complexity of trade-offs have continued to increase as the principles of sustainability, integrated water management, water-sensitive urban design and liveable cities have emerged and evolved (Ferguson et al. 2013, Furlong et al. 2016). To help manage these complexities and trade-offs, and to include principles of sustainability, a number of decision-making frameworks and tools have been developed and adopted.

There are different methods used in the urban water industry to compare the sustainability impacts of different urban water options, with different models preferred (or required by different decision-makers (Fane, Blackburn & Chong 2010). Federal and state governments in Australia generally prefer infrastructure decisions to include cost-benefit analysis (see, for example COAG (Council of Australian Governments) 2007; Commonwealth of Australia 2006; Office of Financial Management 2007; Resources and Industry Division - Queensland Treasury 2000). Cost-benefit analyses can include environmental and social impacts, but they need to be monetised using standard economic techniques, contingent valuation, or willingness-to-pay studies (Commonwealth of Australia 2006). It is common for strictly economic evaluations to largely exclude sustainability and social considerations, as these can be difficult to value. In addition, even seemingly strict economic evaluations can vary due to local politics, time periods or social contexts (Marion 2011).

To overcome some of these limitations a range of alternative quantitative and complementary qualitative analysis tools, designed to include a wide range of non-monetary considerations have been developed and used within the urban water industry. These tools include: multi-criteria analysis (Fane, Blackburn & Chong 2010; Hajkowicz & Higgins 2008; Lundie, Peters & Beavis 2004); triple bottom line assessment (Taylor & Fletcher 2005); SWARD[6] (Ashley et al. 2003) and scenario planning (Deng et al. 2013; Sitzenfrei, Möderl & Rauch 2013). These tools allow for a multi-perspective analysis that helps to compare unquantified considerations and recognise the trade-offs required to balance multiple objectives and multiple viewpoints.

The use of sustainable assessments in infrastructure decision-making has been critiqued from diverse angles. Sustainability assessments can be limited as they contain multiple dimensions and require value judgments (Lai, Lundie & Ashbolt 2008; Marlow et al. 2013). There is also an argument that suggests sustainability assessments can be improved through the collection and calculation of more comprehensive and representative data, or the development of more robust models that allow multiple scenarios to be examined (Fagan, Reuter & Langford 2010; Makropoulos et al. 2008; Sitzenfrei, Möderl & Rauch 2013). To address these concerns, numerous guidance documents have been produced to assist in comparing options. These include: using sustainability assessments in a balanced way (Marsden Jacob Associates 2013; Etnier

[6] Sustainable Water Industry Asset Resource Decisions

et al. 2005; Fane, Blackburn & Chong 2010; Mitchell, C, 2007), selecting the most appropriate decision tool (Asian Development Bank 1999; Institute for Sustainable Futures 2011), identifying appropriate indicators to use in assessments (Balkema et al. 2002; Foxon et al. 2002; Palme et al. 2005; Sahely, Kennedy & Adams 2005) and identifying potential biases that can be considered in sensitivity analyses once the assessment is complete (Watson, Mitchell, C & Fane 2012).

While these guidance documents are useful for comparing similar options, it remains challenging to compare traditional centralised options with less traditional ones. The challenges associated with comparing centralised options with less traditional options is in part due to differences in technologies, services, scales, project boundaries, lifecycles, business models and regulatory, operational and institutional arrangements (Mitchell, C et al. 2007). In addition, there is currently limited practical experience in how to integrate decentralised and centralised infrastructure (Ferguson et al. 2013).

In general, nearly all methods of evaluation require the identification, assessment and comparison of the types of costs and the types of benefits of each option. Pinkham et al. (2004) provides a catalogue of costs and benefits for decentralised wastewater systems. However, they focus on remote decentralised wastewater systems in the American context, with secondary discussion on hybrid models including local recycled water. Whilst the present study was being conducted, Marsden Jacob Associates (2013) developed a framework for the economic assessment of non-potable recycled water schemes. However, this process was developed specifically to make decisions within a cost-benefit analysis framework. Kunz et. al. (2015) took a different approach and reviewed the minimum set of conditions to ensure a particular outcome (i.e. recycled water investment). An important gap remained: there was no comprehensive catalogue of the full range of impacts for local recycled water to assist in making decisions in a range of different frameworks from a range of different perspectives. **Therefore, the first research question of this thesis is: 'What are the impacts of local recycled water systems?'** Addressing this question involved conducting a comprehensive review and characterisation of the full range of impacts for local recycled water systems, as well as an assessment of who is impacted and under what conditions.

1.3.3.2 Limits of institutional and regulatory regime

An alternative view on the limits of urban decision-making is that sustainability assessment improvements are too focused on better data and better models, instead of investigating the trade-offs and interactions between the environment, society and the economy (Pahl-Wostl 2002). Brown and Farrelly (2009), similarly conclude that the barriers to integrated urban water management are largely socio-institutional rather than technical. In addition, it has been recognised that the increased complexity of institutional, regulatory and social/political interactions when integrating non-conventional urban water solutions, particularly of systems at different scales (Bell 2015; Floyd et al. 2014; Institute for Sustainable Futures 2013c; Pahl-Wostl 2007b), creates further challenges to efforts to meet water sensitive city aspirations.

Across Australia, extensive reviews have been undertaken of the institutional and regulatory frameworks for the urban water sector generally (McKay 2005; National Water Commission 2009; Productivity Commission 2011), and more specifically for recycled water (Radcliffe 2004, Kunz 2016), for integrated water management (Mitchell, V 2004) and for water sensitive urban developments (Tjandraatmadja et al. 2008). These reviews have demonstrated that while reforms of the urban water sector have provided wide ranging benefits in terms of efficiency gains, improved environmental and public health outcomes, and improved service levels (LECG Limited Asia Pacific 2011; National Water Commission 2011a), the existing frameworks still have a number of regulatory and institutional characteristics that limit the widespread adoption of alternative urban water solutions. **Therefore, this thesis seeks to establish what types of regulatory and institutional frameworks encourage investment in alternative urban water solutions and compare and contrast them to frameworks that discourage it.**

1.3.3.3 Industry inertia

The existing institutions have evolved over a long period, beginning well before ideas such as integration of services, involvement of the private sector, and the many new services which are now required were envisaged. The water industry can be slow to change (Brown, Ashley & Farrelly 2011; Mitchell, C et al. 2010, pp. 1,10; Water Services Association of Australia 2014b, p. 12). A long history of end-of-pipe solutions providing socially acceptable outcomes, long asset lives and high sunk costs means that accommodating local recycled water systems requires change in various groups (users, government, industry) and in various ways, including new regulatory frameworks, behaviour changes, changes in values, adaptive economic assessment frameworks, and technical advances (Mitchell, C et al. 2010, pp. 1, 4; Brown, Ashley & Farrelly 2011)

Although the urban water industry has recognised the need to adopt alternative approaches, decisions, particularly in times of crisis, tend to default to the status quo (Farrelly & Brown 2011; National Water Commission 2011b, Radcliffe (2015)). It is recognised that this lock-in is in part to be due to the technical, intellectual and capital investment in conventional servicing methods (Brown, Ashley & Farrelly 2011; Etnier et al. 2007a; Marlow et al. 2013). In addition, decisions tend to avoid risk (and hence the less familiar) due to the critical public health aspects of water and wastewater services (Farrelly & Brown 2011; Nelson 2008; Productivity Commission 2011; Turner et al. 2016). This aversion to risk, coupled with the bias towards larger, centralised solutions, limits the adoption of smaller, less well understood options. However, in Sydney, investment in alternative options is occurring. **Therefore, this research examines how the inertia of the existing system has been overcome by investigating and critically analysing where investment has occurred and why.**

1.3.3.4 Complexity and inconsistency of regulatory frameworks

While a suite of policy and regulatory changes have encouraged alternative approaches, the urban water management framework continues to be complex and inconsistent, and this has limited the uptake of these approaches (Brown & Farrelly 2009). The current structure is seen to hamper the delivery of efficient solutions, particularly in respect to meeting varying customer needs and the implementation of water sensitive urban design (National Water Commission 2011; Productivity Commission 2011; Tjandraatmadja et al. 2008).

While there have been no specific reviews of local recycled water systems, a number of broader reviews covering urban water regulation and economic efficiency contain specific findings that are particularly significant for local recycled water. The regulation of recycled water across Australia is quite onerous and complex (National Water Commission 2011b, pp. 33,52; Power 2010, pp. 3,5; Tjandraatmadja et al. 2008, pp. 64-5, 84) and varies across jurisdictions (LECG Limited Asia Pacific 2011). The rapid pace of technological development and the implementation of alternative water management practices have meant practices have been well ahead of regulation (Mitchell, C et al. 2010, p. 3; National Water Commission 2011, p. 53;Mitchell, C 2004, p. 16). Regulations are being developed in all jurisdictions; however, again it is not consistent (Tjandraatmadja et al. 2008, pp. 29, 84). The development, treatment and ongoing management of recycled water systems is controlled by a number of acts, regulations and policies across all three levels of Australian government (National Water Commission 2009). In Sydney alone, a scheme may be covered by six acts and four guidelines, and it may require the approval or advice of up to eight authorities (Watson, Mitchell, C & Fane 2013b).

Reviews are underway that target ongoing efficiencies in regulation, while ensuring customer protection, particularly the protection of public health (NSW Government 2012). However, such reviews have themselves often been lengthy and onerous. For example, in NSW the latest review, and the introduction of changes resulting from it has taken more than five years. Preliminary consultation began in 2011, amendments were tabled in the NSW parliament in June 2014, and new legislation was passed in November 2014. As of December 2016 regulations had not been drafted, and as such the amendments had not commenced (Metropolitan Water Directorate 2015; NSW Government 2012, 2013).

The complexity of regulations, combined with regulatory risk aversion and rapidly changing rules, have the potential to make investing in local recycled water systems expensive, uncertain, prolonged and too difficult to pursue. A common conclusion of the reviews is the complex and onerous nature of the regulatory and instutional framework. **Therefore, this research was designed to uncover and explain what is causing the complexity and the onerous nature of the regulatory and institutional framework and how that impacts investment in local recycled water.**

1.3.3.5 Siloed and poorly defined responsibilities

Although aspirations to create integrated and water sensitive cities are well documented, there is a lack of direction on who should make decisions that address these sustainability goals and how they should do so. This applies particularly to goals related to public and environmental amenity (National Water Commission 2011b). There is no consensus on the key objectives for the water industry, how the trade-offs between costs and benefits should be assessed and managed, and who should pay (and how they should pay) for the indirect benefits of urban water services (National Water Commission 2011b). The lack of clarity on the role of the utility in providing sustainability outcomes may reduce their willingness to invest in local recycled water systems, as they may not be able to recover their costs through existing funding mechanisms. In contrast, when there are clear organisation roles and regulatory predictability innovation and investment are promoted (Lane et al. 2017).

Additionally, the compartmentalised knowledge of (Allison 2002; Etnier et al. 2007a), and siloed responsibility for, the planning and regulation of the different components of the water cycle (catchment management, water treatment and distribution, wastewater collection and disposal, flood management and urban water quality), may also make it difficult to coordinate a whole of water approach (Head 2014, Mukheibir, Howe & Gallet 2014; Tjandraatmadja et al. 2008; Ferguson et al. 2013; Productivity Commission 2011, p. 295). Urban water planning is undertaken by centralised utilities or government agencies. In most jurisdictions there are no formal processes for identifying opportunities for small systems in advance of centralised investment and communicating this to the market. This situation is exacerbated by the limited institutional and regulatory coordination between stormwater service providers and the water and wastewater utilities (Head 2014). This lack of information limits the ability of private investors to suggest other alternatives, or to plan local recycled water developments to maximise benefits to both their customers and the wider centralised system. **Therefore, this research examines who is investing in what type of local recycled water investment, and how institutional responsibility drives and limits this investment.**

1.3.3.6 Community acceptance of recycled water

It has been demonstrated that levels of acceptance of recycled water are determined by community and regulatory risk perceptions, and that the willingness of customers to accept recycled water as a product is critical to project success (Dolnicar & Saunders 2006; Hurlimann & Dolnicar 2010; Mankad & Tapsuwan 2011; Po et al. 2005; Russell & Hampton 2006). Risks and risk perceptions are complex, and are defined differently by different disciplines. For example, a psychological perspective sees risks and risk perceptions as influenced by influenced by a range of factors including the source, the end use, the provider, education, age, sex, historical factors and motivations for use (Mankad & Tapsuwan 2011; Po et al. 2005). Furthermore, the constraining and enabling conditions in the natural environment also contribute to levels of acceptance of recycled water. For example water scarcity has been shown to increase the acceptance that water recycling is necessary (Marks & Zadoroznyj 2005). However, an individual's general acceptance of the need for recycled water use does not directly correlate with the same individual's willingness to use recycled water themselves of the use of recycled water on an individual level (Po, Kaercher & Nancarrow 2003).

Public perceptions and preferences regarding recycled water have changed substantially in recent years. Not long ago, recycled water was seen as an inferior product (Po, Kaercher & Nancarrow 2003). Around the world, recycled water for residential use was sold for much less than the potable water price in an effort to overcome public resistance and encourage usage (NSW Independent Pricing and Regulatory Tribunal 1993; Radcliffe 2004). In response to widespread concern about recycled water use, extensive research has focused on product safety (Fane, Ashbolt & White 2002; Ikehata, Liu & Sun 2009; Toze 2006a), customer perceptions (Dolnicar & Hurlimann 2010; Hartley 2006; Mankad & Tapsuwan 2011; Marks et al. 2003; Marks, Martin & Zadoroznyj 2008; Po, Kaercher & Nancarrow 2003) and effective community consultation (Dolnicar & Saunders 2006; Hartley 2006; Russell & Hampton 2006). Each additional recycled water project provides an opportunity for the community to experience recycled water, and this may increase public acceptance of recycled water and expand community awareness of the range of potential recycled water uses (Anderson 2003; Balkema et al. 2002; Liang & van Dijk 2010; Russell & Hampton 2006; Toze 2006). In addition, each scheme can also provide new insights into how to effectively communicate with, and involve, the community in decisions relating to recycled water services (Balkema et al. 2002; Russell & Hampton 2006). Due to increasing research; experience and knowledge from a growing bank of 'on ground' recycled water projects; and climatic conditions that invoke change, there is now a general acceptance for recycled water use, with it even preferred over desalination for some non-potable uses (Dolnicar & Schäfer 2009).

In fact, in Sydney there is strong support for recycled water throughout the community, despite some lingering concerns regarding costs and ensuring public health. Studies in Sydney have indicated the public's preference for recycled water over other less integrated options, and its willingness to pay a premium for recycled water (Marsden Jacob Associates 2014b; Metropolitan Water Directorate 2014a).

Although the literature now demonstrates a general acceptance of recycled water, particularly for non-potable purposes, there has been limited follow-up research post adoption. The few examples of post-adoption research include: customers' responses to recycled water at Rouse Hill, New South Wales (New South Wales Government 2006, p. 36) and at Mawson Lakes, South Australia (Hurlimann & McKay 2007). There is a gap in the research pertaining to the acceptance and perceptions of users in commercial buildings where they (most likely) have different services to the ones they have at home.

It is clear that while community perceptions and acceptance of recycled water are critical to recycled water uptake and project success, there is widespread acceptance for the non-potable uses covered in this research. **Therefore, this research does not**

intend to review community acceptance. It does however examine how community and social perceptions influence recycled water investment. In addition, the thesis develops and tests a method to determine customer perceptions of the use of recycled water in commercial buildings.

1.4 Synthesis of literature and its relevance to the thesis design: need, scope and gaps

1.4.1 Research need

In Section 1.3.1 it was revealed that there is a desire, if not a need, to change the way urban water services are provided. However, despite the desire to adopt different practices, uptake of alternative options is still limited.

Section 1.3.2 demonstrated that local recycled water is one alternative option which can play a beneficial role in the urban water sector's progress towards sustainable services. Therefore, this research is focused on local recycled water systems. The scope is defined in more detail below.

1.4.2 Research scope: Local (or distributed) recycled water systems

This research focuses on local recycled water – that is, recycled water systems that connect to a centralised network, or that exist within the centralised service area. Local recycled water systems are an emerging application and present a new and relatively unstudied form of infrastructure in which large and small systems are combined to maximise the benefits of each. The research does not cover non-urban recycled water or decentralised systems. Nor does it cover single residential systems, as they have different management and regulatory frameworks. Instead, the research focuses on multi-residential developments, urban irrigation and commercial and industrial developments. The research covers sites operating under a range of public and private ownership models and in doing so reveals some distinct differences.

This research examines the interactions of centralised water and wastewater systems with local recycled water systems. Recycled water was selected because, unlike water tanks or wastewater treatment systems, recycled water options consider both water and wastewater components of the water planning system (i.e. they offer an integrated solution). This research focuses on wastewater recycling, not stormwater, as they are quite different in their planning, management and regulatory institutions. However, stormwater systems are covered in the initial review of recycled water investment in Sydney. Stormwater systems were included in this review to assess whether the different sources led to different investment profiles.

The research focuses on non-potable recycled water investment as this is the type of investment that is currently occurring in Sydney. Potable reuse is currently not supported by the NSW Government (New South Wales Government 2006, p. 31).

1.4.3 A note on terminology

The term 'distributed systems' was initially used to be consistent with the energy sector to indicate a smaller scale (decentralised) system that is connected to the larger centralised system (either as a compliment, supplement or competitor), as discussed in Appendix 3 (Watson 2011). However, as the research has progressed it was suggested in industry forums that the term ' local recycled water' may be more appropriate. As many of the papers have been written with the purpose of communicating with industry, this term has been used throughout the thesis. Table 1 defines local recycled water as used for this thesis using the parameters set Watson (2011) (See appendix 3)

Table 1: Parameters that define local recycled water systems in this thesis

Local recycled water IS	**Local recycled water is NOT**
Scale and proximity	
Community scale recycled water for communities connected to the centralised water and/or wastewater network (for example Sydney Olympic	Centralised system wide recycled water, with networks of a similar size to the centralised network (for example a network that took treated water from one of the three large ocean plants and

Local recycled water IS	**Local recycled water is NOT**
Park)	distributed recycled water across the whole Sydney Area).
Remote communities connected to centralised water networks (e.g.: Bingara Gorge)	Remote communities with no connection to any centralised system.
On-site treatment for commercial buildings, multi-storey residential	On-site treatment at a single household level (for example an onsite enviro-cycle for a single household as is common in unsewered areas)
Relationship to centralised system	
Connected in some way to the centralised system (water and/or wastewater)	Stand-alone systems that are not connected to the centralised system
Source	
sewer mining, blackwater, grey water, industrial process water, wastewater, stormwater[1], groundwater[1]	Household scale rainwater tanks
End uses of recycled water	
Non-potable uses including irrigation, toilet flushing, clothes washing, industrial processes and cleaning.	Potable reuse (direct and indirect) Groundwater recharge

Local recycled water IS	Local recycled water is NOT
	Waterway discharge[2]
Management models	
public utility, private utility, local government, private owner	Single household

Notes: [1]This research focuses on wastewater discharge. However to fully explore the barriers (and enablers) to source integrated recycled water and the role of institutional arrangements in determining the type of investment (see chapters 6 and 7) a greater range of sources were considered.

[2] In chapter 5 recycled water for environmental flows and recycled water discharged into rivers for downstream irrigation extraction is included as part of Sydney's recycled water history.

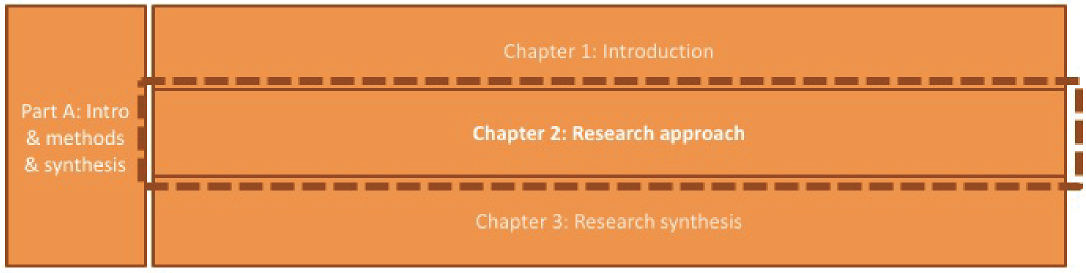
1.4.4 Research gaps

Although Section 1.3.2.2 demonstrated the benefits of local recycled water systems identified both in theory throughout the literature and through practical case studies, Section 1.3.3 revealed there is not wide consensus on the value of investment in local recycled water, and it can be difficult to justify investment in individual projects. Two possible theories emerged in Section 1.3.3 for the limited consensus on local recycled water's value.

The first theory suggests that better assessment techniques and data would improve the robust consideration of local recycled water systems and other alternatives to conventional urban water servicing. While work is ongoing in this area, the lack of a comprehensive catalogue of the full range of impacts of local recycled water to assist in making decisions in a range of different frameworks from a range of different perspectives was identified as a specific and critical gap. This forms the basis of the first research question, detailed in Section 2.1.

The second theory on the difficulties of assessing and valuing local recycled water systems suggests that existing limitations of the institutional and regulatory settings create barriers to investment. Despite the barriers, however, recycled water investment has occurred. Therefore, the second research question seeks to explore the broader framework that influences recycled water investment by establishing where the regulatory and institutional frameworks limit adoption. It also seeks to compare and contrast them with regulatory and institutional frameworks that are promoting investment, as detailed in Section 2.1.

Chapter 2 Research approach, methods and materials



This chapter provides details of the overarching research approach. It starts by stating the research questions. It then justifies the research approach including the use of the Institutional Analysis and Development (IAD) framework and a case study methodology. It then details the data collection and analysis process. As this thesis also contains a selection of stand-alone papers, this chapter focuses on the overarching research methodology and design. Further detail on the methods of data collection and analysis are provided in each paper. Finally, this chapter sets out how each publication relates to the research questions.

2.1 Research questions

This research analyses and critiques the role of distributed (local) recycled water systems in urban water servicing. The research questions were developed based on the hypothesis that local recycled water systems could play an important part in sustainable urban water servicing, and that decision-making frameworks were limiting the efficient and effective uptake of these systems (see discussion in Chapter 1). Therefore, this research sought to first identify the full range of impacts of local recycled water systems, and secondly explore the way these impacts (and other influences) were used to make decisions to invest (or not). This leads to the following overarching research questions:

1. What are the impacts of local recycled water systems?
2. How are decisions to invest (or not invest) in local recycled water systems made?

The research does this first in a theoretical context (see Chapters 4 and 5). The response to Research Question 1 defines, characterises and classifies the actual impacts of local recycled water systems. Research Question 1 has two sub-questions:

- Research Question 1a: What are the impacts of local recycled water systems?
- Research Question 1b: How are the impacts measured?

Once the full range of costs and benefits was identified, the second stage of the research used Sydney as a case study to examine how local recycled water systems were emerging in the market, what impacts were being used to value them, and why.

Research Question 2 examines how and why decisions to invest (or not) in local recycled water systems are made. It has four sub-questions:

- Research Question 2a: What investment has occurred in Sydney and why?
- Research Question 2b: Who makes decisions about recycled water investment?
- Research Question 2c: How are impacts used to make decisions about local recycled water?
- Research Question 2d: How does the wider environmental, social, institutional and regulatory context influence decisions about whether to invest in local recycled water?

The research questions have been designed to fit with the theoretical framework adopted, rather than the existing literature. Table 2 explicitly links the research questions to the literature gaps identified in Section 1.3.

Table 2: Linking the research questions with the literature

Literature		Research question
Section	**Gap**	
1.3.3.1	'What are the impacts of local recycled water systems?'	Research Q1 what are the impacts of local recycled water systems? RQ2c: How are they used to make decisions about local recycled water?
1.3.3.2	'..what types of regulatory and institutional frameworks encourage investment in alternative urban water solutions and compare and contrast them to frameworks that discourage it.'	Research Q2d: How does the wider institutional and regulatory framework influence decisions about whether to invest in recycled water?
1.3.3.3	'examines how the inertia of the existing system has been overcome by investigating and critically analysing where investment has occurred and why.'	Research Q2a: What investment has occurred in Sydney and why
1.3.3.4	'to uncover and explain what is causing the complexity and the onerous nature of the regulatory and institutional framework and how that impacts investment in local recycled water.'	Research Q2d: How does the wider institutional and regulatory framework influence decisions about whether to invest in recycled water?
1.3.3.5	'who is investing in what type of local recycled water investment,…'	Research Q2b: Who makes decisions about recycled water investments?
1.3.3.5	'..how institutional responsibility drives and limits [local recycled water] investment.'	Research Q2d: How does the wider institutional and regulatory framework influence decisions about whether to invest in recycled water?
1.3.3.6	'examine how community and social perceptions influence recycled water investment.'	Research Q2b: How does the wider social context influence decisions about whether to invest in local recycled water?

2.2 Research approach: qualitative case study research using the Institutional Analysis and Development (IAD) framework as an analysis lens

In sustainability terms, the research questions sit principally in the economic domain. Consistent with the requirements theses undertaken at the Institute for Sustainable Futures, to respond to Question 1 (What are the costs and benefits?) a broad net was cast to capture all relevant costs and benefits. To answer Question 2 (How are decisions to invest (or not invest) made?) the Institutional Analysis and Development (IAD) framework proved to be a powerful lens both in analytical and explanatory terms.

2.2.1 Using a broader definition of impacts than strict economic costs and benefits

In answering Question 1, a definition of costs and benefits that extended beyond typical economic assessments was necessary. This broader definition of costs and benefits, and the inclusion of risks, was imperative in order to:

- respond to the critiques identified in Chapter 1 of strict economic evaluations
- recognise the broader range of tools used in urban water industry and;
- take account of the increasing awareness that developed throughout the initial phases of the research regarding the critical role of the change in the distribution of impacts from the distribution which prevails in more conventional systems.

Furthermore, a systematic and comprehensive impacts list created through such a broad process will assist in managing well-recognised decision-making flaws, particularly where the benefits of new options benefits may be outweighed by **unknown** or **unquantifiable** risks or disbenefits (Marlow et al. 2013). Despite the broad definition of impacts, it is important to note that economic rationalism, cost-benefit analysis and financial viability are still key concerns within the industry. Further detail on the method used to define the impacts is provided in Section 2.4.

2.2.2 Using Institutional Analysis and Development (IAD) framework as a lens for analysis

The IAD framework was a powerful tool to analyse and explain the complexities driving and limiting local recycled water investment. In general, for open and competitive markets, economic theories of rational behaviour, using perfect knowledge to maximise outcomes, have proven to be powerful explanatory and predictive tools. However, not only are decisions in local recycled water made with imperfect information, they are being made within an institutional setting designed for non-competitive, public monopoly services. Therefore, to explain, let alone predict, the rationales behind local recycled water investment the broader IAD lens is useful.

The Institutional Analysis and Development (IAD) Framework was developed by Ostrom, in her time at the Bloomington School for Institutionalism and Public Choice (Ostrom 2012). The IAD framework was developed by using new institutionalism to review the theory of public choice (Ostrom 2012, p. 51). The IAD framework has undergone several iterations and transformations as it has been used in a wide range of diverse settings (Ostrom 2005).

The compatibility of the IAD framework with multiple disciplines, and its ability to communicate across and between, them significantly contributes to its power (Poliski & Ostrom 1999). Although it was originally developed for analysing common pool resources, it has also been used in more commercial contexts such as evaluating differences in childcare services (Bushouse 2011), and in the water sector for assessing water resource planning processes and testing the institutional arrangements of water allocations in outback Australia (Smajgl, Leitch & Lynam 2009). More recently the IAD framework has been used in conjunction with value chain analysis to demonstrate the importance of establishing linkages across energy, water and food, and the ways in which institutions limit or facilitate synergies (Villamayor et. al. 2015). The framework has provided a valuable platform for integrating work from a wide range of professions and specialties (Ostrom 2005), such as the engineering, policy and economic specialties spanned within this study.

The analytical and explanatory power of IAD provided a robust and valuable technique to explore and explain the complex interactions[7] of local recycled water investment. That is, the use of the IAD enabled an examination of the critical influence that the wider social and environmental context and rules have on the costs and benefits that occur, who is involved and how decisions are made. The IAD framework has been used as both an explanatory and descriptive tool and as a more normative means of analysis (to argue in favour of a particular change) (Ostrom 2012).

In this research IAD has been applied at its highest level, that of framework analysis, to identify elements, and general relationships between those elements. Importantly for this thesis, it provided a structured platform for initially categorising, and then synthesising, the impacts of a set of influences that is broader than just the costs and benefits. In particular, this study uses the explanatory power of IAD to investigate the significance of the interactions between the costs and benefits, the rules that influence the action situation (the decision to invest in local recycled water systems), the actors (who) and the external context (environmental and social), as outlined in Figure 3 and further detailed Figure 4 and Figure 6. In addition, at the start of chapters 4-9 a diagram is provided to illustrate the synthesis of the chapter in the context of the IAD framework. Finally, Figure 7 provides a summary of the research outcomes situated in the IAD framework.

The need for a broader framework became evident during the initial synthesis and analysis of the broad range of impacts of local recycled water systems, where several key hypothesises were emerging:

1) Rules have a significant influence on what impacts emerge and their absolute and relative magnitudes.
2) The drivers for decisions to invest in local recycled water systems, and the associated benefits, have strong links to the wider environmental context.
3) The impacts are distributed between different groups in ways that are different to those associated with more conventional centralised urban water services.

7

The IAD framework is a well-established tool for investigating how institutions (rules) affect individual incentives and the resulting behaviours (Ostrom 2005), within the context of the community and environment in which the rules are made (Oakerson & Parks 2011). The IAD framework includes all the key elements emerging from the first stage of the research, namely: the costs and benefits; the broader political, social and environmental context; and the role of rules in defining the outcome of decisions. This establishes the framework as a powerful tool for analysing the way the decisions to invest in local recycled water systems are made. The adaptation and application of the IAD framework to the research questions of this thesis is presented in Figure 4.

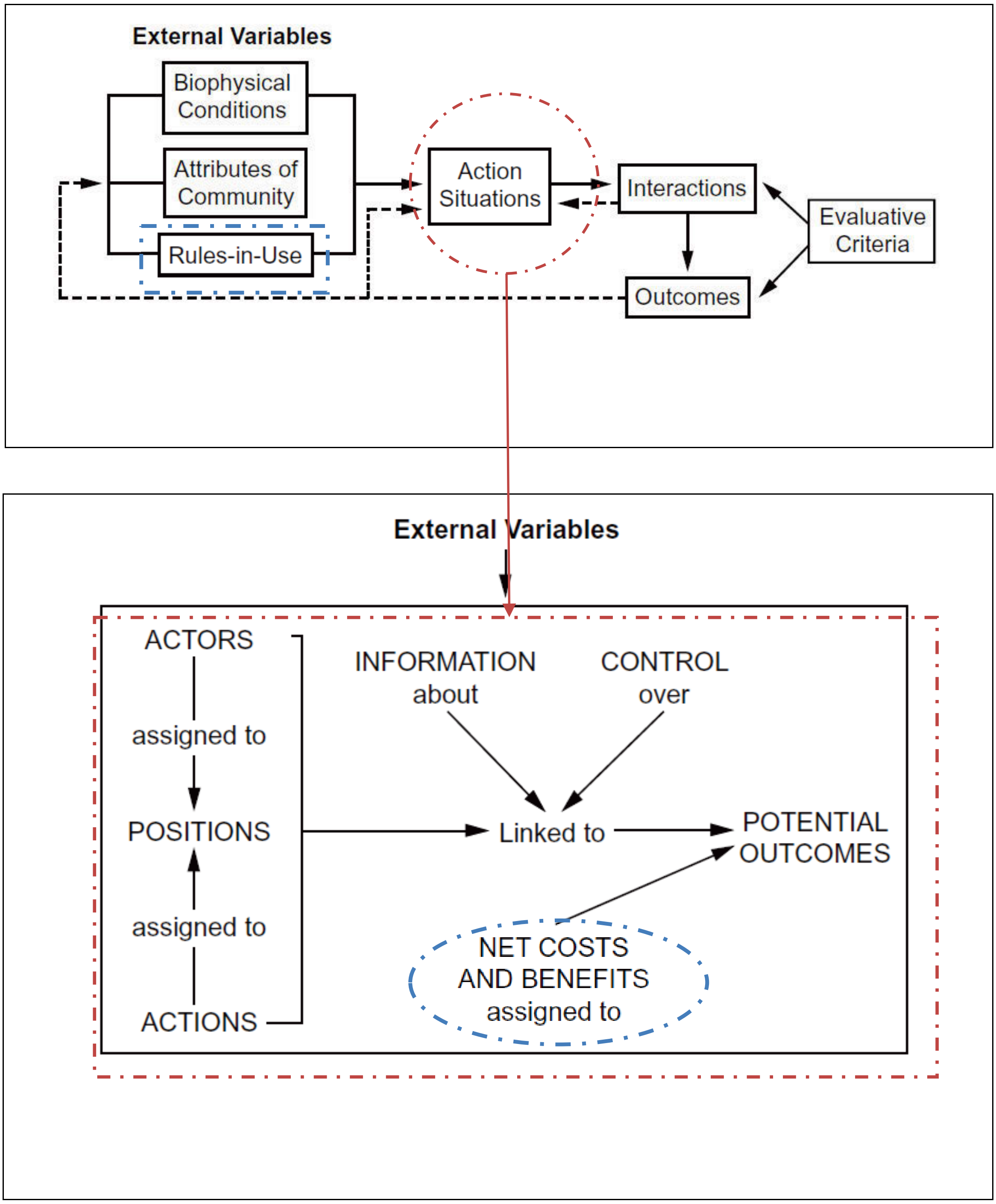


Figure 3: The IAD framework, adapted from Ostrom (2011), figure 1 and figure 2

The IAD framework has provided a structured lens for identifying, categorising, synthesising, simplifying and explaining the complex interactions between external environmental variables, the social context and the rules, the different actors, the costs and benefits, and how decisions to invest (or not invest) are made. This framework was useful as is based on the understanding, gained form the literature, that decisions about whether to invest in local recycled water systems are not just a function of costs and benefits. Rather, they are based on a more complex interaction between a number of factors including who is involved, the social and environmental context and the 'rules' (Figure 4).

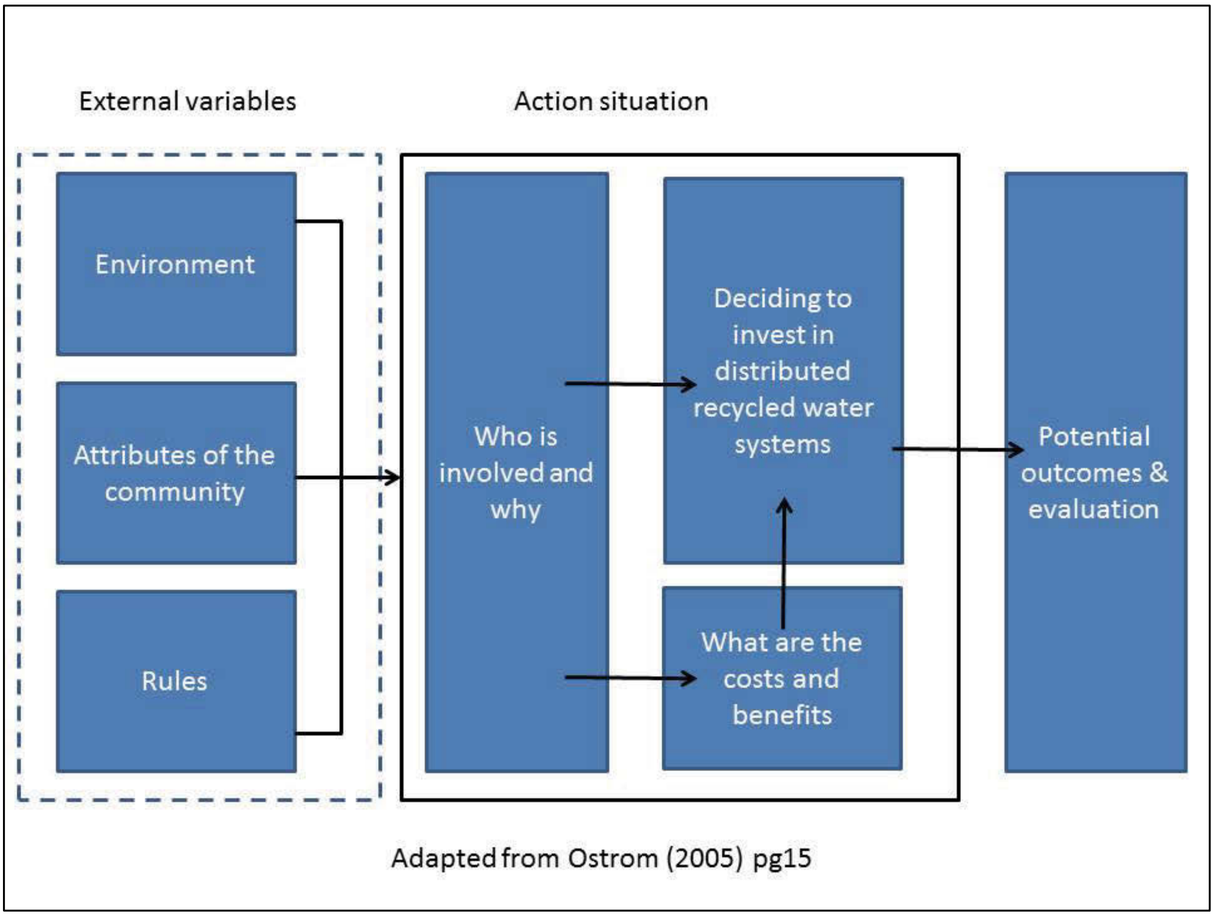


Figure 4: How the IAD framework relates to the research

2.2.3 Using a case study methodology

Research Question 2 is a 'how and why' question, which is a type of question suited to case study investigation (Creswell 1997, p. 17; Yin 1981). The 'how and why' nature of the research question, combined with the (suspected) complex interactions between social, regulatory and environmental contexts, makes a case study methodology useful (Creswell 1997, p. 17; Yin 1981, p. 100).

A case study methodology can use a single case or multiple cases, and both these approaches include subsets of approaches within them (Baxter & Jack 2008; Stake 1995; Yin 2009). While additional sites or cases can provide more information, there is always a trade-off between the sample size, the time available and the level of detail that can be achieved (Creswell 1997, pp. 227-8). A multiple case study method can be particularly useful when the same phenomenon exists in a variety of situations, since multiple cases allow for replicating results, either predicting similar results, or contrasting results for predictable reasons (Yin 2003). However, a single case study approach was adopted for a number of key reasons (discussed further below) including:

- to allow a detailed and rich exploration of the phenomenon (in this instance local recycled water investment) that existed within the single study of Sydney
- to allow data from multiple independent sources to be collected, analysed, compared and contrasted in order to provide more robust conclusions
- to provide consistency of regulatory context, as required by the IAD framework
- to adhere to ethical research requirements of confidentiality and anonymity
- to build on, enhance and differentiate from previous recycled water case study research.

This research uses Sydney as a single case study to examine the impacts of distributed systems and explain how they (and other factors) influence decisions about whether to invest. A single case study was chosen to allow the in-depth study, with ample time to collect, contrast and compare multiple sources of data and explore and unravel the complexity of interactions. Within Sydney a wide range of sites were studied at varying levels of detail. The data was obtained from targeted interviews from a variety of perspectives, overlayed with data from a range of policy documents, and regulatory review processes (all discussed in Section 2.3) in a trade-off between breadth and depth.

Case study methods are often criticised for their lack of generalisability and for being biased towards confirming the researcher's own ideas (Flyvbjerg 2006, p. 221). The particular attributes of Sydney are made explicit in the discussion and it is recognised that they may limit the generalisability of specific details of the research. However, the general themes arising from the analysis are likely to have a broader application. To limit bias, multiple independent data sources are used (see Section 2.3), including public reports, websites, council minutes, surveys and detailed interviews from a range of perspectives. Where appropriate results are compared and contrasted to case studies in other jurisdictions.

A single case study was chosen to provide consistency around the social, environmental and regulatory contexts. In addition, the use of a single case fits well with the IAD framework which assumes all rules are constant over the period of study.

In addition, this research employed a single case study rather than comparing multiple case studies for the following reasons:

- Methodological: Every site was different, limiting the ability to categorise classes of sites for contrast, comparison and generalisation. The number of case studies required to provide a meaningful comparison and generalisation of the original user categorisations of irrigation, high density, low density, industrial would have been unmanageable within the context of this thesis.
- Availability: No one site, let alone the number of sites required for a valid multiple case study approach, was available for the type of in-depth analysis being sought for this study. There was a distinct lack of data or data availability on the costs, benefits and assessment methods. Even when the data was known, it was usually subject to stringent confidentiality and commercial in confidence restrictions, so people were unwilling to divulge the information.
- Ethical: Using Sydney as a single case study rather than using multiple individual studies was particularly important in regards to ethical considerations. Even when sites, companies and people were willing to participate, many requested some form of anonymity. In such a small industry, talking about specific sites was difficult if this anonymity clause was to be honoured. The greater the level of detail I went into for each site, the more

likely the site would have been identifiable, and the data would have breached confidentiality clauses. By using Sydney as a single case study and using the deep insights gained through the interviews to enrich the data, the depth of analysis was balanced with the need to provide anonymity.

Collections of case studies have been used previously to identify project viability (Anderson & Iyaduri 2003; Burgess et al. 2015; Moxon 2004; WERF 2006d), exemplar projects (Hatt, Deletic & Fletcher 2004; Mediterranean Wastewater Reuse Working Group 2007a; Tjandraatmadja et al. 2008), improved decision-making (Institute for Sustainable Futures 2013b) and barriers and limitations to investment (Institute for Sustainable Futures 2013b; Mitchell, C 2004; Po, Kaercher & Nancarrow 2003; Radcliffe 2004). In addition, catalogues of recycled water projects have been developed to track progress toward targets (NSW Office of Water 2010; Sydney Water 2009a; Whiteoak, Boyle & Wiedemann 2008) and funding allocations (NSW Government Office of Environment and Heritage 2011).

This research uses the Greater Sydney Region as a case study, providing a comprehensive catalogue of recycled water investment in the Greater Sydney Region over time. However, as opposed to previous catalogues, it then provides a multi-faceted analysis of the investment based on scale, source, end use and ownership. By using a comprehensive catalogue of investment in a single area, the analysis characterises key trends and unravels the complex interactions between environmental conditions and the social, political and institutional contexts.

2.2.4 The choice of Sydney as a case study

Sydney is Australia’s largest city, with around 4.6 million people living in the Greater Sydney Region (NSW Government 2014). Sydney is serviced by an extensive centralised water and wastewater network, owned and operated by Sydney Water, a state government-owned monopoly provider, with prices and standards regulated by the Independent Pricing and Regulatory Tribunal (IPART). The study area matches Sydney Water’s area of operations, and covers nearly 13,000 km^2.

Sydney provided a unique and interesting case study, providing multiple rich sources of data to explore the research questions in depth. Sydney was selected as a case study because:

- It has an extensive centralised water and wastewater network, with well-established policy, institutional and regulatory frameworks for traditional urban water management.
- There is a long history of recycled water use in Sydney, so there is an existing policy, institutional and regulatory framework for recycled water.
- There has been substantial reform over the past decade to allow and encourage recycled water use, including local recycled water use.
- Substantial investment has occurred in recycled water and local recycled water for a range of end uses, providing a good cross section of sites to investigate.
- It had developed and implemented a unique regulatory framework – '*The Water Industry Competition Act 2006*'. The Act was developed to encourage competition for water services and to facilitate the development of recycled water infrastructure.
- The current mix of public and private investment enabled by the *Water Industry Competition Act 2006* (NSW) is unique, and something that is attracting interest nationally and internationally.

2.3 Data collection and analysis

A mixed methods approach was undertaken using four complementary data sources: an extensive literature review to construct the full range of costs and benefits; a policy and regulatory review; the construction and analysis of a new database comprising 270 local recycled water schemes in Sydney; and in-depth interviews and structured discussions with key informants representing the full diversity of perspectives and experience of local recycled water in Sydney (phase 3). In addition, industry workshops and online surveys were conducted to address gaps in the data, or to triangulate, test and validate the outcomes of the first four data sets.

2.3.1 Literature review to identify collate, synthesise and analyse local recycled water system impacts

An extensive literature review was conducted across products with similar characteristics to local recycled water, potential services that could be provided by local recycled water, and existing products and services that could be replaced by local recycled water. This review encompassed the full range of ownership and decision-making structures. The literature was synthesised and categorised to provide a comprehensive catalogue of real and potential impacts occurring to all parties over the lifetime of the systems. These impacts were then analysed to formulate hypotheses about why assessments of local recycled water systems have proven problematic to date.

2.3.2 Desktop review to construct and analyse an extensive database of local recycled water investment in Sydney

An extensive desktop review was conducted to identify recycled water investments in the Greater Sydney Region (June–August 2015) of over 270 actual local recycled water and stormwater investments in Sydney and construct a database. The first step was to identify sites, using the Metropolitan Water Directorate website augmented and cross-referenced with:

- projects that had funds allocated through the NSW Water Savings Fund and other state and federal grants
- businesses required to develop Water Savings Action Plans under the *Energy Administration Amendment (Water and Energy Savings) Act 2005* (NSW)
- Green Building Council of Australia's registered buildings
- the Water Industry Competition Act licensee database.

To ensure the list of sites was comprehensive, a final web search was conducted for 'Sydney' AND 'recycled water' OR 'wastewater reuse' OR 'water recycling'.

The second step in this phase was to augment the site-specific data for each scheme. Web searches identified the investor, the source of recycled water, the end uses, the capacity of the system, costs and benefits and key drivers. While comprehensive, it is possible this review was not exhaustive. However, the range and number of sites provides a sound basis for the analysis. In addition, the majority of data is self-reported, so numbers likely represent ultimate demand or ultimate capacity, not actual recycled water produced.

Once collated, the data was analysed via an Excel spread sheet to identify key trends in recycled water investment, particularly in driving or limiting factors, investor types, sources of recycled water and end uses.

2.3.3 Desktop review and analysis of the policy, regulatory and institutional framework

A desktop review was undertaken to cover the wide range of relevant policy documents, regulatory instruments, and government reports, as of 2015, including those that provide necessary historical context. This work took as its starting point recent national- and state-level reviews, particularly the National Water Commission review of urban water and the NSW Urban Water Regulation Review. Over 50 documents (acts, guidelines, policy documents and special reports, provided in Appendix G) were analysed to evaluate how they drove or limited recycled water investment.

2.3.4 Interviews from a range of different perspectives

A series of semi-structured interviews exploring participants' experiences of the drivers and limitations which affected existing and proposed recycled water investments were undertaken. Eight interviews, some with multiple participants, covering multiple perspectives, were completed (Table 3). The targeted participants were selected based on their willingness to participate and their experience within the industry, and they represented the full spectrum of perspectives in local recycled water in Sydney (namely developers, operators, utility representatives, and end users). The interviews covered both sewer mining and onsite blackwater treatment processes for a variety of different end uses.

Table 3: Interview perspectives

Interviewees	Perspective				Sites covered
	operator	developer	utility	User	
A	1			1	Sewer mining – irrigation
B	1	1			Sewer mining – irrigation
C+D	1	1		1	Sewer mining post STP – irrigation and network
E					Sewer mining – post STP irrigation + comparison irrigation sites
F+G		1			Sewer mining – irrigation (operational and 3 schemes not developed)
H			1		Multiple
I			1		Multiple
J			1		Onsite blackwater – commercial
K	1	1			Onsite blackwater - commercial

Questions for the interviews were developed based on the key research questions, the identification of the costs and benefits, and the ways in which decisions are made to invest in local recycled water systems. Ethics approval was gained prior to contacting interviewees. The questions were provided to interviewees ahead of time (Appendix B), but generally the interviews were semi-structured, with the questions providing a guide for the discussion when it stalled. The interviews were recorded. There were two exceptions to this process. In the first of these, the interviewee chose to have a conversation via phone, with manual notes taken and in the second, the interviewee chose to provide partial written responses. Notes were taken at the interviews in addition to an electronic recording. The recordings were professionally transcribed and then reviewed and edited by re-listening to the audio while reading. A manual thematic analysis and summary of each interview was then completed.

While the interviewees were very generous with their knowledge and time, they were limited in the information that they were willing to share for this research. In particular, they were reluctant to provide data on costs. This is perhaps best illustrated by one participant who stated that one of the key things they hoped to learn from the research was better information about the full range of costs and benefits, yet they could not/ would not provide any cost data themselves. This is similar to experiences reported in other research projects. For example, a WERF project examining over 300 small and decentralised wastewater systems across 13 American states (Parten 2008) was only able to collect cost data for 60 systems. Yang, Cicek and Ilg (2006) reviewed 339 research papers investigating MBR research (a common technology used for local recycled water systems) and found only three studies on costs. And in a review of stormwater harvesting systems, Fletcher et al. (2008) found very limited and extremely varied information on capital and operating costs.

The first round of analysis examined the costs and benefits and their roles in decisions. While this analysis was useful for supplementing and cementing costs and benefits list, and for the analysis of difficulties and challenges with costs and benefits, it did not do justice to the richness of the data, particularly given the limitations in the cost data sets outlined above. However, emerging from the data were themes of limits and drivers, particularly around the roles of environment, the social context and rules. I then re-reviewed the data with a thematic analysis based on the IAD framework. The analysis involved comparing and contrasting key themes with other interviews and reflecting on the importance and meaning of the similarities and differences between interviewees, particularly based on perspective and scheme type.

Three sites (see Table 4) were analysed in detail to gain deeper insights into: what costs and benefits were measured, what costs and benefits were included in decision-making; the decision-making process more generally; and how costs and benefits were actually realised. For these sites, the interview data was supplemented with data from additional sources, including publicly available information from the internet, reports, council minutes and online surveys (discussed further below). Two sites were initially analysed as site specific studies. This analysis highlighted the immense challenges that would have arisen if this thesis had been presented as a group of site-specific case studies. These challenges included issues around anonymity and confidentiality, which were key issues for consideration in the ethics application process. Therefore, these locations have not been included in the thesis as specific case studies, but the data arising from them has been included in the analysis.

Table 4: Three research sites: comparison of characteristics, data collection methods and perspectives examined

	Site A	**Site B**	**Site C**
source	sewer mining post STP	sewer mining	blackwater
status	operational	operational	operational
use	irrigation	irrigation	toilet, cooling, irrigation, washdown
size	3,000 kL/day	650 kL/day	40 kL/day
approval	self-approved	council	council
Network	yes	no	no
No of users	3+	1	1
treatment	chemical	MBR	MBR
driver	water security, cost control, ww discharge	water security	example, green building
Data	2 interviews, operators online survey	3 interviews, operators online survey	1 interview, written questionnaire, operators online survey, staff (user) online survey
Perspectives	developer, operator, user, utility	developer, operator, user, utility	developer, operator, user

2.3.5 Online surveys

To supplement the limited data on operating perspective and user perspective, two online surveys were conducted. The first survey covered user perspectives on using recycled water and how it was valued in comparison to other green building features (Appendix C). This internet-based survey was distributed through internal newsletters and emails to all Sydney Water Staff (by Sydney Water). Several random prizes of movie tickets were provided as an incentive to participate. Thematic analysis was undertaken using Survey Monkey software to explore:

• awareness of recycled water within the building and its uses

• motivations for Sydney Water to have recycled water, for staff to want to work for Sydney Water and within this building, and what role recycled water played in the overall package of green building initiatives

• risk perception/ trust – whether the interviewer thought the recycled water was safe, whether they thought the recycled water affected the safety of the potable water system, general concerns

• value/cost of the recycled water in relation to other green building initiatives, the value in relation to the cost and price of water, and the value to the employees in terms motivation/pride.

The second survey covered operating issues for small plants in general, and it focused on operators and scheme managers (Appendix D). The second survey was conducted in conjunction with Sydney Water. This internet-based survey was sent to targeted participants identified by Sydney Water through their tradewaste program. A $20 thankyou voucher was offered for participation. The voucher was refused by several participants due to workplace restrictions, but they were still happy to participate. Options of remaining anonymous were provided. Two targeted participants declined the invitation to participate. Trend analysis was conducted using themes of operating issues (which related to the costs of schemes) and regulatory burden (which related to the influence of rules).

2.3.6 Workshops

A workshop investigating the drivers, costs and benefits, and hurdles for recycled water in general was held at OzWater 2011, attended by a broad range of industry professionals. The initial impacts list was presented and discussed, highlighting the importance of salinity, even in an urban context. An interactive session was held where participants identified and discussed drivers, costs, benefits, hurdles and a ‘perfect world' for recycled water. The outcomes of the discussion were transcribed on butchers' paper for theme analysis.

Building on the OzWater workshop, a second workshop was convened at Australia's national Small Water and Wastewater Systems Conference to explore limitations to local recycled water investment. This workshop involved 15 industry participants (four planners/regulators, four public utility employees, five private system operators, two sustainability advocates/researchers). This workshop involved a debate, from which notes were taken, and an interactive exercise identifying limits and ranking then by perspective. The review of the Newcastle workshop is provided in Appendix E.

2.4 Methodology and data as they relate to the research questions

2.4.1 Research Question 1: What is the full range of impacts of local recycled water systems?

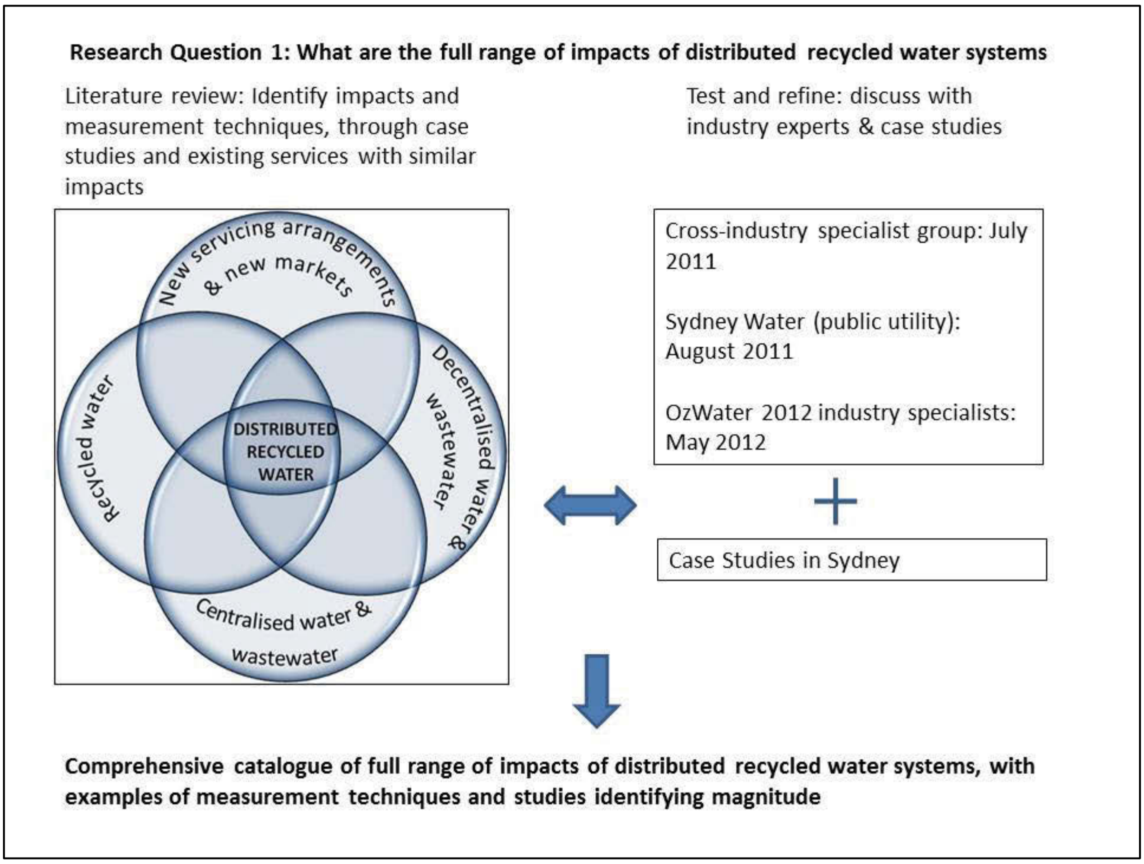


Figure 5: Approach to Research Question 1: What are the costs and benefits of local recycled water systems?

The first set of research questions are 'what, where and how much' questions and these questions are best answered through techniques such as survey and archival analysis (Yin 2003). To answer these questions a comprehensive review of existing literature was conducted to identify and classify all the factors that might affect assessments and/or influence decision-making for or against local recycled water systems, and synthesise how they can be included in decision-making processes. The review included consideration of benefits and disbenefits in the form of both impacts and risks[8] across the full spectrum of affected parties. Impacts refer to actual

[8] Although not strictly impacts, risks have been included due to their apparent influence on the decision-making process. Risks represent a positive or negative deviation from the expected outcome, due to

occurrences, and can be positive or negative. Risks refer to potential occurrences and are associated with uncertainty.

To capture all potential positive and negative impacts, a broad net was cast across products with similar characteristics, potential services that could be provided and replaced and across the different ownership and decision-making structures. The review sought to identify both implicit and explicit impacts across the range of environmental, social, economic, and technical domains.

The range of literature covered reflects local recycled water systems being a specialised subset of recycled water systems and, perhaps, an evolution in decentralised services. Although all recycled water systems have many characteristics in common, the impacts of distributed systems and the associated risks are different from those associated with other more isolated decentralised schemes (Watson, 2011) and from those associated with larger recycled water systems. As well as reviewing impacts from similar types of systems, the review also covers the types of services that distributed systems could provide, augment, duplicate or replace. For example, local recycled water systems can provide a new service – delivering renewable water to 'green markets'. Local recycled water can also augment water supply in the existing system and assist with water security. Local recycled water provides an opportunity for direct private investment in the urban water sector (Watson, Mitchell, C & Fane 2013a). Therefore, to understand the impacts of these new and hybrid servicing arrangements, the literature review also covered investment drivers, regulatory requirements, and existing arrangements, such as customer contracts and sewer mining and trade waste agreements.

Each area was reviewed to the point of saturation to identify both positive and negative impacts and risks. The point of saturation was identified by Strauss and Corbin (1998) as the point at which no new impacts emerged. This approach is useful when, rather than have not enough literature to review, there is such a vast quantity

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uncertainty. Risks also include the perception that something could occur. This is generally consistent with the definition of risk provided in AS/NZS ISO 31000:2009 (Standards Australia 2009).

of literature available that reviewing all of it is impractical. For example, this approach was used in Hacking and Guthrie (2008) when they tried to articulate the dimensions of a range of sustainability tools. The impacts and risks from each of these areas were then reviewed to determine whether the impacts were relevant for a local recycled water system. This required an assessment of the characteristics that gave rise to the risk or impact, and assessing whether they would be the same or similar for a distributed system. Information on how impacts could be measured and the magnitude of measurements was also collected.

The list of impacts was then reviewed and tested in a range of industry forums. This included:

- a review of the draft list of impacts through the (then) Decentralised Working Group – a cross-industry group specialising in local water solutions (including local recycled water) (28 July 2011)
- a workshop with a diverse range of Sydney Water employees to discuss the draft impacts (2 August) (Sydney Water is the public water utility in the case study area)
- a presentation and discussion of impacts at a workshop hosted by Sydney Water (8 May 2012): 'Recycled Water: Who really benefits, who really pays?', as part of OzWater 2012, the pre-eminent national industry conference in Australia.

The final result was a comprehensive synthesis and categorisation of impacts for local recycled water systems, and an analysis of these impacts. This helps to reveal why it is challenging to compare and assess local recycled water systems against more conventional alternatives.

2.4.2 Research Question 2: How are decisions to invest (or not) made for local recycled water systems?

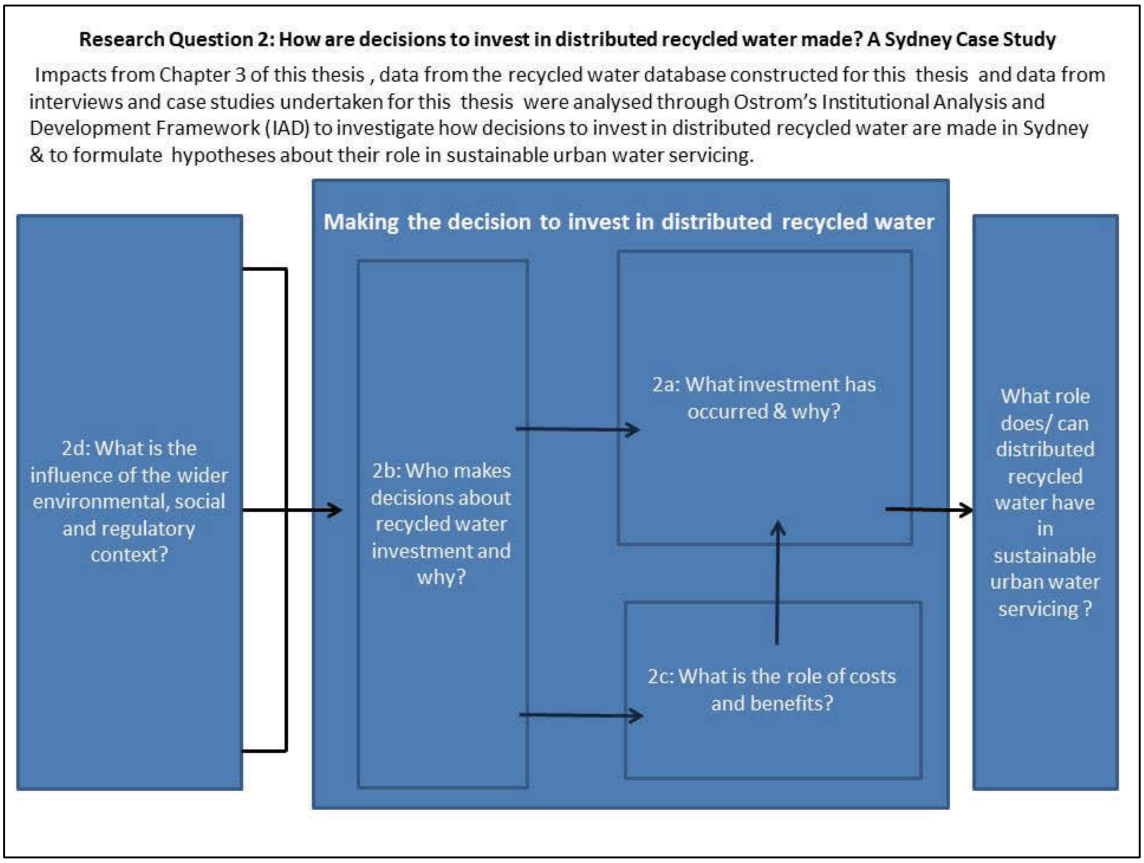


Figure 6: Approach to Research Question 2: How are decisions to invest in local recycled water systems made?

As identified in the literature review, although assessment techniques are an important factor in fairly assessing alternative systems, it is also important to understand the trade-offs and complex interactions between the social, environmental, regulatory and economic factors. This research seeks to situate the assessment of the costs and benefits of local recycled water systems within the broader decision-making framework. It does this by examining the evolution of local recycled water investment in Sydney using the Institutional Analysis and Development framework as an analysis lens (see Figure 6).

Interviews, surveys, regulatory reviews and policy documents were manually analysed thematically, using the categories presented in the IAD framework. Using these categories facilitates an explanation of the nature and complexity of the interactions between the social, environmental and institutional contexts and the decision to invest in local recycled water systems, particularly the impact on the evaluation of costs and benefits. At the start of Chapters 4-9 the way the elements of the IAD framework have been synthesised for that chapter are presented (Figures 8,10,11,23,27,29).

2.5 Justification of the thesis model

The thesis is presented as a 'hybrid thesis' which includes traditional thesis chapters and a mix of peer-reviewed journal papers, peer-reviewed conference papers, industry conference papers and papers under peer-review, presented as stand-alone chapters. The rest of this section specifies how each paper relates to the thesis research questions.

It is anticipated that the outcomes of this research will assist practitioners within the field make better informed investment decisions. The production of stand-alone research papers has assisted with the targeted dissemination of the research findings, and has helped the researcher to maintain close ties with industry partners. The presentation of each chapter as a stand-alone element, each with its own literature, methods, findings and conclusions, has created a format that helps manage the trans-disciplinarity and non-linearity of the concepts covered in this thesis. Should industry partners pick up this thesis, it will be in a form that is easily digested, and which makes it easy to engage with the story as a whole. To assist with early dissemination of information, early papers were presented at conferences as a way of meeting industry expectations and to gain rapid feedback and enable ongoing dissemination of the research. What follows is a short description of all the papers produced during the thesis, and how they have contributed to the research and been incorporated into the presentation of the thesis.

2.5.1 *Paper I:* Wastewater systems: Decentralised or distributed? A review of terms used in the water industry

This paper is included in full in Appendix A, and the findings are incorporated into Chapter 1. This paper identifies local recycled water as an emerging urban water solution. It defines local recycled water and helps define the scope of the research.

2.5.2 *Paper II*: How sustainability assessments using multi-criteria analysis can bias against small systems

This paper is included in full in Appendix B, and the findings are incorporated into Chapter 1.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
				✓	

This paper investigates how impacts are used in to make decisions in one form of sustainability assessment – multi-criteria analysis.

2.5.3 *Paper III*: Review and synthesis of the diverse impacts of local recycled water systems

This paper is presented in draft form in Chapter 4.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
✓	✓				

This paper answers Research Question 1, namely: What is the full range of impacts of local recycled water systems and how can they be measured? The paper systematically defines the characteristics of local recycled water systems, and compares them to other systems with similar characteristics. In doing so it provides an exhaustive catalogue of the full range of impacts of local recycled water systems and how they can be measured. It also provides examples of where and how individual impacts have been measured. This paper catalogues the full range of impacts and where in the literature research and data can be found on similar impacts. Practitioners, researchers and students alike will be able to use this information as a firm foundation for considering which impacts are relevant for a particular situation and decision framework.

The paper goes on to analyse and characterise the impacts, revealing why assessments of local recycled water systems have been problematic to date, particularly in comparison to centralised augmentations and extensions. By examining how the impacts vary from those found centralised schemes this paper not only helps to explain the lack of agreement on the long-term sustainability and viability, of local recycled water systems, but also identifies areas for future research.

2.5.4 *Paper IV*: Local recycled water decisions – ensuring continued private investment

This paper is presented in full in Chapter 5.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
			✓		✓

This paper investigates who makes decisions to invest in local recycled water systems. The focus of this paper is on Research Questions 2b and 2d, namely: Who makes decisions about local recycled water investment? and: How does the wider environmental, social, institutional and regulatory context influence decisions about whether to invest in local recycled water? It examines who makes decisions, and then compares and contrasts the drivers for different decision-makers (in this paper, public and private sector investment). It differentiates between the factors that limit investment for the private sector and those that limit investment for the public sector. It then examines decisions to invest in the context of the wider regulatory and institutional environment. The paper suggests that for continued sustainable private investment in recycled water, it is important to ensure regulatory and institutional barriers are minimised and methods are developed to compensate private investors for the value they provide to existing centralised systems. Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers, firstly to enable them to understand the scale of their impacts, and secondly to enable them to begin to develop strategies to address them, assuming there is a desire to support the private recycled water market in the long term.

2.5.5 *Paper V*: Local recycled water investment in Sydney: who, when and why

This paper is presented in Chapter 6.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
		✓	✓		✓

This paper focuses on Research Question 2 by providing a comprehensive catalogue and analysis of recycled water investment in the Greater Sydney region. It characterises what type of recycled water investment has occurred, by whom and why. By focusing on a single geographic region it reveals how changes in the regulatory, institutional, social and environmental conditions over time impact on project successes and failures. The analysis in this paper characterises key trends in investment and unravels the complex interactions between environmental conditions and the social, regulatory, political and institutional contexts. In doing so, this paper provides important insights into what drove recycled water investment in the past and reveals the important role the wider context plays in shaping the who, what, when and why of recycled water investment. It also provides a key starting point for designing and enabling new policy directions with greater potential to deliver more resilient and liveable urban domains.

2.5.6 *Paper VI*: Local recycled water in Sydney: a policy and regulatory tug-of-war

This paper is presented in Chapter 7.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
					✓

This paper focuses on Research Question 2d: How does the wider environmental, social, institutional and regulatory context influence decisions about whether to invest in local recycled water?. This paper examines the broad range of policy, institutional and regulatory arrangements that influence investment in, and use of, local recycled water. It highlights the complexity driven by the breadth of drivers that influence water sector policy. It demonstrates that even with the best intentions, past, current and future policy, regulatory and institutional environments have a significant and unexpectedly negative impact on why, where and when investment occurs, and what that means for future investment. Identifying and exploring the oppositional nature of these levers enables a better understanding of existing local recycled water investment and provides a basis to develop strategies that address unintended consequences and remove barriers to future investment.

2.5.7 *Paper VII*: Local recycled water systems – hard to justify in Sydney, but it's a great place to learn

This paper is presented in full in Chapter 8.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
			✓	✓	✓

This paper focuses on Research Questions 2b-d, namely who makes decisions, how impacts are used and the influence of the wider context. It examines how the wider historical, environmental, regulatory and institutional context influences decisions to invest in local recycled water. It examines variations in the barriers to investment due to investment size and who is investing. In particular it examines the barriers for investment that occur due to broader water planning processes, pricing regulation, regulatory complexity, geographical features and historical system design features of the centralised water system.

Despite number of drivers that should make Sydney an opportune location for local recycled water uptake, this paper identifies a wide range of limiting factors. These factors are generally based in regulatory, policy or institutional arrangements. The paper includes an examination of: the factors that influence the price differential between general water services and recycled water, factors that influence risk and uncertainty, and factors that hinder efficient decision-making.

Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers for two reasons. Firstly, making them explicit allows the scale of the limitation, and the potential impact on investment, to be assessed. Secondly, by acknowledging the limiting factors it is possible to develop strategies to address them.

2.5.8 *Paper VIII*: Impact distribution matters: investment in local recycled water systems is determined by who is positively and negatively impacted how and when

This paper is presented in revised draft form in Chapter 9.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
			✓	✓	

This paper focuses on Research Questions 2b and c, specifically the interactions between who makes a decision and how that influences which impacts they consider. This paper firstly reviews how impacts (benefits and disbenefits) are commonly used in the water industry to compare options and make decisions. Using the Australian regulatory and institutional context as an example, it then identifies why the use of traditional sustainability assessments is limited in its effectiveness, particularly for private investment in local systems – because conventional sustainability assessments miss the significant changes created by local recycled water in the distribution of impacts. That is, the number of groups impacted, the way positive and negative impacts and risk are distributed between groups, and the timing of the impacts and the scale of the impacts, are different for local recycled water compared to traditional urban centralised water and wastewater services.

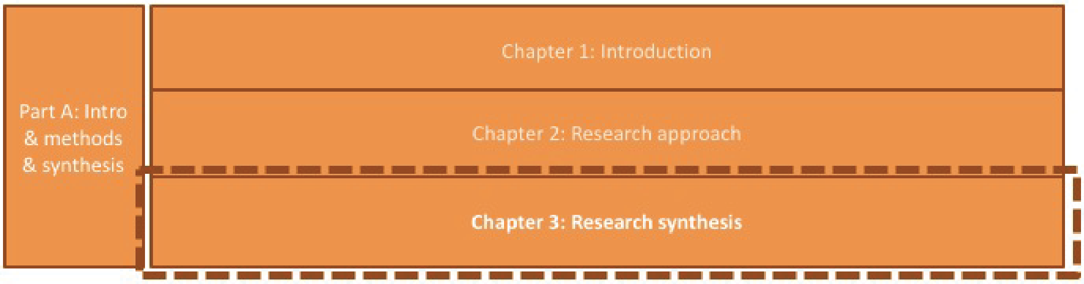
2.5.9 *Paper IX*: What do building occupants think of onsite recycled water?

This paper is presented in full in Chapter 10.

Q1: What are impacts?		Q2: What influences decisions to invest?			
What are impacts?	How can they be measured?	What investment has occurred & why?	Who makes decisions?	How are impacts used?	What is the influence of wider context?
✓	✓	✓	✓	✓	✓

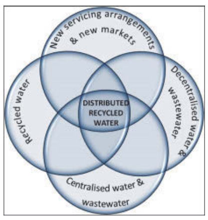
This paper reviews the impacts of local recycled water as part of a green building package. This paper provides a unique review of a commercial building occupants' awareness and safety perceptions of recycled water, and it provides an insight into perceptions of recycled water both generally and in comparison to other green building features. It addresses the research gap related to testing the acceptance and perceptions of users in commercial buildings where they (most likely) receive services that are different to those they receive at home. The paper develops, tests and presents a simple and reproducible online survey to examine building occupants' awareness and safety perceptions of recycled water. This survey tests the hypothesis that in-building recycled water plants provide value through leading by example, delivering water savings and contributing towards green credentials. The survey also confirmed the very real risk of disbenefits if the systems are not properly managed, particularly in relation to aesthetics and costs. In addition, this paper highlights the importance of context in driving decisions, in this case the link between the environment (drought), regulation (water restrictions) and institutional responsibilities (the public utility needing to lead by example).

Chapter 3 Research Synthesis



With the exception of the final chapter, the remainder of this thesis is presented as stand-alone chapters in paper format. To orient and guide the reader this chapter provides a systematic synthesis of the research. Each research question is addressed separately, synthesising the findings and locating where in the thesis further justification of the findings is documented. Thumbnails from the main thesis are included throughout the discussion of the research findings, to assist with situating the conclusions within the context of the overall thesis. The chapter concludes with a synthesis of the findings based on the IAD framework (**Figure 7**).

3.1What are the impacts of local recycled water systems? (RQ1)



Local recycled water systems are an emerging urban water option. They are a specialised subset of recycled water systems, and perhaps, an evolutionary step in decentralised services. Although all types of water systems have many similar characteristics, this research has found that the impacts of distributed systems and the associated risks are different from other more isolated decentralized schemes, and from larger recycled water systems (see Watson (2011) and Chapter 4).

Chapter 4

This thesis has catalogued the full range of impacts of local recycled water systems (see Table 5, Chapter 4), identified how to measure the impacts and provided examples of studies where individual impacts have been measured (see Appendix 1 to Chapter 4). There is a vast range of potential impacts associated with local recycled water systems, and these can generally be classified as:

- impacts that influence the ways in which efficient urban water services are provided, and the ways in which efficient services are reliant on the interactions between the local recycled water systems and the centralised systems
- impacts that improve or degrade the environment
- impacts that arise by differentiating local recycled water systems from conventional centralised water and wastewater services.

When deciding whether to invest in local recycled water, it is not necessary, or even possible, to consider all of the impacts. In addition, only a subset of the impacts will be relevant for each system as a key benefit of local recycled water systems is their flexibility and their ability to adapt to the unique requirements (size, demand, sources) of an individual site or area.

This thesis highlights a number of key issues to consider in decision-making when considering the impacts of local recycled water, namely:

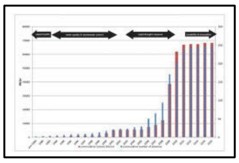
- The scale and materiality of impacts often depends on interactions between the environment and the regulatory framework.
- Scale differences make impacts in relation to the centralised system minimal at an individual site level.
- The distribution of the impacts can vary significantly from more conventional centralised options.

- The benefits of local recycled water systems can be difficult to measure, uncertain, occur in the future, vary according the rules in use at the time, and are difficult to transfer between sites.

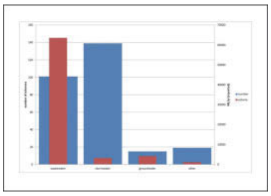
These properties combined can make the inclusion of the full range of impacts in decision-making frameworks challenging, contentious and potentially costly. However, referring to a comprehensive list of potential impacts in the first instance can provide a consistent and justifiable basis upon which to decide which impacts are relevant and appropriate to include in a particular decision-making process. Identifying the full range of impacts, and the literature where research and data on similar impacts exists will enable practitioners, researchers and students alike to have a firm foundation to consider which impacts are relevant for their particular situation and decision framework.

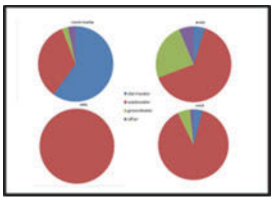
3.2How are decisions to invest in local recycled water made? (RQ2)

3.2.1What investment has occurred to date and why? (RQ2a)



Local recycled water has been used in Sydney since the late 1960s. There have been a number of key phases, including: 1960s–1980s: opportunistic irrigation; 1980–2000: regulation-driven waterway protection through wastewater control and reuse targets; 2003–2010: rapid drought response; and finally post 2010: an uncertain market based on green developments, fringe servicing, integration and liveability (see discussion in Chapter 6, and Figure 12).





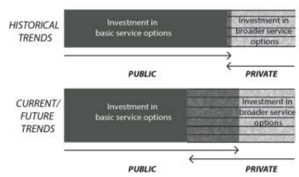
Sydney's local recycled water diversity has increased rapidly in the last decade, driven by water shortages and the associated range of policy and regulatory measures that have encouraged and enabled a broad range of investment outcomes. The examples presented in this thesis (Chapter 6) demonstrate that local recycled water in Sydney is diverse in its sources (Figure 13), scales (Figure 13, Figure 15) end-uses (Figure 15) and ownership models (Figure 16, Figure 17). The majority of the volume is from wastewater, with stormwater having the most number of systems. However, as discussed further in Section 3.2.2 below, although there is diversity in the scale and type of investment across Sydney, the types of investment made by different cohorts of investors vary significantly, and generally reflect their institutional responsibilities (Chapter 6). Of all the projects reviewed, there were very few that had integrated sources, perhaps reflecting the compartmentalised nature of the regulatory framework and institutional responsibilities, combined with the ongoing challenges for implementing integrated water management (as discussed in Chapter 6).

The few projects that did combine multiple sources were driven (at least in part) by sustainable water servicing objectives, and provided a total water service (see WRAMS and Central Park for example). This appears to be a different approach to that taken generally in Sydney where water, wastewater and recycled water projects are evaluated on whether they are the least cost way to provide an individual service. While developments with integrated services are emerging in the private sector, the acknowledgement of their contribution to the overall value of centralised service is still limited.

Chapter 6

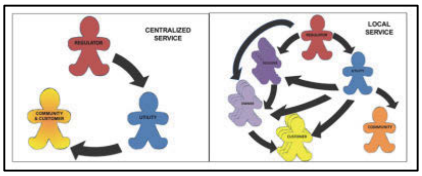
3.2.2 Who makes decisions about local recycled water? (RQ2b)

The paradigm of urban water planning and investment is changing in the face of some key challenges and opportunities. Historically, public investments focused on basic services and private investments targeted more discretionary outcomes. However, as public utilities expand into providing broader service options and private providers are increasingly supplying basic infrastructure, that distinction is blurring. With the introduction of more local options (including local recycled water) into the wider urban water planning process, the mix of private and public responsibilities for the delivery of the options continues to evolve. As this



Chapter 9

research has shown, the changing paradigm results in a different and much broader distribution of impacts than has traditionally occurred (see discussion in Chapter 9).



The introduction of local recycled water systems into an urban water system introduces new, and changes existing, roles and responsibilities for decision-making, ongoing management and funding of water and wastewater infrastructure. This thesis has shown that the variation in roles and responsibilities means decisions for local recycled water systems in Sydney are made by a broader group with a more complex set of interactions than is usual for conventional urban water services. While the traditional characterisation of social, environmental, economic and (at times) technical impacts is systematic, intuitive and fits well within established frameworks, it is limited, particularly for the assessment of small private systems in comparison to large public ones. Therefore, explicitly recognizing the effect of the redistribution of impacts is critical to a fair and robust comparison of local recycled water systems against expansions or augmentations of existing centralised systems. Clearly identifying the differences between the distribution of impacts of centralized systems and local systems can also help to explain different perceptions in the community around the significance of particular impacts and associated risks.

Chapter 9

The prevalence of compartmentalised and complex regulatory frameworks, in conjunction with delineated institutional responsibility, has resulted in clear distinctions in the types of recycled water investment made by the different cohorts of investors. This is particularly noticeable in terms of scale and source (Chapter 6). The exact approval path for each recycled water scheme and style of ongoing regulatory oversight varies depending on the owner (utility, council or private industry), the scale of the system, the source of the recycled water, the ultimate end use and the relationship between the owner

Chapter 6

and the users of the scheme.

The public utility Sydney Water's recycled water investments are generally large. They were initially implemented to manage wastewater discharges and respond to regulatory directions. Later they were made to address water supply limitations, with a particularly rapid response during severe drought. The broad assessment frameworks used by the public sector should enable sustainable alternative service solutions to be developed. However, inherent biases in the decision-making frameworks, regulatory challenges, particularly in relation to financial risk, and conflicting and ambiguous institutional responsibilities make it difficult for small, recycled water options to be selected over more traditional investment options.

Chapter 5,7,9

In Sydney, investments by local councils in recycled water are the most numerous, although they provide only a small amount of the total recycled water capacity by volume. These investments are generally stormwater based, and have been implemented predominantly to provide leadership around sustainability investments and outcomes, and to meet sustainability goals, particularly with regards to local waterway quality and reducing potable water use. Investments have also been made to provide non-restricted irrigation water. The dominance of stormwater schemes is mostly likely due to existing institutional arrangements in Sydney were councils are responsible for the management of stormwater systems, flooding and local water quality, yet they have no responsibility for water supply and wastewater disposal.

Chapter 5,7

Private sector investments were also found to be diverse in their end-uses, scales and sources, reflecting the heterogeneity in responsibility, drivers and risk profiles. Their drivers were found to be: meeting green market demand; providing a secure water source, as a branding tool – particularly to meet

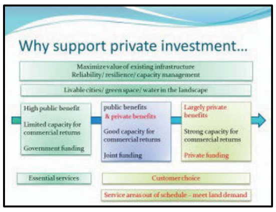
Chapter 5. 7.8 & 9

internal sustainability objectives; reducing potable water use during the drought; reducing centralised water or wastewater charges; meeting regulatory requirements; and servicing developments where water and/or wastewater services are not available.

Within Sydney, direct private investment has been supported and encouraged at a planning and policy level through the Metropolitan Water Plan; via regulation, specifically the *Water Industry Competition Act 2006*; and via incentives including grants and technical support. However, it is sometimes suggested that private sector investment is occurring despite, rather than because of, the regulatory environment. For the private sector, information asymmetry, government pricing policies and complex and risk-averse regulatory structures can make investing in recycled water and competing with existing services challenging.

Chapters 5,7,8 & 9

The private sector is continuing to invest in local recycled water systems despite these barriers. However, it is likely that the barriers are limiting wider implementation of local recycled water. This may be because of the strong market for recycled water, and because the private sector has the autonomy and flexibility needed to accept risk and recover revenue, whereas public water utilities do not. The willingness of the private sector to invest in the water sector is potentially valuable because it could provide new services and increased efficiency through competition, and because it could reduce public investment in centralised infrastructure.



3.2.3 How are impacts used to make decisions? (RQ2c)

Chapters 4 & 9

Which impacts apply, and where they apply, is highly context dependent. Many of the impacts are less familiar than those that accompany public utility-owned and operated centralised schemes (Chapter 4). The impacts of local recycled water schemes impinge on a broader group than do the impacts of existing centralised systems, and they do so in different ways

(Chapters 3 & 8). Furthermore, the benefits of local recycled water systems can be difficult to measure and uncertain, they may occur in the future, they may vary according the rules in use at the time. Finally, the benefits are often very site-specific and it cannot be assumed that the impacts at different sites will be the same. When combined, these issues can make the consideration of the full range of impacts in decision-making frameworks challenging, contentious and potentially costly. It is little wonder then, that despite an increase in the number of local recycled water systems, there is still limited agreement on their long term sustainability and viability.

Despite the broad range of impacts, the case examples reveal that cost was a critical and common component, and the price of recycled water was regularly compared to the cost of potable water. However, a combination of geographical and system design features, government pricing policies, complex and risk-averse regulatory structures and limited information availability, makes competing on price alone challenging in Sydney. Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers. Firstly, making them explicit makes it possible to assess the scale of the limitation, and the potential impact on investment. Secondly, by acknowledging the limiting factors it is possible to develop strategies to address them if necessary.

Chapters 5, 7,8 & 9

Many local recycled water benefits for the community (greening, urban cooling, resilience) and for the environment are cumulative, uncertain, difficult to value and occur in the future. Identifying appropriate benefit transfer mechanisms that reflect value, but are simple and transparent to administer requires further work, particularly if the industry aims to leverage private funds to maximise centralised asset value and provide liveability outcomes.

Chapter 4

The distribution, timing, likelihood and scale of impacts for local recycled water schemes can vary significantly from those of the more traditional centralized water and wastewater infrastructure options. For example, from a utility's perspective, private local recycled water systems can result in extra responsibilities, with little certainty of there being associated benefits. From a developer's perspective, developer charges for recycled water may be required before the lots are sold, imposing and additional cost. Alternatively, where a new development attracts high water and wastewater connection charges due to limited existing system capacity, local recycled water systems may save the developer money and provide an additional marketing opportunity (see Section 9.3 for other examples and further discussion).

Additionally, different groups consider different impacts to be more important, depending on how each group is impacted and what their roles and responsibilities are. In particular, the ability to control the outcome (cost, benefit or risk) will influence the perception of the impacts. For example, although as a strategy local recycled water systems can provide system-wide resilience and reliability benefits, as the public utility has limited control over ongoing decisions in the schemes, it may be seen as a high risk strategy. These variations will have a major impact on whether a decision is made to invest in local recycled water systems and the way those investments are made (see Section 9.3.2).

When choosing between a local recycled water scheme and the expansion or augmentation of an existing centralised system, it is essential to compare their impacts. In doing so, the impacts of local recycled water schemes must be clearly articulated and their distribution must be taken in to account. Clearly distinguishing between the distribution of impacts of centralized systems and local systems can also help to explain different perceptions within the community around the significance of particular impacts and associated risks. The significance and influence of the changes in impact distribution between centralized and local systems should also be considered when making decisions about regulatory frameworks and changes to other government policy positions.

3.2.4 How does the wider environmental, social, institutional and regulatory context influence local recycled water investment? (RQ2d)

As revealed in Figure 7 and the discussion above, although the costs and benefits influence who invests in local recycled water, and where and why they do so, the impacts themselves are only part of the picture. The type and magnitude of impacts for a particular local recycled water system often depend on the interaction between many different factors including:

- local social and environmental conditions
- end uses
- regulatory conditions for both the centralised and recycled water systems
- the trade-offs between capital investment, operating costs and management techniques.

To fully explain investment to date, and the role local recycled water systems may play in the future, the broader environmental, social, institutional and regulatory context must also be considered.

Chapter 4

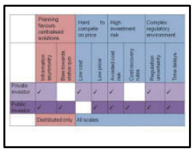
In Sydney, environmental conditions have been critical in creating the context to diverge from conventional centralised water and wastewater service strategies. While many of the large recycled water projects have been driven by long term water quality requirements, it is clear that the recent drought period was instrumental in driving the rapid increase in both the number of recycled water projects and the total recycled water capacity. This rapid increase in investment was enabled by the regulatory, institutional and funding initiatives instituted during the drought to reduce reliance on climate dependent sources.

Chapters 7 & 8

Despite the impetus for change being strongly driven by environmental conditions, the actual type recycled water investment (size, source, end uses, investor) depends on a more complex interaction between:

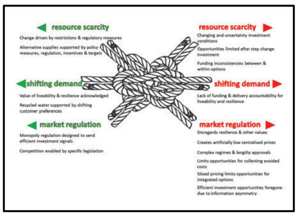
Chapter 6 & 7

- the institutional arrangements – for example, who can invest, why and how
- the regulatory frameworks – for example, the pricing/funding arrangements, investment incentives, wastewater discharge standards and recycled water treatment standards
- local conditions – for example, the end users and source water availability.



This thesis reveals a broad range of policy, institutional and regulatory factors that influence investment in and use of local recycled water, and it shows how they influence different decision makers in very different ways. These factors are generally based in regulatory, policy or institutional arrangements. They include factors that influence the price differential between general water services and recycled water, factors that influence risk and uncertainty, and factors that hinder efficient decision-making. In Sydney, complexity is also driven by the breadth of factors that influence water sector policy and the sometimes oppositional nature of policy, institutional and regulatory arrangements.

Chapter 5. Chapter 8 & Chapter 9



This thesis demonstrates the critical and surprisingly negative role that the policy, institutional and regulatory environment has on local recycled water investment in Sydney. Although these instruments, in conjunction with extreme environmental conditions, have helped to increase local recycled water, multiple opposing levers, particularly in pricing regulation, often negate them. These negative opposing levers are, in some instances, developed for entirely different purposes. Recognising this complex, contradictory and shifting context goes some way to explaining why investment in distributed systems can be

Chapter 7 & 8

perceived as difficult, complex, costly and risky (see Chapters 7 & 8).

Despite the fact that Sydney has some unique regulatory arrangements, identifying and exploring the oppositional nature of these levers is a process which contributes to explaining existing local recycled water investment, and perhaps other non-traditional alternatives, in other contexts. Acknowledging the diversity of influences and the critical interplay between them allows the development of strategies to address unintended consequences and the removal of barriers to future investment.

Chapter 7 &Chapter 8

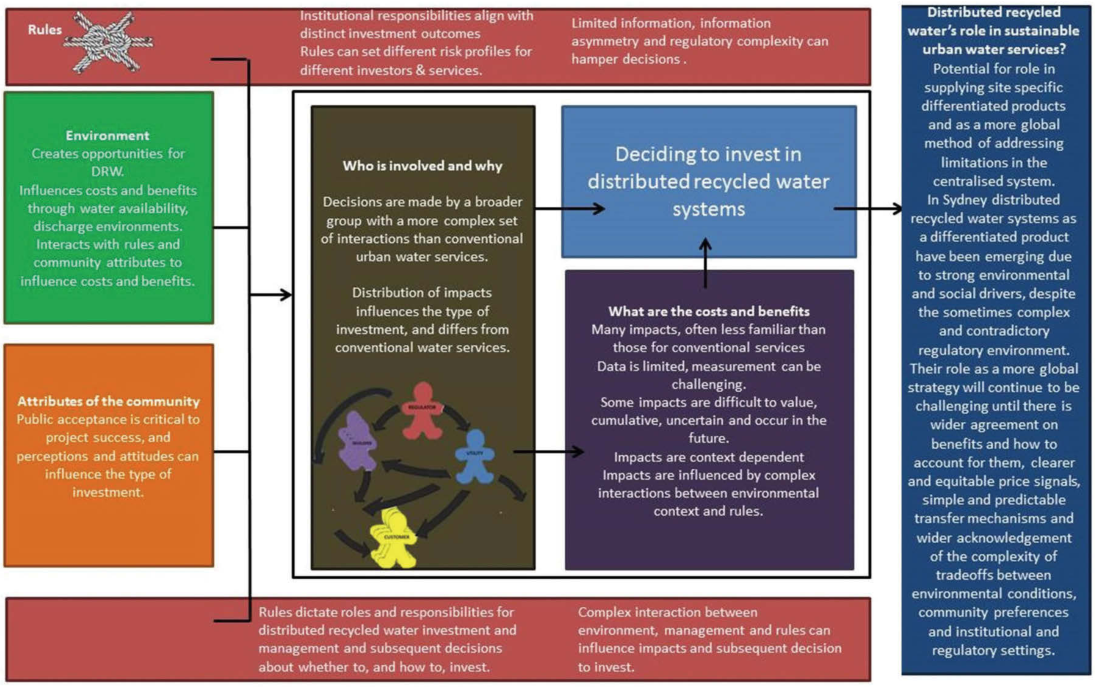


Figure 7: Summary of the research outcomes situated within the IAD framework

Chapter 4 Review and synthesis of the diverse impacts of local recycled water systems.

This chapter consists of a stand-alone paper: 'Review and synthesis of the diverse impacts of local recycled water systems'. This paper is unpublished. The paper systematically defines the characteristics of local recycled water systems, and compares them to other systems with similar characteristics. In doing so, it catalogues the full range of impacts of local recycled water systems and how they can be measured, answering Research Question 1. It also provides examples of situations in which individual impacts have been measured. The paper goes on to analyse and characterise the impacts, revealing why assessments of local recycled water systems have been problematic to date, particularly in comparison to centralised augmentations and extensions.

The paper includes a comprehensive catalogue of the impacts of local recycled water. The paper finds that:

- There are many impacts, with only a subset relevant for any particular site.
- Many of the impacts are less familiar than more conventional options.
- The impact distribution is different to the impact distribution found in more conventional options.
- Many of the benefits are difficult to identify, hard to value or uncertain.
- Understanding the broader regulatory and environmental context is vital for determining impacts.

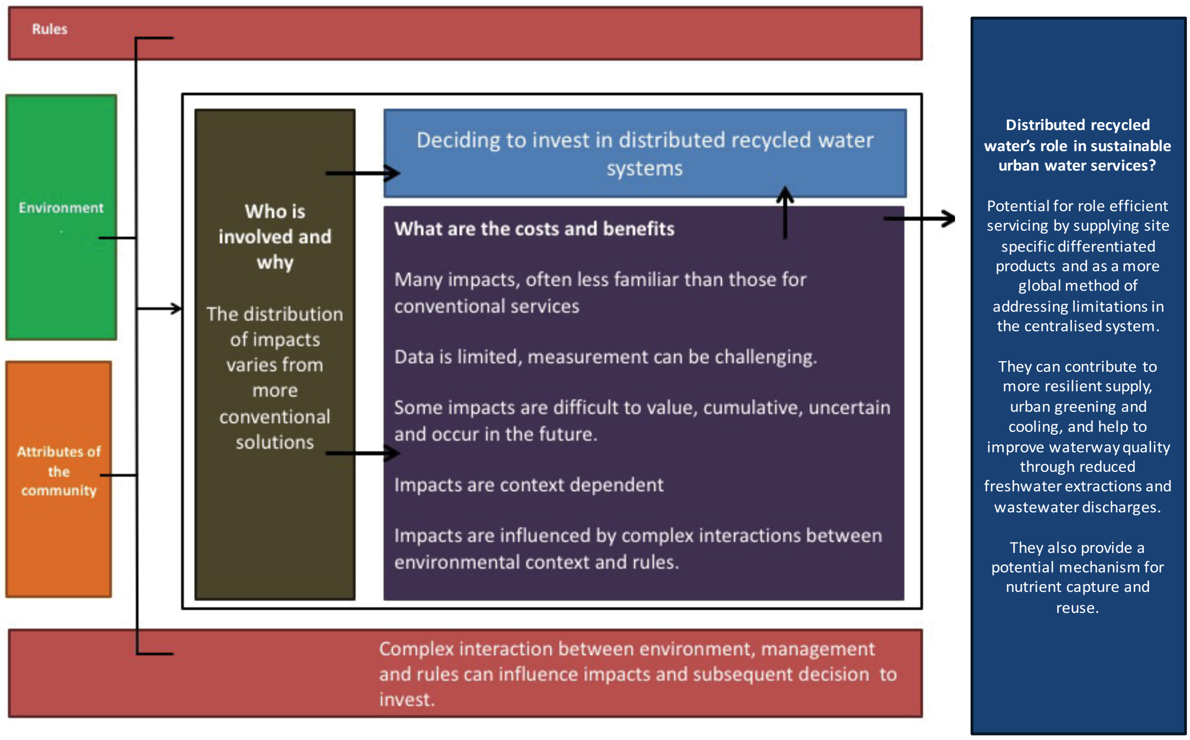


Figure 8: Chapter 4 analysis through the lens of the IAD framework

4.1 Abstract

There are an increasing number of small local recycled water systems being installed within existing centralised water and wastewater networks. A consistent and fair assessment of the value of such distributed recycling systems, particularly in relation to centralised extension, augmentation and replacement, has proved to be problematic. One factor that contributes to the problematic nature of assessments is the lack of a comprehensive catalogue of the costs and benefits of these systems. By systematically defining the characteristics of local recycled water systems, and comparing them to other systems with similar characteristics, this paper catalogues the full range of impacts. Many of the impacts are less familiar than those associated with public utility-owned and operated centralised schemes. By identifying how the impacts differ from those found in centralised schemes, this paper not only helps to explain the lack of agreement on their long term sustainability and viability, but also identifies areas for future research.

Keywords: Impacts, Urban water, Local recycled water, Sustainability assessment

4.2 Introduction: Why explore the range of impacts for local recycled water systems?

Until recently, small water and wastewater systems were generally reserved for locations that were remote and difficult and/or too costly to service. In recent times, the cost effectiveness, sustainability and resilience of large centralised systems have been questioned (Etnier et al. 2007a; Ferguson et al. 2013; Marlow et al. 2013; Mitchell, C et al. 2010; Mitchell, C et al. 2008; Nelson 2008; Pahl-Wostl 2002; Pinkham et al. 2004; Willets, Fane & Mitchell, C 2007). Utilities and developers now consider using small systems in conjunction with existing centralised systems, instead of extending the existing centralised systems (Etnier et al. 2007a; Mitchell, C et al. 2010; Mitchell, C et al. 2008; Nelson 2008; Pinkham et al. 2004; Willets, Fane & Mitchell, C 2007).

These small systems (called distributed systems in this paper, see Watson (2011)) can be very diverse in their sources, treatment methods, discharge locations, end uses and management models (Gikas & Tchobanoglous 2009; Water Services Association of Australia 2010; Watson 2011). Sources can include industrial water, sewer mining, blackwater, greywater and stormwater. Distributed systems can discharge to the environment or back to the sewer. Distributed systems can be owned by the centralised utility or privately owned.

Decisions in the water industry are often complex and require decision-makers to consider a wide range of perspectives and alternatives. By adding small systems into the mix of more traditional centralised options, in conjunction with principles of integrated water management (Ferguson et al. 2013), water-sensitive urban design (Sitzenfrei, Möderl & Rauch 2013) and liveable cities, the range of options to be considered and the complexity of trade-offs has increased (Water Services Association of Australia 2014b).

There are many methods available to compare the sustainability impacts of different urban water options. They include: cost benefit analysis (Marsden Jacob Associates 2013; Office of Financial Management 2007); cost effectiveness analysis (Fane, Blackburn & Chong 2010; Gonzalez-Viar et al. 2106; Giurco et al. 2010; Mitchell, C et al. 2007); multi-criteria analysis (Fane, Blackburn & Chong 2010; Hajkowicz & Higgins 2008; Lundie, Peters & Beavis 2004); triple bottom line assessment (Taylor & Fletcher 2005); SWARD (Ashley et al. 2003) and scenario planning (Deng et al. 2013; Sitzenfrei, Möderl & Rauch 2013). Different decision-makers prefer (or require) different methods (Fane, Blackburn and Chong, 2010). However, in general, nearly all methods require the identification, assessment and comparison of the types of costs and the types of benefits of each option.

Although local recycled water systems have many similar features to existing water options, the unique and new application of these localised systems within the centralised system requires detailed consideration of the range of impacts they can cause. Options analysis can take many forms in the water industry, so it is important that the net cast in the review of impacts was broad, allowing the full range of impacts to be considered, even if they are not applicable in all assessment processes.

This paper sets out the method used to identify the impacts of local recycled water systems. It then synthesises the literature to classify these impacts, identify how they can be measured and analyse the limits to their inclusion in traditional assessments.

4.3 Method

4.3.1 What do we mean by impacts?

This review seeks to include all the factors that might affect assessments and/or influence decision-making for or against local recycled water systems. It also seeks to identify how they can be included in decision-making processes. It includes benefits and disbenefits in the form of impacts and risks[9] across the full spectrum of affected parties. Impacts refer to actual occurrences. Risks refer to potential occurrences and are associated with uncertainty. Both impacts and risks can be positive or negative.

[9] Although not strictly impacts, risks have been included due to their apparent influence on the decision-making process. Risks represent a (positive or negative) deviation from the expected outcome, due to uncertainty. Risks also include the perception that something could occur. This is generally consistent with the definition of risk provided in AS/NZS ISO 31000:2009 (Standards Australia 2009).

4.3.2 Identifying the impacts

This review uses a broad literature base that reflects the different elements of distributed systems (see Figure 9). To capture all potential positive and negative impacts, a broad net was cast across products with similar characteristics, potential services that could be provided and replaced, and the different ownership and decision-making structures. The review sought to identify both implicit and explicit impacts, across the now familiar range of environmental, social, economic and technical domains.

The range of literature covered reflects that local recycled water systems are a specialised subset of recycled water systems and, perhaps, an evolution in decentralised services. Although they have many similar characteristics, the impacts of distributed systems and the associated risks are different from other more isolated decentralised schemes (Watson, 2011) and from larger recycled water systems. As well as reviewing impacts from similar types of systems, the review also covers the types of services that distributed systems could provide, augment, duplicate or replace. For example, local recycled water systems can provide a new service by delivering renewable water to the 'green markets'. Local recycled water can also augment water supply in the existing system and assist with water security. Local recycled water provides an opportunity for direct private investment in the urban water sector (Watson, Mitchell, C & Fane 2013a). Therefore, to understand the impacts of these new and hybrid servicing arrangements, the literature review also covered investment drivers, regulatory requirements, and existing arrangements, such as customer contracts and sewer mining and trade waste agreements.

This paper identifies the basis for the impacts, which areas of the literature are likely to have information on the specific impacts and how the results might be adapted for local recycled water systems. This characterisation provides a useful guide for practitioners and researchers seeking to identify, characterise and evaluate contributions to the sustainability of small systems

Each area was reviewed to the point of saturation[10] to identify both positive and negative impacts and risks. The impacts and risks were then reviewed to determine whether the impacts were relevant for local recycled water systems. This required an assessment of the characteristics that gave rise to the risk or impact, and an assessment of whether they would be the same or similar for a distributed system. The list that was developed was then reviewed and tested in a range of industry forums.[11]

The resulting contribution is a detailed impacts list, specifically for local recycled water systems, and an analysis of how they can be measured for inclusion in traditional decision-making processes. Because of the broad assessment frameworks used in the water industry, the varying perspectives of different stakeholders, and who is impacted by local recycled water systems were also identified. Identifying the impacts and how they can be measured, in conjunction with who is impacted, provides valuable insights into why obtaining consistent and fair assessments of distributed recycling systems, particularly in relation to centralised extension, augmentation and replacement, has proved to be problematic. Areas for future research are also identified.

[10] Saturation was defined as the point at which no new impacts emerged. This technique was developed by Strauss and Corbin (1998) and is useful when, rather than not enough literature, there is such a vast quantity of literature available that reviewing all of it is impractical. This approach was used in Hacking and Guthrie 2008 when they tried to articulate the dimensions of a range of sustainability tools.

[11] These forums included a workshop with a cross industry group specialising in local recycled water in Sydney (July 2011), Sydney Water (August 2011), the centralised water and wastewater service provider in Sydney servicing over 4.5 million people, and an industrial group specialising in local recycled water, and at OzWater 2012, the pre-eminent national industry conference in Australia.

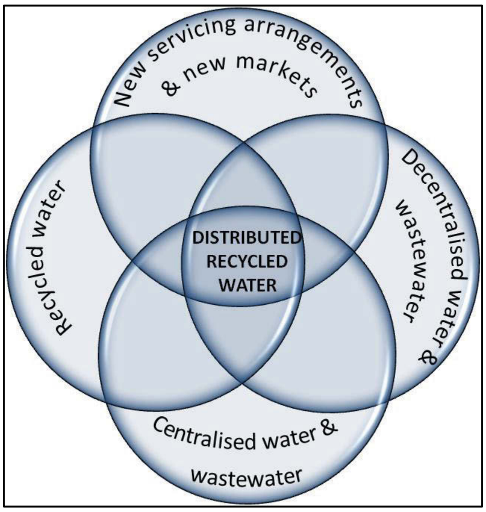


Figure 9: Existing areas of research relevant to the impacts of local recycled water systems

4.4 Findings: Impacts of local recycled water systems

The literature review revealed a broad range of impacts which are summarised in Table 5. The review of the recycled water literature identified benefits, such as increasing water supply resilience, reducing environmental degradation and supporting social benefits, particularly through supporting healthy green open space. It also highlighted risks to human health and existing infrastructure. The recycled water literature also identified the value of providing new products to both existing and new markets. This benefit was also discussed in the decentralised wastewater and new markets literature.

The review of decentralised wastewater systems literature identified benefits associated with flexible and adaptable infrastructure, which could provide services of the same type as the centralised system and new types of services. It also noted that keeping the impacts of water and wastewater services localised helps to promote equity. It also highlighted the costs and risks associated with planning, managing and regulating many small discrete investments. In this area, Pinkham et al.'s (2004) detailed analysis of the impacts of decentralised (isolated) wastewater schemes and WERF's 'When to consider distributed systems for urban and suburban development' (WERF 2006d) were particularly influential.

The review of new markets identified the many benefits associated with green infrastructure and competition, while noting the increased regulatory burdens, costs and risk associated with learning in emerging markets. It also identified the challenges associated with securing funding for broader social outcomes, including liveability and environmental improvements.

Finally, the review of centralised systems identified reliability, resilience and longevity benefits that could be provided to the centralised services through the integration of LOCAL RECYCLED WATER SYSTEMS with centralised systems. This literature also identified the costs of managing the interface between the two systems, and the financial, social and infrastructure risks associated with reduced flows and customers in the centralised system.

Overall, the impacts of local recycled water systems are summarised in Table 5, and can be categorised as:

- impacts that influence how efficient urban water services are provided, and are reliant on the interaction between the local recycled water systems and the centralised systems
- impacts that improve or degrade the environment
- impacts that arise by providing a different type of service conventional centralised water and wastewater services.

These impacts, how they can be measured and the implications for decision-making are discussed in detail below.

4.4.1 The interaction between local recycled water investment and centralised systems

Local recycled water systems can both replace some existing centralised urban water services (specifically non-potable water supply and wastewater treatment and disposal), and complement existing services by maximising the population that existing infrastructure can service efficiently. This section outlines the impacts of local recycled water systems, specifically in terms of infrastructure investment, the provision of non-climate dependent irrigation sources, and equity of servicing.

4.4.1.1 Infrastructure investment

Infrastructure cost trade-offs

There are many different types of recycled water treatment technologies available, all of which have different costs, land requirements, labour requirements and treatment capabilities. Because of their variability due to their flexibility and adaptability to local circumstances, comparing costs between schemes is challenging, particularly if the boundary conditions, costing methods and underlying assumptions are not clearly stated (Asano 2002; Mitchell, C et al. 2007; Mitchell, V 2004).

In addition, the availability of cost data for comparison purposes is limited, and collection of this data has been challenging. For example, a WERF project examining over 300 small and decentralised wastewater systems across 13 American states (Parten 2008) was only able to collect cost data for only 60 systems. In a review by Yang, Cicek and Ilg (2006) of the literature on MBR (a common technology used for local recycled water systems) only three studies on costs were identified in 339 research papers. And in a review of stormwater harvesting systems, Fletcher et al. (2008) found very limited and extremely varied information on capital and operating costs.

Several studies have directly examined the costs and economies of scale of local recycled water systems, both in theory and through case studies (Butler & MacCormick 1996; Chanan & Ghetti 2006; Friedler & Hadari 2006; Giurco et al. 2010; Yamagata et al. 2003; Zhang, Wang & Wang 2010). Marsden Jacob Associates suggest that recycled water costs within Australia vary from $2/kL or less up to over $10/kL, with costs increasing rapidly with increasing distribution and treatment requirements (Marsden Jacob Associates 2013, pp. 23-4). In Japan it has been shown that the cost of water from small reuse systems within buildings was around $2.00/kL[12], with economies of scale for systems producing over 1ML/day (Ogoshi, Suzuki & Asano 2001; Yamagata et al. 2003). In China it was shown that the unit cost ($/kL) of a 1 ML/day local recycled water system was half the unit cost of a 200kL/day system (Liang & van Dijk 2010;

[12] Amounts are in $US. The study was conducted in 1999 and reported in 2001.

Zhang, Wang & Wang 2010). Zhang also showed that matching capacity to demand was also vital, with a rapid decrease in efficiency and an increase in $/kL when utilisation rates dropped below 80% (Zhang, Wang & Wang 2010).

In addition, there has been research identifying the rapid advances in the capability, and accompanying cost decreases, for small scale treatment technology (Mitchell, C, Abeysuriya & Willetts 2008; Pinkham et al. 2004), particularly for membrane bioreactors (Côté, Masini & Mourato 2004; DeCarolis, Hirani & Adham 2009; Libralato, Volpi Ghirardini & Avezzù 2012; Melin et al. 2006, p. 275; Santos & Judd 2010; Santos, Ma & Judd 2011). Studies have identified costs in the range of $US0.40–$0.65/kL, although these estimates were for plants producing 4ML/day or more (Côté, Masini & Mourato 2004; Daigger et al. 2005; DeCarolis, Hirani & Adham 2009). Friedler and Hadari (2006) found that MBR-based systems only became economically feasible for single buildings when they exceeded 40 stories, or when a single plant served a cluster of buildings.

The treatment process, in conjunction with the input and output quality and quantity, also influence energy and chemical requirements and waste production. However, as recycled water systems are integrated with centralised systems it is often difficult to determine which costs are associated with general wastewater treatment and which are associated with recycled water treatment. Clearly, identifying the point of delineation between wastewater treatment and recycled water production is important, particularly where the products are priced separately on a cost basis.

Benefits of flexible investment units

Local recycled water systems offer a potentially efficient form of investment for managing demand growth and other infrastructure constraints. Due to their scaleability, local recycled water systems provide flexibility in size, timing, location, source and technology (Pinkham et al. 2004), allowing for the most appropriate and efficient form of treatment to be implemented where and when it is required. By continually investing in small units, rather than in single large supply options to avoid critical failure, economic benefits such as reduced capital outlay, reduced idle capacity, reduced borrowing costs, reduced lead time and reduced risk of overbuild can be realised (Pinkham et al. 2004; WERF 2006b). The efficiency benefits of flexible, small unit investments has been demonstrated, not just at the single site level, but also at the broader precinct and city levels. A recent study in Melbourne demonstrated significant opportunities for long term efficiencies (in the order of billions of dollars) through ongoing investment in demand management and integrated water solutions when the opportunity arises, as opposed to demand-triggered investment in the next tranche of desalination (Institute for Sustainable Futures 2011).

Lack of coordination between investments and regulatory risk management requirements can lead to inefficiency through duplication

Although distributed systems are intended to make investment more efficient, duplication may lead to inefficient investment. Non-potable recycled water systems require infrastructure investment over and above that required for potable water and wastewater servicing. Additional pipes are required to distribute the recycled water, and in most cases the wastewater stream will require localised treatment. When planning is undertaken at a centralised level, it generally preferences centralised solutions (Etnier et al. 2007b; LECG Limited Asia Pacific 2011). This means distributed solutions may be additional components, rather than parts of the overall planning model, resulting in unnecessary duplication. This duplication can occur due to redundant capacity in each small plant, as well as capacity remaining in the centralised system to meet back up, top up, and supplier of last resort obligations. The extent of efficiency gains or inefficiencies is highly dependent on how both the centralised and distributed systems are planned and regulated.

Poor long term design may also lead to inefficiency due to systems being turned off (Liang & van Dijk 2010) or performing badly, which will in turn impact on regulator and customer perceptions of the industry (Parten 2008; Tchobanoglous & Leverenz 2008). Where land release is driving the creation of recycled water systems, developers may choose capital efficiencies over long term operating effectiveness and efficiency (Etnier et al. 2007a; Parten 2008). Limited information is available on the extent of trade-offs, and in conjunction with limited capital and operating cost data (see discussion on infrastructure cost trade-offs, above), this can make it difficult to evaluate these trade-offs at the planning phase. During the course of this research, only very limited real cost data was collected. However, in several examples it was found that operating costs, particularly costs associated with labour, and with compliance reporting and testing, were greater than anticipated.

Local recycled water change reliability and resilience standards

Local recycled water can improve water security by providing an alternative water supply to the potable system, which is usually climate dependent (Mukheibir et al. 2012). By diversifying supply sources and providing a (relatively) climate independent supply, local recycled water systems may improve the reliability or resilience of the existing centralised system (Anderson 2003; National Water Commission 2010; New South Wales Government 2006; Toze 2006a). The potential for such improvements in resilience and reliability has been acknowledge in Sydney, although it is recognised that the benefit was difficult to measure and even more challenging to attribute to individual sites (NSW Independent Pricing and Regulatory Tribunal 2015b).

Small systems reduce the consequences of failure when used in conjunction with centralised and/or networked systems, and could help to reduce vulnerability to natural shocks and infrastructure failures and disruptions (Gikas & Tchobanoglous 2009; Pinkham et al. 2004). This helps increase the general reliability and resilience of the existing centralised system (Gikas & Tchobanoglous 2009; Pinkham et al. 2004; WERF 2006c).

While local recycled water systems may help to provide the total urban water system with greater reliability and resilience, individually small systems are more vulnerable to misuse and shock loading (Etnier et al. 2007a; Pinkham et al. 2004). In addition, as Liang demonstrates, the way systems are financed and managed can impact on individual reliability and the benefits they provide to the centralised system more broadly (Liang & van Dijk 2010).

Investing in local recycled water systems may avoid costs in the centralised network

Local recycled water systems have the potential to enable costs to be avoided in the centralised systems (Chen & Wang 2009; NSW Independent Pricing and Regulatory Tribunal 2011; Marsden Jacob Associates & Brisbane City Council 2011; NSW Independent Pricing and Regulatory Tribunal 2007; Pinkham et al. 2004). The types of avoided costs and savings include:

- water and wastewater transmission costs
- water and wastewater treatment costs
- capital savings from delaying or avoiding supply and treatment augmentations.

Local recycled water systems may help extend the life of centralised assets and avoid augmentations (Gikas & Tchobanoglous 2009; Liang & van Dijk 2010; Pinkham et al. 2004). Local recycled water systems can reduce the average and peak demands on water and wastewater networks (Gurung et al. 2015; Willis et al. 2011), which can in turn positively influence network capacity, long term infrastructure augmentations and pumping costs. Local recycled water systems also have the capacity to reduce the nutrient, BOD and suspended solids loads, compared to standard residential wastewater discharge, which can reduce networks and wastewater treatment costs. Greatly reduced flows may facilitate land development, even when centralised system capacity is limited (Liang & van Dijk 2010). Who benefits and how depends on local rules relating to infrastructure funding arrangements.

Identifying avoided costs for distributed local recycled water systems can be challenging due to indistinct boundary conditions, information limitations, modelling complexities, and scale differences (Watson, Mitchell, C & Fane 2013b). Although Sydney has a formal process for calculating avoided costs (NSW Independent Pricing and Regulatory Tribunal 2011) it can be difficult for centralised providers to delineate between general wastewater treatment costs and recycled water treatment costs, and therefore it is difficult for them to identify costs that are avoided through the recycled water process (NSW Independent Pricing and Regulatory Tribunal 2015b; Sydney Water 2012a). In addition, as distributed systems become more prevalent, defining the base case can make identifying avoided costs for each system challenging. The significant scale differences between centralised assets and local systems also limit the contribution a single individual system can make to avoiding centralised augmentations, transmission and treatment costs (NSW Independent Pricing and Regulatory Tribunal 2015b, p. 64).

Avoided costs in the transmission and treatment of recycled water are more easily identified as they are actual costs. Although transmission is a dominant cost factor for centralised systems, it is substantially made up of capital and maintenance costs, not the costs due to the transmission itself (Water Services Association of Australia 2007, pp. 9-10). This means that opportunities to avoid these costs are limited, even when centralised wastewater transportation and treatment is reduced.

Depending on centralised pricing arrangements, customers with local recycled water systems can reduce their payments for centralised water and wastewater services. The ability to do this depends on the price structure, particularly the balance between fixed and variable prices (Watson, Mitchell, C & Fane 2013b).

Wastewater extractions for recycled water production may cause degradation in centralised assets

Extracting wastewater from existing networks and treating it locally will reduce the base flow in the centralised system, and this has the potential to cause sludge build up, odour and corrosion downstream in gravity sewer networks (Frontier Economics 2008; Sydney Water 2006a). Local recycled water systems discharging brine or sludge streams into low flowing sewers have the potential to exacerbate corrosion and sludge build up issues. Furthermore, if local recycled water systems became a significant portion of the customer base, it is possible that some assets would become hydraulically ineffective or redundant. Overall, the impact of low flows and increased concentration on sewers is heavily dependent on the management techniques for the interface between the two systems (for example rules around how much flow can be extracted, or including minimum flow requirements before discharge of sludge or brine is allowed) (Governments of Canada and British Columbia and the Capital

Regional District 2012; Gray 2008; Sydney Water 2006a, 2010b, 2010c). Although restorative costs can be calculated, establishing a base case and attributing degradation to a specific scheme is difficult, particularly as one moves further away from the discharge location.

Recycled water may damage infrastructure

The physical characteristics of recycled water (particularly salt and colour) can impact on the performance and durability of existing physical infrastructure, particularly cooling towers, pipes, washing machines and toilets. Recycled water use in cooling towers has the potential to cause scaling and corrosion, although this can be managed through higher levels of treatment and appropriate material selection and operating procedures (Zavoda 2005). Over-treatment of water can also cause infrastructure degradation, for example calcification of highly treated recycled water was required in one instance to avoid damage to water fittings (Institute for Sustainable Futures 2013a). It is also possible that residual colour in recycled water can stain toilets or result in additional cleaning products being used (Mainali et al. 2011). Again, while these impacts can be measured, the occurrence, let alone magnitude, depends on the interactions between recycled water quality, end use and ongoing management choices including fixtures and equipment.

Centralised funding shortfalls

The interaction between local recycled water systems and the existing centralised system has the potential to affect centralised revenue. Centralised systems generally have large sunk costs, and the commonly used postage stamp pricing mechanism depends on all customers contributing to these costs over long time periods (Australian Competition and Consumer Commission 2007; Water Services Association of Australia 2007). Privately owned distributed systems have the potential to remove revenue from the centralised system, leaving the remaining customers with higher costs (Frontier Economics 2008; Sydney Water 2015a; Water Services Association of Australia 2007) and decreasing government dividend payments (LECG Limited Asia Pacific 2011). The magnitude of these changes will depend on ownership models, the market penetration of distributed systems, price structures and the way the distributed systems interact with the centralised system.

4.4.1.2 Reliable irrigation in times of water shortage

Healthy green open space has been linked to many environmental, social and economic benefits, and requires adequate water availability, particularly during hot, dry periods. In areas that rely on surface water supplies, restrictions are often used to manage water supplies in periods of drought, which are also the times when irrigation is most needed. Local recycled water is an option that can provide a reliable source of irrigation water during periods of surface water shortage.

Using water to maintain healthy open space can provide social and environmental benefits

Healthy open spaces and playing fields are pivotal in maintaining social harmony and pride (Bedimo-Rung, Mowen & Cohen 2005; Green & Beard 1994), mental and physical health (Bedimo-Rung, Mowen & Cohen 2005; Lee & Maheswaran 2011; Sugiyama et al. 2008), public recreation and active lifestyles, including social sport (Binney et al. 2010). In contrast, the decay of playing fields through lack of adequate water supplies can lead to increased injuries (Dragoo & Braun 2010; Orchard 2002; Otago et al. 2007), negative social impacts (such as increases in antisocial behaviour) (Bedimo-Rung, Mowen & Cohen 2005; Green & Beard 1994) and increased costs for repairing or reinstating fields when water is finally available (Carrow 2006; GHD 2007; Green & Beard 1994; McAfee Dr 2011). During the last drought in Sydney, some playing fields had to be abandoned, and maintaining business viability for some golf courses was challenging (Morgan 2009; WERF 2006a). Maintaining the viability of playing surfaces has been identified as a driver for several local recycled water systems in Sydney. See, for example Pennant Hills (WERF 2006a), the Cronulla-Woolooware reuse scheme (Sutherland Shire Council 2008) and the Blacktown Workers Club (Aquacell 2013).

Well-kept green open space can assist in improving air quality, provide beautification, reduced dust and reduced noise (Green & Beard 1994; Marsden Jacob Associates & Brisbane City Council 2011; Mulley, Simmons & Maheshwari 2007; Nelson 2008).

Green open space, particularly grassed areas, can protect receiving water quality by reducing runoff, minimising soil erosion and encouraging inorganic solids and organic chemical decomposition (Green & Beard 1994). In addition, retaining water within the urban landscape and maintaining green space is an essential part of urban cooling (Green & Beard 1994). In Australia, heat waves already cause more deaths than any other type of natural disaster (Steffen, Hughes & Perkins 2015). Studies in Sydney have shown the severe impacts of heat islands and predicted worsening conditions due to increased urbanisation and climate change (Jacobs & Delaney 2015). Local recycled water systems provide water to maintain vital green open spaces and the potential to retain water in the landscape, minimising heat island effects.

Property values increase when in close proximity healthy open spaces and conservation features associated with local recycled water.

Individual property values can also benefit from proximity to well-kept open spaces. A number of location-specific hedonic pricing studies have shown an increase in property value associated with proximity to golf courses, parks and lakes (Anderson & West 2006; Cho, Bowker & Park 2006; Do & Grudnitski 1995; Lutzenhiser & Netusil 2001). Bowman et al. (2009) also found property value increases associated with well integrated conservation features (for example stream corridors) and open spaces in residential subdivisions. It is difficult to determine what role, if any, the recycled water supply plays in keeping the space in a state that provides value. However, in a recent hedonic pricing study in Sydney following a severe drought, a property value increase of around 0.72% for homes that had recycled water which allowed them to irrigate when other residents faced severe restrictions (Marsden Jacob Associates 2014a).

The social and environmental impacts associated with healthy open space are difficult to measure (Lee & Maheswaran 2011). In addition, the quality of open space depends on a wide range of factors, of which water availability is but one, and therefore, apportioning the social impacts to a local recycled water development is even more challenging. The economic benefits of open spaces are more reliably valued, although techniques can be complex and costly, for example hedonic pricing studies. The cost of field rehabilitation is easier to measure, although again, the availability of water is not the only factor in field decay (McAfee Dr 2011; Sydney Water 2011a). While it is evident that recycled water can assist in maintaining healthy green open space during times of potable water limitations by providing a climate independent water source, the benefit will depend on both the environmental conditions and the way centralised water services are planned and managed.

4.4.1.3 Local recycled water may change the distribution of impacts and therefore influence the overall social equity of urban water service provision

Social equity of urban water servicing can be managed in many different ways. Distributed options imply changes in the roles and responsibilities of the different stakeholder groups involved (Pahl-Wostl 2002). These changes may lead to social equity concerns, as the impacts may be distributed in a very different way to existing centralised option. These differences may be particularly noticeable in:

- the price signals and total bills different customers receive
- the standard of service including quality and continuity that customers receive
- exposure to environmental impacts including odour and noise.

Centralised services often use postage stamp pricing, where everyone pays the same for the same service, regardless of the cost to service. In contrast, the price structure and the service received for local recycled water can vary both from the conventional centralised service and between different recycled water systems. For example, recycled water is often charged at a lower price (Radcliffe 2004) and can be of a different quality (see discussion in Watson (2014) and Institute for Sustainable Futures (2013f)). However if, as is the case in Sydney, the full costs of local recycled water must be collected from just the direct customers of the system, the smaller customer base has the potential to focus the impact of any technical or financial failure on a small, potentially vulnerable group (Etnier et al. 2007a). In some ways this direct cost reflection promotes equity through its user pays orientation. However, when systems are close to larger systems that use postage stamp pricing to flatten price signals, this can create cost inequities between seemingly similar user groups.

Local recycled water services could change the services people receive. For example, during the recent drought in Sydney, only potable water was subject to restrictions, while locations with access to recycled water could irrigate gardens and parks. The Rosehill scheme provides water with very low dissolved solids, so some customers have made significant savings in cooling tower and boiler costs (due to water and chemical use, and equipment replacement) (Institute for Sustainable Futures 2013f). In other schemes, recycled water is sometimes a different colour and odour (Hurlimann & McKay 2007; Watson 2014). These differences mean that different parties incur different costs and benefits, which can create disparities in service not just between potable and recycled customers, but between recycled water customers in similar areas serviced by different schemes.

Local recycled water systems can change the location and magnitude of environmental impacts. Local recycled water systems potentially keep the impacts of water use local (Etnier et al. 2007a; Gikas & Tchobanoglous 2009), as opposed to centralised systems where the impacts of water extraction and wastewater discharge are often transferred to external catchments.

4.4.2 Environmental interactions

Using local recycled water can both improve and degrade the existing environmental conditions. It can do this through changes to water extraction, changes to the way water is used in the environment, and changes to the movements of nutrients through the environment.

4.4.2.1 Improved water quality through reduced extraction and disposals

Recycled water directly contributes to water quality by reducing surface water extraction (Toze 2006a), supporting groundwater recharge (Melin et al. 2006; Schwecke, Simmons & Maheshwari 2007) and reduced nutrient discharges in wastewater (Anderson 2003; Lazarova et al. 2001; Toze 2006a). Measuring the benefits of water quality improvements is difficult as changes occur slowly, and are cumulative, with negligible benefit from one small site.

4.4.2.2 Nutrient capture/ disposal

Residual nutrients in recycled water can also encourage healthy plant and grass growth and reduce the need for further fertilisation (Anderson 2003). Fine and Hadas (2012) showed that not only could this reduce fertiliser use and save valuable phosphorous reserves, but if treatment levels, crops and fertiliser requirements were matched efficiently, there could be substantial greenhouse gas emission reductions.

Conversely, high salt concentrations in recycled water can impact on soil structure and crop yields (Estévez et al. 2010; Hurlimann & McKay 2007). The availability of recycled water, or a regulatory requirement to use it rather than discharge it, can lead to over irrigation or leaching which will increase the salinity of the groundwater and increase the nutrient levels in runoff (Estévez et al. 2010; Toze 2006a).

4.4.3 Providing services for a changing urban water industry

Local recycled water systems have the potential to provide:

- new services – for example ‘green’ products and liveable cities
- alternatives to existing services – for example a more secure water supplies for irrigation or higher quality water for industry
- services in new way – for example private sector provision in a competitive market

4.4.3.1 Providing a mechanism for competition and the leveraging of private funds

Local recycled water systems provide a mechanism to increase competition in the water sector (Australian Competition and Consumer Commission 2007; LECG Limited Asia Pacific 2011; NSW Government 2006) which should lead to more efficient and effective service delivery throughout the industry. Sydney has a unique regulatory framework, specifically designed to stimulate competition – the *Water Industry Competition Act 2006* (NSW). However, nearly a decade after it was established, entry to the market is still limited, and is focused on fringe and boutique developments. Nevertheless, in some instances the framework has allowed development to proceed outside the planning horizon set by the public utility, Sydney Water (Urban Development Institute of Australia 2015). The type and magnitude of the benefits (and costs) of private sector service provision are still being debated (NSW Independent Pricing and Regulatory Tribunal 2015b).

In addition, local recycled water has the potential to leverage private funding for projects that provide both public and private benefit (Infrastructure Finance Working Group 2012; Watson, Mitchell, C & Fane 2013a). The overall benefit of leveraging private funds can depend greatly on the planning and regulatory management of both the centralised and the distributed systems. For example, in China, developments are required to incorporate a local recycled water system to minimise the impact on the centralised networks (Liang & van Dijk 2010). However, although these systems are installed, their operational benefit is minimised through poor operation (Liang & van Dijk 2010). In Sydney, Australia, local recycled water systems are voluntary, but a lack of coordination with the centralised planning framework and excess capacity in the centralised network also minimises their beneficial contribution to the centralised operation (Watson, Mitchell, C & Fane 2013b).

4.4.3.2 Providing alternative services

Local recycled water can provide a mechanism for customers to choose to pay to avoid limits on water use, and restrictions on how and when water can be used (Hensher, Shore & Train 2006; Marsden Jacob Associates & Brisbane City Council 2011). During the Sydney drought (2003-2009), the ability to choose a more secure water supply was most clearly demonstrated through the rapid increase of local recycled water schemes for irrigation, particularly for golf courses. However, the benefits of avoiding restrictions will vary from location to location, depending on the climatic conditions, the extent to which irrigation is limited by the restriction regime, and the value irrigators place on irrigating during periods when restriction are imposed.

It has been suggested that small scale provision of recycled water is a viable mechanism to provide different levels of water services to different customers (National Water Commission 2011b). The value of recycled water as a product free from restrictions has already been discussed above. In addition, the standard of treatment for recycled water can also provide a more valuable product to customers. As discussed in Section 4.4.2.2, the nutrients in recycled water can be used to reduce reliance on fertilisers. It has also been shown that the use of high quality recycled water produced through reverse osmosis can save money on cooling tower operational costs (Institute for Sustainable Futures 2013f). However, as noted in Section 4.4.1.1, differences in water quality and reliability can also be detrimental.

4.4.3.3 Servicing a new market

The value of green

Producing recycled water onsite and capturing and reusing stormwater can provide extra points needed to obtain prestige building ratings (Green Building Council of Australia 2013b). Literature associated with the green building market indicates there are a range of general benefits to the owners and users of green buildings, including the ability to charge higher rents, improved productivity, green branding, easier access to finance and reduced environmental risk exposure (Fuerst & McAllister 2011; Green Building Council of Australia 2008b, 2011; Institute for Sustainable Futures 2013a; McGraw-Hill Construction 2006; Melaver & Mueller 2009; Pivo & Fisher 2010). It is also possible to gain planning concessions such as increased floor areas by meeting green building requirements (Ryde City Council 2010). However, it is difficult to attribute these general green building benefits directly to recycled water provision, as they form part of an overall building package. Watson (2014) found that occupants in one Sydney building rated recycled water rated favourably in comparison to other green building features. Watson also found that even with initial operational issues, occupants generally believed using recycled water in the building was a positive option on an individual and company level (Watson 2014). However, a study by Kats in 2003 only attributed three per cent of actual savings in green buildings to water (World Green Building Council 2013, see figure 9, p. 56.). Even these savings would not be totally reflective of recycled water, as it also includes water efficiency measures, and stormwater and rainwater harvesting.

Some green building literature suggests that green buildings can change the social demographics of a location (Blackburn 2009). However, it is difficult to prove a link between green buildings and positive social demographic changes, let alone quantify the role recycled water plays in this change.

It is also possible that green building ratings may be driving perverse economic outcomes, both now and in the future. Building-scale recycled water often requires a small construction footprint, which means high energy processes are used to meet regulatory water quality standards. This can mean processes use significantly more energy for water and wastewater treatment than a centralised supply, particularly if the centralised supply uses gravity, dam water and ocean disposal.

The green building movement is broadening from rating individual buildings to rating entire developments and precincts. Decisions by property developers to incorporate recycled water as part of a green development package, for either commercial or residential development, and the increasing frequency and success of these developments, demonstrates the growing market for discretionary water services (Chanan & Ghetti 2006; Water Factory 2013).

The value of recycled water is influenced by social preferences and perceptions

Public perceptions and preferences regarding recycled water have changed substantially in recent years. The acceptance of recycled water is determined by community and regulatory risk perceptions (Dolnicar & Saunders 2006; Mankad & Tapsuwan 2011; Po et al. 2005; Russell & Hampton 2006). Risks and risk perceptions are complex, and are influenced by a range of factors including the source, the end use, the provider, education, age, sex, historical factors and motivations for use (Mankad & Tapsuwan 2011; Po et al. 2005). The level of acceptance for particular sources of recycled water and for the particular end-use of recycled water influences its uptake and therefore its value (Po et al. 2005). Until fairly recently, recycled water was seen as an inferior product. Today however, recycled water is seen as a valuable complement to conventional water supplies (Dolnicar & Schäfer 2009). Studies in Sydney have indicated the public's preference for recycled water over other less integrated options and consumers' willingness to pay a premium for recycled water (Marsden Jacob Associates 2014b; Metropolitan Water Directorate 2014a).

Regardless of the scientific data, the risk perceptions regarding the acceptability of recycled water can vary greatly (Institute for Sustainable Futures 2013d). How risk and risk perceptions are managed is important because it can involve significant capital, operating and management costs (Institute for Sustainable Futures 2013d; Schimmoller, Kealy & Foster 2015).

Contributing to liveable cities

Local recycled water systems have the potential to contribute towards liveable cities[13] by providing a mechanism for customer choice, retaining water in the environment, contributing to urban cooling and providing flexibility to deliver a range of services from different of sources that best suit local circumstances. Their ability to contribute towards liveable cities is particularly valuable in initiatives to convert large established cities that already have large centralised water networks (WERF 2006b, pp. 5-6). However, planning for liveable cities requires the coordination and consideration of the city and its services in total. At the moment, water authorities have very little ability to influence urban planning policies, which makes it difficult for water services to effectively contribute towards liveable cities (Binney et al. 2010).

Although local recycled water systems can contribute towards more liveable cities, what constitutes a liveable city, and what role water plays, are poorly understood and vary from location to location (Binney et al. 2010). There is often a lack of clear regulations and policies which identify who is responsible for delivering and funding solutions that contribute towards liveable cities (National Water Commission 2011b). This means it can often be difficult to justify or fund alternative solutions that provide benefits above and beyond those provided by traditional water services.[14] This has been demonstrated in the City of Sydney, where a decentralised water master plan

[13] See (Binney et al. 2010) for a discussion on how water services in general contribute to the creation of liveable cities.
[14] See for example the discussion on funding liveability in: NSW Independent Pricing and Regulatory Tribunal (2015a).

was developed, but sourcing funds for implementation has been challenging (City of Sydney 2012).

Integrated supply

A potential advantage of local recycled water is its flexibility, which enables it to incorporate principles of water sensitive urban design by providing opportunities for integrated water solutions that include multiple sources and cater for a range of end uses (Cook et al. 2009; Nelson 2008; Watson 2011; WERF 2006c). This has the potential to result in more sustainable long term water solutions for customers (Anderson 2006). However, the current regulatory frameworks associated with integrated water solutions are complex and inconsistent. This means there are often delays and additional regulatory costs associated with small alternative recycled water systems (National Water Commission 2011b; Power 2010).

4.4.3.4 Preparing for and managing change

Providing education, awareness and social learning

Recycled water schemes, decentralised wastewater systems and local recycled water systems can increase social awareness and they can be valuable public education tools (Chen & Wang 2009; Liang & van Dijk 2010; Pinkham et al. 2004). Each additional recycled water project provides an opportunity for the community to experience recycled water, which may increase public acceptance of recycled water and expand community awareness of the range of potential recycled water uses (Anderson 2003; Balkema et al. 2002; Liang & van Dijk 2010; Russell & Hampton 2006; Toze 2006a). Each scheme can also provide new insights into how to effectively communicate with, and involve, the community in decisions relating to recycled water services (Balkema et al. 2002; Russell & Hampton 2006). In Sydney, one scheme was used to demonstrate the safety of recycled water use in cooling towers by demonstrating that the nutrient load would not encourage microbial regrowth. Other schemes in Sydney are collecting monitoring data to assist with accreditation and validation protocols.

Each new recycled water project provides the opportunity to demonstrate the links between water quality, treatment levels, waste water discharges and costs, and allow the industry to study the value small systems may provide in terms of resilience to the centralised system (Mukheibir & Mitchell, C 2014). Although each system may be just a ‘little bit different or unique’, in combination they can produce common lessons and powerful insights that are integral to learning lessons that will help better decision-making in the future (Institute for Sustainable Futures 2013b). However, specifically identifying the benefits of increased awareness and education and measuring them is challenging and imprecise.

In Sydney there has been evidence of continual improvement in both the regulatory and administrative processes as the number of distributed local recycled water schemes has increased. Streamlined procedures for sewer mining and private sector licencing, in particular, have been developed through a series of iterations between applicants and regulators. Again these educational and efficiency benefits are difficult to identify and measure.

Efficient and effective regulation of new markets and services

To accommodate both the changing methods and types of service delivery it is essential to adapt existing regulatory frameworks to ensure fair competition and the continued protection of public health (Mitchell, V 2004; NSW Department of Water and Energy 2008). Existing frameworks are biased towards large providers, and in conjunction with a history of inadequate regulation of small schemes (Tchobanoglous & Leverenz 2008; Victorian Auditor-General 2006), this creates cost, time and motivational barriers to local recycled water schemes (Etnier et al. 2007a; Frontier Economics 2008; Mitchell, C et al. 2010; Pinkham et al. 2004; Tchobanoglous & Leverenz 2008; Tjandraatmadja et al. 2008). Developing these regimes takes time and resources. Once established, there is an additional regulatory burden of monitoring many sites and many providers, a task which is not present in the existing centralised model.

Local recycled water systems can be used to provide both discretionary and essential water services. Regulators differentiate between these services, requiring higher levels of supply security for essential services, particularly toilet flushing. Security can be provided via storage, or through back up centralised supply. In some jurisdictions regulators have designated suppliers and retailers of last resort in case a supplier becomes unable to provide an acceptable level of service (NSW Government 2006; NSW Office of Water 2011; OFWAT 2003). The trade-offs between infrastructure investment and reliability effect the costs of local recycled water systems, the resilience benefits provided within the centralised system and the level of customer service. These complex interactions between the decisions of the owners of the local recycled water system, the owners of the centralised system and the regulators, and their implications for costs and benefits, further increase the difficulty of assessing the relative merits of urban water options.

Regulation may need to adapt to provide customer protection

There is the potential for recycled water to adversely impact human health. Human health risks arise from contaminants being present in the recycled water in combination with a mechanism for exposure. Human health can be affected by microbial pathogens, pharmaceutically active compounds (PACs), endocrine disrupting chemicals (EDCs) and heavy metals (Natural Resource Management Ministerial Council, Environment Protection and Heritage Council & Australian Health Ministers Conference 2006; Toze 2006b). Generally, heavy metals are removed by primary treatment and cannot be detected in crops above background levels (Toze 2006a). In untreated wastewater heavy metals can be taken up in crops, but at very low levels which would only be of concern if the crop formed a substantial part of the diet (Toze 2006a). Similarly, secondary processes and disinfection are usually adequate to treat most microbial pathogens (Toze 2006a). Research has demonstrated that EDCs pose minimal risk for humans, but they have been found to affect animals that are in constant contact with the water (Toze 2006a, p. 152). Even persistent PACs pose very little risk to humans in non-potable recycled water, due to their low concentrations, but they can create antibiotic resistance in the soil and microorganisms in the soil (Toze 2006a, p. 153). If treatment processes are inadequate, or if plumbing mistakes result in cross connections contaminating the water supply, there is an increased risk of illness[15], mainly due to pathogens present in the wastewater (Institute for Sustainable Futures 2013d; Sydney Water 2005).

Although poorly treated recycled water may adversely affect human health, regulations in some instances require treating water to such a level that it is of the best available quality rather than just fit for purpose (Institute for Sustainable Futures 2013d). The level of treatment required to meet standards and meet expectations of risk management have a direct influence on capital and operating costs (Tjandraatmadja et al. 2008; Watson, Mitchell, C & Fane 2013b).

[15] Studies have shown cross connections in Australia to be rare. As recycled water has become more prevalent, experience in minimising, identifying and managing cross connections has improved, and as a result the incidence of cross connection has reduced (Institute for Sustainable Futures 2013d, p. 9).

Table 5: Summary of local recycled water system impacts

		Impact	Category	Who is impacted
			Positive + Negative – Risk ?	
Efficient urban water services – the interaction between centralised and distributed	Infrastructure investment	Efficiency though flexible investment	Economic +	Utility Community, Owner
		Inefficiency through duplication	Economic -	Owner, Customer, Utility, Community
		Inefficiency through loss of economies of scale (management and treatment)	Economic -	Owner, Customer,
		Gains in wider system reliability/ resilience	Economic +	Utility, Community
		Individual system vulnerability to shocks, loss of reliability	Economic – Social -	Owner, Customer
		Infrastructure capital and operating costs	Economic -	Developer, Owner, Customer
		Avoided centralised system costs (augmentation, transport, treatment)	Economic +	Utility, Community
		Avoided water and wastewater charges	Financial +	Owner, Customer
		Centralised system lost revenue	Financial -	Utility
		Stranded and unfunded assets	Economic ?	Utility
		Degraded centralised assets due to low flows	Economic ?	Utility
		Degraded recycled water assets due to water quality	Economic ?	Customers
	Reliable irrigation in times of surface water shortages	Social health benefits associated with healthy open space	Social +	Community
		Avoided field rehabilitation costs by having adequate irrigation	Economic +	Community
		Avoiding loss of business due to inadequately or costly irrigation	Economic +	Customer
		Air quality, water quality, beautification enhancements through healthy green space	Social + Environmental +	Community, Environment
		Property value increases with open space and integrated conservation features	Economic +	Community
		Property value increases with recycled water or green services	Economic	Customer
	Equity	Different service standards for similar customers	Social ?	Customer
		Different cost impacts for similar customers	Financial ? Social ?	Customer, Community
		Keeping impacts local	Social +	Community
Environmental interactions	Reduced extraction / disposal	Improved water quality through reduced surface water extractions	Environmental +	Environment, Community
		Improved water quality through reduced wastewater discharge	Environmental +	Environment, Community
	Nutrient capture / disposal	Reduced nutrient use for crops	Economic + Environmental +	Customer, Environment
		Reduced crop yields and soil quality due to salinity	Economic ? Environmental ?	Customer, Environment

		Impact	Category	Who is impacted
			Positive + Negative – Risk ?	
		Reduced water quality due to salinity and nutrients from recycled water use, runoff or discharge	Environmental ?	Environment
A changing urban water industry	Existing services – new options	Dynamic competition	Economic +	Owner, Customer, Community
		Leverage private funds	Financial +	Community
		Servicing new developments outside of planning horizon	Economic	Developer, Customer
		Develop and maintain regulatory regimes	Economic -	Regulator
		Individual reliability (avoid restrictions)	Economic +	Customer
	Service new markets	Green building benefits	Economic + Social +	Developers, Owners, Customers
		Branding	Economic +	Developers, Owners, Customers
		Water quality differentiation	Financial	Customer
		Servicing customer preference for recycled water & sustainable services	Social +	Customers
		Health risks	Social ?	Customer
		Education	Social +	Community, Regulatory, Utility, Customer
	liveability	Contributing to liveability in the urban landscape	Social + Environmental +	Community, Environment
		Contributing to urban cooling through retaining water in the environment	Social + Environmental +	Community, Environment
		Providing opportunities for integrated water management	Environmental +	Environment

4.5 Discussion

It is clear from the discussion above and Table 5 that there is a very long and broad range of impacts for local recycled water systems. When deciding whether to invest in local recycled water, it is not necessary, or even possible, to consider all of the impacts. In addition, only a subset of the impacts will be relevant for each system, as a key benefit of local recycled water systems is their flexibility and their ability to adapt to the unique requirements (size, demand, sources) of an individual site or area. However, referring to a comprehensive list of potential impacts in the first instance can provide a consistent and justifiable base to decide which impacts are relevant and appropriate to include in any decision-making process.

The identification of the full range of impacts for local recycled water systems and how they can be measured highlights three key issues for consideration in decision-making: Firstly, the impacts often depend on interactions between the environment and the regulatory framework; secondly, scale differences mean that the impacts of individual recycled water systems on the centralised system are minimal; and thirdly, the distribution of the impacts can vary significantly from the distribution of impacts found in more conventional centralised options. In addition, the benefits of local recycled water systems can be difficult to measure and it often uncertain when or if the impacts will occur. They may occur in the future, they may vary according the rules in use at the time, and they are difficult to transfer between sites. Combined, these properties, can make the inclusion of the full range of impacts in decision-making frameworks challenging, contentious and potentially costly.

Even when an impact exists for a particular system, and it is possible to determine its magnitude, the choice of decision-making framework will define the range of impacts that can be included in the assessment, and the perspective used to assess the impacts. Thus, the decision-making framework and the perspective of the assessment will be critical in determining which impacts are included in the assessment.

4.5.1 Identifying and measuring impacts for local recycled water systems can be challenging

Identifying and measuring the impacts of local recycled water systems can be challenging. Many of the impacts discussed above either rely on expensive evaluation techniques, are site specific and difficult to transfer between sites, are difficult to identify, are part of a broader benefit of which recycled water is only a small component, vary depending on how the centralised system is managed or environmental conditions, or some combination of the above. Even when impacts are easy to identify and measure (for example capital and operating costs), there is limited verifiable data available. The difficulties in measuring and including impacts in assessment processes is compounded by their flexibility, making it difficult to compare costs and benefits between systems. Appendix H provides examples of studies where impacts have been valued.

In some instances there is still work to be done identifying robust and practical ways to include impacts in assessments. In particular, evaluating developing local recycled water systems as a strategy to augment the existing centralised system will remain challenging until flexibility and adaptability can be accounted for in a fair and robust manner.

4.5.2 The type and magnitude of the impacts of local recycled water systems depends on interactions between the centralised system, the environment and the broader regulatory context

The impacts of a particular system will depend on where it is, what the surrounding environmental and social conditions are, and how the system interacts with other systems. Some impacts will depend to some extent on characteristics of the receiving environment, such as the soil type, sensitivity of waterways to nutrients and the amount of water available. For example, reductions in nutrient discharge are likely to provide greater benefit when wastewater is discharged to rivers and streams than when wastewater is discharged through deep ocean outfalls. Some impacts will exist only during certain time periods or climatic conditions. For example, keeping open space green is only relevant during dry or drought conditions. Some impacts will only exist if particular social drivers or markets exist, such as green building and agriculture benefits. A few of the impacts, for example stormwater benefits, will only apply if multiple sources are used. Finally, some impacts will only apply if there are existing or impending future limitations in the centralised infrastructure, for example avoided water supply augmentation costs.

The regulatory environment can also directly influence the type and magnitude of costs and benefits. For example, the way restrictions are used to respond to variations in water supply will influence where and when recycled water systems will be of benefit. Although technology choice can dominate capital and operating costs, the selection of a particular technology is often driven by space and a number of contextual rules (both regulatory, policy and social). As with other water and wastewater infrastructure, recycled water systems are subject to legislation, regulations, and policies associated with planning, approvals and monitoring. The rules that govern the use of recycled water and discharge requirements will significantly influence the type of treatment and infrastructure. Recent research has shown that differing perceptions of risk seem to lead to a situation where over-treatment is the norm, which results in unnecessary increases in costs and environmental impacts (Institute for Sustainable Futures 2013d).

Some impacts depend on the way the centralised and distributed systems (as well as their interfaces) are planned, regulated and managed. Through their interactions with the centralised system, local recycled water systems can contribute to efficient urban water servicing by increasing system resilience, reducing idle capacity, reducing overbuild in the centralised system and avoiding the financial impacts of large step augmentations. In identifying and evaluating these impacts, it is important to identify how the existing centralised systems is managed, and how the impacts from local recycled water systems would be different.

Impacts can also depend on the way extractions and discharges from both the centralised system and the distributed systems are regulated. For example, if large centralised augmentations are made for water, there may be plenty of water available for irrigation, even during extremely dry periods. If there are limitations in the centralised system, rules can force investment in local recycled water (as seen in China (Liang & van Dijk 2010)), or incentive payments (such as in New York (Zavoda 2005)). This can result in different drivers and types of investment, with differences in the distribution of costs and benefits. Furthermore, impacts such as damage to centralised assets from low flows or waste discharges rely on the way the interface between the two systems is managed.

4.5.3 The scale difference between local recycled water systems

The scale difference between a local recycled water system and more conventional centralised solutions compounds the challenges of identifying and valuing benefits. Often, impacts will only be realised when a certain critical number of local recycled water schemes are implemented in a particular area. For example, many of the benefits that local recycled water systems can provide for extending the capacity and resilience of centralised systems rely on cumulative impacts.

4.5.4 Distribution of impacts varies between systems and from conventional urban water service options.

As shown in Table 5, who bears the impacts of local recycled water systems can vary significantly from the situation for more traditional centralised water and wastewater infrastructure options. Where benefits go to an individual, and that individual has the opportunity to make a decision and secure funding, local recycled water investment has been occurring – for example in irrigation schemes and industrial reuse. This investment occurs even when the full range of benefits are difficult to directly attribute to recycled water, for example in green buildings. Where benefits are global and there is regulatory direction that enforces local recycled water installation, such as in China, investment still occurs but the benefits depend greatly on the type of investment, the way it is managed and the interactions with the centralised system management (and pricing).

When social and environmental benefits are provided through centralised water and wastewater services, the cost of providing the benefit is generally recovered from the community that receives the water services. In contrast, in the case of local recycled water systems it is often a much smaller group that is paying for the water service, even though the wider community receives many of the benefits, particularly for privately owned local recycled water. The role of different funding mechanisms, and how they influence who, where and why local recycled water investment occurs, is an area for further research.

Furthermore, an impact that is a benefit from one perspective can be a negative from another perspective. For example, combining multiple local recycled water systems with the centralised system can improve overall resilience, reliability and supply security. However, the resilience and reliability of each individual local recycled water systems could be much lower than a centralised service.

4.6 Conclusion

Local recycled water systems are a unique subset of recycled water systems and have characteristics both similar to and different from a wide range of alternative decentralised and more traditional centralised systems. This paper has used an array of literature to identify, articulate and categorise the full range of impacts for local recycled water systems. It has identified the full range of impacts of local recycled water systems, and it has indicated where in the literature one can find research and data on these impacts. This will provide practitioners, researchers and students with a firm foundation for considering which impacts are relevant to particular situations and decision frameworks.

This paper has demonstrated there is a vast range of potential impacts associated with local recycled water systems. Many of the impacts are less familiar than those that accompany a public utility-owned and operated centralised scheme. Which impacts apply, and where they apply, are highly context dependent. In addition, the impacts affect a broader range of stakeholders than existing centralised systems, and these impacts are felt in different ways. It is little wonder then, that local recycled water systems are gaining in popularity yet there is still limited agreement on their long-term sustainability and viability.

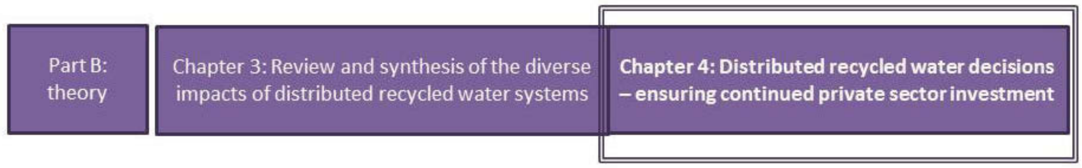
The type and magnitude of impacts for a particular local recycled water system often depend on the interactions between many different factors. Local social and environmental conditions, end uses, regulatory conditions for both the centralised and recycled water system, and the trade-offs between capital investment, operating costs and management techniques all influence the type and magnitude of impacts for local recycled water systems. Clearly identifying the interplay between these environmental, social and regulatory factors is critical to explaining how, where and why local recycled water investment is (and is not) occurring.

Furthermore, in instances where benefits are both cumulative and difficult to evaluate, including them in assessment frameworks becomes even more challenging. Many community and environmental benefits (greening, urban cooling, resilience) of local recycled water systems are difficult to value; they are cumulative, uncertain and occur in the future. Identifying appropriate benefit transfer mechanisms that reflect value, but are simple and transparent to administer, is another area where further work is required, particularly if the industry aims to leverage private funds to maximise centralised asset value and provide liveability outcomes.

The significant contribution of this paper is to articulate the breadth of the potential costs, benefits and risks of local recycled water systems to provide a broader starting point that might be useful for investors or planners seeking to make a more convincing argument for their schemes, or for researchers to develop more applicable sustainability assessment processes.

Chapter 5 Local recycled water decisions – ensuring continued private sector investment

Watson, R., Mitchell, C., Fane S., (2013). Local recycled water decisions – ensuring continued private investment. OzWater 2013. AWA. Perth, Australian Water Association.



This chapter consists of the paper 'Distributed recycled water decisions – ensuring continued private investment' which was peer-reviewed and presented in Perth at the 2013 OzWater conference. This paper focuses on Research Questions 2b and 2d, namely: Who makes decisions about local recycled water investment? and: How does the wider environmental, social, institutional and regulatory context influence decisions about whether to invest in local recycled water?. This paper reviews who invests in local recycled water and why. It then goes on to identify regulatory and institutional barriers for both public and private investment, comparing and contrasting the factors influencing public and private sector investment.

Highlights:

- Contrasts recycled water drivers and constraints by investor type
- Identifies who invests in local recycled water and why
- Reveals information asymmetry, pricing policy, regulatory complexity are key limitations to private investment.

(note the published version of this paper used the term distributed recycled water in place of local recycled water. Local recycled water has been substituted for consistency for this thesis

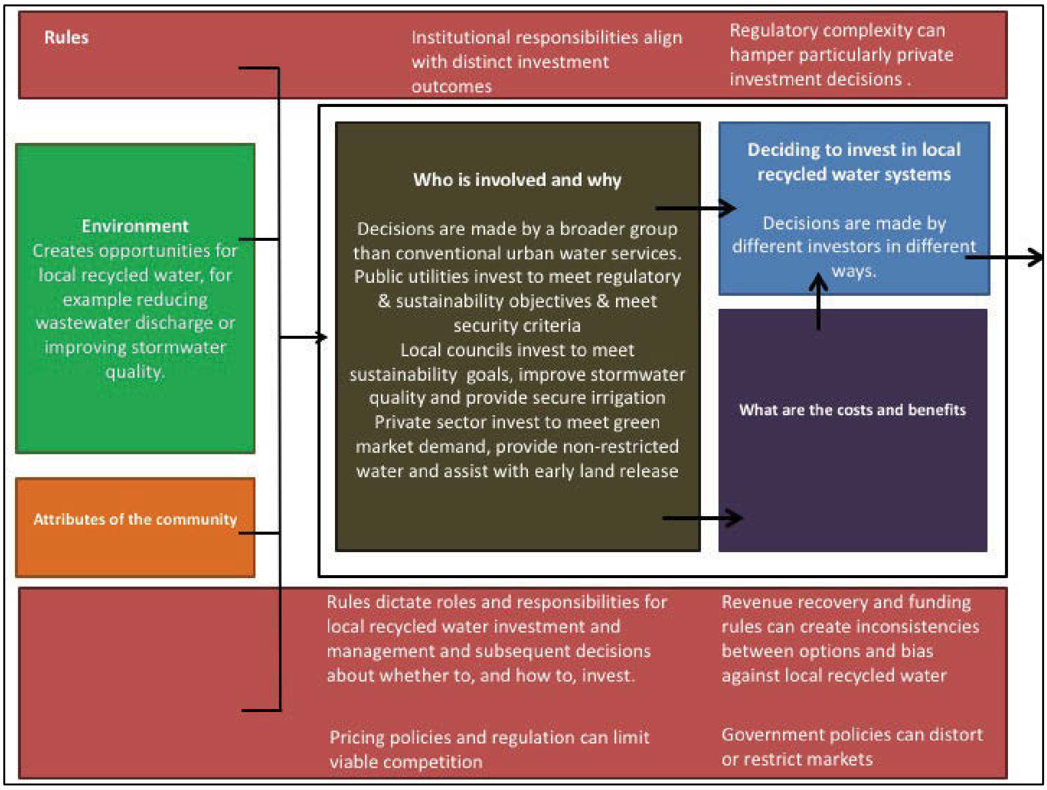


Figure 10: Chapter 5 analysis through the lens of the IAD framework

5.1 Abstract

The green market, prolonged water restrictions and a suite of regulatory changes have facilitated direct private investment in water infrastructure. This is particularly true for local recycled water systems (small, local systems that are a complement to, or are in competition with, a centralised service).

This paper compares and contrasts the drivers and constraints that are influencing how the public and private sectors are making decisions about whether to invest in the local recycled water market, and what this means for their future uptake. In particular, it reviews why it is important to ensure regulatory and institutional barriers are minimised in order to continue sustainable private investment in recycled water.

5.2 Introduction

Australia is one of the driest continents, with erratic climate patterns and low rainfall. However, we still generally rely on cheap surface water runoff for water supplies and mostly coastal environmental discharge with minimal treatment for wastewater disposal. Water and wastewater services are predominantly supplied by government-owned water authorities operating as regulated monopoly businesses.

However, the water industry is entering a period of challenge and change. Continuing to maintain and expand the capacity of existing centralised systems to manage and respond to ageing infrastructure and demand growth, while managing shifting expectations in terms of sustainability, liveability, resilience and security, is proving both expensive and technically challenging. The combination of these drivers, plus technological change, government incentives and new markets, is providing an opportunity to fundamentally shift the current water service and delivery paradigm

The green market, prolonged water restrictions and a suite of regulatory changes have facilitated direct private investment in water infrastructure. Direct private investment in small scale water infrastructure like rainwater tanks and simple on-site wastewater treatment systems is common practice in rural areas (and, with rain tanks, in new development areas in many states). However, the current scale of private investment in water infrastructure within already serviced urban areas is unprecedented in Australia. Private investment has evolved rapidly, and appropriate regulatory frameworks are still being developed and adapted. There is still great uncertainty about how direct private investment in the water sector is best managed and how broader public benefits are best accounted for.

One area where private investment has been active in high density urban centres is local recycled water systems (small recycled water systems that are a complement to, or are in competition with, a centralised service). The public sector is also investing in small recycled water systems, but in major urban centres at least, the market is being driven by the private sector.

This paper compares and contrasts how the public and private sector are making decisions to invest in the local recycled water market and what this means for their future uptake. It identifies who invests in distributed systems and what drives that investment. It then looks specifically at the public sector and examines why, despite using broad assessment frameworks, investment in these small systems is limited by a range of regulatory and institutional barriers. Next the paper discusses why the private sector is driving this market, even though there are still many regulatory and institutional barriers to investment. By understanding what drives and restricts investment by different groups in local recycled water we will be better able to develop and manage existing regulatory and institutional frameworks to assist long term sustainable investment by both the public and private sector.

5.3 What are local recycled water systems and who invests in them

Distributed water systems can be very diverse, in their source, treatment methods, discharge locations, end uses and management models (Gikas & Tchobanoglous 2009; Water Services Association of Australia 2010; Watson 2011). Sources can include industrial water, sewer mining, blackwater, greywater and stormwater. Distributed systems can discharge to the environment or back to the sewer. Distributed systems can be owned by a public utility or one or more private water service providers.

The drivers to invest in local recycled water schemes are made for the following reasons:

- The public water utilities –to manage wastewater discharges, to manage centralised infrastructure constraints, to improve service levels, to improve reliability, to meet drought security criteria, and to increase efficiency
- Local councils – to meet sustainability goals, to provide leadership around sustainability investments and outcomes, to manage wastewater discharges, to improve stormwater quality, to provide non-restricted irrigation water
- Private investors – to service developments where water and wastewater services are not available, to meet 'green' market demand, to provide non-restricted non-potable water (e.g. industrial uses, irrigation).

The ways decisions are made by each of the above groups are quite different. It is generally accepted that the decision to invest in a discretionary good in a competitive market place by a private investor is usually made from the perspective of a single private investor and be weighted towards financial viability. Local councils, governments and public utilities may also consider the financial viability or may take a wider, 'whole of society' economic perspective and perhaps include externalities.

Water and wastewater services are recognised as a government responsibility with benefits that are not always reflected in market signals. This means that the broad assessment frameworks available to the public sector should enable sustainable alternative service solutions, like local recycled water. However, as we will see, inherent biases in the decision making frameworks, knowledge gaps, unclear responsibility for delivering water sensitive urban design and inflexible risk and cost recovery criteria is potentially limiting the uptake of decentralised recycled water systems by utilities. In contrast, in many cases the private sector is driving investment in decentralised recycled water systems. This is despite the significant barriers to private investment, including a complex, inconsistent and changing regulatory environment, institutional setting that favour large centralised investments and pricing policies that make competition on price alone difficult.

5.4 Traditional public investment in water services – and how this applies to small scale recycled water

Water is generally viewed as a necessity and Governments are expected to guarantee a safe, reliable and reasonably priced water supply (Warnken, Johnston & Guilding 2009) While public decisions seek to provide value for money, a number of frameworks (such as multi criteria analysis and cost benefit analysis) have been developed to allow the decision maker to consider social and environmental benefits to the whole of society. However, the public decision making frameworks that are generally employed are far from perfect (for example see the discussion in Watson, (2012)).

Most public sector investment assessment frameworks have difficulty including risk and uncertainty which biases against less well understood options, including small scale recycled water. Due to the public health aspects of water and wastewater services, decisions tend to avoid risk (Nelson 2008; Productivity Commission 2011;

Water Corporation 2011). This risk adversity affects smaller, less well-understood options and is compounded as decision makers commonly recall and place more emphasis on dramatic or bad outcomes (Hammond, Keeney & Raiffa 1998). This can lead to the positive risk benefits of small systems being negated by the negative risks and results in the early exclusion of potential small options due to perceptions of poor public acceptance or high health risks. On the other hand, large centralised solutions are susceptible to optimism bias, where planners overestimate benefits and underestimate costs, which again favours larger options (Commonwealth of Australia 2006; Office of Financial Management 2007).

Most sustainability decision frameworks also have difficulty incorporating the value of flexibility, a key benefit of small recycled water systems. Finally, the distribution of impacts for small systems and centralised alternatives is often different. Many assessment frameworks used in the public sector consider the project from a whole of society or a utility perspective. However, small system alternatives often rely on individuals or smaller groups for funding and ongoing management. The additional risk and uncertainly introduced with the change in distribution (for example ongoing capacity and capability of the systems, and community acceptance of alternative options) may reduce the willingness of public utilities to invest in small scale recycled water.

Even though public utilities have decision making frameworks that include a wider range of considerations, restrictions with the methods and practical application can make it difficult for local recycled water to be preferred over more traditional service options. This is compounded as the biases in the decision making frameworks closely matches the benefits of small systems (for example flexibility, efficiency, risk reduction, customer choice in service level) (Watson, Mitchell, C & Fane 2012).

In addition to barriers in the assessment frameworks, recycled water is more frequently seen as a discretionary good, not an essential public service. This is reflected in the requirement for utilities to apply different assessment criteria to recycled water projects (regardless of scale). In particular, risk and cost recovery criteria for recycled water projects are more stringent than those applied to assess water and wastewater services deemed essential. For example, in NSW there are a number of factors that differentiate between water and recycled water services and the way costs can be recovered. There is a ‘postage stamp’ (common) price for basic water and wastewater services, while recycled water costs must be recovered directly from the user. There are no developer charges levied for water and wastewater but there are developer charges for recycled water services. These distinctions exacerbate the difference between prices and the revenue risk profiles for general water and wastewater services and those for recycled water within the one utility.

These different revenue recovery and funding rules have generally been established to encourage competition in the sector and limit the ability of utilities to use monopoly power to dominate the recycled water market (NSW Independent Pricing and Regulatory Tribunal 2006). However, in practice they can limit the viability of public sector investing in local recycled water.

The lack of clarity in the institutional landscape for delivering water sensitive urban design further exacerbates the situation. There are many different bodies that have responsibility for the various social and environmental aspects of urban water services (flood protection, reliability and quality of supply, receiving water quality, changes to local hydrology). There is also limited guidance on how the social and environmental costs and benefits associated with sustainable solutions should be recovered. The lack of clarity on the role of the utility in providing sustainability and liveability outcomes, and how costs should be recovered may reduce their willingness to invest in local recycled water systems as they may not be able to recover their costs through traditional funding mechanisms.

Even with these limitations some investment in local recycled water systems is still occurring within the public sector, particularly in conjunction with stormwater, in smaller or in more remote areas, where there is a need for an alternative water supply or there are limits on wastewater discharges.

5.5 Private investment in water services – and how this applies to small scale recycled water

Private sector involvement in the urban water industry has most frequently been through providing services to the water utilities (LECG Limited Asia Pacific 2011). In Australia, this involvement is significant. In 2009-10 between 90-100% of capital expenditure was outsourced for major Australian Water utilities and 60-70% of operating expenditure was outsourced for many utilities (Productivity Commission 2011).

Although direct competition from the private sector for water services is relatively new in Australia, the theoretical enablers and barriers for private investment are well studied. Successful private investment in the water industry depends on a stable investment environment (stability, security, predictability), the economic/ commercial viability of the project, appropriate risk allocation, technical strength of the project and capabilities of the proponent (Tenenbaum & Izaguirre 2007; Zhang 2005). Conversely, political interference in decision-making, the low level of cost recovery in the water sector and uncertainty over future government action will limit private investment in the water industry (Harris & Pratap 2009; Liang & van Dijk 2010; Productivity Commission 2011; Smith 1997).

Whilst small recycled water systems continue to be planned and built there are still many cost, risk and institutional barriers that make it difficult for them to compete against other traditional water services. In Australia, there are three key areas that could be expected to limit private investment in water services:

- regulation is complex, which leads to higher costs, time delays and uncertain outcomes
- regulatory pricing policies limit viable competition
- government policies distort or restrict markets.

5.5.1 How does the regulatory environment limit private investment?

Australia's urban water sector has undergone substantial reforms in the last two decades. These reforms have successfully improved service levels, encouraged efficiency gains, and improved environmental and public health outcomes (LECG Limited Asia Pacific 2011; National Water Commission 2011b). Despite the major reforms the regulatory framework is still overly complex (National Water Commission 2011b; Power 2010). For example in NSW a decentralised recycled water system may trigger 6 Acts, be covered by 4 specific guidelines and require the approval or advice of up to 8 authorities, although this is currently under review (NSW Government 2012).

The change in focus from prescriptive end product management to a risk management approach for recycled water[16] (LECG Limited Asia Pacific 2011) has failed to deliver. While a risk management framework is, in theory, more flexible, it has been suggested that the uncertainty surrounding new technologies and unclear policy positions has created a climate of risk aversion (Tjandraatmadja et al. 2008). This has resulted in delays and additional costs (for example validation testing (Power 2010)) and a perception that best quality and not 'fit for purpose' water is required which again increases costs (Tjandraatmadja et al. 2008).

The complexity of regulation, combined with the risk adversity has the potential to make investing in local recycled water systems expensive, uncertain, prolonged and too difficult to pursue.

5.5.2 How do pricing policies limit viable competition?

There are several ways utility water and wastewater pricing policies affect the financial viability of local recycled water systems including the:

- ability to access avoided costs
- ability to be competitive due to the low unit price of potable water

[16] Specifically a change from the prescriptive National Water Quality Management Strategy (NWQMS) *Guidelines for Sewerage Systems: Use of Reclaimed Water* (ARMCANZ-ANZECC-NHMRC 2000) to the risk management approach outlined in the Australian Guidelines for Recycled Water (NRMMC) 2006

- ability to recover costs and be price competitive due to the regulated water and wastewater service charge structure, particularly postage stamp prices.

Calculating avoided costs is generally not well understood[17]. Lack of experience makes outcomes uncertain and it is difficult to calculate the value of avoided costs for small increments of demand in relation to infrastructure with very large capacity[18]. This is particularly true for water as:

- once a lumpy investment has been made it is usually viewed as a 'sunk' or unavoidable cost in the context of cost-benefit analysis (Commonwealth of Australia 2006). This means once a decision to augment infrastructure is made there is little opportunity over the short to medium term for decentralised investments to 'avoid' costs.
- networks can account for up to 80 percent of total system capital costs and wastewater capital costs are often based on factors that are unlikely to be reduced with individual distributed schemes (Water Services Association of Australia 2007).

Current avoided cost calculations mitigate against investment in local recycled water systems. Current methods for avoided costs use a system wide average approach[19], however avoided costs vary significantly across the network (Mitchell, C et al. 2007). Postage stamp pricing can mask where opportunities for more efficient alternative investments may be available. The significance of the high level of variance in cost to service customers in Sydney is perhaps best demonstrated by the degree of concern expressed by Sydney Water around 'cherry picking' throughout the review of Services Sydney's application to access Sydney Water transmission services, and in WSAA's

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[17] For example – IPART identified Sydney Water were concerned with having avoided cost calculations reviewed through price path as it exposed them to risk of incorrectly calculating avoided costs and investing in a scheme which once reviewed would become uneconomic (i.e. if avoided costs were reviewed down by the regulator) (NSW Independent Pricing and Regulatory Tribunal 2011). If this lack of uncertainty is seen as a risk for Sydney Water in a government pricing path process, it is likely to be even harder to estimate for a private company wanting to seek avoided costs from the utility.

[18] For example Malabar STP treats about 500ML/d (average dry weather flow), the Sydney desalination plant at Kurnell can produce 250ML/d, compared to a local recycled water plant (Pennant Hills Golf Course 0.6ML/d, Pitt Town and Discovery Point 0.3ML/d)

[19] See Appendix C, particularly pg77-78 (NSW Independent Pricing and Regulatory Tribunal 2006)

review of cost drivers of wastewater assets (Australian Competition and Consumer Commission 2007; Water Services Association of Australia 2007).

Even when distributed systems manage to generate avoided costs they still may not be able to claim the full amount. In NSW, IPART have suggested that the payment of avoided costs generated by the scheme, but could be reduced depending on the recycled water users' willingness to pay (NSW Independent Pricing and Regulatory Tribunal 2006). This means that, depending on what the 'willingness to pay' is assessed to be by the independent regulator.

The low price of water makes it hard for small private recycled water schemes to compete on unit price alone. The unit price of water across Australia remains low despite the substantial progress utilities have made towards cost reflective pricing. Historically we have harnessed cheap surface water supplies. Water is generally priced to the long run marginal cost. This reflects a suite of measures, some much cheaper, and some much more expensive (NSW Independent Pricing and Regulatory Tribunal 2006). Even when a local recycled water scheme makes up part of an efficient suite of measures to meet the supply demand balance, unless it costs less than the average long run marginal cost, it will be difficult for it to be competitively priced by a private supplier. Changes in capital funding arrangements and cost recovery mechanisms for water infrastructure mean many pre-price-regulation assets were substantially written down, so prices do not reflect the full value. For example in 2000, with the start of price regulation, IPART drew a 'line in the sand' and wrote down asset values by over half (regulatory asset base is about $13 billion, the depreciated replacement cost is over $30 billion)(Sydney Water 2010a). This is exacerbated with many utilities receiving a very low rate of return on these already written down assets.[20]

Postage stamp pricing arrangements allow large utilities to spread the cost of traditional water and wastewater infrastructure over a large customer base.

[20] The current rate of return achieved by Australian water utilities is too low, even for risk free investment. 5% is the 10yr government bond rate (generally equivalent to the risk free rate)In 2005-06 the average economic rate of return was close to 5%, in 2008-09 the median rate of return for large utilities with over 100,000 customers was about 1/2 at 2.4% (Productivity Commission 2011)

Decentralised solutions, particularly local recycled water solutions often have to recover costs directly from the users. This makes comparing centralized extensions and augmentations to decentralised solutions difficult, particularly when assessing revenue recovery methods and risk (Mitchell, C, Abeysuriya & Willetts 2008).

5.5.3 What government policies restrict private investment?

Government policies have the ability to distort or restrict the market for local recycled water or introduce further risk. In addition to setting efficiency and recycled water targets Australian governments have occasionally limited or restricted certain supply options, such as decisions on dams (Welcome Reef Dam in Sydney) and indirect potable reuse (Toowoomba, NSW). These decisions introduce additional risk for private investment, as investments may become redundant if barriers to cheaper sources were removed in the future (LECG Limited Asia Pacific 2011).

Inconsistent water conservation and recycling targets make investment decisions more complex and the arbitrary nature of differences introduces further risk into investment decisions. Water conservation targets for new homes vary across Australia. In some jurisdictions there is an overall target (see for example targets in NSW and ACT) and it is the developer/homeowner who chooses how to meet the target. Other jurisdictions specify how water savings are to be met (for example in Queensland certain devices are specified) so recycled water would be an additional cost. Other jurisdictions do not allow blackwater recycling on a lot scale (Tjandraatmadja et al. 2008).

5.5.4 Other factors that limit private investment

An additional barrier for decentralised systems is most of the urban water planning is undertaken by the centralised utilities. There are no formal processes in most jurisdictions for identifying opportunities for small systems in advance of centralised investment and communicating this to the market. This lack of information limits the ability of private investors to suggest other alternatives or plan developments to maximise benefit to both their customers and the wider centralised system.

Despite the barriers to private investment in the Australian water industry private decentralised recycled water systems are being planned and installed throughout Australia. In the residential sector planning legislation often requires alternate water sources in addition to the centralized supply. In the commercial building sector, green building assessment frameworks reward on-site recycling. In many cases recycling water provides a prestige factor in the major cities property markets. Meanwhile, some local governments are undertaking their own master planning processes to identify local opportunities for recycling, for example the City of Sydney has developed its own Decentralised Water Master Plan which has local recycled water targets.

5.6 What can we do to foster the development of an effective and efficient industry?

If the aim is to sustain private investment in distributed recycling systems and work towards an efficient and sustainable competitive market we must continue to minimise regulatory and institutional barriers and seek ways to appropriately share risks and rewards. There are a number of actions that would assist the transition to an effective, competitive and efficient market:

- Acknowledge the current system is not perfect and has limitations. Build this acknowledgement into the mechanisms developed for fostering and encouraging the development of an efficient industry.
- Provide consistent and simple regulation, particularly within and across States.
- Ensure that long term objectives and government goals, regulation and administrative application are clear and consistent.
- Develop better processes for sharing risks and rewards.
- As an interim measure, given all the other factors restricting the market perhaps risk and reward sharing should be simplified to encourage ‘investments at the margins’ and help establish an effective private industry market.
- Overcome information asymmetry. This could include developing mechanisms that share preliminary planning information that would provide opportunities

for private investors to propose options that support both their objectives and provide value to the centralised system.

- Continue to communicate and learn.

5.7 Conclusion

Local recycled water has the potential to provide effective and efficient solutions to many of the key issues facing the water industry. The capacity of distributed systems to provide efficient servicing at the urban fringes and in constrained areas, increase the resilience of the centralised system and provide customers differentiated services is well recognised. Private investment in this sector has the potential to allow competition in a monopoly industry, foster innovation and decrease the public funds required for infrastructure augmentation. In the current setting both public and private investment is occurring, yet it is restricted through a combination of regulatory, policy, pricing and institutional arrangements.

The broad assessment frameworks used by the public sector should enable sustainable alternate service solutions. However, inherent biases in the decision making frameworks, regulatory challenges and conflicting and ambiguous institutional responsibilities make it difficult for small recycled water options to be selected over more traditional investment options. In addition, regulatory and business requirements can make it challenging[21], or unfavourable[22] , to support private investment.

For the private sector information asymmetry, government pricing policies and complex and risk adverse regulatory structures can make investing and competing with existing services challenging. However, despite these barriers the private sector is continuing to invest in local recycled water systems.

This may be due to the strong market for recycled water and the autonomy and flexibility the private sector has to accept risk and recover revenue than is currently

[21] For example calculating and funding avoided costs & communicating planning information

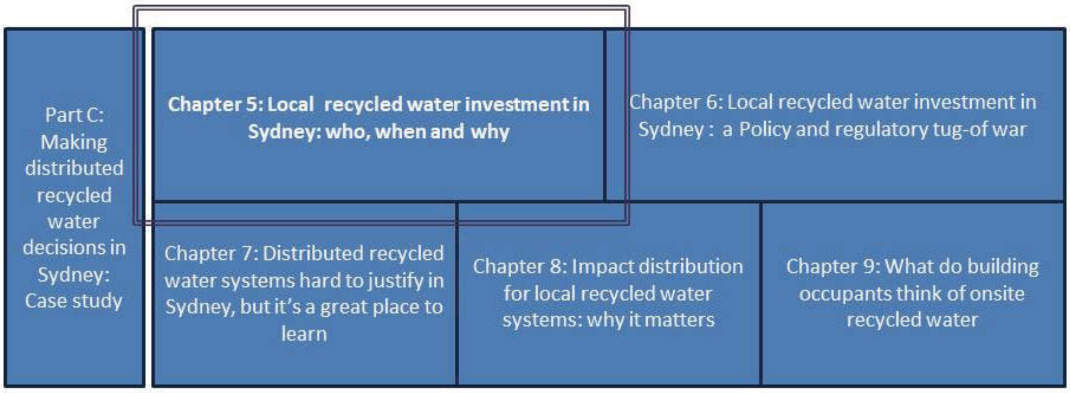
[22] For example cherry picking, risk of sewer mining damaging assets

allowed in the public water utilities. The willingness of the private sector to invest in the water sector is valuable in its potential to provide new services and increased efficiency through competition, and its potential to reduce public investment in centralised infrastructure.

This paper has identified a wide range of factors that limit investment in the market including regulatory, policy or institutional arrangements. Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers, firstly to understand the scale of their impacts, and secondly to begin to develop strategies to address them, assuming there is a desire to support the private recycled water market in the long term. To sustain this private investment we must continue to minimise regulatory and institutional barriers and seek ways to provide compensation for the value they provide to existing centralised systems.

Chapter 6 Local recycled water investment in Sydney: who, when and why

This chapter has been adapted into:. Watson, R., P. Mukheibir and C. Mitchell (2017). ‘Recycled water investment in Sydney - what’s happening and why.’ *OzWater 17*. AWA. Sydney, Australia.



This chapter consists of a stand along paper ‘Driving recycled water investment in the Greater Sydney region: who, when and why’. This paper was adapted for presentation at OzWater 2017. This paper focuses on Research Questions 2a-d, and examines what investment has occurred, by whom and why, and how the wider context influences decisions.

Highlights:

- provides a comprehensive catalogue of recycled water investment in the Greater Sydney Region over time
- provides a multi-faceted analysis of investments by scale, source, end use and ownership
- analyses the key trends for local recycled water investment
- reveals and explains the complex interactions between environmental conditions and the social, political and institutional contexts
- reveals how reveals how changes in environmental, social, political and institutional conditions over time impact on project successes and failures.

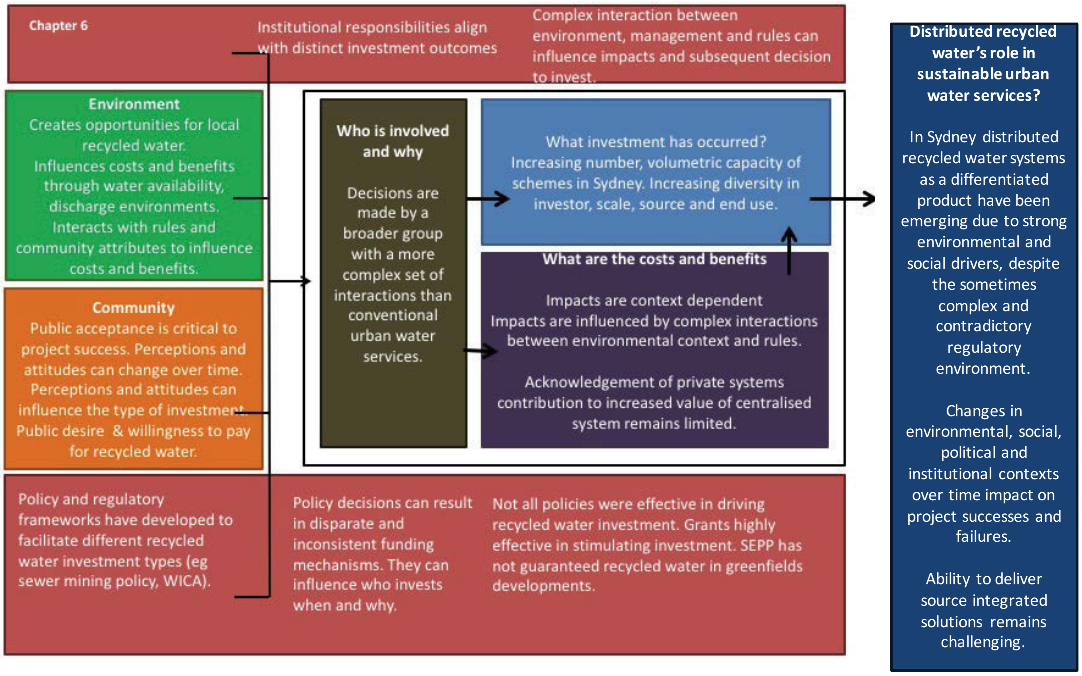


Figure 11: Synthesis of Chapter 6 through lens of IAD framework

6.1 Abstract

We know now that improving infrastructure and increasing diversity in infrastructure is key to improving resilience of our cities, and that local scale recycled water systems have much to offer in this regard. During recent extreme water shortages there was a surge of investment in recycled water in Sydney, but once the water shortages eased, the value of past investments in recycled water has been questioned. This paper reviews who invested in local recycled water, where, when and why, and in doing so it provides important insights into what has driven recycled water investment in the past. It also provides a key starting point for designing and enabling new policy directions with better potential to deliver more resilient and liveable urban domains.

Keywords: recycled water, urban water policy, integrated water services, sustainable urban water

6.2 Introduction: The last decade in urban water – a period of challenge and change driving recycled water investment

Providing efficient, affordable and reliable urban water and wastewater services has become more challenging over the last few decades (Brown, Ashley & Farrelly 2011; Ferguson et al. 2013). Changing environmental conditions, particularly limited surface water availability; more stringent environmental regulations, particularly for the protection of waterways; and high levels of urban growth have challenged the efficiency, affordability and reliability of conventional centralised systems (Marlow et al. 2013). In addition, the increasing use of sustainability principles has meant we look for options that mimic the natural water cycle, rather than separating water, wastewater and stormwater services (Ferguson et al. 2013).

While integrated water solutions, and water sensitive cities are identified in the literature as the future for urban water supply, meeting this aspiration is proving challenging (Ferguson et al. 2013; Marlow et al. 2013; Pahl-Wostl 2007a; Wong & Brown 2009). The technological capabilities of recycled water are well understood (Yang, Cicek & Ilg 2006), performance is improving and costs are continually decreasing (DeCarolis, Hirani & Adham 2009; Santos, Ma & Judd 2011). However, industry inertia (Brown, Ashley & Farrelly 2011; Marlow et al. 2013), managing risk (Turner et al. 2016), and the increased complexity of institutional, regulatory and social/political interactions (Bell 2015; Floyd et al. 2014; Institute for Sustainable Futures 2013c; Pahl-Wostl 2007b) continue to challenge progress toward water sensitive city aspirations.

Like many other major cities, Sydney is looking for ways to adapt to the broad range of challenges in the urban water industry, and has aspirations of achieving liveability outcomes (NSW Office of Water 2010). Sydney is Australia's largest city with around 4.6 million people in the greater Sydney region (NSW Government 2014), and is serviced by an extensive centralised water and wastewater network, owned and operated by Sydney Water, a government owned monopoly provider. Regional and local master planning have identified recycled water investment as an important part of securing water supplies and creating a resilient and liveable city (City of Sydney 2012; NSW Office of Water 2010). These plans have been supported with political and policy decisions that aim to promote recycled water options and support increased competition within the water sector (New South Wales Government 2006).

Within this context recycled water infrastructure in Sydney has increased rapidly in the last decade. While recycled water is just one option that can help address the numerous challenges facing urban water, it does provide an integrated solution that benefits water supply and reliability; improves waterway quality by reducing wastewater disposal, nutrient loadings and water extractions; manages the impacts of growth on existing infrastructure; and helps support liveability options (Burgess et al. 2015; Libralato, Volpi Ghirardini & Avezzù 2012; Tram Vo et al. 2014; Turner et al. 2016; Watson, Mitchell, C & Fane 2013b). Despite recycled water's many benefits and increased public acceptance (Dolnicar & Schäfer 2009), in Australia it is often difficult to justify investment in individual projects (Marsden Jacob Associates 2013).

In the past, collections of case studies have identified project viability (Anderson & Iyaduri 2003; Burgess et al. 2015; Moxon 2004; WERF 2006d), exemplar projects (Hatt, Deletic & Fletcher 2004; Mediterranean Wastewater Reuse Working Group 2007a; Tjandraatmadja et al. 2008), improved decision-making (Institute for Sustainable Futures 2013b) and barriers and limitations to investment (Institute for Sustainable Futures 2013b; Mitchell, V 2004; Po, Kaercher & Nancarrow 2003; Radcliffe 2004). In addition, catalogues of recycled water projects have been developed to track progress toward targets (NSW Office of Water 2010; Sydney Water 2009a; Whiteoak, Boyle & Wiedemann 2008) and funding allocations (NSW Government Office of Environment and Heritage 2011).

This paper uses the Greater Sydney region as a case study, providing a comprehensive catalogue of recycled water investment over time. However, unlike previous catalogues, it then provides a multi-faceted analysis of the investment by scale, source, end use and ownership. By using a comprehensive catalogue of investment in a single area, the analysis in this paper characterises key trends and unravels the complex interactions between environmental conditions and the social, political and institutional contexts. In doing so, the paper reveals the important role that environmental, social, political and institutional contexts have in shaping the type and timing of recycled water investment. By focusing on one geographic region rather than a set of distinct case studies, it reveals how changes in these conditions over time impact on project successes and failures.

The paper is structured as follows:

Firstly, it identifies four distinct phases of investment drivers: first opportunistic, then waterway protection, followed by rapid drought response and finally ‘green’ integrated services.

The paper then examines who has invested in recycled water. This examination reveals a clear distinction between the investment profiles for urban utilities, local councils and private investors, and it identifies how they align with investor responsibilities and priorities and builds on the insights revealed in a report by the Institute for Sustainable Futures (2013e).

Finally, the paper analyses how regulatory and funding policies have driven different types of investment. It reveals the overall success of policies supporting recycled water investment and the diversification of investors over the course of the 2003-2009 drought. In addition, the paper also explores the efficacy of different policies. Policies providing funding, supporting private investment or restricting water supply, were very successful in driving a rapid increase in recycled water investment. In contrast other policies, such as those encouraging infrastructure in growth communities, were less successful.

In combination these insights are critical in evaluating the success and value of recycled water investment, particularly in the context of changing environmental, social, political and regulatory conditions. This analysis is valuable in providing a historical documentation of drivers for recycled water investment, and in providing a platform for retrospective review. The paper provides a basis for evaluating the success of past policy measures designed to enable recycled water investment and sustainable urban water services. It also provides a starting point for reviewing the continued appropriateness of the existing policy and regulatory environment and, if required, designing and enabling new policy directions with better potential to deliver more resilient and liveable urban domains.

6.3 Method

This paper focuses on the question: 'Why does investment occur in local recycled water in the urban context?' By using Sydney as a case study, it reviews a broad range of recycled water investments to identify who invests in local recycled water, when and why.

Sydney provides a useful case study as it has a long history of planned recycled water schemes, with a rapid increase over the last decade. The regulatory and policy framework allows a diverse cohort to invest in recycled water. In fact, recycled water investment, particularly by the private sector, has been encouraged through a suite of policy and regulatory initiatives (see Chapter 7). In addition, Sydney has experienced tightening environmental standards, surface water shortages exacerbated by extreme drought, urban growth and a thriving green building market, all of which have been identified as drivers of investment in recycled water. Only non-potable recycled water schemes are covered in this research, as there is currently no potable reuse in Sydney, with the option not supported by the government (New South Wales Government 2006, p. 31).

The research started with an extensive desktop review of information from over 270 local recycled water and stormwater investments in Sydney, cross-checked against multiple water agency databases and web-based information. The majority of this data is self-reported, so numbers are often for design capacity, not actual demand. The data was then enriched by incorporating insights gained through nine semi-structured interviews to establish the developer, operator, utility and user perspectives from three sites.

6.4 Findings

6.4.1 Phases of recycled water investment in the Greater Sydney region

6.4.1.1 A long history of recycled water

There is a long history of recycled water in Sydney. According to Sydney Water the first planned recycled water system was established in 1886 when wastewater was disposed of at Botany Sewage Farm (Sydney Water 2013a), although the system was decommissioned 20 years later. It is interesting however, to note how long ago recycled water was recognised as an integrated water supply and viable wastewater disposal tool, as well as a valuable source of nutrients. Similarly, the decommissioning after only 20 years because rapidly increasing daily flows caused operational issues including flooding and odours (Beasley 1988) also demonstrates the difficulty of predicting long term demand and the aesthetic and health issues associated with the poor planning, design and operation of recycled water schemes. These factors are still very relevant to the success of recycled water projects today (see for example the discussion in Institute for Sustainable Futures (2013f) and Watson (2014)).

6.4.1.2 1960s-1980s: opportunistic irrigation

In Sydney, planned recycled water did not re-emerge until the late 1960s, with a small wave of recycled water schemes which began in the late 1960s and lasted until the end of the 1980s. Treated wastewater from Sydney Water treatment plants, which had previously been discharged into the Hawkesbury Nepean system, was diverted to irrigate golf courses and a racecourse (Richmond Golf Club: 1967, Ashlar Golf Course:1976, Warwick Farm Racecourse: 1980, Castle Hill Golf Club: 1983). These early irrigation systems were all within 5km of local sewage treatment plants that were already providing a high level of treatment. These schemes were seen as a valuable way of reducing nutrient and wastewater impacts on sensitive inland river systems (Sydney Water 2011b, 2011c) and of providing reliable (and sometimes cheap) irrigation (Moxon 2004).

6.4.1.3 1980–2000: regulatory drivers improving waterway quality through wastewater control and reuse targets

During the 1990s a number of regulatory changes focused on improving waterway health by reducing fresh water extraction and minimising wastewater discharge helped promote larger recycled water schemes. When Sydney Water was corporatized, its act (*Sydney Water Act* 1994) and operating licence (1995–1999) included provisions to reduce the amount of water drawn from all sources (other than re-use) on a per capita basis[23] and to reduce discharges of wastewater to waterways[24] (Sydney Water 2002). The targets were included as an outcome of negotiations with peak environmental, consumer and welfare groups. In addition to water conservation targets and a general objective to reduce wastewater discharge, in 1995, the Minister set Sydney Water a reuse target of 58 megalitres per day under section 27(2) of the Act.[25] This target was gazetted on 30 June 1995 (NSW Government 2000, p. 21). At the same time environmental regulations were becoming more stringent, with a particular focus on reducing the impacts of sewage treatment discharge on waterways (*Water Board (Corporatisation) Bill - Second Reading Speech* 1994).

By the late 1990s, a unique combination of population growth, water quality issues, community pressure and regulatory direction created the opportunity to develop Sydney's first large residential recycled water scheme (Cooper 2003; Dean 2004), although it didn't begin supplying customers with recycled water until 2001. While the potable water savings were recognised when the scheme was planned, it was substantially designed to protect the Hawkesbury Nepean from the impacts of wastewater discharge (Cooper 2003). When Rouse Hill was established, residential use of recycled water was novel and there was careful regulatory oversight to ensure the feasibility and safety of the scheme (Cooper 2003; Sydney Water 2002).

[23] Cl8.1.1 of Sydney Water's Operating Licence 'Sydney Water must take action to reduce the quantity of water (other than re-use water) it draws from all sources to the following target levels ("water conservation targets"): (a) 364 l/c/d by 2004/5 (b) 239 l/c/d by 2010/2011…'
[24] Sydney Water Act 1994 s27 'the Corporation is to adopt as an ultimate aim the prevention of all dry weather discharges of sewage to waters, including from ocean outfalls, except to the extent that this is necessary to safeguard public health or prevent environmental degradation, or both.' and Sydney Water Operating Licence 2000-2005 cl8.3
[25] Government Gazette 30 June 1995

In the early 2000s irrigation schemes for Picton (2000) and Gerringong Gerroa (2002) were established. Again, these schemes were designed to use highly treated wastewater to irrigate adjacent farm land and stop discharges into sensitive waterways (Mediterranean Wastewater Reuse Working Group 2007b; Radcliffe 2004).

The protection of waterways was also a key driver of the Wollongong recycled water plant – an outcome of the Illawarra Wastewater Strategy (Prothero et al. 2004). Although this strategy was developed in the late 1990s, recycled water wasn't delivered to the first customers until 2006, by which time water savings were a much more significant focus (Sydney Water 2009b).

With pressure to increase recycling, reduce wastewater discharges and reduce its own potable water use, Sydney Water also instigated a program to increase effluent reuse at its sewage treatment plants, and decrease water use. In its audit reports for 2000/01 and 2001/02, IPART expressed dissatisfaction[26] with Sydney Water's efforts to reduce water extractions and increase the reuse of effluent (NSW Independent Pricing and Regulatory Tribunal 2003). However, by 2003–05 a reuse investment program at sewage treatment plants (STPs) had substantially increased recycling within STPs (Sydney Water 2006b, pp. 7,8). To ensure improvement continued, the 2005–2010 operating licence included clauses to ensure recycled water constituted 85% of total water use at most STPs[27] by 2006 (Sydney Water 2006b), and substantial potable water reductions were made at the remaining STPs.[28] Today, Sydney Water reuses around 14,700 ML/yr of wastewater at its 14[29] water recycling plants and 16 wastewater treatment plants (Figure 16) (Sydney Water 2015b).

6.4.1.4 2003-2010: rapid drought response and increasing diversity

Although recycled water use had been increasing steadily in Sydney for almost 40 years, it was during the extreme drought conditions of 2003-2009 that the explosion in

[26] As evidenced by low and partial compliance rankings
[27] Except the big three coastal plants and storm flow plants. Recycling for treatment processes has since been undertaken at these sites as well.
[28] Sydney Water's Operating Licence 2005-2010 cl 7.3.1, cl 7.3.2
[29] Hoxton Park is classed as a recycled water plant by Sydney Water, but as yet does not supply any recycled water to customers.

recycled water investment occurred. As can be seen in Figure 12, from when drought conditions first developed in the late 1990s there was almost exponential growth in recycled water schemes, with the largest growth (in number and volume) in 2009 and 2010, at the end of Sydney's worst drought on record.

In response to water shortages a wide range of options were investigated, through a whole of government planning process to ensure Sydney's long term water security (New South Wales Government 2006). Emerging from this process was a wide range of mechanisms to both encourage and require alternative water source investment, encourage innovation in recycling and particularly private sector involvement. These mechanisms included:

- Regulatory measures: These were regulations which restricted certain uses of potable water, driving investment in alternative sources, particularly for irrigation (see Section 6.4.3.2). The regulations were included in the *Water Industry Competition Act* 2006, which set the framework for private sector water service provision and access arrangements, and the *Energy Administration Amendment (Water and Energy Savings) Act* 2005 which required high water users to develop water savings plans.
- Recycled water targets: These were set as part of long term supply/ demand planning to decrease climate dependency of water supply in the Sydney region (New South Wales Department of Infrastructure Planning and Natural Resources 2004; New South Wales Government 2006; NSW Office of Water 2010).
- Enquiries into pricing mechanisms: Enquiries were undertaken to ensure equity between Sydney Water and private sector entrant in recycled water and sewer mining pricing (NSW Independent Pricing and Regulatory Tribunal 2006), avoided costs (NSW Independent Pricing and Regulatory Tribunal 2011) and access arrangements
- Policies to provide investment certainty: This involved developing policies such as the *State Environmental Planning Policy (Sydney Region Growth Centres)* 2006.

- Technical and funding support: This support was provided through mechanisms such as the Every Drop Counts Business program (technical support)(Sydney Water 2009a) and the Water Savings Fund (financial support) (NSW Government 2008).
- Access to recycled water through sewer mining (Sydney Water 2008).

As the drought continued to worsen, the role recycled water could play in waterway protection was again reviewed, but with very different outcomes. Rather than removing wastewater from inland waterways, major projects diverted highly treated wastewater to particular sections of the Hawkesbury Nepean, either to replace environmental flows which were no longer coming from dams, or to provide water for downstream extraction by irrigators. These releases have become a substantial portion of Sydney Water's wastewater reuse (see Figure 18).

The broad range of policy and regulatory levers influenced who invested in recycled water and how. They worked in very different ways (see Section 6.4.2) and had varying degrees of success in promoting recycled water investment (see Section 6.4.3).

6.4.1.5 Post 2010: changing drivers including efficiency, green markets, innovation, integration and liveability

Since the decision to construct a desalination plant in Sydney[30] and the subsequent end to the drought, government funding and support of new recycled water schemes has been limited (Turner et al. 2016) and there has been a distinct decline in new recycled water schemes (see Figure 12). In addition, past recycled water investments have been called into question (for example see: NSW Independent Pricing and Regulatory Tribunal (2016, pp. 57-8)). However, there are still some important, if no longer urgent, drivers for recycled water investment in Sydney, including meeting customer expectations (Metropolitan Water Directorate 2014a), contributing to liveability outcomes and managing the impacts of growth on the existing infrastructure and surrounding waterways.

[30] Completed in 2010

Although government funding is no longer a significant driver of recycled water schemes, recycling as part of sustainable buildings and developments is continuing to increase the amount of recycled water available in Sydney. The use of recycled water as part of a 'green development' marketing strategy is not new. The Water Reclamation and Management Scheme (WRAMS) at Sydney Olympic Park was planned and developed as part of the commitment to delivering the most sustainable Olympic Games ever (Campbell 2001), and was the first in a growing number of privately owned 'green' developments. This project is owned and operated by the Sydney Olympic Park Authority, and is one of the genuine source-integrated systems in Sydney. It uses both stormwater and wastewater generated from a mix of residential and commercial premises in the development to produce recycled water (Sydney Olympic Park Authority 2006).

Since the implementation of the WRAMS development there has been a continuing shift in expectations in the water industry. In Sydney, there is a growing number of customers seeking more than a least-cost basic water service (Jenkins & Storey 2012), and the rapid advances in the capability and cost of small scale treatment systems is providing an avenue to supply the 'green' market via sustainable, flexible, adaptable and competitive services. The commercial building sector has identified and leveraged the emerging green market's green building assessment frameworks which reward on-site recycling. In Australia, the Green Building Council was established in 2002 and by 2012 there were 98 buildings with a green star certification in NSW (Green Building Council of Australia 2013b). In Sydney, eight 5- and 6-star Green Star rated buildings with in-building recycled water capacity were identified (see Figure 20).

The benefits of green marketing have seen private recycled water investment extend in Sydney to low and high density residential communities. For example, in central Sydney, Central Park promotes itself as 'the sustainable community of the future … smart in every aspect, maximising self-sufficiency through … sustainable water supplies' (Flow Systems 2016).

In low density developments on the fringes of Sydney, the sustainability benefits have also been enhanced by limited wastewater solutions, as is demonstrated by these quotes from Bingara Gorge, a community on the outskirts of Sydney.

'the [recycled water] plant is part of Bingara Gorge's commitment to being a sustainable community'

'located outside the normal wastewater network' …'the [recycled water treatment plant] is the first step towards delivering an overall solution for the Bingara Gorge community' (Bingara Gorge Online 2011)

There are currently eight boutique[31] and three developments on the fringes of the Sydney region incorporating recycled water as part of sustainable packages, and more are planned (NSW Independent Pricing and Regulatory Tribunal 2015c). However, the continued success of these developments will depend on the evolution of private sector regulatory requirements and ongoing changes to urban water planning and pricing regimes.[32]

6.4.2 Who invests in recycled water and why – Sydney's diverse investment profile

Over 250 recycled water systems were identified in Sydney, covering diverse end uses, capacities, sources of water, ownership and funding models. As can be seen in Figure 12, there is reportedly enough capacity to provide around 70 billion litres of recycled water a year, which is in line with targets set by the NSW Government in 2006 through Metropolitan Water Plan (New South Wales Government 2006, p. 6). This growth was on a fairly steady upward trend through the eighties and nineties, with almost exponential growth in capacity and numbers in the mid-2000s through the drought period and then stagnation after the drought.

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[31] Boutique developments incorporate green features to attract a premium rent or purchase price.
[32] For example see the Urban Water review discussion papers and submissions http://www.metrowater.nsw.gov.au/water-industry-reform/urban-water-regulation-review and IPART review of wholesale prices for Sydney Water and Hunter Water discussion paper and submissions http://www.ipart.nsw.gov.au/Home/Industries/Water/Reviews/Metro_Pricing/Review_of_wholesale_pricing_for_Sydney_Water_and_Hunter_Water

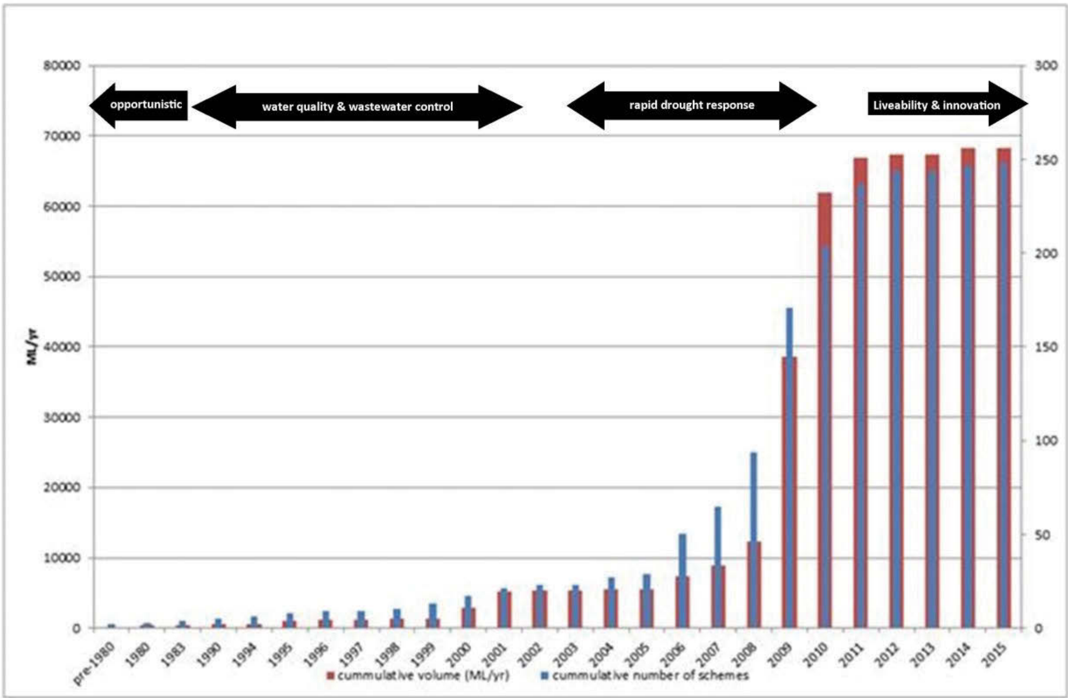


Figure 12: Reuse schemes in Sydney 1980–2015

6.4.2.1 Different recycled water sources are associated with recycling schemes that are distinctly different in scale and number

Recycled water is produced from stormwater, groundwater and wastewater, and a few other minor sources including mines and quarries (see Figure 13). This diversity of sources has increased rapidly in the last 10 years (Figure 14) driven by water shortages and the associated range of policy and regulatory measures (as outlined in Section 6.4.3.2).

The majority of the recycled water volume is from wastewater, however, stormwater collection systems make up around half of the total number of schemes. Of all the projects reviewed, there were very few projects that integrated sources, perhaps reflecting the compartmentalised nature of the regulatory framework and institutional responsibilities, and the ongoing challenges for implementing integrated water management that have been commented on by other researchers (see for example Brown & Farrelly (2009); Ferguson et al. (2013); Floyd et al. (2014); Mitchell, V (2004)).

Stormwater has the most collection systems, but a relatively small portion of the overall volumetric total (see Figure 13). Stormwater recycling is predominantly used for irrigation purposes, with less than five per cent of the schemes used for other purposes. In around 10 per cent of the irrigation schemes, the recycled water was also used for toilet flushing.

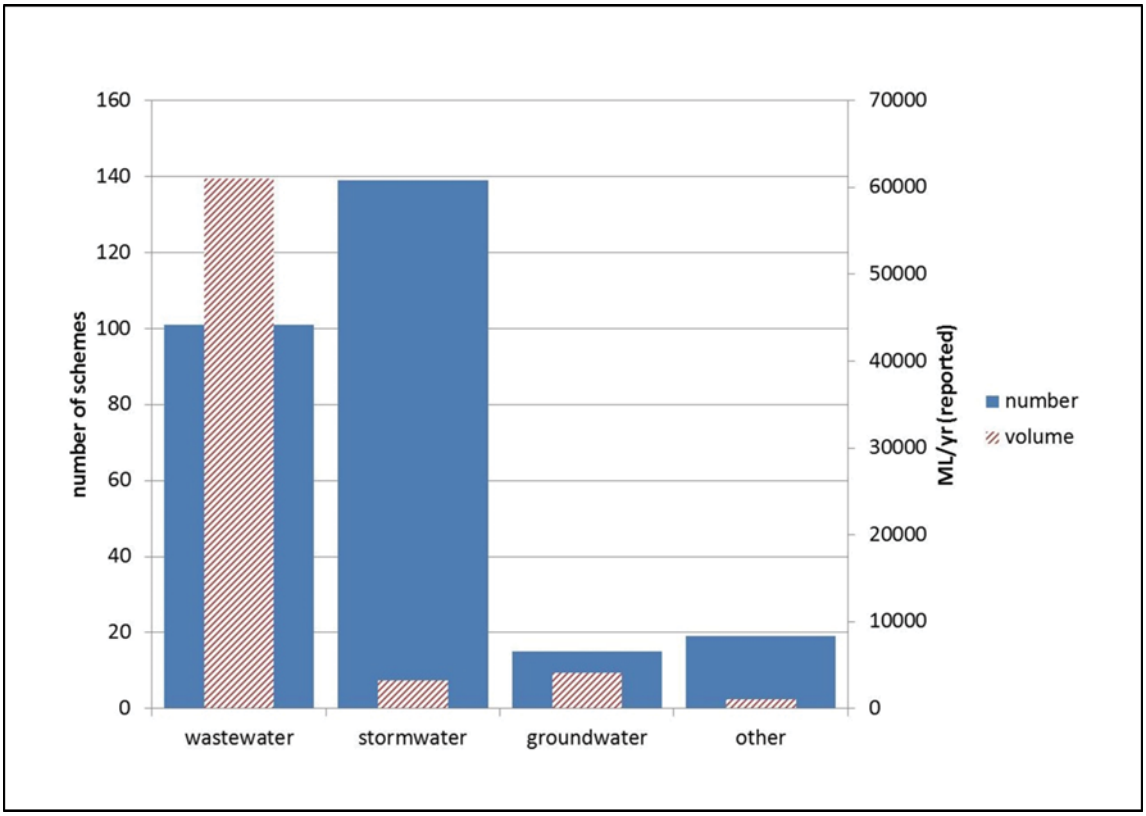


Figure 13: Sources of recycled water in Sydney

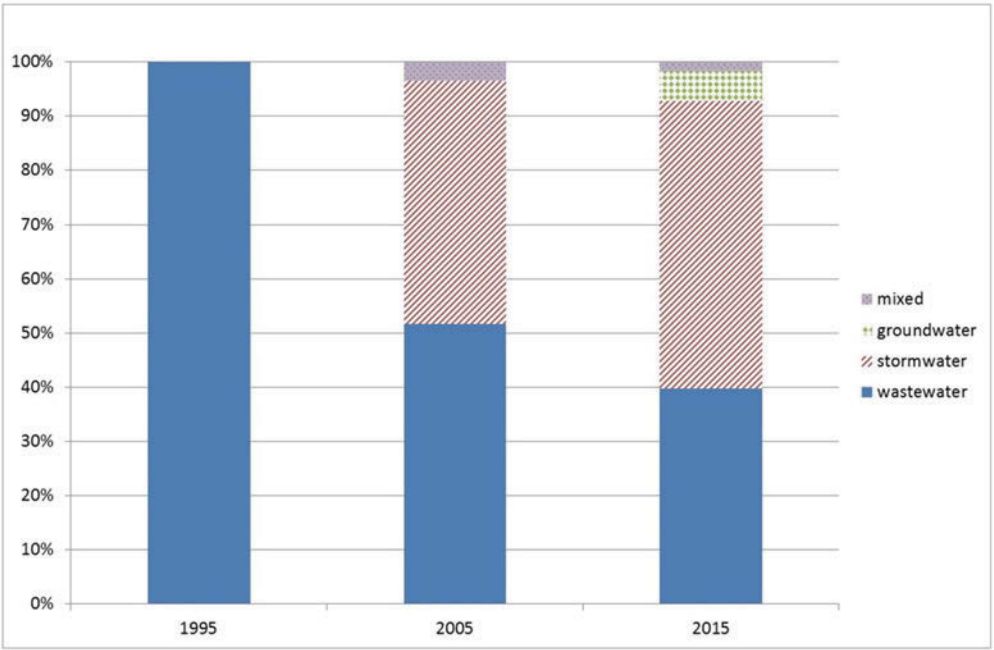


Figure 14: Diversification of recycled water sources over time in Sydney (% of total number of schemes)

As shown in Figure 13, the majority of the recycled water capacity in Sydney is sourced from wastewater. Wastewater recycling can use highly treated water from sewerage treatment plant (STP) effluent, sewer mining, industrial process water, onsite blackwater, onsite greywater or some combination of these sources. In addition to varied sources, wastewater recycling also has a wide range of scales and end uses. As shown in Figure 15, recycled wastewater is used for irrigation, industrial processes including onsite reuse at sewerage treatment plants, residential third pipe systems, commercial buildings (predominantly toilet flushing and cooling) and river releases (either for environmental flows or downstream extraction). The reported size of schemes is vast, ranging from very small onsite treatment and reuse (around 1ML/yr) to larger centralised residential third pipe schemes (around 2GL/yr) and very large centralised treatment and discharge for environmental flows (over 18GL/yr).

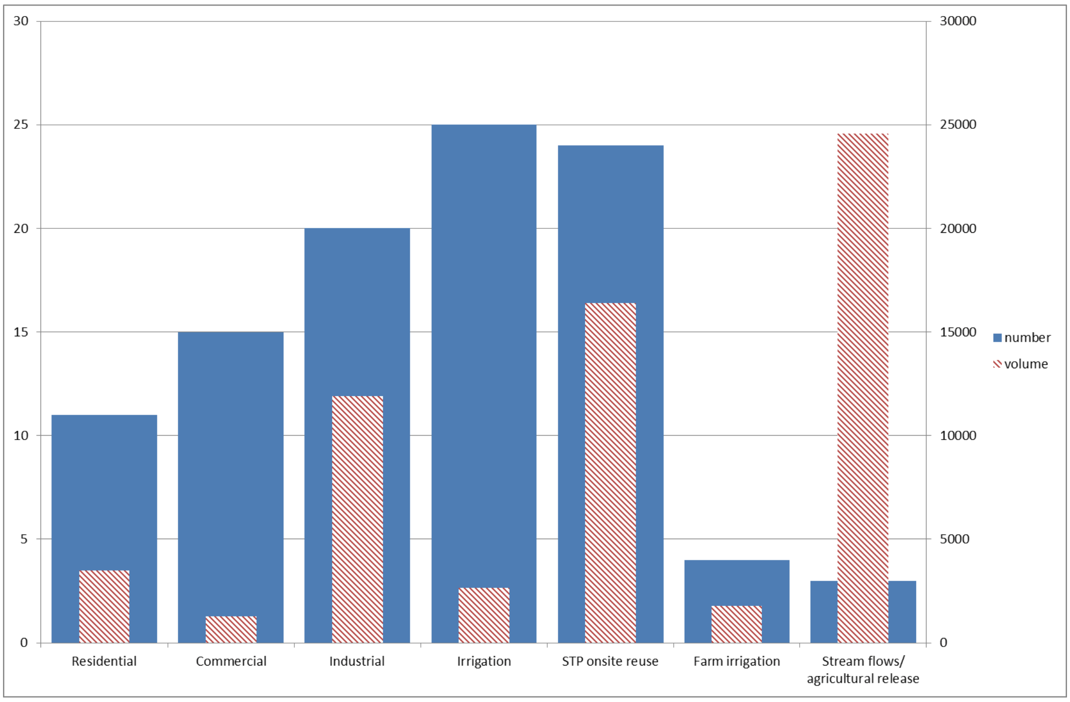


Figure 15: Wastewater recycling by (main) end use

6.4.2.2 Institutional accountability and regulatory compartmentalisation shapes the type of recycled water investment made by different investors.

In Sydney and elsewhere, decisions to invest in recycled water can be, and are, made by a broad range of actors for a variety of reasons (Watson, Mitchell, C & Fane 2013a), (see Figure 16). Recycled water schemes in Sydney have been developed and are owned by a range of investors including: the public utility, Sydney Water; private industry; council and public institutions. As can be seen in Figure 16, the majority of the recycled water capacity is provided by Sydney Water through a range of large scale schemes. However, the private sector and local councils have by far the greatest number of schemes.

Compartmentalised and complex regulatory frameworks, in conjunction with delineated institutional responsibility, have resulted in clear distinctions in the types of recycled water investments made by different cohorts of investors. This is particularly noticeable in terms of scale and source. The exact approval path for each recycled water scheme, and the style of ongoing regulatory oversight, vary depending on the owner (utility, council or private industry), the scale of the system, the source of the recycled water, the ultimate end use and the relationship between the owner and the user of the scheme (NSW Government 2012). Regulation of recycled water in Sydney, as is the case in much of Australia, is quite onerous and complex (National Water Commission 2011b, pp. 33,52; Power 2010, pp. 3,5; Tjandraatmadja et al. 2008, pp. 64-5, 84). The development, treatment and ongoing management of recycled water systems is controlled by a number of acts, regulations and policies across all three levels of Australian government (National Water Commission 2009) and in Sydney they may be covered by six acts and four sets of guidelines, and they may require the approval or advice of up to eight authorities (Watson, Mitchell, C & Fane 2013b). Reviews are underway that target ongoing inefficiencies in regulation, while ensuring customer protection, in regard to public health (NSW Government 2012). However, these reviews themselves are lengthy and onerous[33]. It is possible, therefore, that the demarcation between different investor types is partly set by the regulatory and institutional frameworks, and partly a result of investors sticking to one path to manage and minimise the complexities created by the regulatory environment.

[33] The latest review has taken more than five years. Preliminary consultation began in 2011, amendments were tabled in the NSW Parliament in June 2014, and new legislation was passed in November 2014, although as of June 2016 regulations had not been drafted, and as such the amendments had not commenced.

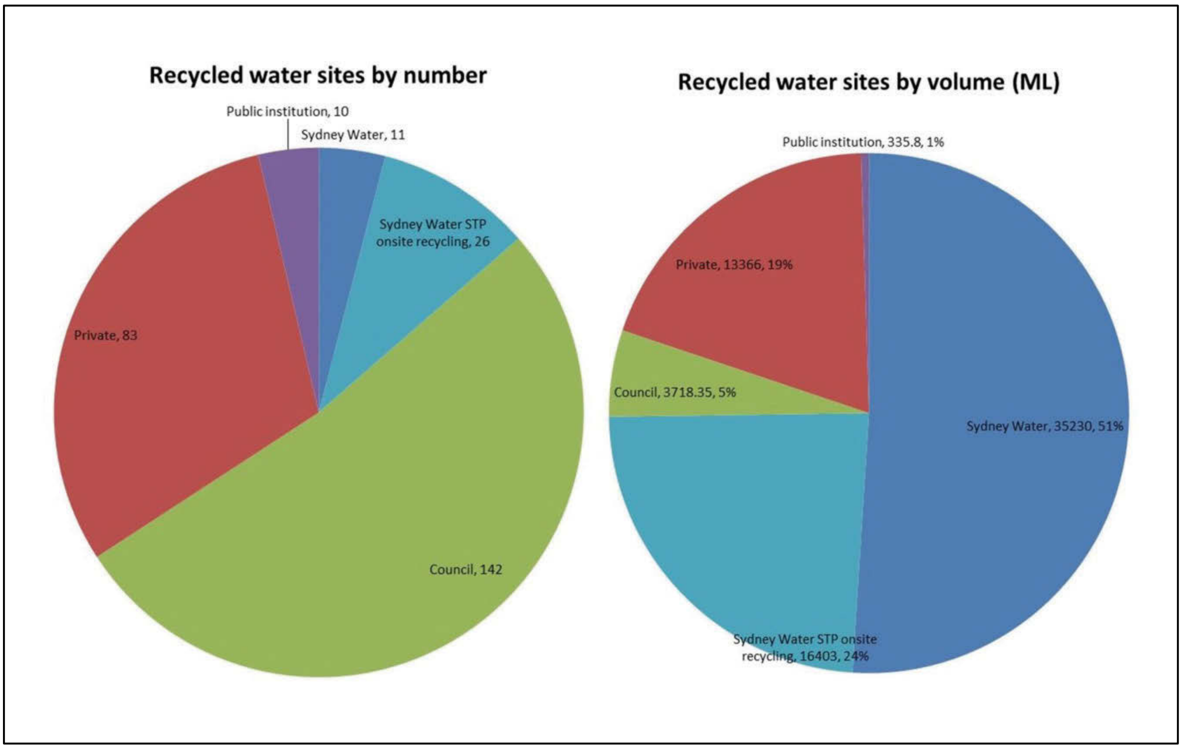


Figure 16: Who recycles in Sydney

The size and type of investment vary distinctly between the different investor types. As can be seen in Figure 17, while wastewater is the predominant source of recycled water, and the sole source for Sydney Water's recycled water activities, council recycled water comes predominantly from stormwater. These distinctions align closely with the roles and responsibilities of the investors, which is consistent with findings in other research (for example see Institute for Sustainable Futures (2013e)).

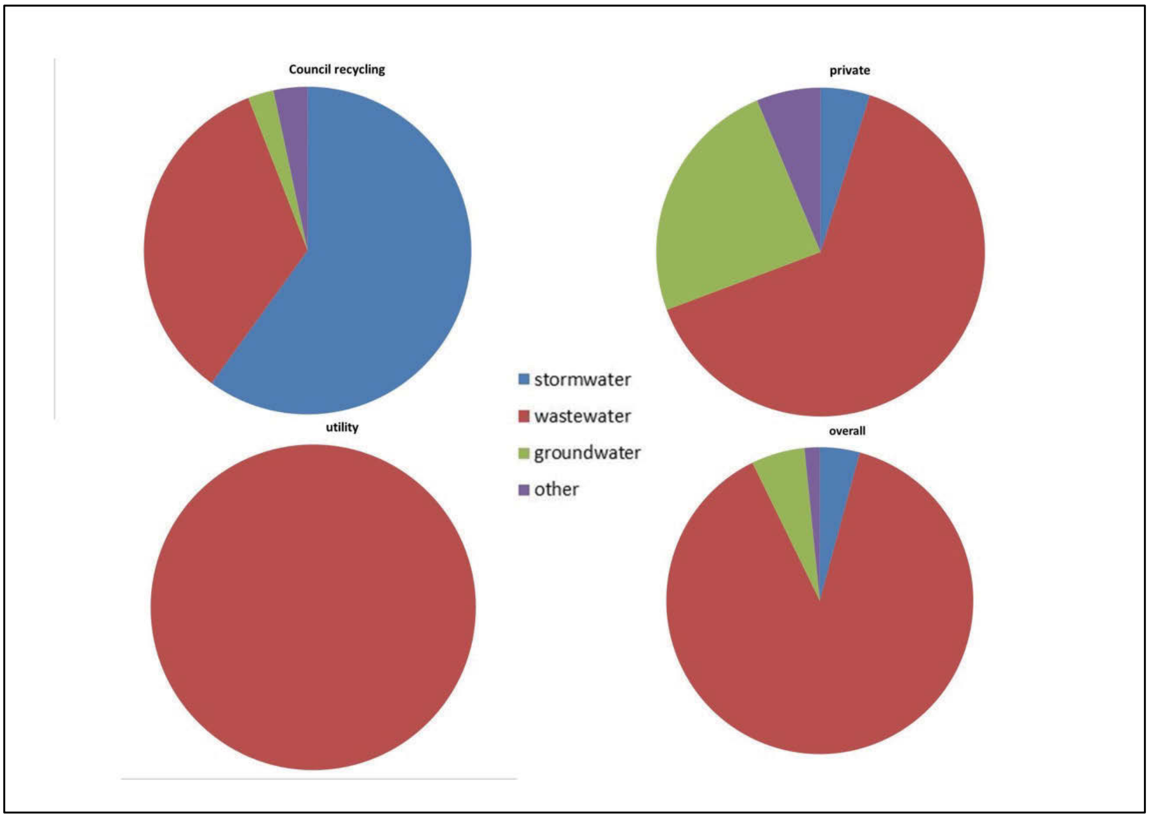


Figure 17: Who recycles by source

Sydney Water recycling

Sydney Water provides around 75 per cent of Sydney's recycled water capacity, mainly through large scale wastewater reuse schemes (Figure 16 and Figure 17). Sydney Water supplies around 43,000 ML/yr of recycled water from 13 recycled water plants. The schemes include:

- residential third pipe schemes
- industrial reuse
- environmental flow and agricultural releases
- irrigation
- process water recycling at 30 treatment plants.

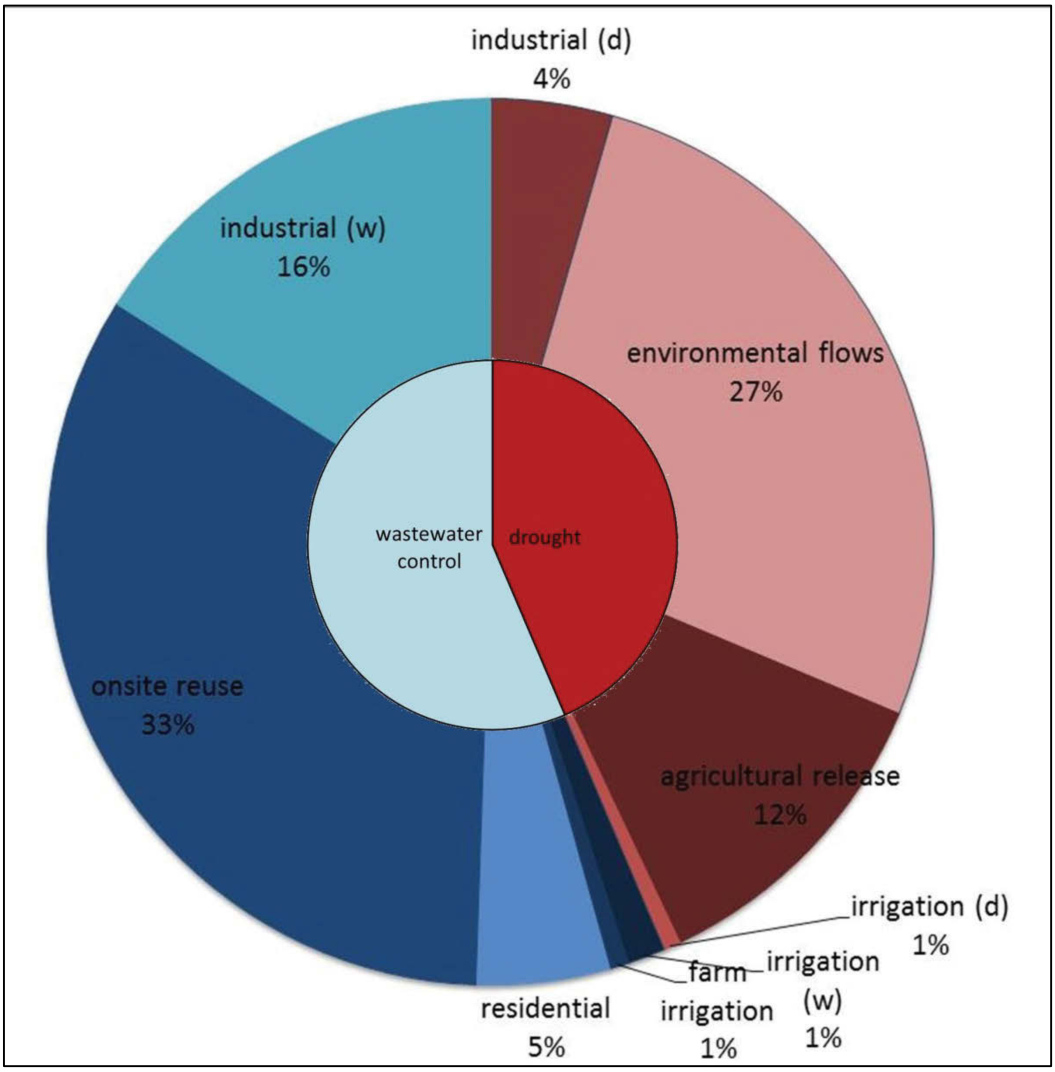


Figure 18: Sydney Water wastewater reuse by end user

As discussed in Sections 6.4.1.3 and 6.4.1.4, operating licence conditions and environmental discharge requirements were instrumental in the initial development of Sydney Water's recycled water portfolio, and of other recycling schemes in Sydney. It wasn't until the extended and severe drought which lasted from 2004 until 2010, and in which long term water shortages were experienced, that recycled water became primarily a supply solution. As shown in Figure 18, over half of Sydney Water's recycled water portfolio was driven initially by the need for wastewater control measures. For these projects detailed options assessments found that recycled water provided the best way to meet water quality outcomes, with the additional benefit of providing recycled water (Cooper 2003; Prothero et al. 2004). These initial schemes were important, not just for their wastewater protection significance, but also for establishing water quality standards and appropriate institutional arrangements, and for building customer confidence in recycled water. These projects built up slowly, until the recent severe drought drove an almost doubling of the portfolio, significantly through environmental flow and irrigation release projects. The intensive investment program over this period increased and diversified Sydney Water's recycled water portfolio.

Council recycling

Council recycling is dominated by many small stormwater schemes. Councils have the largest number of schemes, although they account for a relatively small proportion of the total recycled water volume (see Figure 16). While wastewater is the dominant source of recycled water for the Sydney area generally, local councils are responsible for by far the majority of stormwater reuse (see Figure 17). Council recycling projects generally use stormwater for irrigation purposes (see Figure 19). The dominance of stormwater schemes is mostly likely due to existing institutional arrangements in Sydney where councils are responsible for the management of stormwater systems, flooding and local water quality, yet they have no responsibility for water supply and wastewater disposal.

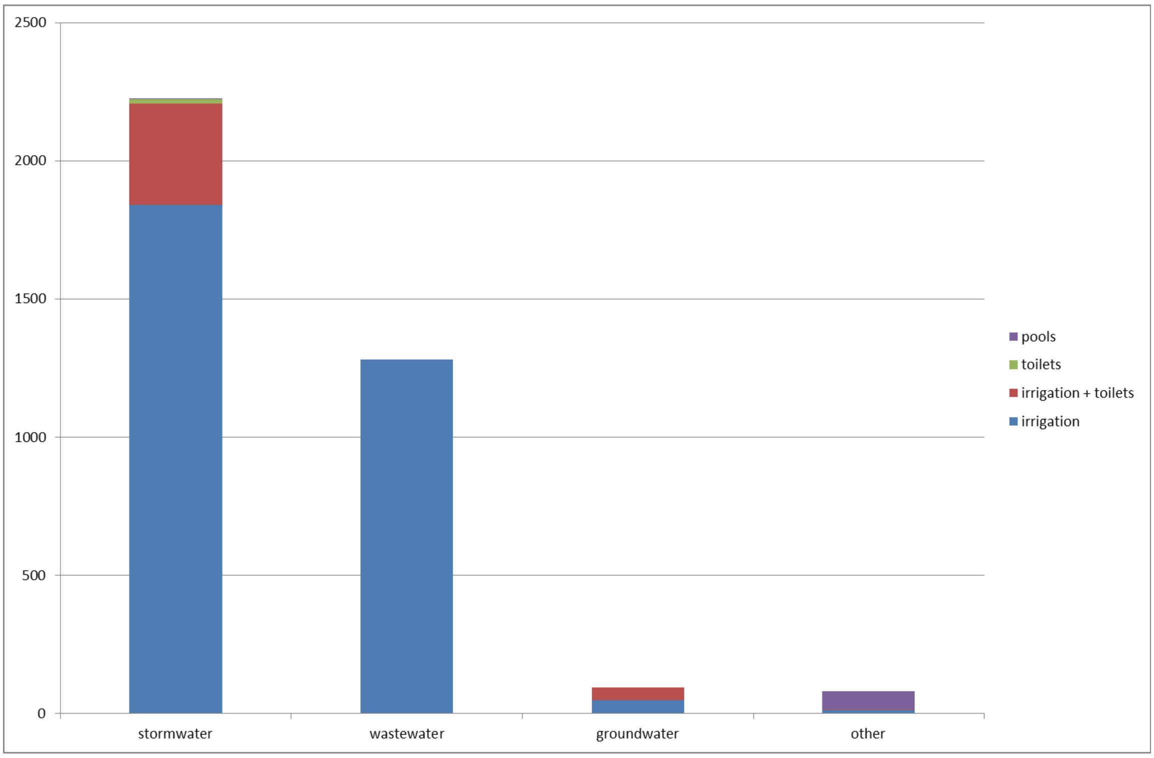


Figure 19: Council recycling – end use by source

Where council uses recycled wastewater they are predominantly schemes that leverage off the back of existing high level sewerage treatment. In these schemes council buys recycled water from Sydney Water through a recycled water agreement, or takes recycled water after treatment at a sewerage treatment plant but before discharge via a sewer mining agreement. Under recycled water agreements, Sydney Water charges its recycled water customers, and contractually agrees to volume and quality criteria. Under sewer mining agreements, there is currently no cost (NSW Independent Pricing and Regulatory Tribunal 2006) but Sydney Water makes no guarantee regarding quality or quantities available (Sydney Water 2008). Therefore, the substantial difference between the two is in the allocation of cost and risk.

Private recycling

Recycling by private entities has the greatest diversity in end use, scale and source (see Figure 17 and Figure 20). This is in contrast to Sydney Water and council schemes and is likely a reflection of the greater diversity in responsibilities, drivers and risk profiles for the private sector when compared to the public sector.

Since the early to mid-2000s a combination of factors including improvements in technology cost and performance (DeCarolis, Hirani & Adham 2009; Libralato, Volpi Ghirardini & Avezzù 2012; Santos & Judd 2010; Santos, Ma & Judd 2011), legislative changes supporting and encouraging private investment, particularly the *Water Industry Competition Act* 2006 and sewer mining policy (Sydney Water 2006a), drought and water restrictions and the rise of the green market have led to an increase in the number and diversity of privately owned recycled water schemes. While some of the earliest recycled schemes in Sydney were privately operated[34], the greatest shift in private recycled water has occurred as a result of drought response, supplemented by green markets. As discussed in Section 6.4.1.4, policy incentives and regulatory changes made in response to drought from the mid-2000s created an unprecedented environment that promoted the increase in private investment in urban recycled water in Sydney.

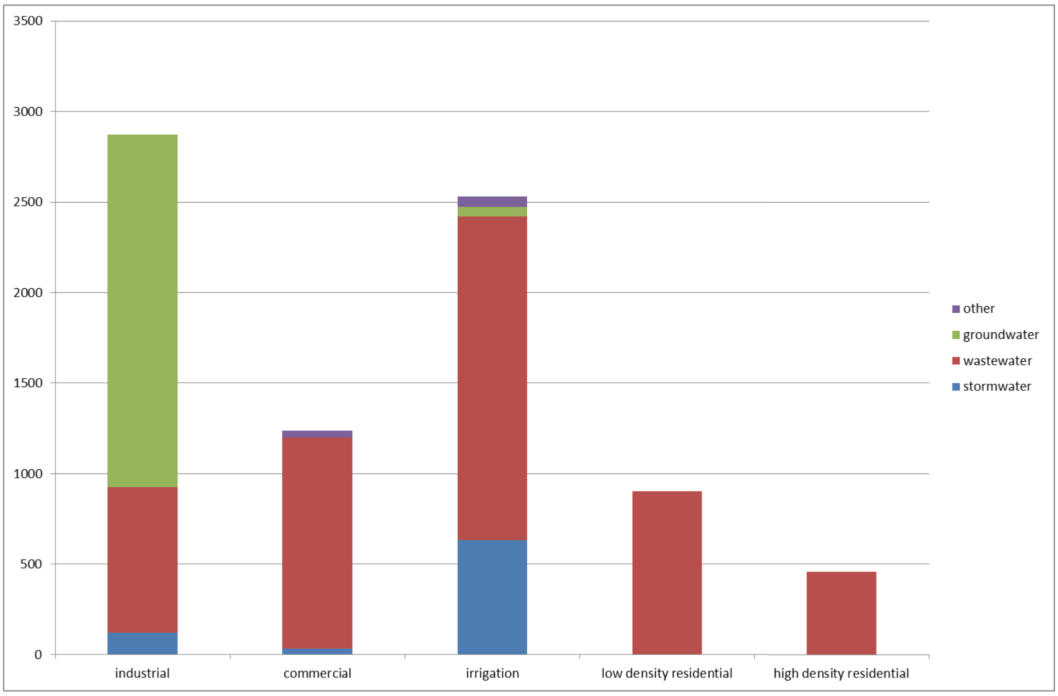


Figure 20: Private recycling by source and end use

[34] Although like council schemes they relied on Sydney Water to produce the recycled water.

6.4.3 Evaluation of the success of different policies in driving efficient recycled water investment in Sydney

6.4.3.1 Targets and waterway protection driving recycled water investment

As can be seen in Section 6.4.1.3, the waterway protection drivers, in conjunction with targets for reducing water use and wastewater discharge, have driven a substantial portion of recycled water investment, particularly for Sydney Water (Figure 18). However, some of these projects were later identified as major contributors to drought response (for example Rouse Hill and Wollongong).

The schemes developed with waterway protection drivers have demonstrated varying effectiveness in preventing wastewater discharge and reducing potable water use. Reuse at wastewater treatment plants comprises nearly a quarter of the recycled water capacity in Sydney (Figure 16), it has substantially reduced potable water use at the plants, and it has increased the percentage of wastewater reused. However, it has had a minimal impact on the eventual discharge of wastewater. In contrast, irrigation schemes like those at Picton and Gerroa substantially reduce wastewater discharge, and help to improve the environment, but do very little to reduce potable water use. Nevertheless, Wollongong and Rouse Hill reduce wastewater discharge and potable water use, and in the case of Rouse Hill provide customer benefits such as drought resilience and property value increases (Marsden Jacob Associates 2014a). Evaluating these projects under current standards of economic efficiency and cost recovery requires consideration of their underlying drivers. If these drivers are no longer relevant, a review of the ongoing viability of the scheme may be warranted. However, in some cases changing environmental and social conditions have increased the value of projects through benefits that were previously not considered.

6.4.3.2 Drought driven policy and regulatory measures

Recycled water delivered to increase security and resilience under regional supply/ demand planning

In Sydney the 2004–2010 drought triggered a planning policy response that focused on an ‘optimal mix of measures to secure Sydney’s current and future water needs’ (New

South Wales Government 2006, p. 10) – with recycled water options just one of the measures. As the drought worsened, the timeline for action and investment decisions truncated, which led to projects being evaluated not just on their economic value, but also in relation to their social acceptability, environmental impacts (including reduced water demand, wastewater discharge, stormwater discharge and greenhouse emissions), functionality and implementation certainty (including time, cost and water savings) (Sydney Water 2006b).

The truncated timeline and need for certainty led to a focus, particularly for Sydney Water, on large projects with implementation certainty, which is similar to what happened around Australia (National Water Commission 2011b; Werbeloff & Brown 2011). While the planning framework provided a basis and justification for, and successfully encouraged the delivery of, the current suite of options, including a diverse recycled water portfolio, the construction of the desalination plant in Sydney[35] and the end of drought conditions has meant past recycled water investments have been called into question (for example see: NSW Independent Pricing and Regulatory Tribunal (2016, pp. 57-8)).

Although an options approach and investment in small opportunistic initiatives can have economic benefits in a wide range of scenarios (Mukheibir & Mitchell, C 2014), under limited circumstances large supply augmentations will still be required. In these circumstances (such as those that occurred in Sydney with the building of the desalination plant) the overspend and excess supply after investing in a large last-resort option is highly visible, particularly if it coincides with the ending of drought conditions. The visibility and scrutiny of this over-supply contrasts sharply with the less visible overspend under the majority of scenarios if small opportunistic investments are ignored and only the large supply augmentation is employed.

Recycled water: responding to restrictions

The use of recycled water for irrigation in Sydney was well established before the drought, but the introduction of severe water restrictions, in conjunction with reduced

[35] Completed in 2010

natural rainfall during the last drought, was a strong driver of new recycled water investment. One of the earliest recycled water schemes in Sydney irrigates the Richmond Golf Club with water sourced from Richmond Sewage Treatment (water recycling) Plant (Sydney Water 2011b). Up until 2000 the private schemes were all irrigation schemes, located close to an inland sewage treatment plant. However, as the drought worsened, the lack of natural rainfall, in conjunction with water restrictions, wreaked havoc with the quality of playing fields, parks and golf courses, as demonstrated by quote from one system operator interviewed as part of this research: 'we were affected by the water restrictions … playing fields were just turning to dust.'

As can be seen in Figure 21, after the drought started there was a large increase in recycled water irrigation on golf courses, the majority of which came from local wastewater treatment, using sewer mining, rather than treated wastewater from sewage treatment plants. This removal of the distance from a sewage treatment plant as a barrier to wastewater irrigation was made possible through a combination of improved technology (WERF 2006a) and investment in facilitation mechanisms, particularly the development of a sewer mining policy (Sydney Water 2006a). Since restrictions were introduced in 2003, irrigation of golf courses with treated wastewater has tripled. These schemes are seen as instrumental in providing high quality golf courses: 'players will love the lush open fairways of Richmond thanks to the use of recycled water' (Court 2013).

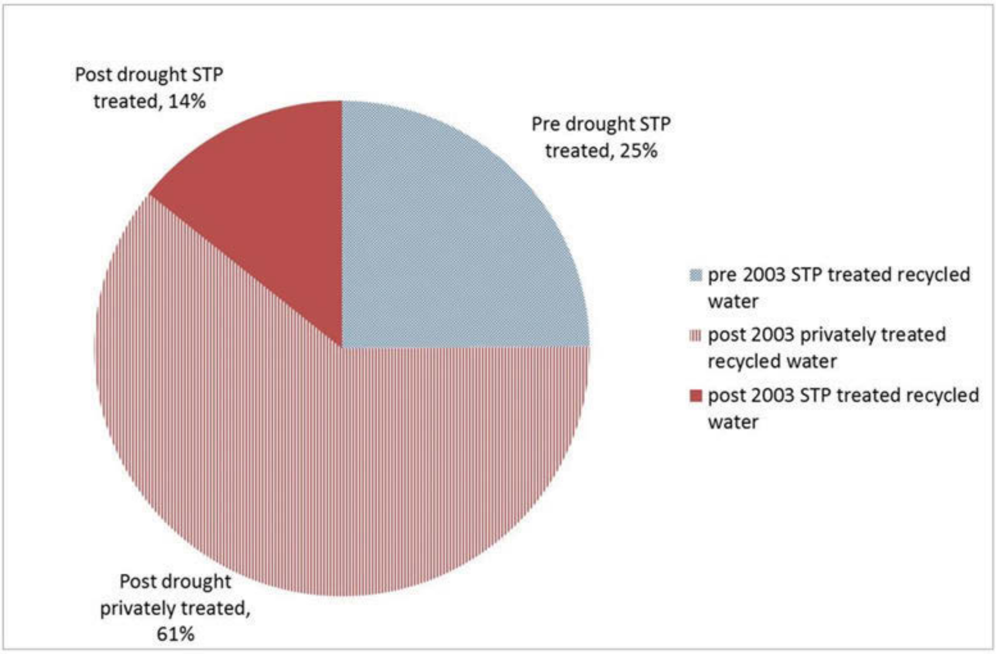


Figure 21: Golf course irrigation pre and post drought

Targeting high water users: awareness, carrots (funding and technical assistance) and potential sticks driving recycled water investment

An innovative multi-pronged approach involving awareness campaigns, carrot and potential stick components was developed through the Metropolitan Water Plan to curb high water use and share the burden of water conservation. The first part of the process was enacted through the *Energy Administration Amendment (Water and Energy Savings) Act 2005* (NSW), which gave the (then) Department of Energy, Utilities and Sustainability the power and responsibility to improve water efficiency across businesses, local governments and state government agencies. Under this act, large water users (more than 50ML/year) were identified and were required to develop Water Savings Action Plans (WSAPs). The introduction of WSAPs was ultimately aimed to encourage large water users to improve their knowledge of water use in their operations, and to identify opportunities for savings. The second part of the approach involved providing support through technical expertise (for example Sydney Water's Every Drop Counts Business Program) and funding (such as the Water Savings Fund). Of the recycled water schemes identified in this research, 31 were required to develop WSAPs, potentially reusing over 12 GL/year. Of these schemes nearly half received some funding through the water savings fund, which provided three rounds of grants in December 2005, May 2006 and December 2006 (NSW Government 2008). Although, as can be seen in Figure 22, there was some delay in these projects being implemented.

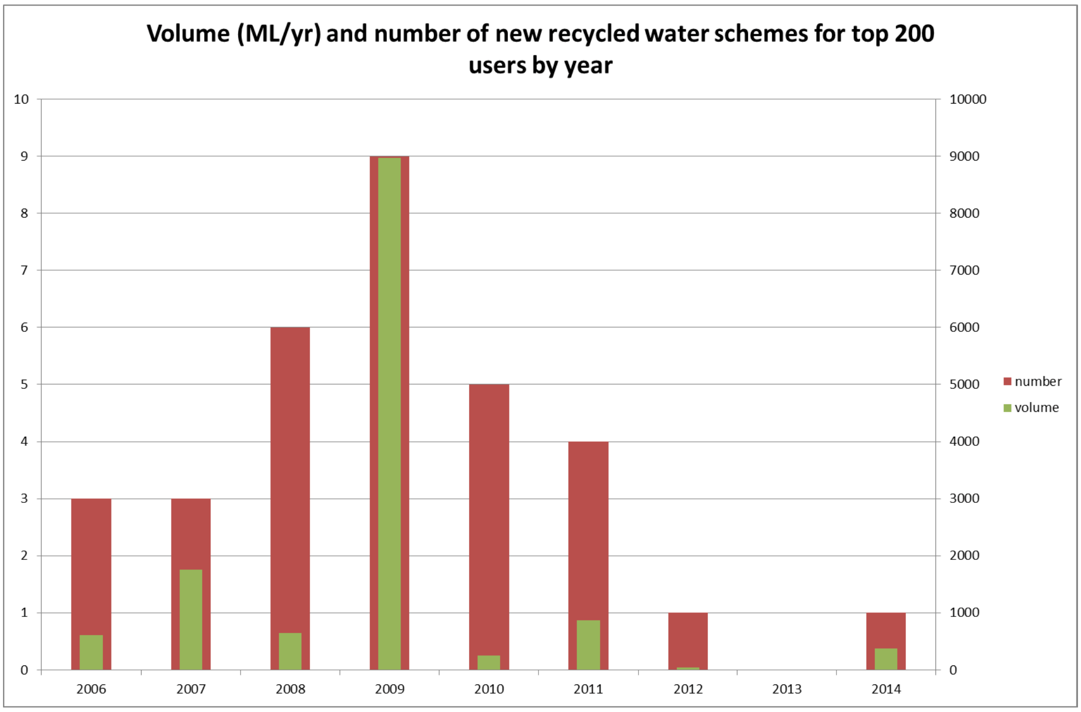


Figure 22: Recycled water investment by high water users

6.4.3.3 Encouraging innovation and recycled water use by creating competition for the market: the Water Industry Competition Act

A significant evolution in the Metropolitan Water Plan, from traditional urban water planning, was the position that securing water supply required the 'innovation, resources and cooperation of both the government and the private sector' (New South Wales Government 2006, p. 8). The *Water Industry Competition Act2006* (NSW) (the WIC Act) was designed to facilitate the development of a competitive market (NSW Government 2012, pp. 32,5). It established an access regime (allowing private entities to access already established water and wastewater infrastructure rather than replicate such infrastructure at high cost) and a licensing framework for the private sector provision of drinking water, recycled water and wastewater services. There are currently 13 recycled water schemes licensed under the WIC Act in the Sydney area, with the potential to supply around 11.7 gigalitres a year. These include eight boutique developments within existing urban areas, three fringe developments and two industrial developments (NSW Independent Pricing and Regulatory Tribunal 2015c). Although this is not a significant volume of recycled water, the WIC Act has been successful in providing a clear path for private investment (Water Factory 2013) and for supporting innovative and integrated servicing options (Metropolitan Water Directorate 2014b).

One of the major recycled water projects identified through the Metropolitan Water Planning process, as part of its portfolio diversification and options approach, was the Rosehill recycled water project (NSW Office of Water 2010). This project is owned and operated by a private consortium. It provides highly treated recycled water to industrial customers and was the first scheme delivered by the private sector under the WIC Act (Institute for Sustainable Futures 2013f; Water Services Association of Australia 2012). The project was a milestone project as it helped demonstrate the NSW government’s commitment to encouraging innovative private sector participation in the water industry. It also increased the recycled water portfolio during drought and increased industry’s contribution to recycled water targets (Water Services Association of Australia 2012). To assist with the appeal of the project and ensure delivery, unique contractual arrangements were developed. Foundations customers pay 90 per cent of the potable water price, with Sydney Water paying the scheme owners for around 3.8 gigalitres, even if demand is lower than supply (Institute for Sustainable Futures 2013f). The scheme is in part funded through the wider potable water price, an arrangement that is now being questioned, due to the substantial cost of the scheme in the light of significantly lower demand and a secure water supply (NSW Independent Pricing and Regulatory Tribunal 2016, pp. 57-8). The reassessment of this scheme is an example of changing conditions significantly changing the perceived value of a recycled water investment.

6.4.3.4 Recycled water to manage growth

Under the Metropolitan Water Plans, new suburbs were identified as good opportunities to use large scale residential water recycling to manage the impacts of increased demand due to population growth (New South Wales Government 2006). To complement BASIX – a planning requirement that all new homes implement measures that will reduce their water consumption by 40% compared to similar sized homes – the NSW Government committed to providing recycled water to all new homes in Sydney's North West and South West growth centres. To help provide certainty for recycled water investment and to encourage private investment, the *State Environmental Planning Policy (Sydney Region Growth Centres) 2006* (NSW) required all developers to connect to a recycled water system if one was available. These policies were not particularly successful at ensuring recycled water was available for new developments, and many developments have gone ahead without recycled water. The lack of recycled water investment for new growth is probably due to a combination of factors including: the lack of a wastewater regulatory driver, with wastewater transferred to ocean disposal catchments; the high level of treatment and regulatory oversight required for third pipe systems; and the increased financial risk associated with recycled water due to differences in funding arrangements and demand risk (Institute for Sustainable Futures 2013d; Turner et al. 2016; Watson, Mitchell, C & Fane 2013b).

However, as discussed in Section 3.3.3, a group of fringe and boutique developments is using recycled water and sustainable water services as a tool to market and differentiate developments.

6.5 Conclusion

This paper has provided an overview of the evolution of recycled water investment within the Greater Sydney region. Initial investments were opportunistic win-win solutions where irrigation was used to reduce the impacts of wastewater discharge to sensitive waterways. Over time the size, diversity and complexity of recycled water projects increased. Early residential projects provided valuable lessons in governance, social acceptability and technological robustness. These early projects provided the groundwork to allow the rapid increase and diversification of recycled water investment that has occurred over the last decade.

From the analysis above it can be seen that in Sydney, environmental conditions have been critical in creating an environment that encouraged divergence from conventional centralised water and wastewater service strategies. While many of the large recycled water projects have been driven by long term water quality requirements, it is clear that the recent drought period was instrumental in driving the rapid increase in both the number of recycled water projects and the total recycled water capacity in Sydney. This rapid increase in investment was enabled by the regulatory, institutional and funding initiatives instituted during the drought to reduce reliance on climate dependent supply. It is important to note that the recycled water options developed over this period formed part of 'achieving an optimal supply and demand mix' for Sydney, and considered 'the cost of the whole portfolio of measures, not just the cost of each option in isolation' (New South Wales Government 2006, p. 11). In addition, during the drought, recycled water measures were also seen as a critical part of 'an adaptive approach as opposed to lumpier [large] investments that may become stranded' (New South Wales Government 2006, p. 11). However, as conditions have changed, the prudence of this approach, and several of the investments that resulted from it, have come into question.

Despite the impetus for change being strongly driven by environmental conditions, the actual type of recycled water investment (size, source, end uses, investor) depends on a more complex interaction between:

- the institutional arrangements – for example who can invest, why and how
- the regulatory frameworks – for example the pricing/funding arrangements, investment incentives, wastewater discharge standards and recycled water treatment standards
- local conditions – for example the end users and source water availability.

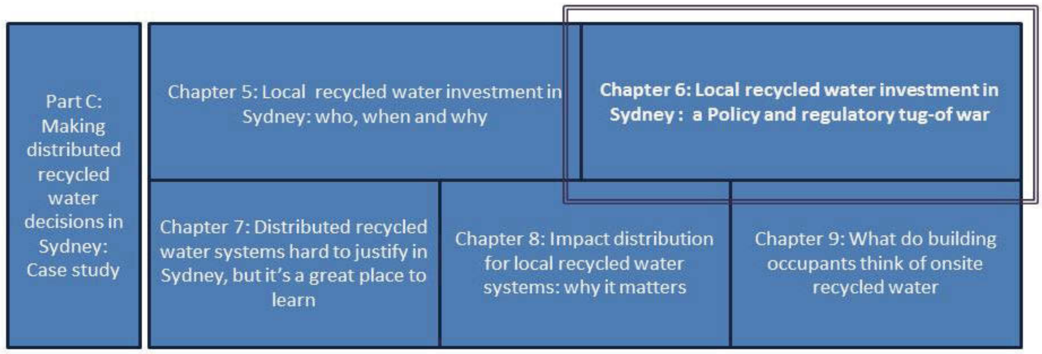
In Sydney, the impact of the environmental drivers has been a diverse recycled water market. Recycled water investment for councils and the public utility, Sydney Water, have closely aligned with their core responsibilities. Private investment is more diverse, reflecting the diversity of investors. Investors include: industry managing discharges and corporate responsibilities, irrigators securing climate independent supply and entrepreneurs carving out a new niche in sustainable water services. Considering the increasing diversity in investors, technologies and drivers for recycled water, investment is vital in developing future policy, regulatory and institutional arrangements.

The ability to deliver truly integrated services continues to be challenging, with very few examples of projects that combine multiple sources. This perhaps reflects the complex and segregated regulatory environment. In general, the small number of projects that did combine multiple sources were driven by sustainable water servicing objectives, and the objective of providing a total water service (see WRAMS and Central Park for example). This appears to be a different approach to that taken generally in Sydney where water, wastewater and recycled water projects are evaluated according to whether they are the least cost way to provide an individual service. While developments with integrated services are emerging through the private sector, the acknowledgement of their contribution to the overall value of centralised service is still limited.

This paper has identified some clear phases in recycled water investment in Sydney. They include opportunistic investment, water quality improvements, ground breaking innovation, and rapid drought response. Over the period of the 2004–2010 drought, the many benefits of recycled water were demonstrated. Now that the drought conditions have ended, and water supply is secure, recycled water investment is being re-evaluated in terms of economic efficiency, particularly in comparison to the cost of providing potable water. Identifying how and why recycled water investment has occurred in the past provides a context for examining and comparing the value of projects when drought conditions no longer apply. Identifying the conditions that drive recycled water investment, and who invests in it and when, can provide a useful starting point for reviewing whether current policies are driving the desired short and long term outcomes.

Chapter 7 Local recycled water in Sydney: a policy and regulatory tug-of-war

Watson, R., Mukheibir, P., and Mitchell, C., 2017 'Local recycled water in Sydney: policy and regulatory tug-of-war'. *Journal of Cleaner Production* vol. 148: pp. 583-594



This chapter consists of the paper 'Local recycled water in Sydney: policy and regulatory tug-of-war' published in *Journal of Cleaner Production*. This paper focuses on Research Question 2d, which examines how the wider context influences decisions, in this instance specifically the policy and regulatory environment. The paper identifies the broad range of policy, institutional and regulatory arrangements that influence the investment in, and the use of, local recycled water, highlighting the complexity driven by the breadth of drivers that influence water sector policy. Finally, it discusses the oppositional nature of the policy, institutional and regulatory arrangements.

Highlights:

- Recycled water has increased rapidly in the last decade.
- Investment has been supported by numerous policy and regulatory incentives.
- The benefits of policy levers can be counteracted by other levers which unintentionally oppose them.
- Exploring the oppositional nature of these levers helps explain existing investment.
- Identifying the critical interplay between levers helps address unintended consequences

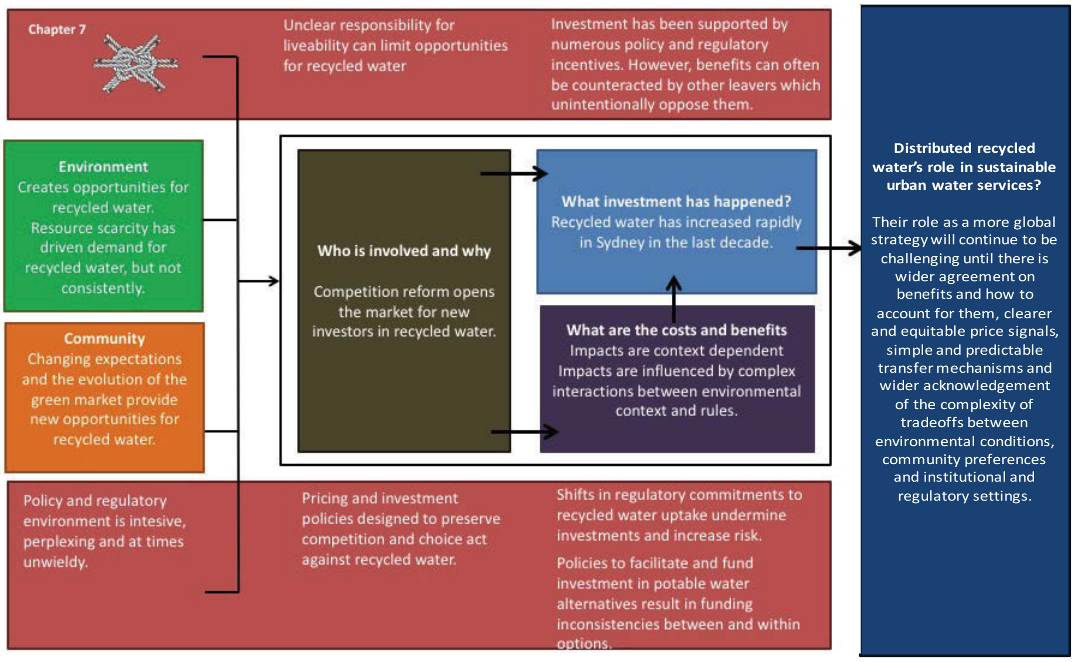


Figure 23: Synthesis of chapter 7 through lens of IAD framework

7.1 Abstract

Local recycled water can potentially contribute to resilient and sustainable urban water services critical to liveable cities. Investment in these systems has increased rapidly in Australia in the past 10 years, yet public and private investment in these systems can still be difficult, complex, costly and risky. An in-depth case study analysis of Sydney, revealed that while the local policy, institutional and regulatory environment is on the surface conducive to the uptake of local recycled water, actual practice has surprisingly mitigated against further and broader investment in these systems. These instruments are often counteracted by multiple opposing levers that in some instances were developed for entirely different purposes. The generalizable insight is that a systematic, systemic, detailed review of these instruments and levers can reveal unexpected contradictions and provide a strong and defensible base from which to develop strategies to address unintended consequences and remove barriers to future investment.

Keywords: urban water policy, recycled water investment, sustainable urban water services, urban water regulation

7.2Introduction

Local[36] (i.e., distributed or decentralised) assets and service provision can help to alleviate the substantial challenges faced in recent decades by conventional methods of urban water servicing. Urban centres throughout the developed world have depended on large centralised water and wastewater networks, to deliver safe clean drinking water and remove, treat and dispose of wastewater and stormwater (Gikas & Tchobanoglous 2009). These centralised systems have provided substantial economic, health (Gikas & Tchobanoglous 2009; Harremoës 1998) and (arguably) environmental benefits (Tchobanoglous & Leverenz 2008). However, these systems are now subject to increasing and diversifying challenges such as climate adaptation, resource scarcity, ageing infrastructure and rapid demand growth (American Water Works Association 2001; Infrastructure Partnerships Australia & Water Services Association of Australia 2015; Marlow et al. 2013; Warner 2009). At the same time societal, regulatory and industry expectations are shifting, particularly around the outcomes of sustainability, liveability, resilience and security (Fane, Blackburn & Chong 2010; Mukheibir, Howe & Gallet 2015; Werbeloff & Brown 2011). Expanding and maintaining the capacity of centralised systems in response to these pushes and pulls creates significant technical and financial challenges (Marlow et al. 2013). Furthermore, in some jurisdictions the efficiency and effectiveness of the single public monopoly provider is being dismantled and competition in different forms is being introduced (Department of the Prime Minister and Cabinet 2006; LECG Limited Asia Pacific 2011; Productivity Commission 2011). In response to these challenges, a growing body of academics and professionals advocate alternative approaches centred on including local assets and service provision within existing centralised urban water and wastewater service areas (El-Sayed Mohamed Mahgoub et al. 2010; Mitchell, C et al. 2010; Nelson 2008; Willets, Fane & Mitchell, C 2007).

Local recycled water has been identified as one of a suite of options that could contribute to resilient and sustainable urban water services critical to creating liveable

[36] Local recycled water can cover a widely diverse set of scales, sources, treatment levels, technologies and end uses. Critically, local recycled water systems interact with components of both wastewater disposal and water supply, and, at times, stormwater management (Watson 2011).

cities now and into the future (Marsden Jacob Associates & Brisbane City Council 2011; Newman, Dandy & Maier 2014; Sharma et al. 2009; Willets, Fane & Mitchell, C 2007). Rapid technological and cost improvements mean it is financially and technically feasible to treat and reuse wastewater locally (DeCarolis, Hirani & Adham 2009; Melin et al. 2006; Santos & Judd 2010; Santos, Ma & Judd 2011). By reducing sewerage discharge and potable water demand, local recycled water systems can also reduce the impacts of growth on existing infrastructure and improve waterway quality by reducing wastewater disposal, nutrient loadings and water extractions (Libralato, Volpi Ghirardini & Avezzù 2012). In addition, local recycled water can help meet changing customer demands, for example some customers prefer recycled water for particular uses (Dolnicar & Schäfer 2009), and are willing to pay more for recycled water to be used even if they do not the end beneficiaries (Marsden Jacob Associates 2014b). Finally, in the context of increasing pressure on government funds and increasing costs of public infrastructure, local recycled water systems are a way of leveraging private funds to maximize the life and capacity of existing public investment (Watson, Mitchell, C & Fane 2013a). A range of case studies have demonstrated the broad range of benefits local recycled water systems can provide when used in conjunction with existing urban water infrastructure (see for example (Anderson 2006; Chanan & Ghetti 2006; Chen & Wang 2009; City of Sydney 2012; Liang & van Dijk 2010; Mediterranean Wastewater Reuse Working Group 2007b; Mukheibir & Currie 2016; Mukheibir & Mitchell, C 2014).

The scale of change required to enable local recycled water systems is substantial, but significant inertia inhibits the rate of change: policy, regulatory and administrative frameworks have generally failed to match the speed of implementation of these new approaches (NSW Government 2012; Tjandraatmadja et al. 2008). The existing institutions have evolved over a long period, beginning well before ideas such as integration of services or involvement of the private sector were envisaged. Assessing the water industry against Dolata's (2009) analytical framework for innovation and sectoral change is instructive (Mitchell, C et al. 2010). The water sector has low adaptability to change: in Australia at least, it is characterised by 'persistence and structural conservatism on both the system and the actor level' (Dolata 2009, p. 1070).

This conservatism means the structural and institutional framework is quite stable, which 'impedes early and directed sectorial change and causes crisis-ridden adjustment processes' (Dolata 2009, p. 1070) such as the massive investment in desalination plants in response to the Millennial drought (White, Noble & Chong 2008). Even the Australian urban water sector's own industry body notes the water industry typically can be slow to change (Mitchell, C et al. 2010, pp. 1,10; Water Services Association of Australia 2014b, p. 12) with its long history of end of pipe solutions providing socially acceptable outcomes, long asset lives and high sunk costs. All of this means that accommodating local recycled water systems requires change in all key actor groups (users, government, industry) and in diverse ways (new regulatory frameworks, behaviour changes, changes in values, adaptive economic assessment frameworks, and technical advances) (Mitchell, C et al. 2010, pp. 1, 4; Mukheibir, Howe & Gallet 2014).

In response to urban water industry challenges and opportunities, policy and regulatory changes have encouraged alternative approaches around the world (Tram Vo et al. 2014), and have led to an increased recycled water investment in Australia (Radcliffe 2010) and specifically in Sydney (Figure 1) , yet it is still often difficult to justify investment in individual projects (Marsden Jacob Associates 2013). The technological capabilities of recycled water are well understood (Yang, Cicek & Ilg 2006), and performance and costs are continually improving (DeCarolis, Hirani & Adham 2009; Santos, Ma & Judd 2011). However, industry inertia (Brown, Ashley & Farrelly 2011; Marlow et al. 2013); managing risk (Turner et al. 2016); and increased complexity of institutional, regulatory and social/political interactions (Bell 2015; Floyd et al. 2014; Institute for Sustainable Futures 2013b; Pahl-Wostl 2007) continue to challenge progress toward water sensitive city aspirations and broader uptake of recycled water options. This paper focuses on how the complexity of institutional, regulatory and social/political interactions influences local recycled water investment.

To date extensive reviews have been conducted throughout Australia examining the institutional and regulatory framework for the urban water sector generally (McKay 2005; National Water Commission 2009; Productivity Commission 2011), and more specifically for recycled water (Radcliffe 2004, 2006; Radcliffe 2010; Turner et al. 2016), integrated water management (Mitchell, C 2004) and water sensitive urban developments (Tjandraatmadja et al. 2008). These previous reviews in Australia have found urban water frameworks complex and variable between jurisdictions and highly compartmentalised between different products (water, wastewater, stormwater, recycled water)(Brown & Farrelly 2009; National Water Commission 2011; Power 2010; Tjandraatmadja et al. 2008). Adding in recycled water and competition to the existing urban framework has only increased its complexity, particularly for planning and decision-making (Watson, Mitchell, C & Fane 2012; Watson, Mitchell, C & Fane 2013a, 2013b). Urban water institutional, regulatory and policy frameworks vary between jurisdictions, necessitating a location-based approach to analysis. This paper uses local recycled water in Sydney, Australia to:

(1) evaluate the critical role the policy, institutional and regulatory environment has in both driving and limiting recycled investment helping to explain how, where and why local recycled water investment is and is not occurring.

(2) demonstrate how a systemic, systematic and detailed review of arrangements can reveal unexpected contradictions and provide a basis on which to revise existing structures to counter any unintended consequences.

7.3 Method

A mixed methods approach was undertaken using three complementary data sources: a policy and regulatory review (phase 1); the construction and analysis of a new database comprising 250 local recycled water schemes in Sydney (phase 2); and in-depth interviews and structured discussions with key informants representing the full diversity of perspectives and experience of local recycled water in Sydney (phase 3).

In phase 1, the wide range of relevant policy documents and regulatory instruments, as of 2015, including those that provided necessary historical context, were identified and reviewed. This work took as its starting point recent national and state level reviews, particularly the National Water Commission review on urban water and the

NSW Urban Water Regulation Review. Over 40 documents (Acts, guidelines, policy documents and special reports, provided in Appendix G) were analysed to evaluate how they drove or limited recycled water investment.

The second phase comprised an extensive desktop review of over 270 actual local recycled water and stormwater investments in Sydney. The first step was to identify sites, using the Metropolitan Water Directorate website augmented and cross referenced with:

- projects that had funds allocated through the NSW Water Savings Fund and other State and Federal grants;
- businesses required to develop Water Savings Action Plans under the *Energy Administration Amendment (Water and Energy Savings) Act* 2005;
- Green Building Council of Australia's registered buildings;
- the Water Industry Competition Act licensee database

To ensure the list of sites was comprehensive, a final web search was conducted for 'Sydney' AND 'recycled water' OR 'wastewater reuse' OR 'water recycling'.

The second step in this phase was to augment the site-specific data on each scheme. Web searches identified the investor, the source of recycled water, the end uses, the capacity of the system, costs and benefits and key drivers. This data was generally self-reported, so numbers likely represent ultimate demand or capacity, and publicly available information reported drivers rather than limitations.

The data and information on all 270 schemes was aggregated into a new database to facilitate trend analysis.

The third phase significantly enriched the study with primary qualitative data. Two approaches were used. In the first instance, a structured workshop involving 15 industry participants (4 planners/regulators, 4 public utility employees, 5 private system operators, 2 sustainability advocates/researchers) was convened at Australia's national Small Water and Wastewater Systems Conference to explore limitations to local recycled water investment.

In the second instance, semi-structured interviews exploring experiences of drivers and limitations to existing and proposed recycled water investments were completed with key informants representing the full spectrum of perspectives in local recycled water in Sydney (four developers, five operators, four utility representatives, and two users). Interviews were thematically analysed.

- Sydney was selected as a case study for this research because:
- It has an extensive centralised water and wastewater network, with well-established policy, institutional and regulatory frameworks for traditional urban water management.
- There is a long history of recycled water use in Sydney, so there is an existing policy, institutional and regulatory framework for recycled water.
- There has been substantial reform over the past decade intended to allow and encourage recycled water use, including local recycled water use.
- Substantial investment has occurred in recycled water and local recycled water for a range of end uses, providing a good cross section of sites to investigate.

By way of background, Sydney is Australia's largest city with around 4.6 million people in the greater Sydney region (NSW Government 2014). Sydney's urban water services are delivered by a small number of large scale assets linked by extensive pipe networks. Over 80% of water is sourced from Warragamba Dam. The remainder comes from eight small dams. Towards the end of the recent drought a desalination plant was built providing water security for the next 30 years (NSW Auditor-General 2012). Over 75% (or about 900ML/d) of Sydney's wastewater is disposed of via three high-rate primary treatment plants, with disposal via deep ocean outfall. The remainder is disposed via 13 wastewater treatment plants or 14 water recycling plants, with more plants planned to meet urban growth demands (Sydney Water 2010b, 2015a).

7.4 Results

This section sets the foundation for the analysis by exploring the historical trends in local recycled water investment and the broad governance context. Thereafter, the impacts of and changes in four significant groupings of policy and regulatory mechanisms are explored: responses to resource scarcity, reforms in economic efficiency and pricing, competition reforms, and aspirational 'green' shifts.

7.4.1 Recycled water investment in Sydney to date

The use of recycled water in Sydney has a long history, although the majority of this capacity has been installed in the last decade (See Figure 24). From the 1960's – 1990's recycled was used as a cheap source of cheap irrigation source and a way of disposing of wastewater, until after a unique combination of population growth, water quality issues, community pressure and regulatory direction created the opportunity for Sydney's first large residential recycled water scheme at Rouse Hill (Cooper 2003; Dean 2004).

Ongoing drought from 2000-2009 highlighted the vulnerability of current dam dominated supplies[37] and also emphasised the need to provide adequate environmental flows to maintain waterway health (New South Wales Department of Infrastructure Planning and Natural Resources 2004). During this period the number of recycled water systems rapidly increased and diversified, as is evident through the graphical representation of the 270 schemes reviewed for this research (see Figure 24). As can be seen in Figure 1, a number of events combined in 2010, including substantial supply augmentation (through a desalination plant), the end of drought and accompanying water restrictions and cessation of funding assistance for recycled water projects, which resulted in a rapid slowing of new recycled water systems.

[37] For example in Sydney dam levels dropped significantly from 90% in 2001 to nearly 30% in 2007 (National Water Commission 2011).

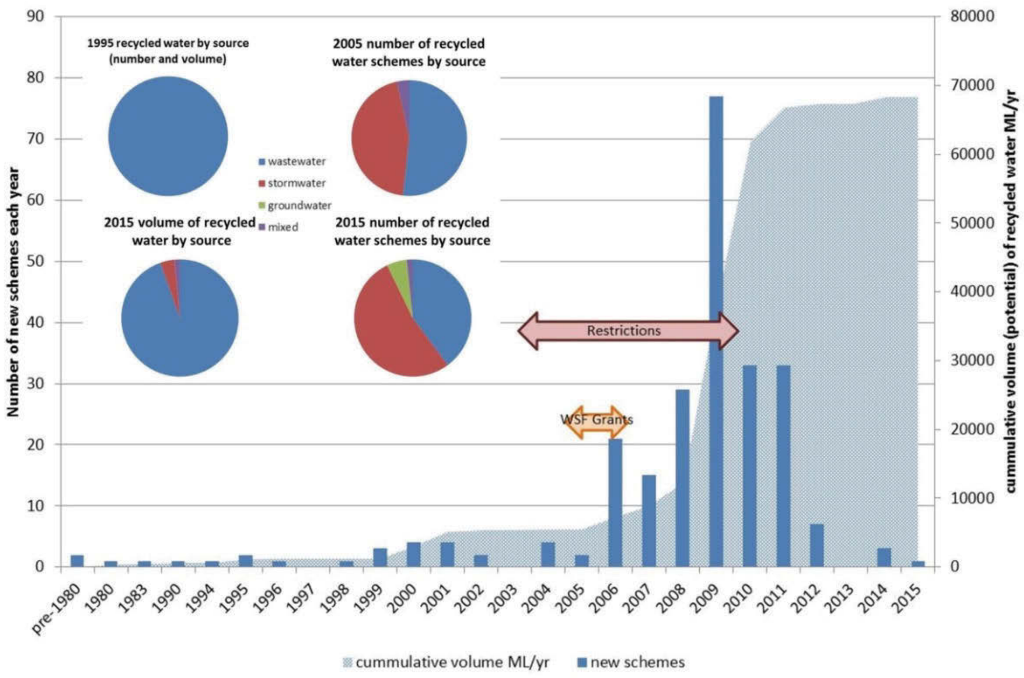


Figure 24: Reuse schemes in Sydney

7.4.2 The water governance context for Sydney

In Sydney, urban water management is a predominantly government domain. Water is sourced mainly through WaterNSW. Long term water planning is conducted by the Office of Water via the Metropolitan Water Plan. Sydney's centralised water supply and wastewater disposal is provided by a State government owned monopoly provider, Sydney Water, with prices and standards regulated by the NSW Independent Pricing and Regulatory Tribunal (IPART). The Environmental Protection Authority (EPA) issues environmental protection licences to manage the environmental impacts of the wastewater systems. Responsibility for stormwater management generally lies with local government, although Sydney Water has responsibility for some major trunk stormwater assets. More recently the private sector has begun to directly provide urban water services under the Water Industry Competition Act (2006) or the Local Government Act (1993), although this accounts for only a very small portion[38] of

[38] 13 schemes in Sydney with capacity of just under 12GL/yr (NSW Independent Pricing and Regulatory Tribunal 2015c)

services. The water governance responsibilities for Sydney, summarised in Figure 25 are complex and involve many agencies operating at different jurisdictional scales.

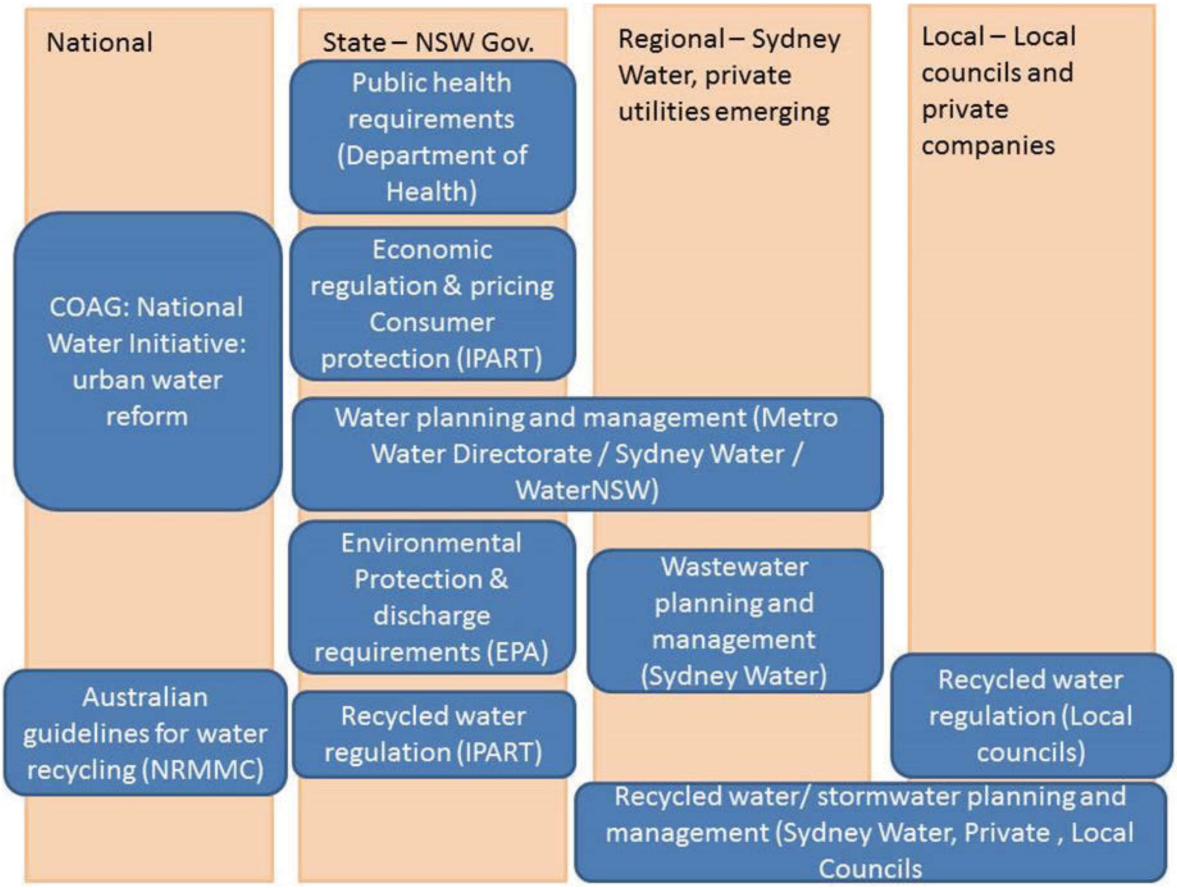


Figure 25: Water governance responsibility in Sydney - adapted from (National Water Commission 2011b)[39]

Although water governance is predominantly a State government domain (Figure 25), there has been an increasing federal influence since the mid 1990's. Federal intervention into water planning and governance is mainly through intergovernmental agreements, particularly the National Water Initiative, driving policy development and reform, funding the research agenda, developing guidelines and the granting or withdrawal of funds (McKay 2005; Productivity Commission 2011, pp. 50-8). Importantly for this research these interventions have focused on encouraging economically efficient water investments and full cost recovery through user pays mechanisms, promoting competition in the urban water market and encouraging

[39] NRMMC – Natural Resource Management Ministerial Council

investment in recycled water (Council of Australian Governments 2004, p. 19, 2008). The reforms have identified and created unprecedented opportunities for both private sector involvement, through the promotion of competition, and alternative water service options, including local recycled water. However, the sheer number of policies and regulatory instruments (see Supplementary Material), combined with the diverse range of institutional responsibilities is, in itself an indication of the intensive, intricate, perplexing and at times unwieldy nature of urban water management in Sydney.

7.4.3 Resource scarcity drives recycled water opportunities, but not consistently

Despite long-standing drivers for recycled water adoption[40] the use of recycled water only became widespread in Sydney during the Millennium drought (Figure 24). As was the case throughout Australia during that drought, recycled water was seen as a useful addition to water portfolios as it reduced demand on existing sources and reduced wastewater discharge whilst introducing a largely climate independent source.

In Sydney, drought coupled with expectations of extensive population growth lead to the State Government assuming overall responsibility for long term supply demand planning through the Metropolitan Water Plan, supported by a number of other policy and regulatory instruments. Over the period of the drought, governments at all levels developed a wide range of mechanisms to encourage innovation in recycling and particularly private sector involvement. The implications of each of these for local recycled water schemes are explored below: most were positive but inconsistencies lead to negative impacts.

7.4.3.1 Water restrictions drive alternative sources

Water restrictions drove investment in many recycled water irrigation schemes to provide water not affected by restrictions to maintain green open space, healthy playing fields and quality golf courses. This research identified over 183 irrigation

[40] For example since 1995, the Sydney Water Act (s21(7)) has included a provision "to adopt as an ultimate aim the prevention of all dry weather discharges of sewage to water including from ocean outfalls". Sydney Water's Operating Licence (1995)(cl8.3.1) stated that Sydney Water must "reduce discharges through non-potable reuse". Nutrient limits on discharge to the Hawkesbury Nepean drove the Rouse Hill residential recycled water scheme.

schemes (Figure 24), of which 45 used treated effluent. Since restrictions were introduced in 2003, irrigation of golf courses with treated wastewater has tripled. Nearly all of these schemes identified securing a source of water free from restrictions as a benefit of the scheme, not just giving them security to water, but security to schedule and manage their maintenance procedures, as these quotes from irrigation sites exemplify:

'when we had water restrictions I could never plan.. I would have 10 tonnes of fertilizer here waiting for it to rain, now I can program'

'we were affected by the water restrictions….., playing fields were just turning to dust.'

'an abundant supply of recycled water ensures superior course condition all year round.'

7.4.3.2 Sewer mining policies facilitate private recycled water investment

Sydney Water's sewer mining policy was a key component in facilitating private recycled water, particularly for irrigation. As part of the NSW Government's commitment to assist private local recycled water projects (New South Wales Government 2006), Sydney Water developed a sewer mining policy that streamlined the application process and clearly documented the key roles and responsibilities as well as providing advice on the process of setting up a successful sewer mining operation (Sydney Water 2006). The combination of technological improvements and a clear sewer mining policy meant using recycled water for irrigation was no longer limited by proximity to sewage treatment plants. As at 2015, there are 10 sites actively sewer mining in Sydney (Sydney Water 2015b) with more planned.

7.4.3.3 Recycled water targets encourage investment in recycled water

Targets for recycled water use were established at national, state, regional and local levels. The national reuse target was 30 percent of wastewater effluent by 2015

(Whiteoak, Boyle & Wiedemann 2008). Whilst this ambitious target was not met in many states, it triggered multiple programs and funding mechanisms.

In Sydney, recycled water targets were set as part of the long term supply - demand planning policy (New South Wales Government 2006), creating a stimulus for recycled water projects. The first version of this plan committed to a number of projects anticipating further increases in recycled water for growth servicing, irrigation, industrial reuse and replacing planned environmental flows from the dam (New South Wales Department of Infrastructure Planning and Natural Resources 2004). As the drought worsened in NSW the recycled water targets increased (New South Wales Government 2006, p. 6), along with a range of measures including funding mechanisms to further support recycled water projects. In 2006 there were 14 recycled water schemes in greater Sydney that recycle approximately 15 GL of wastewater per year (New South Wales Government 2006). This research identified around 270 schemes in 2015 with the potential to recycle around 70 GL (see Figure 24). However, as water crises eased, target prominence and funding support eased substantially.

7.4.3.4 Regulatory measures to reduce potable water use provide opportunities for recycled water

The *Energy Administration Amendment (Water and Energy Savings) Act 2005* gave the (then) Department of Energy, Utilities and Sustainability the power and responsibility to improve water efficiency across businesses, local governments and state government agencies. Under this Act large water users (more than 50ML/year) had to develop Water Savings Action Plans (WSAPs). The WSAPs ultimately aimed to encourage large water users to improve their knowledge of how and where water is being used in their operations and to identify opportunities for savings. Of the recycled water scheme identified in this research, 31 were required to develop WSAPs, potentially reusing over 12 GL/year, with nearly half receiving some funding through the Water Savings Fund, In 2004 the Government also implemented BASIX (Building Sustainability Index)[41]. BASIX required all new homes to implement measures that would reduce their water consumption by 40% compared to a similar sized home. The BASIX target required single dwelling homes to install water efficient fixtures and an internally connected alternate water supply. The BASIX driver is important for recycled water in several ways. Firstly it provided a consistent and predictable level of additional water to be sourced by buildings. Secondly the cost of meeting BASIX with a rainwater tank became a price-point comparison for identifying viable recycled water schemes. However, a fundamental principle of the BASIX policy is that it is outcomes based. Therefore the government does not mandate how the target should be met. This can lead to increased financial risk for recycled water schemes (as opposed to other water infrastructure), since there may not be a requirement to connect to schemes that are built.

7.4.3.5 Shifts in regulatory commitments to recycled water uptake undermine investments and increase risk

In addition to BASIX requirements, the NSW Government made further commitments to supplying recycled water for new homes in the outer growth regions (New South Wales Government 2006, p. 36). It was anticipated that the private sector would develop these schemes and to provide certainty of connection (and overcome some of the financial risk discussed above) the NSW Government incorporated a provision [cl18] in the State Environmental Planning Policy (Sydney Region Growth Centres) 2006 that requires developers to connect to a recycled water system, if one is available. However, once the desalination plant was built and the drought broke, the commitment to recycled water for new growth was substantially scaled back (Sydney Water 2011e).

7.4.3.6 Policies to facilitate and fund private investment in alternatives to potable water result in funding inconsistencies

A range of new funding arrangements provided critical support for the wide range of recycled water projects required to meet the ambitious targets set in the Metropolitan

[41]State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004 (the BASIX SEPP)

Water Plan. The Water Savings Fund (and subsequent iterations)[42] allocated funds between September 2005-December 2006 (Figure 24) (NSW Government 2008, p. 28). In addition Sydney Water's Every Drop Counts business program assisted businesses to become more water efficient (New South Wales Government 2006) and the Urban Sustainability Program also provide grants (totalling around $80 million) to councils for stormwater harvesting and other measures designed to save water and protect the environment under the City and Country Environment Restoration Program. Overall at least 65 projects were funded in part by grants including 50 through the Water Savings Fund. This funding helped to make some projects viable, as quotes from scheme owners demonstrate:

'the cost of the plant has been assisted by the Water Savings Fund'

'the project was made possible through a grant'

Inconsistencies emerged in funding mechanisms. Whilst all recycled water systems provide ongoing contributions to Sydney's long term supply demand balance, funding arrangements do not reflect this. Many smaller recycled water grants received partial grant support for construction only. A small number of larger schemes received the backing of regulatory direction, enabling them to be built into the potable water price, and thereby ensuring their financial viability (for example Rosehill). Yet other schemes are ring-fenced and required to be fully self-funded from their immediate customer base (for example Hoxton Park).

7.4.3.7 Changes in supply security criteria and their enforcement change investment incentives for recycled water

Security and reliability criteria come under close scrutiny during drought conditions. Reliability and security criteria have long been established for Sydney's water supply (restrictions on average 3.6 months every 10 years) but have been greatly exceeded in

[42] The Water Savings Fund/ Climate Change Fund were established under the *Energy and Utilities Administration Act* 1987 s34(A). Part 6 of the Act established the fund and the purposes of the fund. Then the Minister gave a contributions order direction – which if the utility had prices determined by IPART the contributions order was treated for the purposes of s16A of the *Independent Pricing and Regulatory Tribunal Act* 1992 as a requirement with which the agency must comply (s34L(3)).

the last decade. These extended periods of restrictions were instrumental in the increase in irrigation schemes (Figure 24). In 2006, the Metropolitan Water Plan considered decreasing the reliability criteria, which would result in more frequent restrictions (New South Wales Government 2006, p. 16), further increasing the value of recycled water for irrigation. However, since the investment in desalination, future restrictions regimes and security criteria have eased, creating uncertainty about the extent of restrictions in the future, which undermines the value of recycled water investments for irrigation.

7.4.4 Efficiency and pricing reforms

7.4.4.1 Reforms sometimes provide clear(er) investment signals

Federally driven efficiency and price reforms implemented at a state level led to the establishment of, the NSW Independent Pricing and Regulatory Tribunal (IPART) in Sydney (NSW Government 1992). Since the beginning of price regulation IPART have made a number of structural reforms to water pricing to target full cost recovery for water services and consumption based pricing (Tisdell, Ward & Grudzinski 2002, p. 27).

Clear, transparent and fully funded price signals are important for investment decisions in local recycled water because they:

- Set the comparative benchmark for alternative services
- Set the scope for savings by investing in alternative water service infrastructure (that is: avoided costs in the centralised network, or savings through avoided water/ wastewater charges/ developer charges.)
- Potentially signal where and when alternative water service infrastructure is most efficient.

That said, postage stamp pricing limits price and market signals for location-based investment. Sydney’s cost reflective pricing policies are intended to provide clear and efficient signals for alternative water investment, but prices are cost reflective on a business-wide basis. A policy of postage stamp pricing means all customers using the same service pay the same amount, even though the cost to service customers varies substantially across the area of operation, particularly for wastewater. This limits the ability of the price to signal where alternative investments are most efficient.

7.4.4.2 The historical legacy of monopoly pricing regulation can create barriers to recycled water investment

Some peculiarities in Sydney's history make it even more challenging for private recycled water systems to compete on price alone with the more conventional alternatives. Favourable geography provides Sydney with generally low cost surface water supply, ocean disposal of wastewater services (Watson, Mitchell, C & Fane 2013b) and low transport requirements (Cook, Hall & Gregory 2012). This is further compounded through historical regulatory decisions that further lower the overall price of water and wastewater services. Changes in capital funding arrangements and cost recovery mechanisms for water infrastructure mean many pre-price regulation assets were substantially written down, so prices do not reflect the full value of even these relatively cheap sources. In 2000, with the start of price regulation IPART wrote the asset base down by over half – the depreciated replacement cost of assets is estimated to be over $30 billion while the regulatory asset base is only valued at $13 billion (Sydney Water 2010a). These examples show that even in an environment where economic efficiency and full cost reflectivity is used to promote efficient investment, past practices and decisions can significantly hamper new investment.

7.4.4.3 Investment is constrained when long run marginal cost is the benchmark

In Sydney the water usage charge is set at 'long run marginal cost' (LRMC)[43], which is regularly used as the benchmark for efficient investment. Many local recycled water schemes compare the cost of providing water simply to the water usage charge (currently set at LRMC), as these quotes from sites using recycled water exemplify.

'Recycled water is less expensive than mains water supply'

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[43] the incremental cost of measure to bring supply and demand into balance in the longer term' (Cox 2010)

'[Recycled] water supplied at a rate ...slightly cheaper than mains water'

'The cost of the recycled water is far less than the cost of the drinking water that is currently being used for irrigation'.

Although some schemes can supply recycled water at less than LRMC, the simple comparison may also create barriers to individual recycled water projects, particularly private schemes. Even when a local recycled water scheme makes up part of an efficient suite of measures to meet the supply demand balance, unless it costs less than the average LRMC, it will be difficult for it to be competitively priced by a private supplier. In addition, the LRMC comparison fails to recognise the reliability benefits of diversified non-rainfall dependent sources (National Water Commission 2011b), or the integrated nature of local recycled water investments and their influence on the wastewater system.

7.4.4.4 Avoided cost recovery processes are well-intentioned, but limiting in practice

Assessing and acknowledging avoided costs accruing from recycled water investments is critical for market competition, but is complex. Pricing policy can provide clarity and certainty by identifying avoided cost processes and setting methods for avoided cost recovery. In Sydney, there is a formal documented process for claiming payment (to ensure competitive neutrality) where a recycled water system has allowed the utility to 'avoid costs' in their existing centralised system - for example by deferred system augmentations or avoided pumping or treatment costs (NSW Independent Pricing and Regulatory Tribunal 2011).

While in theory the method to calculate and recover avoided costs is clear, in practice these costs are difficult to identify and collect. For example, information asymmetry means competitors rely on information from the utility to identify what costs could potentially be avoided, and this information is not readily accessible. The application of Sydney's avoided cost formula is also labour intensive, uncertain and inflexible: even utilities report difficulties implementing it successfully (NSW Independent Pricing and

Regulatory Tribunal 2011, p. 4, 2015b; Sydney Water 2012a). In addition, the small scale of individual local systems can limit their impact, yet collectively, for example as an investment strategy, they can provide substantial long term savings to the centralised system (NSW Independent Pricing and Regulatory Tribunal 2015b, p. 64; Institute for Sustainable Futures 2011). Together, these hurdles combine to make claiming avoided costs unreliable and unpredictable, particularly for private local recycled water systems.

The additional cost of recycled water use could be partially funded by an associated reduction in water and wastewater costs however; the magnitude of this offset will depend on how fixed and variable prices are calculated. local recycled water systems reduce both potable water use and wastewater discharge charges, and in Sydney, this means reduced charges for these conventional services by local recycled water system users. The certainty and magnitude of these savings is subject to the regulated price structure. Changes in the conventional price structure such as moving towards fixed non-usage based prices can have significant implications for the viability of local recycled water systems. In recent years, IPART has decreased the portion of the bill that is variable for both residential and non-residential customers, on the basis that the existing tariff structure created 'perverse incentives for large customers to adopt on-site recycling where it was not economically efficient' (NSW Independent Pricing and Regulatory Tribunal 2012). This meant volumetric charges reduced by over 30% in the four year regulatory period, decreasing the savings from on-site recycling.

7.4.4.5 4-year regulatory price paths limits opportunistic recycled water for new growth

Although pricing policy sends clear investment signals, the process for determining regulated prices continues to be managed through a 4-year regulatory cycle that considers different water 'products' separately. The focus is on separate four year efficiencies for water, wastewater, stormwater and recycled water services. The implication is that the focus on least cost 'just in time' delivery of large scale infrastructure may miss opportunities associated with incremental integrated infrastructure (National Water Commission 2011). Under current planning and pricing conditions, many new developments in the outskirts of Sydney have no recycled water, with their wastewater being transported up to 50km to an ocean outfall. This is despite growth predictions forecasting up to three new sewage treatment plants to service the outskirts (Sydney Water 2015a, p. 239), more stringent inland discharge limits being foreshadowed by the environmental regulator[44] (Environmental Protection Authority 2015) and the substantial technical, social and economic costs associated with retrofitting recycled water into already established areas (Water Services Association of Australia 2009).

Contrasting this separated approach with an opportunistic integrated investment approach is salutary. Research completed for the Water Supply and Demand Strategy for Melbourne demonstrated significant opportunities for long term efficiencies (in the order of billions of dollars) through ongoing investment in demand management and incremental integrated water solutions when the opportunity arises (Mukheibir & Mitchell, C 2014).

7.4.5 Competition reform

7.4.5.1 Competition reforms open the market and recycled water emerges as an avenue for product differentiation.

Competition reforms created the potential for previously unimagined private participation in the urban water sector. The bill that corporatized Sydney Water in 1994 included provisions that created the opportunity for others to enter the corporation's area of operations to compete to provide services' (*Water Board (Corporatisation) Bill - Second Reading Speech* 1994). For the first decade post corporatisation, competition and private sector involvement was predominantly restricted to the private sector competitively bidding to deliver products and services to Sydney Water, rather than to customers (Sydney Water 2010a, pp. 12-3). In 2004, Services Sydney made a formal application to the National Competition Council requesting access to Sydney Water's monopoly assets to develop a recycled water network. In 2005, the National Competition Tribunal declared access for 50 years

[44] Which would potential force treatment levels to that much closer to recycled water

(Australian Competition and Consumer Commission 2007), requiring Sydney Water to provide private parties with access to their three major wastewater transport networks. While the Services Sydney proposal never came to fruition, the challenge in the ACCC and the subsequent granting of access rights was part of the impetus for NSW to develop the landmark Water Industry Competition (WIC) Act (2006).

7.4.5.2 The Water Industry Competition Act – creating opportunity but with some implementation issues

The *Water Industry Competition Act 2006* has created certainty of entry, which has been instrumental in stimulating private sector investment (City of Sydney 2013; NSW Independent Pricing and Regulatory Tribunal 2013; Water Factory 2013). Designed to facilitate the development of a competitive market (NSW Government 2012, pp. 32,5), the WIC Act established an access regime (allowing private entities to access already established water and wastewater infrastructure rather than replicate such infrastructure at high cost) and a licensing framework for private sector provision of drinking water, recycled water and wastewater services.

However, implementation of WIC has been a lengthy, uncertain and time-consuming process. The Act has already undergone two reviews, the mandate (particularly who is covered by the Act) has changed twice, and a workable retailer and supplier of last resort regime has only just been established. The latest review has taken more than three years and as of November 2016 the amendments are not yet in force and regulations not released. The changing and uncertain regulatory regime combined with the pre-existing complexity make local recycled water investment challenging, time intensive and risky.

7.4.5.3 Pricing and investment policies designed to preserve competition and choice act against recycled water

In Sydney there is currently a marked difference in regulations governing revenue collection for conventional versus recycled water services. While water and wastewater services are based on a geographically averaged postage stamp price, recycled water prices are ring-fenced. This means recycled water investments must be locally self-funding, unless there is a clear regulatory direction stating otherwise. To compound this distinction there is also a difference in how the capital for infrastructure is funded. As part of a decision to make housing more affordable, the NSW Government abolished developer charges for water and wastewater services (Premier Nathan Rees 2008), but not for recycled water in order to allow competition and choice in meeting BASIX targets. Whilst the distinctions in the treatment of recycled water stem from an intention to minimize the competitive advantage of the incumbent utility, the result is a higher cost structure, and a riskier revenue recovery structure for recycled water compared to conventional services.

Furthermore, the prices new market entrants are charged for connection to monopoly water and wastewater infrastructure can be critical to market viability. Historically, new entrants in Sydney who provide water, wastewater and recycled water services to a whole development have been charged a single non-residential customer tariff ('at the gate'), with fixed charges based on meter size (thus pipe & capacity) and volumetric charges, including an allowance for a per kilolitre sewerage usage charge (Flow Systems 2015). While this price structure based on usage and discharge is standard for large water users, it is not usually applicable to residential customers. This price methodology was originally adopted for new entrants as it reflects the much lower water and wastewater demands (both average and peak) that such developments place on the existing centralised network (when compared to similar developments without local recycled water). However, pricing changes are being proposed to either treat all local recycled water systems as access seekers, thereby charging the full residential rate for each actual resident within the development, minus any avoided costs (Sydney Water 2015a) or adopt some other form of retail minus approach (NSW Independent Pricing and Regulatory Tribunal 2016). This change, which hinges on defining what type of customers are local water service providers, has the potential to significantly undermine the financial viability of these emerging integrated private water solutions (City of Sydney 2015; Flow Systems 2015; Infrastructure Partnerships Australia 2015).

7.4.6 Changing expectations and the evolution of the green market provide new opportunities for recycled water

7.4.6.1 Sustainability aspirations and expanding customer expectations result in policy aspirations that support recycled water

The water industry locally and globally has embraced the concept of liveability. In Sydney, this has resulted in water policy which 'aims to support liveable and resilient urban communities and helps protect the health of rivers impacted by water supply dams' (Metropolitan Water Directorate 2015). The desire for liveable resilient urban communities and the important role water plays in delivering these outcomes is echoed by industry (Sydney Water 2014; Water Services Association of Australia 2014a). In addition, Sydney customers and the wider community have indicated their preference for recycled water over other less integrated options and their willingness to pay a premium for recycled water options (Marsden Jacob Associates 2014b; Metropolitan Water Directorate 2014a). The combination of sustainability and liveability aspirations embedded in policy has created opportunities for recycled water.

In Sydney, the emerging green property market[45], primarily realised through the commercial building sector appears to be increasing. Ten years after the Green Building Council of Australia's establishment, there were 98 buildings with a green star certification in NSW (Green Building Council of Australia 2013b). In Sydney, at least eight of the 5/6 star Green Star rated buildings have in-building recycled water capacity, helping to contribute to their high rating. In addition, recycling water provides a prestige factor in the major cities property markets (Institute for Sustainable Futures 2013a). In some areas, council policy encourages or rewards recycled water for new development (City of Sydney 2012; Ryde City Council 2010).

7.4.7 Unclear regulatory responsibility for liveability can limit opportunities for recycled water

Although policy statements supporting liveability are common, in Sydney a lack of regulatory clarity around expectations, funding and delivery responsibility has limited

[45] Where a price premium is gained for premises promoted as having higher environmental standard compared to similar premises.

expenditure on liveability-related options, including local recycled water (NSW Independent Pricing and Regulatory Tribunal 2015a; National Water Commission 2011). In addition, the regulatory framework for determining prices and funding in Sydney mitigates against including these broader customer preferences (NSW Independent Pricing and Regulatory Tribunal 2015a). Instead, it actively discourages integration through reinforcing historical practices of planning, pricing and regulating least cost single product solutions.

7.5 Discussion: The push and pull of regulation and policy

The research presented in this paper make it clear that opposing forces within the domains of pricing policy, competition and resource security can significantly influence recycled water investment (Figure 26). The widespread institutional and regulatory reforms, in conjunction with technology changes and changing consumer expectations have created unprecedented opportunities for recycled water provision within the urban water sector. However, the institutional legacy of over 100 years of government-provided, separated, centralised services and the practical implementation of many of the policies discussed above, have unintended consequences.

The sheer number of policies and regulatory instruments to be considered (see Supplementary Material), is, in itself an indication of the intensive, intricate, perplexing and at times unwieldy nature of urban water management in Sydney. In combination with this diverse range of institutional responsibilities, the sometimes inconsistent and competing policy objectives and reforms designed to promote competitive, innovative, and climate independent sources often inadvertently create powerful limitations on local private recycled water.

While policies previously aimed at addressing resource scarcity successfully drove recycled water investment, changing conditions, particularly in relation to funding and investment security (combined with increased water availability), has led to a more stringent financial evaluation of individual recycled water projects to get then over the line. The recent step change in supply provided through the desalination investment has not only changed long term investment conditions for recycled water in relation to drought, it has also influenced the long run marginal cost calculations and decisions relating to price structure.

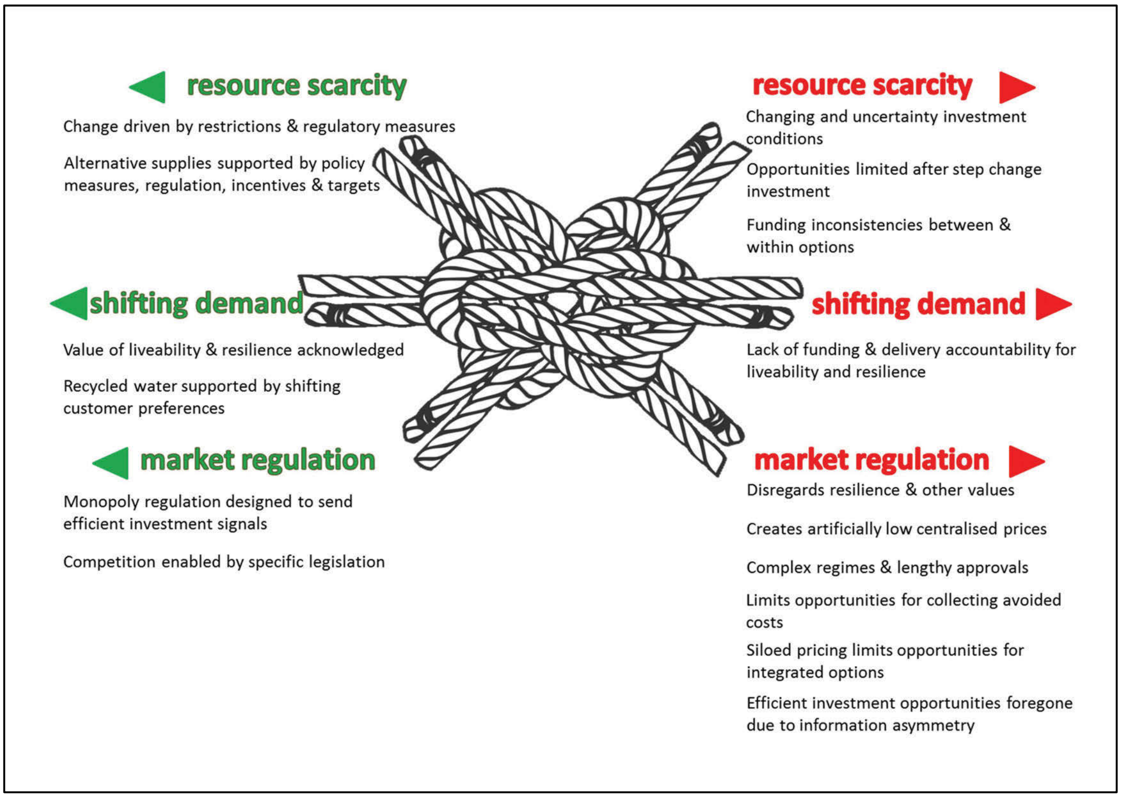


Figure 26: The policy and regulatory tug-of-war for local recycled water

Competition reforms, particularly the Water Industry Competition Act, have successfully opening market to unprecedented private sector involvement, particularly for recycled water. Private recycled water developments have successfully supported local liveability goals and aspirations, helped meet changing customer preferences and provided individual customers with water security and ongoing resilience. However, the lack of regulatory accountability for broader liveability objectives and complex and lengthy approvals processes for private schemes are hampering the development of innovative recycled water options. If the overall aim were to practically promote local, innovative, resilient and integrated solutions, then defining clear regulatory objectives, defining the responsibility for liveability, and providing enabling funds could assist in overcoming current hurdles and biases.

The regulatory pricing framework and its application can have significant influence on infrastructure planning and the relative value of future investments. Funding structures designed to support recycled water have been applied inconsistently, potentially creating confusion and false expectations around the scale and viability of existing and future recycled water projects. When assessing these projects retrospectively it is important to acknowledge the existing policy, regulatory and climatic conditions under which they were implemented.

Institutional arrangements that create information asymmetry, in conjunction with pricing policies that remove location-specific investment signals (i.e. postage stamp pricing and the removal of developer charges), can limit the capability of the sector to predict centralised infrastructure constraints and provide alternative proposals incorporating recycled water in an efficient and timely manner. While competition, in the form of pockets of private integrated service provision, is starting to emerge in Sydney, changes in policy decisions in conjunction with pricing methodologies have the potential to stifle the existing market. Although the economic rigour in an access charging regime (discussed in 3.4.4) is well documented, in light of other limitations and the limited market, continuing with a low transaction cost, simple, predictable and transparent charging mechanism would potentially be more effective, if the aim were to continue to encourage local, innovative and integrated solutions.

For all its economic rigour, price signals in Sydney still disregard resilience values. In addition, policy changes designed to support competition and customer choice have actually created price disparities between recycled water and conventional options, potentially making recycled water a riskier investment. Even when recycled investments are evaluated to be efficient, based on existing price structures, the signals have changed over time[46], which can in turn influence the financial value of existing scheme, and perceptions of future schemes.

[46] For example investments have been compared to long run marginal costs (see section 4.3.2.1) only to have it almost halve. There have also been changes to the balance between fixed and variable costs (see section 3.4.2.3) and potential changes to customer definitions (section 3.4.2.3) that can influence the future financial outcome of recycled water investments.

Overall, although there has been significant investment and effort in designing institutional arrangements that support local recycled water, the inconsistency within the overall water management framework creates unnecessary investment risk, and potentially limits public centralised recycled water investment and local private recycled water investment. However, this research has shown that a systematic and detailed review of the full regulatory and policy framework can provide valuable insights into recycled water investment conditions. In turn this provides a robust basis on which to revise existing structures to counter any unintended consequences.

7.6 Conclusions

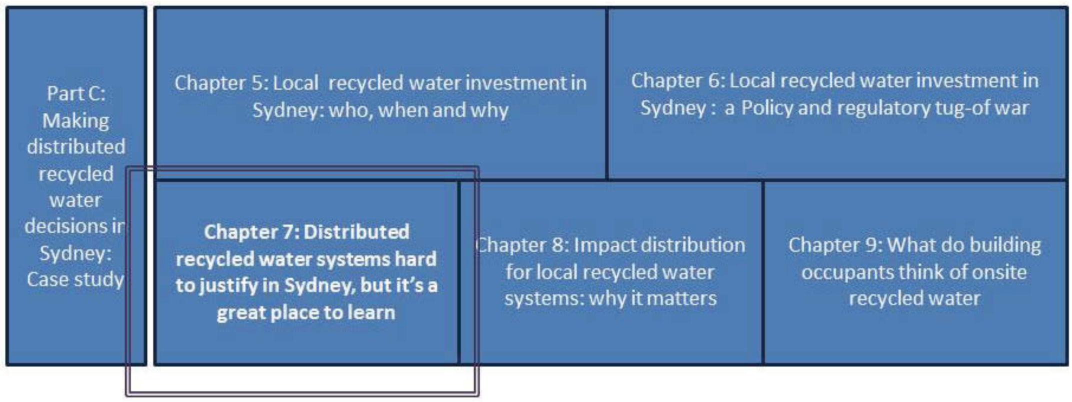
This paper has demonstrated that while local recycled water investment can contribute to resilient water services and liveable cities, their uptake is proving challenging in Sydney for both public and private investors. This is particularly surprising, because Sydney's innovative and unique Water Industry Competition Act was designed to enable the opposite outcome. The research illustrates that even with the best intention, past, current and future policy, regulatory and institutional environments have a significant and unexpectedly negative impact on why, where and when investment occurs and what that means for future investment.

Policy and regulatory instruments are designed to achieve specific outcomes. Over the last 10 years there have been a number of changes in the water sector designed to encourage competition and innovative solutions and promote integrated climate independent sources. Combined, these initiatives have supported new investment, including local recycled water systems. However, as this paper has shown, a number of other initiatives, policies, regulations and institutional arrangements, while often effective in achieving their designed purpose, have undermined the effectiveness of the policies designed to support competition, innovation and recycled water. To explain how, where and why local recycled water investment is occurring, it is necessary to examine both the policies that drive investment and those from a broader context that may counter or redirect investment in unintended ways.

By identifying and acknowledging the oppositional nature of these levers we can better explain how, where and why local recycled water investment has occurred in the past. Additionally, by acknowledging the wide range of influences and the critical interplay between them it is possible to develop strategies to revise existing institutional structures to address unintended consequences, and encourage investment that will support a resilient and adaptable water industry into the future.

Chapter 8 Local recycled water systems: hard to justify in Sydney, but it's a great place to learn

Watson, R., Mitchell, C, Fane, S (2013). Distributed recycled water systems – hard to justify in Sydney, but it's a great place to learn. Asia Pacific Water Recycling Conference. Brisbane, AWA, WSSA, WateReuse Australia.



This chapter consists of the paper 'Distributed recycled water systems – hard to justify in Sydney, but it's a great place to learn' which was presented in 2013 at the Asia Pacific Water Recycling Conference in Brisbane. This paper focuses on Research Questions 2a-d, which examine: who makes decisions, how impacts are used, and the influence of the wider context. This paper identifies barriers to local (distributed) recycled water investment in Sydney, particularly in the planning process, pricing regulation, regulatory complexity and existing geographical and system design features. It reveals the different impacts of these barriers based on variations in investment size and investor type.

Highlights

- There are strong drivers for local recycled water in Sydney.
- We identify historical, institutional and regulatory factors that are limiting investment.
- The limiting factors vary depending on investor type and investment scale.

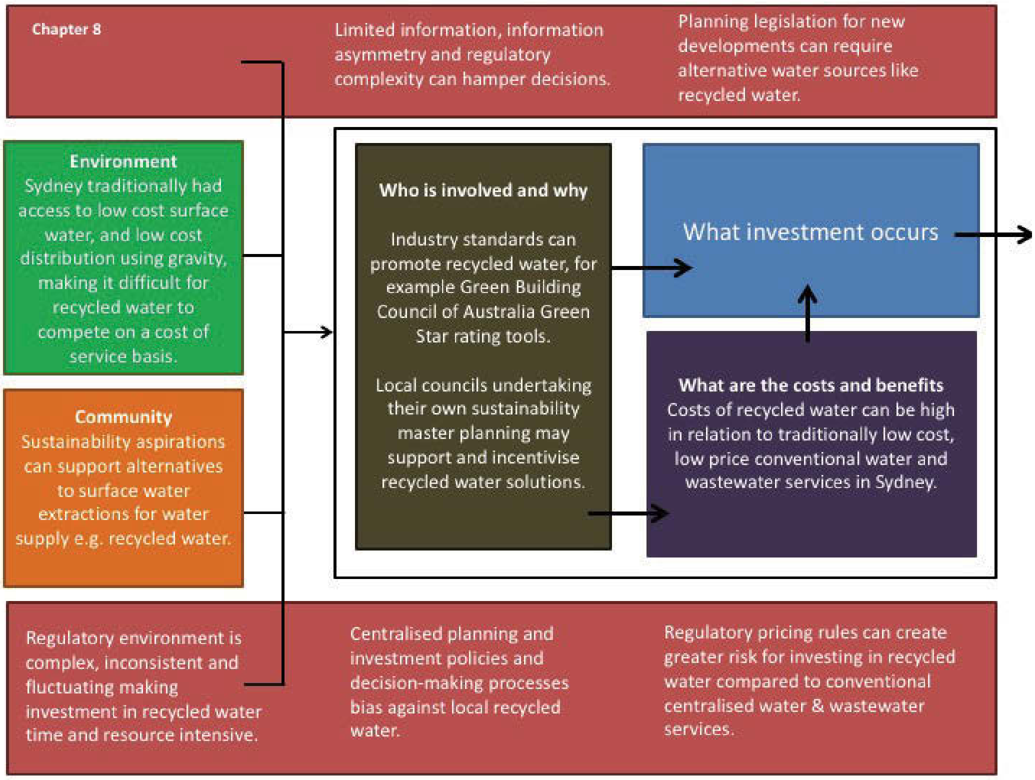


Figure 27: Synthesis of Chapter 8 through lens of IAD framework

8.1 Abstract

There are strong drivers for local recycled water systems in the wider Sydney area. However, a particular set of historical and contextual factors unique to Sydney limit the viability of recycled water systems, and need to be overcome if small scale systems are to reach their potential to contribute to improving the value and overall robustness of the Sydney network. This paper identifies those factors and discusses why some of the factors also make Sydney a great place to test and learn from these new systems.

8.2 Introduction

Sydney is the largest city in Australia. The water and wastewater supply for the Greater Sydney Region services over 4.6 million people. A government owned monopoly provider, Sydney Water, provides Sydney's centralised water supply and wastewater disposal. There is significant investment in large water supply options, wastewater treatment plants and networks to transport the water and wastewater.

Over 80% of water is sourced from Warragamba Dam. Towards the end of the recent drought a desalination plant was built providing water security for the next 30 years. Over 75% (or about 900ML/d) of Sydney's wastewater is disposed of at one of three primary treatment plants, with disposal via a deep ocean outfall. The water network is over 21,000 km of pipes, the wastewater network has over 24,000 km of pipes. Overall it is estimated there are over $30 billion of assets[47].

The existing large centralised services provide many health, environmental and efficiency benefits. In the last 10 years though, a number of separate, but compounding drivers have led practitioners in the water industry to consider alternatives to the large, separated, centralised water and wastewater service delivery paradigm.

These drivers are powerful when making choices between small systems or centralized systems. However, the decision-making process can become more complex when a centralized system already exists. In these circumstances there is often a range of historical and contextual factors that make it difficult to fairly compare alternatives, so they work to negate the benefits of small systems and limit their uptake.

This paper uses Sydney as an example to specifically consider the factors that limit sustainable investment in small recycled water systems as a complement or competitor to existing centralized services (called local recycled water systems in the rest of the paper, see (Watson 2011)). The paper then goes on to demonstrate why, if we are serious about developing a competitive and integrated water industry, some of the factors also make Sydney a great place to test and learn about these new systems.

8.3 Why should we consider alternatives to the centralized system in Sydney

There have been a number of changes in the water industry over the last few decades. The increasing use of sustainability principles has meant we look for options that mimic the natural water cycle, rather than separating water, wastewater and

[47] Depreciated replacement cost of assets.

stormwater services. Recent droughts and a better understanding of the impacts of climate change and population growth have led us to consider additional, reliable supply sources. Many major cities have extensive but ageing and capacity-constrained networks. Expanding these networks to meet the demands of population growth is challenging financially, technically and logistically.

These infrastructure challenges and changes have been coupled with political and policy decisions that aim to promote recycled water options and support increased competition within the water sector. In the residential sector, planning legislation that drives potable water reduction targets for new developments can often require alternative sources. Some local governments are also undertaking their own master planning processes to identify local opportunities for recycling (see for example City of Sydney's Decentralised Master Plan). If we place these drivers in the context of rapid advances in the capability and cost of small scale treatment systems and an active market for 'green products', we can see that there are many reasons to consider alternatives to centralized services, and local recycled water systems in particular.

8.4 What limits local recycled water investment in Sydney?

Despite the many drivers for local recycled water systems there are still a wide range of historical and contextual factors that are limiting investment. These factors are reinforced through regulatory, policy and institutional arrangements. The main factors in Sydney are outlined in Figure 28 and include:

- It is challenging for recycled water to compete with more conventional water and wastewater services on cost and price
- The current regulatory pricing rules create greater risk for investing in recycled water compared to conventional centralized water and wastewater services
- The current regulatory environment is complex, inconsistent and fluctuating, making investment in recycled water, particularly local recycled water, time and resource intensive
- Current centralized planning and investment policies and decision-making processes preference large, just in time, centralized solutions.

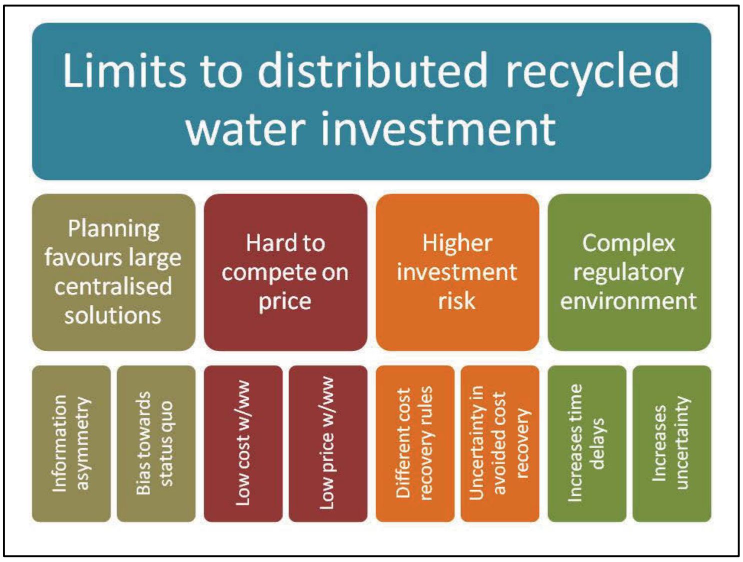


Figure 28: Limits to recycled water investment

Some of these issues affect recycled water products in general, and some issues affect just small recycled water (local recycled water) products. Some are relevant to private investment or public investment only, and some are relevant to both. The spread of these issues is outlined in Table 6.

Table 6: Limitations vary depending on who is investing and at what scale

	Planning favours centralised solutions		Hard to compete on price		High investment risk		Complex regulatory environment	
	Information asymmetry	Bias towards status quo	Low cost	Low price	Avoided cost risk	Cost recovery rules	Regulation uncertainty	Time delays
Private investor	✓		✓	✓	✓		✓	✓
Public investor	✓	✓		✓	✓	✓	✓	✓
	Distributed only		All scales					

Some limits apply in all situations, regardless of scale or investor: competing on price is always hard and there is always uncertainty in avoided cost recovery. Some limits impact private providers more strongly: the regulatory environment is always complex and time consuming with uncertain outcomes. Some limits apply only to public investment: different cost recovery rules for recycled water compared to conventional alternatives are an issue for any public recycling scheme. Some limits apply only to distributed systems: planning's preference for centralised solutions impacts on both private and public investment in distributed systems. Below, we explore and explain these factors in more detail.

8.4.1 Factors that make it difficult for recycled water to be price competitive

There are several geographical and system design features that provide Sydney with low cost solutions for the bulk of its water and wastewater services. These low costs are exaggerated in the price through regulatory decisions that exclude some costs from being considered in pricing determinations. The resulting low price[48] particularly affects the ability of private recycled water systems to compete on price alone with the more conventional alternatives. The low average cost and price of conventional services has less effect on the choice between options for public investment. This is because when system augmentation is required they include the next most efficient option and roll that into the average price.

8.4.1.1 The average cost of water and wastewater services are low in Sydney

Sydney has a number of factors that contribute to the low average cost of water and wastewater services. Over 80 percent of water is sourced from Warragamba Dam. This water is relatively cheap[49]. About 75 percent of Sydney's wastewater flows mainly via gravity to three large primary treatment plants and the disposed of in ocean outfalls. This is also a very cheap form of wastewater disposal. Sydney's geography also means it has very low water and wastewater transport requirements (Cook, Hall & Gregory

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[48] Not only is the price of water low in relation to the relative (true) cost of service and other alternatives, it is also low in relation to other jurisdictions, for example South Australia pay $4.46/kL and the national average is $2.99/kL, compared to Sydney $2.19/kL.(ABS 2015). Further the average total bill in Sydney (water and wastewater fixed and variable charges) is one of the lowest in Australia.(BOM 2016)

[49] Dam water and treatment is about $166 of $1000 water bill and is about 80% of the water. Desalinated water accounts for about $100 of $1000 bill and is only 15% of the water (Sydney Water 2010a).

2012). Combined, this makes the current average cost of water and wastewater services very low.

8.4.1.2 The price of water and wastewater services are low in Sydney

On top of the low average cost of water and wastewater services there have been a number of regulatory decisions that make the price of water services even lower. This makes it even harder for recycled water services to compete. In 2000, when price regulation began in Sydney, the asset base was substantially written down[50]. The depreciated replacement cost of assets is estimated to be over $30 billion while the regulatory asset base is only $13 billion (Sydney Water 2010a). This should be corrected, as new assets are added, but the correction will take a very long time. Based on the current situation, prices should increase by 1-1.5% each year to cover these replacement costs (Sydney Water 2011d).

In addition the rate of return on assets since price regulation has traditionally been very low. Between 2005-2009 many utilities across Australia earned well under the average 10 year government bond rate of 5 percent, which is the minimum rate to be considered commercially viable (Productivity Commission 2011). In IPART's latest pricing decision for Sydney Water they allowed a rate of return of about 5.6%, which will be achieved only if demand forecasts are not overstated and efficiency measures are met (NSW Independent Pricing and Regulatory Tribunal 2012). It is important to note that this low rate of return is on the already substantially written down regulatory asset base.

8.4.2 Factors that increase the investment risk

The current regulatory environment in NSW makes investment in recycled water services more risky than conventional water and wastewater services. This is true for public and private investors. The rules for revenue recovery discriminate in several ways between conventional water/ wastewater services and recycled water, increasing revenue risk for recycled water. There is the potential ability to avoid some costs by

[50] The depreciated replacement cost of assets is estimated to be over $30 billion. The regulatory asset base is only $13 billion. (Sydney Water 2010a)

using recycled water, either through reduced water and wastewater charges or more formal avoided cost payments. However, these are also uncertain and subject to change.

8.4.2.1 Different cost recovery rules for different services

The current price regulation framework in NSW differentiates between the way costs are recovered for conventional services and recycled water services. This greatly affects the revenue and investment risk profile for utility-driven recycled water. There are no developer charges in Sydney for water and wastewater services[51]. The cost of servicing new growth is recovered from the whole customer base. However, for recycled water, developer charges must be recovered directly from the users of the system. Similarly water and wastewater services have a postage stamp price. That is, the price is the same throughout the system regardless of how much it costs to service the customer. For recycled water, each scheme must reflect the true cost, and be recovered directly from the customers using the system. These rules were developed to assist with customer choice and to facilitate private competition. However, in practice it means in addition to challenges competing with conventional services due to cost and price issues, recycled water services are required to be locally cost reflective as opposed to conventional services which are currently not cost reflective at either the local scale or across the whole area of operations.

These rules not only differentiate the price for the two services, but also increase the revenue risk for the utility. This is because the revenue for conventional water and wastewater services is fully recovered from the whole customer base (over 1.7 million households and businesses) (Sydney Water 2012b). Connection to a recycled water system is discretionary, so not only is the revenue recovered from a smaller customer base, thereby increasing demand risk, but also it is subject to connection (or customer number) uncertainty.

[51] Water and wastewater developer charges in Sydney were abolished on 17 December 2008 to facilitate housing affordability (Premier Nathan Rees 2008)

8.4.2.2 Rules for avoidable or avoided costs

In Sydney there are two ways developers and users of local recycled water schemes can avoid some costs. The first is by setting up the system to reduce payments for conventional water and wastewater services. The current pricing framework in Sydney sets prices based on the customer type: residential or non residential; and meter size. If a residential complex installs a local recycled water system there is the potential to change to a non-residential wastewater discharge structure, and use a smaller water meter, both of which have the potential to reduce yearly fixed costs. However, this reduction is not certain. Due to pricing rules, special exemptions need to be gained to allow the change in classification, even though it reflects the low impact the customers are having on the water and wastewater networks. A recycled water system will also provide savings, by using less water and discharging less wastewater. However, even the relative savings here are subject to change. In their latest pricing determination, IPART changed the price structure for fixed and variable charges, as they were concerned that by not reflecting short run marginal cost. They believed the existing structure created 'perverse incentives for large customers to adopt on-site recycling where it was not efficient' (NSW Independent Pricing and Regulatory Tribunal 2012). This meant usage charges reduced by over 30% in the four year regulatory period, decreasing the savings from on-site recycling.

In theory there are methods to calculate and recover avoided costs. These are costs in the centralised water and wastewater system that are avoided by recycling. However, in practice these avoided costs are difficult to identify and collect. The nature of the existing assets and system design requirements in Sydney limits the impact an individual small recycled water system can make (scale). The outcome of the formula is also uncertain. This is perhaps best highlighted through the decision on avoided costs for Sydney's Rouse Hill recycled water system. Sydney Water had applied the formula outlined by IPART and liaised with IPART during the calculation process. Yet, in their draft determination IPART rejected the estimates, leaving Sydney Water 'with no confidence in IPART's regulatory framework for recycled water avoided costs' (Sydney Water 2012a). As private developers have even less access to the information required for the formula, their risk is even greater.

8.4.3 Complex regulatory environment

Despite substantial reforms over the past two decades, the regulatory framework is still overly complex (National Water Commission 2011b; Power 2010). For example, in NSW a decentralised recycled water system may trigger six Acts, be covered by four specific guidelines and require the approval or advice of up to eight authorities, although this is currently under review (NSW Government 2012).

The change in focus from prescriptive end product management to a risk management approach for recycled water[52] (LECG Limited Asia Pacific 2011) has failed to deliver. While a risk management framework is, in theory, more flexible, it has been suggested that the uncertainty surrounding new technologies and unclear policy positions has created a climate of risk aversion (Tjandraatmadja et al. 2008). This has resulted in delays and additional costs (for example validation testing (Power 2010)) and a perception that best quality and not 'fit for purpose' water is required which again increases costs (Tjandraatmadja et al. 2008).

In NSW the *Water Industry Competition Act 2006* was designed to encourage competition for water and wastewater services and facilitate investment in recycled water infrastructure[53]. However, the Act is in its infancy and has already been subject to several changes, and the current review proposes more. These changes include licensing schemes that previously fell outside of the Act, which has the potential to increase operating costs substantially.

The complexity of regulation, combined with the risk adversity and rapidly changing rules has the potential to make investing in local recycled water systems expensive, uncertain, prolonged and too difficult to pursue.

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[52] Specifically a change from the prescriptive National Water Quality Management Strategy (NWQMS) *Guidelines for Sewerage Systems: Use of Reclaimed Water* (ARMCANZ-ANZECC-NHMRC 2000) to the risk management approach outlined in the Australian Guidelines for Recycled Water (NRMMC) 2006

[53] *Water Industry Competition Act* 2006 Long title: An Act to encourage competition in relation to the supply of water and the provision of sewerage services and to facilitate the development of infrastructure for the production and reticulation of recycled water; and for other purposes.

8.4.4 Policy choice uncertainty

Government policies have the ability to distort or restrict the market for local recycled water or introduce further risk. In addition to setting efficiency and recycled water targets, Australian governments have occasionally limited or restricted certain supply options, such as decisions on dams (Welcome Reef Dam in Sydney) and indirect potable reuse. These decisions introduce additional risk for private investment, as investments may become redundant if barriers to cheaper sources were removed in the future (LECG Limited Asia Pacific 2011).

8.4.5 Planning and institutional frameworks that favour large centralised solutions

The current planning, regulatory and institutional frameworks have been developed over a long period of time based on public monopoly supply of standard centralised services. In recent years they have been adjusted and adapted to accommodate integrated options and private competition. However, there are a number of factors that result in conventional centralised services being chosen over local recycled water solutions.

Urban water planning is undertaken by the centralised utilities or government agencies. There are no formal processes in most jurisdictions for identifying opportunities for small systems in advance of centralised investment and communicating this to the market. This is exacerbated by the limited institutional and regulatory coordination between stormwater service providers and the water and wastewater utilities. This lack of information limits the ability of private investors to suggest other alternatives or plan local recycled water developments to maximise benefit to both their customers and the wider centralised system.

Decisions tend to bias towards maintaining the status quo (investments that are similar to ones we have made in the past) (Hammond, Keeney & Raiffa 1998). When a centralised agency is making choices between options it is likely they will bias towards conventional centralised solutions. Finally historical asset choices can influence the future cost difference between options. For example in Sydney, a decision was made to construct the majority of the infrastructure for both stages of the desalination plant. This decision means supplying the next phase of desalination is cheaper than the current phase. This dramatically reduces the viability any other supply options, including demand reduction.

8.5 How do these barriers provide opportunity?

In the context of the discussion above, it would seem very difficult to justify investment in recycled water, particularly small recycled water schemes, in Sydney. However, many of these factors have the potential to change in the medium to long term. For example, the combination of changing pricing policies, the need to duplicate extensive network infrastructure and further efficiency developments in small scale treatment could significantly improve price competitiveness. Yet, as we have seen towards the end of the last drought, our current planning system encourages waiting until capacity is very limited then investing in large scale expensive assets to ensure capacity for another 30 plus years (desalination plants around Australia illustrate this example well) (White, Noble & Chong 2008).

Small scale recycling has the potential to increase the number of customers that existing networks can support and reduce demand on water supplies and wastewater treatment. This is particularly valuable for the large amount of infill growth that major capitals are expecting, where augmentation and duplication is problematic. For this potential to be realised, investment is required continually over a sustained period of time. However, there is a great deal of uncertainty that surrounds the viability of this strategy. Nearly every scheme that has been developed has provided some form of learning opportunity, and that is where we can see Sydney as an opportune testing ground.

The large size of the Sydney system gives it capacity to provide redundancy for these systems at negligible additional cost. Most of Sydney's sewage is largely untreated before ocean discharge, so the additional environmental impact of distributed system discharge to sewer is negligible, and the cost/energy impost is also negligible. From a process perspective, Sydney's high sewer flows minimize the potential for local sludge issues. At the same time, there is an apparent willingness to pay in the high-end property and urban irrigation markets.

Combining these opportunities and potentials makes Sydney an ideal location to test, monitor and develop the capacity of both the systems and the private sector operators, without placing unacceptable impacts on the existing system, the environment or the community.

8.6 Conclusion

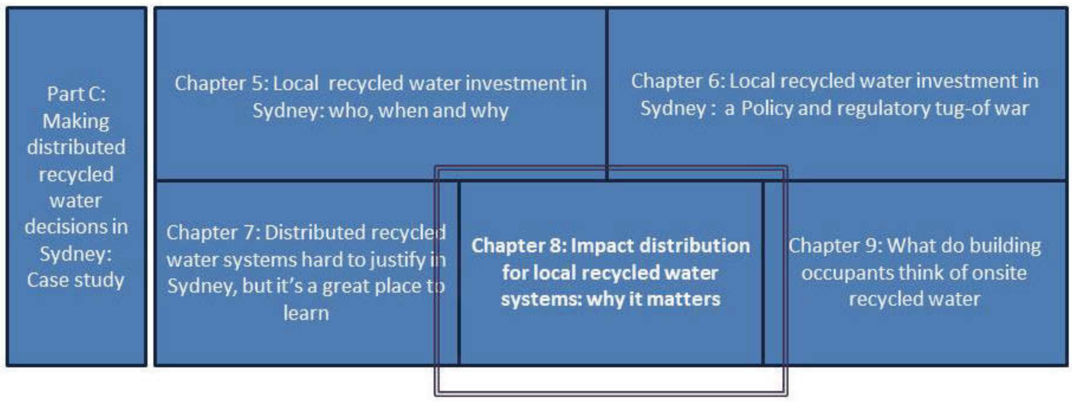
While Sydney has a number of drivers that should make it an opportune location for local recycled water uptake, this paper has identified a wide range of limiting factors. These factors are generally based in regulatory, policy or institutional arrangements. It includes factors that influence the price differential between general water services and recycled water, factors that influence risk and uncertainty and factors that hinder efficient decision-making.

Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers. Firstly, making them explicit allows the scale of the limitation, and the potential impact on investment, to be assessed. Secondly, by acknowledging the limiting factors it is possible to develop strategies to address them. This assumes there is a desire to support the private recycled water market in Sydney, and throughout Australia in the long term.

However, the same factors that limit the opportunities for recycled water investment in Sydney also provide a unique, low risk environment to learn about and test the value of these systems. Supporting and monitoring the private recycled water market in this short period of low risk to the existing system, the environment or the community may help create a viable market long term that would substantially change the way water and wastewater services are delivered into the future.

Chapter 9 Impact distribution for local recycled water systems: why it matters

Watson, R., Fane, S. and Mitchell, C., 2016 Impact distribution for local recycled water systems: why it matters.' *International Journal of Water Governance* Vol. 2016 (4) pp.1-18



This chapter consists of the paper 'Impact distribution for local recycled water systems: why it matters', published in *International Journal of Water Governance*. This paper focuses on Research Question 2b: Who makes decisions about recycled water investment?

Highlights:

- Conventional assessment approaches are problematic for decentralised infrastructure.
- Impacts (costs, benefits, risks) of decentralised infrastructure are distributed.
- Distribution differs markedly between centralised and decentralised infrastructure.
- Who bears what impacts, and when, matters for investment decisions.

Figure 29 : Synthesis of Chapter 9 through lens of IAD framework

9.1 Abstract

Small-scale or local recycled water systems are increasingly being installed in urban centres in Australia, and throughout the world. These (often private) systems are in building basements, in parks, on industrial sites and within small communities that are already serviced by existing public centralized water and wastewater networks. A consistent and fair assessment of the value of such local recycling systems, particularly in relation to centralized extension, augmentation and replacement, has proved to be problematic. This paper reveals why. It suggests that the traditional classification of impacts into social, environmental, economic and at times technical groupings misses a key factor needed for understanding the relative costs, benefits and risks of these systems: their distribution across the wide range of stakeholder groups. This paper proposes that accounting for the distribution of impacts is critical for assessments that include options of different scales and different levels of responsibility, as there is a significant difference in impact distribution between conventional urban water services and small-scale, local recycled water systems. Explicitly considering impact distribution will help practitioners better understand the consequences of varying the

impact distribution, particularly when moving from substantially public responsibility and ownership of assets to a mix of public and private responsibility and ownership.

Keywords: Urban water planning, Decentralized infrastructure, Sustainability assessments

9.2 Introduction: What are local recycled water systems and why would they be considered as an option in the urban context?

Until recently, decentralized water and wastewater systems have generally been reserved for locations that were remote, difficult and/or too costly to service. However, the water industry is entering a period of challenge and change. It is proving both expensive and technically challenging to maintain and expand the capacity of existing centralized systems in order to manage and respond to ageing infrastructure and demand growth, while managing shifting expectations in terms of sustainability, liveability, resilience and security (Marlow et al. 2013). The combination of these drivers, plus technological change, has led practitioners in the water industry to consider alternatives to the large, separated, centralized water and wastewater service delivery paradigm (Etnier et al. 2007a, Ferguson et al. 2013, Marlow et al. 2013, Mitchell, C et al. 2010, Mitchell, C et al. 2008, Nelson 2008, Pahl-Wostl 2002, Pinkham et al. 2004, Willets et al. 2007).

One option gaining popularity is the use of small recycled water systems (called local systems in this paper) within the urban system (Etnier et al. 2007a, Mitchell, C et al. 2010, Mitchell, C et al. 2008, Nelson 2008, Pinkham et al. 2004, Willets et al. 2007). These (often private) systems are being installed in building basements, parks, on industrial sites and within small communities, to supplement the existing public centralized water and wastewater networks. When located within the urban water system, local systems can be extremely diverse in their sources, treatment methods, discharge locations, end uses and management models (Gikas and Tchobanoglous 2009, Watson 2011, Water Services Association of Australia 2010). Sources can include industrial water, sewer mining, blackwater, greywater and stormwater, and the systems can discharge to the environment or back to the sewer. These local systems create variations in geographical scale of service compared to the existing centralized water and wastewater services. In addition, due to potential differences in ownership and management models, local recycled water systems can also shift the conventional allocations of risk and responsibility associated with larger scale water infrastructure solutions.

A consistent and fair assessment of the value of local recycled water solutions, particularly in relation to centralized extension, augmentation and replacement, has proven to be problematic. It is challenging to consider and compare options that vary in scale, in service outcomes and in where the responsibility lies for planning and operation (Mitchell, C et al. 2007). Decisions in the water industry are generally complex and require decision makers to consider a wide range of perspectives and alternatives. Adding small systems into the mix of more traditional urban options increases both the diversity of options to be considered and the complexity of trade-offs (Ferguson et al. 2013).

This paper firstly reviews how impacts (benefits and disbenefits) are commonly used in the water industry to compare options and make decisions. While there are many studies on the economics of potable and non-potable reuse (Khan 2013; Marsden Jacob Associates 2013; Raucher et al. 2006), very few take into consideration the distribution of costs and benefits across the range of stakeholders, including developers, small system owners, customers, the broader community and the utility. Using the Australian regulatory and institutional context as an example, this paper identifies why the use of traditional sustainability assessments is limited, particularly for private investment in local systems – because they generally cannot or do not consider the significant changes in the distribution of impacts created by local recycled water systems. That is, the number of groups impacted, the way positive and negative impacts and risk are distributed between groups, and the timing and scale of the impacts are different for local recycled water compared to traditional urban centralized water and wastewater services.

This paper argues that clearly identifying the distribution of the impacts, who is impacted, and how and when they are impacted, will help explain why the assessment and implementation of these local systems has been problematic to date. Further, articulating the significance and scale of impact distribution helps identify why these systems are so different to conventional urban water services. It is important to make transparent both the assessment of impacts for the whole of society and the allocation of costs, benefits and risks across all of the affected stakeholders. This will allow for perverse outcomes for some stakeholders to be revealed, which will be informative for decision makers, particularly when considering whether to assist the industry in its initial stages or to make regulatory changes to more fairly distribute impacts in the long term.

9.3 Reviewing urban water planning and delivery frameworks – examining sustainable decision-making frameworks in the context of changing roles and responsibility

9.3.1 The public sector is traditionally responsible for planning and managing urban water services

Delivering urban water and wastewater services is widely recognised as a government responsibility. Decisions in the water industry are complex and decision makers must consider a wide range of perspectives and alternatives. Furthermore, in Australia at least, decisions have become highly politicized from time to time (Productivity Commission 2011; Water Services Association of Australia 2013) In the context of already complex decisions, the range of viable options and the complexity of trade-offs have continued to increase as principles of sustainability, integrated water management, water-sensitive urban design and liveable cities have emerged and evolved (Ferguson et al. 2013).

To help manage these complexities and trade-offs, and to include principles of sustainability, a number of decision-making frameworks and tools have been developed and adopted. There are different methods used in the urban water industry to compare the sustainability impacts of different urban water options (Fane et al.

2010). Federal and state governments in Australia generally prefer infrastructure decisions to include cost-benefit analyses (see, for example COAG (Council of Australian Governments) 2007; Commonwealth of Australia 2006; Office of Financial Management 2007; Resources and Industry Division – Queensland Treasury 2000). Cost-benefit analyses can include environmental and social impacts, but they need to be monetized using standard economic techniques, contingent valuation, or willingness-to-pay studies (Commonwealth of Australia 2006).

Commonly, strictly economic evaluations largely exclude sustainability and social considerations as these can be difficult to value. A range of alternative and complementary qualitative analysis tools, designed to include a wide range of (non-monetary) considerations have been developed and used within the urban water industry. These tools include multi-criteria analysis (Fane et al. 2010; Hajkowicz and Higgins 2008; Lundie et al. 2004), triple bottom line assessment (Taylor and Fletcher 2005), SWARD (Ashley et al. 2003) and scenario planning (Deng et al. 2013; Sitzenfrei et al. 2013). These tools allow for a multi-perspective analysis that helps to compare unquantified considerations and recognize the trade-offs required to balance multiple objectives and multiple viewpoints.

There are a number of critiques on the use of sustainability assessments in infrastructure decision-making. Sustainability assessments can be limited, as they contain multiple dimensions and require value judgments (Lai et al. 2008; Marlow et al. 2013). There is also an argument that suggests sustainability assessments can be improved through the collection and calculation of more comprehensive and representative data, or the development of more robust models that allow multiple scenarios to be examined (Fagan et al. 2010; Makropoulos et al. 2008; Sitzenfrei et al. 2013). An alternative view is that sustainability assessment improvements are too focused on better data and better models, instead of investigating the trade-offs and interactions between the environment, society and the economy (Pahl-Wostl 2002). In the context of the need to better understand the trade-offs and interactions between the environment, society and the economy, this article suggests that considering impact distribution is particularly critical when comparing large centralized options with many smaller decentralized options.

In situations where the planning, delivery, risk and cost recovery all remain with the same party or the general community, these broader sustainability assessment processes can be useful aids to help incorporate wider social concerns and environmental values into the decision-making process (Ashley et al. 2003, Hajkowicz 2007, Wang et al. 2009). However, local recycled water systems can substantially shift the roles and responsibilities of the different stakeholder groups (Pahl-Wostl 2002). So, when the responsibility for planning is separate from delivery and operation, and when there is not adequate consideration of the impacts of that change on where responsibility lies, these whole of society assessment processes can neglect important outcomes. For example, in China, the best whole of society economic solution was identified as new developments incorporating a local recycled water system in their basement to minimize the impact on the constrained centralized system (Liang & van Dijk 2010). Although these systems are installed, the total benefit obtained from them is reduced due to poor operation (Liang & van Dijk 2010).

9.3.2 The dominance of public sector responsibility for delivering all urban water services is changing

A close nexus between decisions, investment, responsibility and cost recovery has historically held for urban water and wastewater infrastructure. Government-owned water authorities, the predominant suppliers of urban water and wastewater services, have been operating as regulated monopoly businesses. The majority of decision-making and investment in urban centres has been publicly driven and backed. Postage stamp pricing (where everyone in a given area pays the same price, regardless of local costs) is common (Productivity Commission 2011).

The water industry has entered a period of challenge and change (Howe and Mitchell, C 2011). Technological change, government incentives and new markets are providing an opportunity to fundamentally shift the current water service and delivery paradigm. The green market, prolonged water restrictions and a suite of regulatory changes have facilitated direct private investment in water infrastructure. Historically, direct private investment in small-scale water infrastructure has been common practice in rural areas but usually at the household scale (e.g., rainwater tanks and simple on-site wastewater treatment systems). This type of investment is on the rise in urban areas (e.g. mandated rain tanks in new development areas in many states). However, the current scale and location of private investment in local infrastructure beyond the household scale in urban areas with existing centralized services is unprecedented in Australia.

The drivers to invest, and therefore the ways in which decisions are made by public water utilities and private investors, can be quite different (Institute for Sustainable Futures 2013, Watson et al. 2013). In the historical urban water context, public investment has been for broader social and environmental benefits. Private investment has generally been instigated in more discretionary circumstances and is more likely to be financially motivated.

The historical paradigm of urban water service provision (including governance, planning, investment, operation and maintenance) is changing in the face of some key challenges and opportunities. Figure 22 demonstrates the changing space of water infrastructure investment. As can be seen in the top half of the figure, historically, public utilities have been the principal investors, and they have focused only on basic service provision (e.g. near term investment in response to drought; medium term investment in response to capacity constraints from population growth or to replace ageing infrastructure). Decisions based on sustainability assessments align well with the broader social and environmental outcomes that traditional public centralized urban water services have sought to provide. The more traditional large infrastructure options have remained a public responsibility and have been funded in the usual manner through the postage stamp pricing. Historically, private sector investment was aimed at meeting broader service outcomes (e.g. to meet green market requirements; to service outlying areas beyond public utility service coverage), as can also be seen in the top half of Figure 30. Discretionary private sector services such as in-building and precinct recycled water for green building credits are delivered based on willingness to pay and market forces.

With the range of services and the role of both the public and private sectors evolving, as demonstrated in the lower half of Figure 22, the lines between public service provision and private discretionary services is blurring. Increasingly, public utilities are adding 'liveability' to their mission statements, and investing in broader service options, and private providers are providing basic infrastructure, such as desalination plants. Recently though, there have been examples both internationally and locally that have used sustainability assessments to demonstrate the potential of local systems to provide a benefit to society overall as well as private benefits (Chen and Wang 2009, Ferguson et al. 2013, Lazarova et al. 2001, Liang and van Dijk 2010, Lundie et al. 2004, Marsden Jacob and Brisbane City Council 2011, Mukheibir et al. 2013, Schwecke et al. 2007, Sharma et al. 2009, Yamagata et al. 2003). Including both small and large scale options into the assessment process has often been associated with changes in funding, risk and responsibility. With the introduction of more local options into the wider urban water planning process, the mix of private and public responsibilities for the delivery of the options continues to evolve. See for example the mix of source, scale and ownership models assessed for Kalkallo, Melbourne Australia (Sharma et al. 2009), or Melbourne's Northern Growth Corridor (Yarra Valley Water, Melbourne Water & Office of Living Victoria 2013). Local and site-based options have had a wider mix of responsibility mechanisms, including private responsibility for delivery, operation and funding, even though they help to provide broader service outcomes.

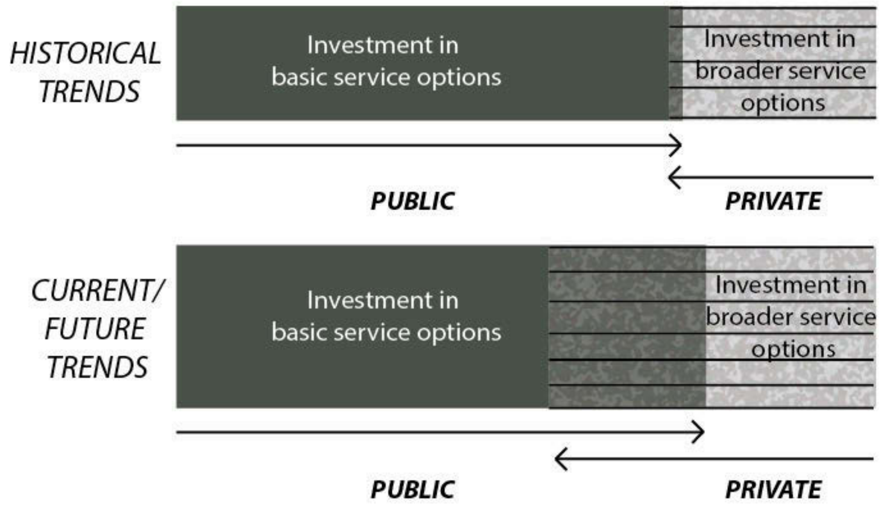


Figure 30: The changing space of water infrastructure investment: Historically public investments focused on basic services and private investments targeted more discretionary outcomes, but that distinction is blurring

9.4 Variations of scale and changing responsibilities between public centralized options and private local options make the consideration of distribution critical

9.4.1 The groups impacted by public centralized systems differ from private local systems

The introduction of local recycled water systems into an urban water system introduces new roles and responsibilities and changes existing ones, for decision making, ongoing management and funding of water and wastewater infrastructure. For example, when recycled water systems are installed in building basements for green building credits, or on golf courses for secure irrigation, the ownership, funding and management of those systems is private, whereas water and wastewater services are generally owned and managed by public utilities. On the other hand, some new developments such as Bingara Gorge, Sydney have private suppliers responsible for wastewater and recycled water management and planning, and the public utility plans and manages the water supply. As can be seen, a major difference between centralized systems and local recycled water systems is that local systems are more likely to be privately owned. For a centralized system there are four key impact groups: the environment; the regulators; the community and the utility (illustrated on the left of Figure 23). The whole community generally uses the service and the utility is usually the owner, operator and developer, although they may contract out some of these responsibilities. Current pricing, institutional and regulatory frameworks have been established in the urban water industry based on monopoly service provision, where the community as a whole pays equitably for a system and generally they all receive similar benefits and services. However, for a private local system there are seven or eight key impact groups: the environment, the regulator, the utility, the wider community serviced by the utility, the user of the local recycled water system, the owner (and/or operator) of the local recycled water system, and the developer of the local recycled water system (illustrated in the right of Figure 23). The distribution of impacts becomes important because, as the next section will show, the distribution, particularly of costs and risks, shifts to groups that are fundamental to ensuring the ongoing viability of the system, while the benefits are still spread over a much broader group.

The complexity of impacts and interrelations is increased with the introduction of a private system within a larger publicly-owned system, as can be seen in Figure 23. Even for the environmental and regulatory categories where the types of impacts are similar, the management of the impacts, and therefore the risk profile and magnitude of potential cost, becomes more complex. For example, the regulators change from managing one (or a few) large uniform entities to managing many small and diverse entities. It is likely that the increase in the number of entities will increase costs for the regulator. For example, in NSW it is estimated it costs more to regulate a small number of private providers under the WIC Act, than it costs to regulate the four major public water utilities (NSW Independent Pricing and Regulatory Tribunal 2013). In contrast, Pinkham et al. (2004) found no evidence to support claims of higher regulatory burden for smaller schemes. Therefore, increased regulatory costs are likely to be highly dependent on the requirements of specific regulatory regimes.

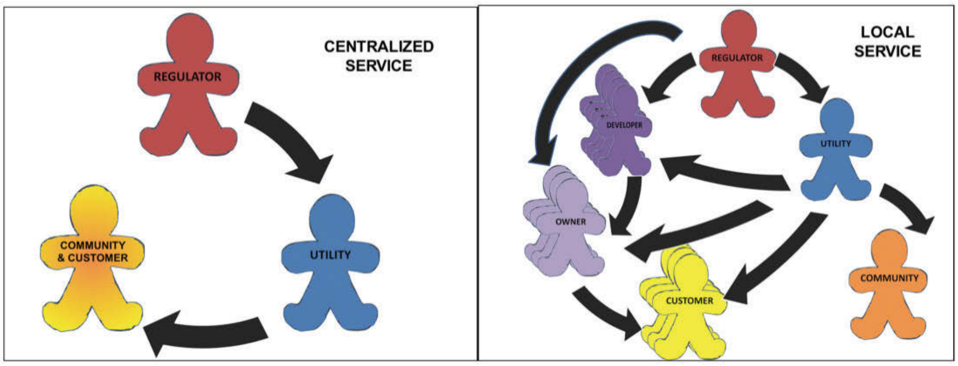


Figure 31: Mapping roles and interactions for conventional centralized and emerging local approaches. Local approaches have more stakeholders and more complex arrangements

Traditional sustainability assessments are limited in that they generally fail to examine and account for. Firstly, they fail to consider distribution and the role distribution plays in the viability of the preferred options, and secondly, they fail to consider risk, albeit to a lesser extent. This is not to say distribution and risk are not considered at all – they often are, but in a separate process (for example in a risk assessment, resilience assessment or a sensitivity analysis) (Institute for Sustainable Futures 2011). Where the local recycled water systems (or other local solutions) are developed and owned by someone other than the centralized water utility, the distribution of impacts (who is impacted, when and how and to what extent) changes significantly when compared to a centralized water service scenario, as the remainder of this paper will show.

9.4.2 The distributions of positive and negative impacts and risks are different for centralized systems and local systems

Not only is distribution important in localized systems because there are more groups to consider, but the groups are now affected in different ways. The impact balance (i.e. the positive impacts versus the negative impacts) in the context of risk will dictate how valuable local recycled water is to any particular group.

Table 7 presents a summary of the types of impacts of local recycled water. Although some impacts listed in Table 7 may seem to have minimal significance from a whole of society perspective, they are potentially very significant from the perspective of the person impacted. This is particularly important if the impact becomes the main or only impact a group experiences, or if the change represents a major shift from the centralized scenario.

Table 7: Impacts of local recycled water systems

	Benefits	Costs	Risks
Economic	Flexibility (size, timing, location, technology, source); scalability [Ut][D][C][Com] Centralised resilience; reliability; maximise centralised asset life; water security [Ut][Com] Avoided costs in centralised system; private funding leverage [Ut][Com] Increased property values [D][O][Com][U]; planning concessions [D]; premium rent/ price for prestige 'green buildings' [O]; productivity benefits of green buildings [U], branding [D][O][U] Reduced fertiliser costs [U]; reduced injury/ field rehabilitation costs [Com] Business resilience due to 'non-restricted' outdoor water use	Capital and operating costs; loss of treatment/ management economies of scale [O][U] New regulatory regimes; increased regulatory burden [R] Loss of centralised revenue and payments [Ut]; subsidies for new markets and meeting political targets [Com]	Degradation of centralised & other recycled water using infrastructure; stranded assets [Ut] $ associated with time delays; extra planning scrutiny & approval effort & regulatory & institutional barriers & complexity [D] Vulnerable to misuse/ shock loads; poor performance due to skills shortage; poor capital/operating tradeoff decisions [O][U] Duplication; inefficient treatment; redundant capacity [O][U][Com] Emergency failure provisions/ Provider of last resort [Ut][Com]

	Benefits	Costs	Risks
Environmental	Reduced discharges and extractions from environment nutrient recovery; water quality improvement; groundwater recharge; organic chemical breakdown [Com] Reduced heat islands, reduced soil erosion & air quality benefits from green open space; [Com] Treatment targeted for source and end use; incorporation of WSUD; potential for stormwater integration [Com]	Energy consumption; reduced water return to the environment [Com]	Reduced crop yields [U], reduced soil health [U][Com], water quality reductions from salinity, nutrients and other concentrated pollutants; [Com] Poor allocation of resources due to duplication [Com]
Social	Customer choice; new or different services; different levels of service available [U] heath & social benefits from green open space; contribution to liveable cities [Com] Public & industry education; private sector opportunities; equity with impacts being closer to users [Com]	Aesthetic impacts [Com]	Human health; poor public perception [U] Costs & consequences of failure can have greater impact on small group [U][O];

Key: [C] – customers of local recycled water system; [U] – user of local recycled water system; [Ut] – centralized urban utility; [D] – developer of local recycled water system; [O] – owner of local recycled water system; [Com] – wider community

In Sydney, the economic regulator (IPART) developed and now must manage an entirely new regulatory regime to accommodate private entry into the water market. While this one-off cost and effort may be minor in the long term, and it may be outweighed by the overall benefits of effective competition, it is a substantial burden for the regulator in the short to medium term. For example, in NSW the Water Industry Competition Act 2006 has already undergone two lengthy reviews, the mandate (particularly who is covered by the act) has changed twice, and a workable retailer and supplier of last resort regime has only just been established.

Public health regulators go from managing one large, generally public utility, to managing many small, possibly unknown and unproven entities. The public health regulator gets limited benefit from the reduced risk of a major failure or contamination event, but they get greatly increased risk from multiple smaller providers. The change in risk profile for health regulators is a major concern, particularly when coupled with the past historical failures of small systems and the proven health benefits of centralized systems (see for example the discussion in NSW Government (2012) on the increased challenges in protecting public health with increased use of small scale, integrated privately provided solutions). Even if public health risk has a minor influence in the overall sustainability assessment, it is very important for the health regulator and has a major influence on their perception of the value and sustainability of local recycled water systems, especially those operated by lesser known entities.

From a public utility's perspective, private local recycled water systems may result in extra responsibilities. Examples include: calculating avoided costs, managing system interfaces, being nominated as retailer or supplier of last resort and potentially dealing with customers who are confused as to who their service provider is for recycled water. The utility may also lose revenue, and there may be pressure to develop a different price structure for systems that have reduced demand, even if there is no change to the utility's costs. For example, in Sydney an independent review of pricing was conducted following concerns of revenue loss by the public utility, with a perception that private utilities may focus on projects in low cost areas, leaving a smaller customer base to cross-subsidize the more expensive parts of the system (NSW Independent Pricing and Regulatory Tribunal 2015a, 2015b; Sydney Water 2015). The utility does potentially receive benefits in terms of reliability, resilience and avoided costs, but these benefits are currently poorly understood, and there is no consistent and agreed way to calculate their value (Watson, Mitchell, C & Fane 2013).

In some circumstances there may be a 'green' market for a recycled water system, or recycled water may be included as part of a greater green building package (Chanan and Ghetti 2006, Green Building Council of Australia 2010, Hurlimann and McKay 2007). However, the difficulties and costs associated with managing and maintaining a recycled water system may still result in the system being poorly managed or switched off. There is a particular risk of a capital/ operating cost imbalance if there is a weak link between construction responsibility and operating responsibility. This risk was identified by Pinkham et al. (2004) in their assessment of decentralized wastewater risks. Anecdotal evidence from the green building industry in Australia also suggests this is a risk, particularly where the focus is on design and construction, and not long term performance.

The balance between positive and negative impacts for any group involved in decision-making is critical to the viability of the scheme. Any group involved in the decision-making at a planning or operational stage is likely to make decisions to minimise the negative impacts and risks it is exposed to, and maximize the positive impacts. For example, a sustainability assessment from a whole-of-society perspective may suggest that local recycled water is a sustainable solution for a particular development (as was the case in Liang and van Dijk (2010)). However, the more tangible and direct costs and the risk and responsibility burden may shift from a broad and general distribution for centralized systems (the whole of society) to a much smaller group. This may be seen as a fair and equitable means of shifting the cost burden of growth and development to the beneficiaries (the developers or the owners) (Pinkham et al. 2004). However, if this results in systems being mandatory and there is no mechanism for transferring the value of the less tangible and less direct benefits that accrue to society, the systems may struggle to be financially feasible/ viable, causing them to be poorly operated or switched off (Chen and Wang 2009; Liang and van Dijk 2010).

These examples demonstrate that the decision-maker’s perception of the balance of costs, benefits and risks is a critical factor in whether the system will be installed and/or efficiently and effectively operated. However, it is not just a question of control over the decision in relation to costs and benefits; it is also a question of when a particular group has the opportunity to understand the costs and benefits, and when they are able to make decisions. These individual decision points are separate and distinct from the assessment of the sustainability of the system from a whole-of-society perspective.

As Pinkham identified, part of a decision-maker's perception will be based on whether the risks are controllable (i.e. the particular group has the opportunity to manage the risks) or uncontrollable (i.e. the group has no ability to manage the risk) (Pinkham et al. 2004). For example, private local recycled water systems can provide resilience and reliability benefits to the centralized system (Institute for Sustainable Futures 2011). However, depending on the regulatory and planning framework, utilities may see this as a high-risk way of obtaining reliability and resilience benefits. The utility may have no or limited influence over ongoing decisions regarding operation, capacity and management of the small systems. From a utility's perspective, it may be able to obtain many of the benefits private local recycled water systems provide (resilience, reliability, and avoided costs) through its own planning processes and it may be able to reliably recover the additional costs through postage stamp prices.

The shifting of the burden of risk can also affect decisions about whether to proceed. If a developer is installing traditional infrastructure, the risk of delays during the planning approval phase is minimal. However, non-traditional infrastructure such as local recycled water systems can have a very long and complex approval period that may result in delays, which is a significant direct upfront cost to the developer (NSW Government 2013). The difference in risk profile is critical to the developer's decision about whether to install a local recycled water system. Although the delays may be minor in the life of the infrastructure as a whole, they are significant to the developer's timeframe.

9.4.3 The timing of positive impacts in relation to negative impacts will influence decisions

Who receives the costs and benefits, and when and how that value is recognized, is an important factor in determining the overall success of a scheme. The timing of the costs, particularly when the costs are realized in relation to the benefits, will also influence the decision about whether to invest in local recycled water. In NSW, there is a requirement for new housing to meet BASIX requirements. BASIX requires new homes to be 40% more energy and water efficient than an average home (NSW Government No Date). If recycled water is used to meet these requirements in a new development, the developer may be required to pay developer charges to the supplier upfront before the lots are sold. If a rainwater tank and efficient appliances are used to meet the requirements, the cost is covered by the property purchaser when building the home. In contrast, in the middle of a drought when a golf course is rapidly losing members, investing in a recycled water system immediately provides water that improves course conditions critical to ongoing business viability (WERF 2006).

For local recycled water systems, most of the major economic costs and risks, such as the capital, the regulatory burden, and the planning risk, occur before opportunities to collect revenue. Some of the economic and social benefits, such as planning concessions, capital savings and increased service choice will also occur before or just after operation commences. However many of the economic benefits cannot occur until the scheme is operating. Furthermore, some economic benefits are entirely contingent on other external and regulatory factors, and their realization is unpredictable. For example, centralized resilience and reliability and the benefits of delayed centralized infrastructure augmentation are both difficult to measure and the benefits are only realized at some point in the future, depending on other factors such as environmental stresses on existing supplies and overall demand growth. In addition many social and environmental benefits can only occur in the future, and are difficult to measure and directly attribute to the local recycled water system. These benefits include public and industry education, water quality improvements, heat island reductions, values associated with healthy green space and improved playing field conditions.

9.4.4 Global averages used for centralized planning have very little meaning at a small local scale, limiting benefit transfer

In many planning and assessment processes for water and wastewater services, multiple small local options are amalgamated to allow them to be compared to a single large centralized option. The amalgamation process can overlook many of the key localized benefits or make them difficult to identify using averages. For example, flexibility is a key benefit of decentralized systems (Pinkham et al., 2004). Flexibility is not just about 'just in time' investment; it is also about improved matching of technology choices with treatment levels, discharge, end use or waste contamination levels. Using small systems allows the best technology and option to be used at each location at different times. This can allow the inclusion of integrated solutions, recycled water of different standards, and different sources where appropriate. However, using a generic option to describe, cost and score a non-uniform and adaptable option often results in flexibility benefits being overlooked (Watson et al. 2012). For example, in the City of Sydney strategic servicing strategy, developed by Sydney Water and government stakeholders, the 'decentralized' options were not specific about whether they included stormwater reuse, rainwater tanks, sewer mining or only in-building blackwater recycling. Each of these kinds of options has different benefits and limitations, and these differ further according to the context (scale and timing) of each option.

Although it is acknowledged that local recycled water systems can help existing centralized systems manage the impacts of growth and reduce public expenditure on centralized augmentations, quantifying this benefit is not a simple process. How benefit transfer is managed depends on the actual benefit and perceptions of why the scheme is being installed and who should contribute, as demonstrated in the following three very different examples. In some areas where the centralized system is severely constrained, installing local recycled water systems for new development is mandatory, and receives no public funding. For example in Beijing, China, building developers and building owners fund the full costs as a reflection of their benefiting from the development going ahead (Liang and van Dijk 2010). In New York State, USA where installing local recycled water systems is voluntary, an ongoing 25% discount is given off water and wastewater bills as a reflection of avoided costs to the centralized network, both in operating costs and future capital expenditure (Etnier et al. 2007b, Zavoda 2005). In Sydney, Australia, where the installation of local recycled water systems is also voluntary, two different approaches have been used. When Sydney was subject to a severe drought and the government wanted to encourage recycling and private investment to improve supply reliability, one-off grants were provided (for example through the NSW Government's Water and Energy Savings Fund). However, once large capital investments were made to secure water supply for Sydney in the medium term and the drought broke, the government subsidies and grants ceased. Calculations for the funding of small systems in Sydney are now based on the avoided costs they can provide for the centralized system (if any) less the customers' willingness to pay (NSW Independent Pricing and Regulatory Tribunal 2011).

The scale difference between local systems and large centralized infrastructure can be a significant factor when calculating the potential costs local systems avoid in the centralised network. It is difficult to calculate the value of avoided costs for small increments of demand in relation to infrastructure with very large capacity. This is particularly true for water, since once a lumpy investment has been made, it is usually viewed as a 'sunk' or unavoidable cost in the context of cost-benefit analysis (Commonwealth of Australia 2006). This means once a decision to augment infrastructure is made, there is little opportunity over the short to medium term for decentralized investments to 'avoid' costs. Also, networks can account for up to 80 per cent of total system capital costs and wastewater capital costs are often based on factors that are unlikely to be reduced with individual local schemes (Water Services Association of Australia 2007). For example, the Malabar sewage treatment plant treats about 500ML/d (average dry weather flow), the Sydney desalination plant at Kurnell can produce 250ML/d. In comparison local recycled water plants are usually much smaller, for example the Pennant Hills Golf Course system treats 0.65ML/d, and Pitt Town and Discovery Point treat 0.3ML/d each. The very large flows in the large centralized systems make it difficult for any one local recycled water scheme to create enough of a difference to qualify for avoided costs. However, as has been shown in projects such as the City of Sydney Master Plan (Healey et al. 2012) or in Melbourne (Mukheibir & Mitchell, C 2014), the cumulative impact of many discrete local recycled water projects can have a significant impact on future centralized infrastructure planning. In Melbourne, a policy of investing in small scale recycled water infrastructure as opportunities became available has potential savings in the order of billions of dollars over a 50-year time horizon in comparison to an approach that focuses only on extending supply through increasing desalination (Mukheibir, Boyle & Mitchell, C 2013).

9.5 Conclusion

This paper makes three clear and distinct contributions to knowledge in this sector. Firstly, it demonstrates that the distribution, timing and certainty of impacts for local recycled water schemes can vary significantly from the impacts of the more traditional centralized water and wastewater infrastructure options. Secondly, it demonstrates that these variations will have a major impact on whether a decision is made to invest in local recycled water systems and the way those investments are made (particularly who funds the investment and the capital and operating trade-offs). Thirdly, it proposes that the conventional categories for sustainability assessment be extended to include the recipients of the impacts and the timing of the impacts.

The implications of these findings are significant. While traditional sustainability assessment can make the general case for recycled water systems, further analysis is needed. The further analysis needs to explicitly recognize the effect of the redistribution of impacts on a range of parties.

While the traditional characterization of social, environmental, economic and (at times) technical impacts is systematic, intuitive and fits well within established frameworks, it is limited, particularly for the assessment of small private systems in relation to large public ones. The clear articulation and consideration of the distribution of local recycled water impacts is critical to a fair and robust comparison between developing local recycled water schemes and expanding or augmenting an existing centralized system. Clearly identifying the differences in the distribution of impacts of centralized systems and local systems can also help to explain different perceptions within the community around the significance of particular impacts and associated risks.

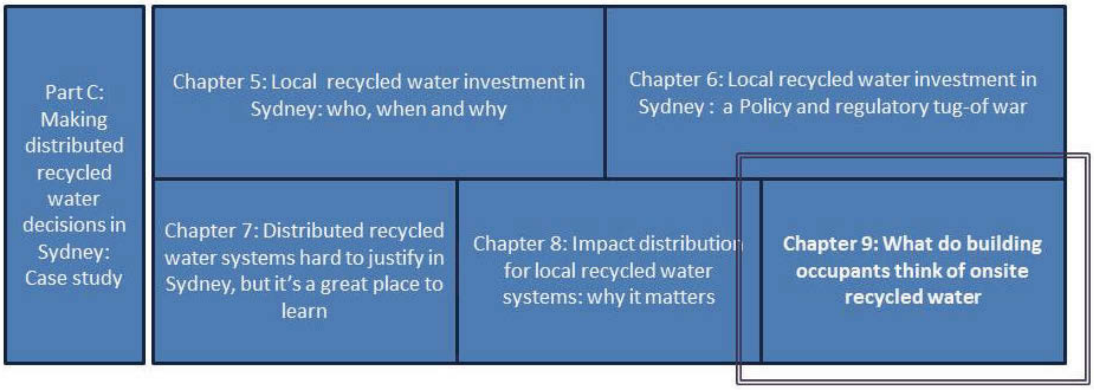
The categories of developer, owner, user, utility, regulator, environment and wider community directly reflect the way impacts are distributed. By examining the range, magnitude and timing of impacts via their distribution, a better understanding of the importance of the distribution of impacts on decisions about whether to use and invest in this type of infrastructure can be gained.

The issue of impact timing, particularly costs in relation to benefits, is also key for some parties. The timing and relative certainty of the costs in relation to benefits can directly influence decisions about whether to invest in local recycled water. Because of the much larger number of parties involved at different stages of the decision-making process for local recycled water, compared to centralized systems, the decision-making time horizon for many parties is often quite different to the 'whole-of-society' long term view.

The point of considering the timing of impacts and their relative distribution is to help to identify whether there are currently costs or benefits which are being unfairly apportioned, and whether there is a case for developing mechanisms to redistribute the impacts. Identifying the significance, scale and timing of impact distribution of different options is an important precursor to investigating how or when transfer payment mechanisms may be appropriate, either to assist the industry in the initial stages or to more fairly distribute impacts in the longer term. The significance and influence of the changes in impact distribution between centralized and local systems should also be considered when making decisions about regulatory frameworks and changes to other government policy positions.

Chapter 10 What do building occupants think of onsite recycled water

Watson, R. (2014). What do building occupants think of onsite recycled water? Small Water and Wastewater Systems Conference. AWA. Newcastle, Australia.



This chapter consists of the paper 'What do building occupants think of onsite recycled water', presented in 2014 at the Small Water and Wastewater Systems Conference in Newcastle. This paper covers all of the research questions from a very limited perspective; that of users of local recycled water in a commercial 'Green Star' building.

Highlights:

- The study gauges customer perceptions to in-building recycled water use, with generally positive responses.
- The study compares perceptions of in-building recycled water to other green building features, with recycled water rating favourably.
- The study found a high awareness of recycled water use in toilets but low awareness for other uses.

10.1 Introduction

The number of recycled water plants in the basements of commercial buildings has increased in recent years, as a way to gain the extra points needed to achieve prestige building ratings. A great deal of research has attempted to gauge customer perceptions to recycled water use in general. However, this research is usually done before recycled water is in use. There is currently very little data on customer perceptions post occupation, particularly for commercial buildings with in-building recycled water in Australia.

This paper reviews the findings of an internet based survey that examined building occupants' awareness and safety perceptions of recycled water. The survey also sought to gauge what the occupants' reactions to the recycled water plant generally and how the plant compared to other green building features.

10.1.1 Why ask building occupants about recycled water?

With the increase in numbers of green buildings there has also been a growing body of research associated with the value of green buildings. The added value of a green building can include (Blackburn 2009, pp. 116-21; Coyne 2009):

- developers and building owners using green branding to secure finance, attract quality clients and tenants (long term, high profile, and secure payers)
- building owners and tenants reducing water and energy bills
- tenants using green branding as a positioning and marketing tool, attracting better staff and increased staff productivity
- the community benefiting from social improvement, and wider portions of the community being exposed to the benefits of sustainable buildings and products such as recycled water.

However, except for the water savings (which are also in part due to the water efficient fixtures in the building), it is very difficult to determine what role recycled water plays in the overall green building package. This survey tried to determine how occupants rated recycled water in relation to other green building features.

Research on recycled water shows there is a general acceptance for non-potable purposes, although much of this research is done before the recycled water is adopted (see for example (Dolnicar & Schäfer 2009)). The few examples of post adoption research include; Sydney Water has conducted research into customers' responses to recycled water at Rouse Hill, New South Wales (New South Wales Government 2006, p. 36) and Mawson Lakes, South Australia (Hurlimann & McKay 2007). Marsden Jacobs has recently conducted hedonic pricing to gauge the value recycled water adds to housing in Rouse Hill (Marsden Jacob Associates 2014a). However, there is very little research in the reaction of recycled water users in commercial buildings where they (most likely) have different services at home. The survey discussed in this paper provides some insight into the users' perceptions as to quality and safety of the recycled water product, and gives some qualitative assessment of the value they place on recycled water as a product.

10.2 Method

10.2.1 How was the survey designed?

An internet based survey was constructed in the web based program SurveyMonkey©. The survey was designed to identify responses to four key areas:

1. Motivation – for the organization rent a green building with recycled water and to use recycled water, for staff to want to work in a green building with recycled water.
2. Awareness – of recycled water within the building and its uses.
3. Risk perception/ trust – whether they think the recycled water is safe, whether they think the recycled water affects the safety of the potable water system, general concerns.
4. Value/cost – value of the recycled water in relation to other green building initiatives, the value in relation to cost and price of water, the value to the employees in terms motivation/pride.

The survey was designed to be time efficient, taking most respondents less than ten minutes. The survey consisted of 17 questions with some skip logic (see Appendix D for full list of questions). Five of these questions were demographic, asking whether people actually worked in the building, the part of the company they worked in, their age and their sex. The majority of the questions were closed questions where participants selected from a range of options. There were five open ended questions, two of which were skipped depending on previous responses. The survey was anonymous.

10.2.2 Where was the survey conducted?

The survey was carried out for the building at 1 Smith Street, Parramatta, as part of a wider research project. This building was first occupied in early-mid 2009, having started design in 2007. The building was designed and built to achieve a 5 five star Green Star building rating, with maximum points for water consumption and a five star NABERs rating. As part of achieving the maximum points for water consumption an onsite blackwater treatment system was installed in the basement of the building. The treatment system recycles the building's wastewater, as well as rainwater from the onsite collection and storage system, and return water from the building's cooling towers. The system can produce up to 41,000 litres of recycled water per day to supply a range of non-potable uses including toilet-flushing, cooling and landscape irrigation. At the time of the survey, recycled water had been available in the building for about four years.

The building is a unique arrangement. Sydney Water owns the land and engaged Brookfield Multiplex to build, own and manage the building (and therefore operate the recycled water plant), leasing it back to Sydney Water on a long term lease. The green building design was an integral part of the tendering and contractual arrangements. Other green building features include:

- construction materials made from renewable sources and/ or containing recycled content
- solar heating panels that supplement hot water requirements
- chilled beam cooling instead of conventional air conditioning
- light sensors that turn off lights when a room or area is not being used

- high performance glass façade that controls the amount of heat entering the building
- water efficient showers, toilets and taps
- 100,000 litre rainwater tank.

The building has approximately 1,400 staff, the majority of whom are Sydney Water employees (with the exception of some contractors and hospitality workers). The survey results are strongly biased as all the respondents were working in the water industry. However, it is still an interesting case study as:

- it is one of the longest running in-building blackwater recycled water plants in a commercial building in Sydney
- it demonstrates how simple and easy it is to review occupants' general awareness perceptions and concerns with recycled water use and perceptions of the value of recycled water in relation to other green building features
- it clearly identified that despite some concerns the recycled water was perceived to be of value to both Sydney Water as a tool to demonstrate leadership and to the employees more generally
- it identified some simple communication measures that could assists with ongoing concerns and perceptions of trust.

The survey was distributed in May 2013 to all employees of Sydney Water through their local intranet site and their weekly newsletter. It was available for access for two weeks. As an incentive for completing the survey, participants could enter a draw for one of five double movie passes.

10.3 Results

10.3.1 Response rate

There was a reasonable response rate for the survey with 146 participants. Most (80 per cent) of these participants were based in the building on a regular basis. There was a broad coverage in terms of differing roles, age, gender and time in the building, and length of service with Sydney Water.

10.3.2 Motivation

The reasons for having a recycled water plant were well understood by respondents.

Question 6 asked respondents ‘Why do you think Sydney Water has a recycled water plant in the building’. Participants could select up to three of the ten answer choices (as shown in Figure 32).

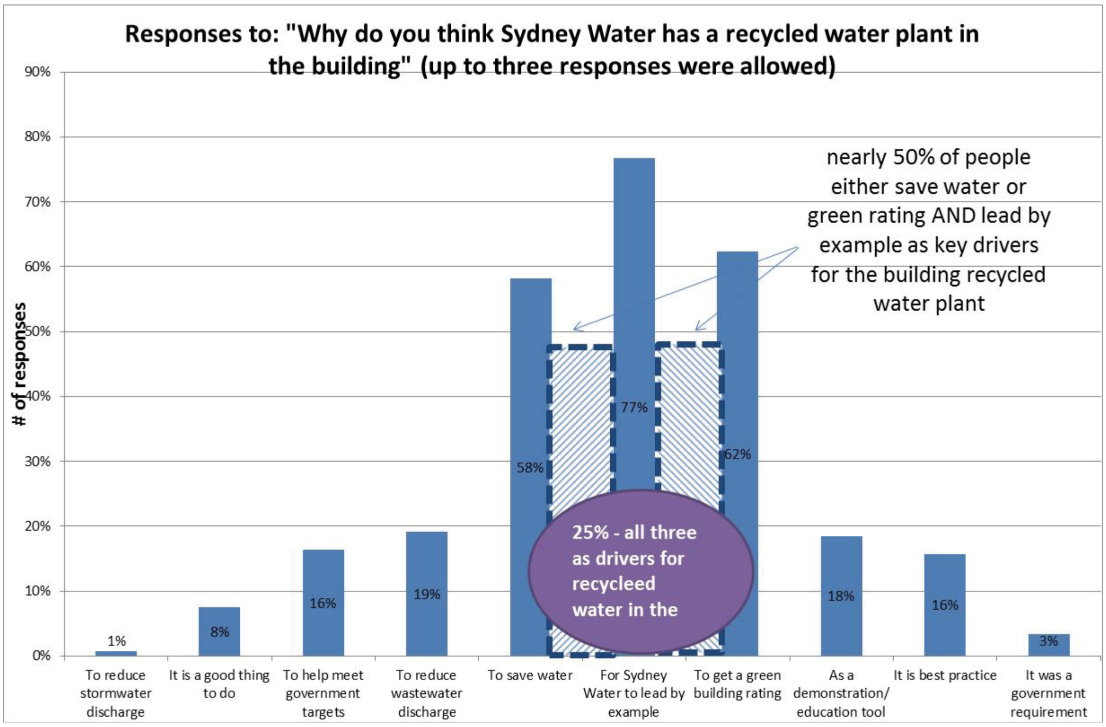


Figure 32: Responses to question 6: 'Why do you think Sydney Water has a recycled water plant in the building?'

Over 80 per cent of respondents thought that Sydney Water had a recycled water plant in its building to lead by example. The other most popular answers were to get a green building rating (66 per cent) and to save water (61 per cent). These three answers match well with the actual drivers for the recycled water plant. The building was planned, designed and built during the worst drought on record. Sydney was experiencing severe water restrictions, and Sydney Water’s pitch at the time was ‘every drop counts’. Sydney also had a recycled water target of 12 per cent, so there was an expectation that Sydney Water, as the water utility, would do its bit to save water and use recycled water (Green Building Council of Australia 2013a). There was also a clear corporate direction for the new building to achieve a 5 star green star rating and to achieve maximum water consumption points (Green Building Council of Australia 2013a).

However, by the time the building was occupied the decision to build the desalination plant had been made and by the time this survey was conducted the desalination plant had been built and water restrictions had been lifted. The survey was conducted in a period where the water crisis was over and the focus had returned to customer service, business excellence and forward thinking. Even in this context the majority of employees think that the plant is a positive initiative, both from a personal perspective and as a reflection of Sydney Water’s values (see Figure 33).

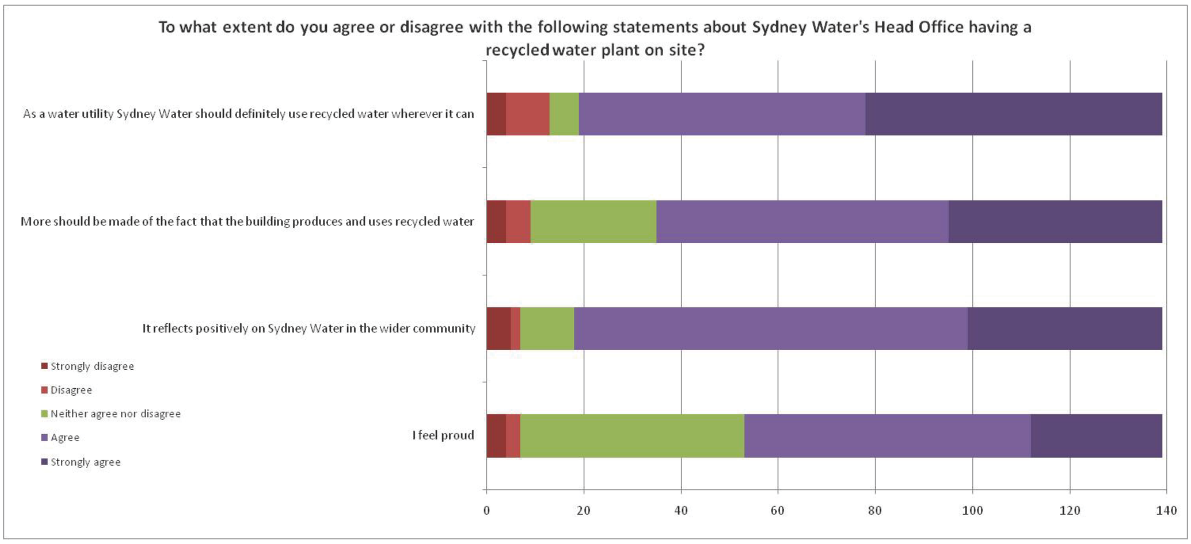


Figure 33: Feelings and attitudes towards recycled water in the building

10.3.3 Awareness

Nearly everyone knew there was a recycled water plant in the building and that recycled water was used in toilets. However, no one correctly identified all of the uses.

The first question of the survey asked whether respondents were aware (before taking the survey) that there was a recycled water plant in the building. Most people (nearly 90 per cent) knew that there was a recycled water plant in the building, and just over a third had toured the plant (question 3).

Question 4 asked respondents to describe the recycled water uses. This question was deliberately left open ended to reduce prompting. There were mixed responses in terms of knowing what the recycled water was used for. The range of terms used to describe the uses of recycled water are provided in Figure 34, and the identification of uses and the combination of uses are provided in Figure 35 and Figure 36.

Figure 34: Word cloud of responses to question 4:'what do you think the recycled water is used for?'

The recycled water is actually used for toilet flushing, the irrigation system, air-conditioning cooling towers and some taps, which are coloured lilac, although it was difficult to confirm where these taps are located. Over 95 per cent of people correctly identified that the recycled water is used for toilet flushing. However, less than 20 per cent knew it was also used for irrigation and cooling. None of the responses correctly identified all of the current uses. Some of the responses in the 'other' category showed there were some misperceptions about the uses, which in turn was linked with safety concerns. These incorrect uses included:

- Basins in the toilets (1)
- Floor cleaning (1)
- General cleaning (2)
- Not sure about the safety of using it in the fire hoses (1)

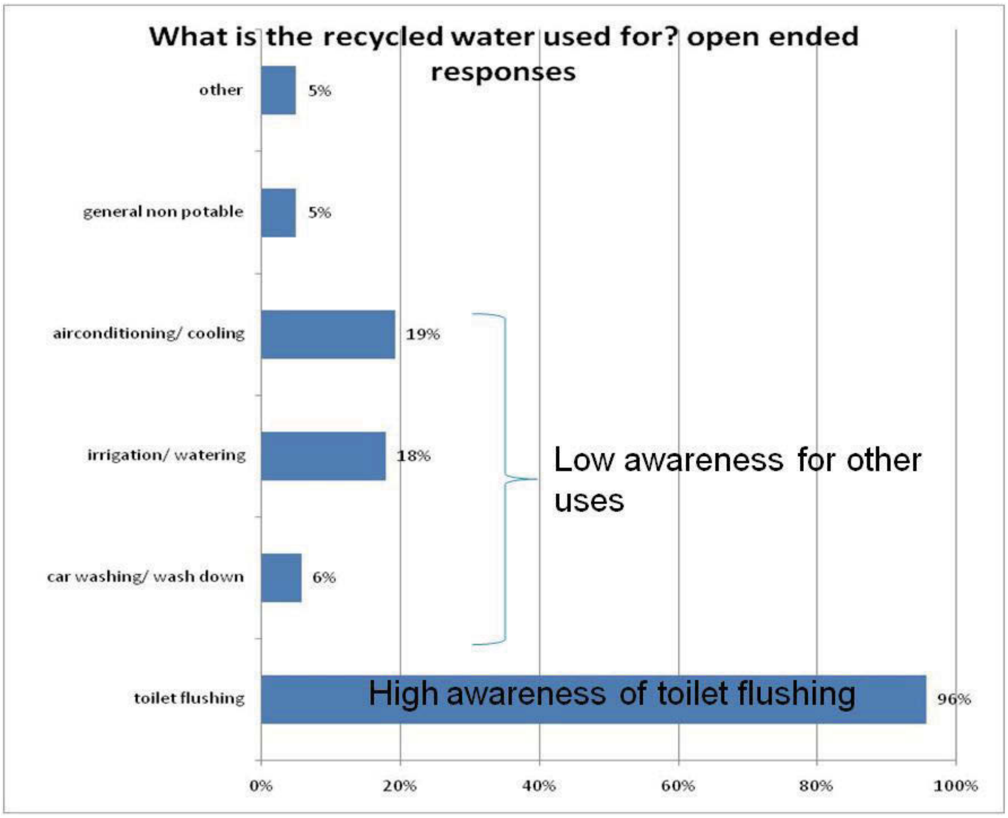


Figure 35: Categorised responses to question 4: 'what is the recycled water used for?'

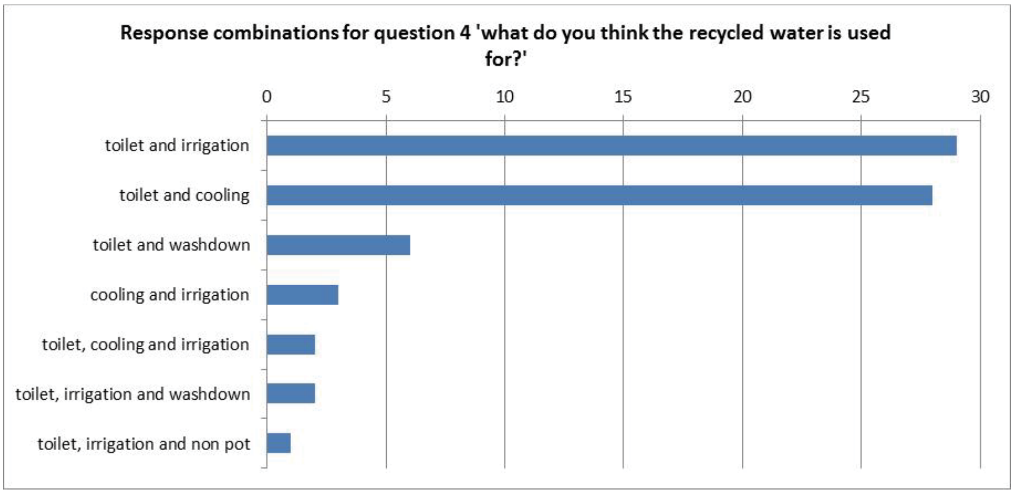


Figure 36: The combination of uses identified in response to question 4

While there was a high level of awareness of the plant, the majority of people (60 per cent) would like to know more about the plant (question 10). When specifically asked what they would like to know more about (question 11) there was a very wide range of responses. The greatest request was for general information on how the plant works (30) including how recycled water was distributed (2) and how recycled water was used (14). Nearly 20% of people specifically requested a tour to help them understand what happens in the plant. The numerous requests for more detailed technical information (14) perhaps reflect the engineering base and specific interests of Sydney Water employees.

Other information specifically requested included:

- Cost information (19)

- Environmental data, including energy use (7), potable water saved (9), recycled water use (10) and life cycle analysis (3)

- Operating performance, (14) including safety/ emergency procedures (5), maintenance (4) how issues have/ are dealt with (including colour and odour) (9)

- Information about other green building features (2)

Clearer signs, offers of a short tour and information fact sheets showing simplified treatment process and flow through the building would potentially satisfy many of these requests. These simple measures could improve general knowledge about the plant and recycling in general and increase confidence in the recycled water system overall.

10.3.4 Risk perceptions/ trust

Most people saw the recycled water as safe and had confidence of the integrity of the entire system.

The survey explored participant's feelings and attitudes towards the recycled water system. This included the safety of the recycled water itself and whether they thought the recycled water system affected the safety of the potable water system. Most participants were confident about the safety of the recycled water (Figure 37). About 10 per cent (15 people) stated they were worried about the safety of the recycled water. Even fewer people were worried about the safety of the water system being compromised by the recycled water system (around 8 responses).

About half of the small group that were concerned with the recycled water being unsafe or affecting integrity of the water system still believed that the recycled water system was impressive and that the recycled water plant reflected positively on Sydney Water in the wider community. This group highlighted concerns about safety particularly the risk of cross connections, colour and odour and the quality of the recycled water plant. Most had not been on a tour and several specifically requested either a tour or access to further information. These respondents were more likely to ask for information about uses, how the recycled water was delivered in the building and worry about cross connections. Even some respondents that didn't state they were concerned about the safety of the recycled water or the water system in general raised concerns in other areas of the survey. For example, one respondent asked why there were filters on the drinking fountains. There may be an opportunity for reinforcing the key messages about quality, safety and uses of recycled water in the building.

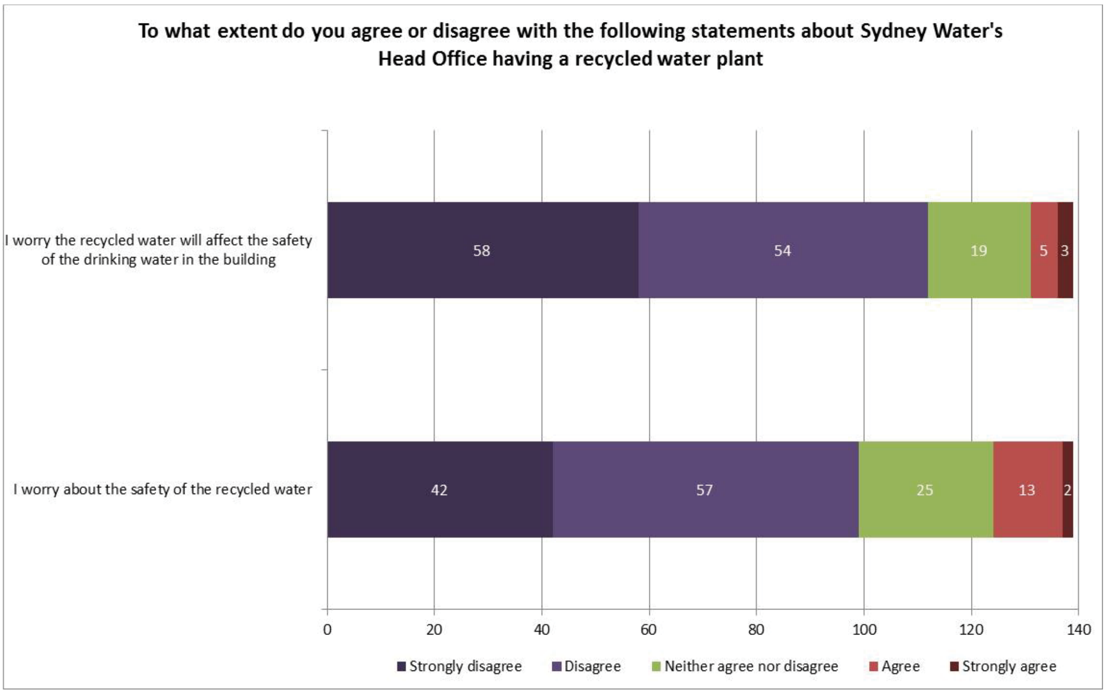


Figure 37: Responses to question 7 – Feelings and attitudes towards the safety of recycled water and water in general.

Value

The recycled water ranked highly in relation to other green building features although it did tend to divide opinion. There was a very strong belief that it was critical for Sydney Water to lead by example and demonstrate the safety and value of recycled water. There was a very strong indication that working in a building with recycled water made people feel proud. There were many questions in relation to its cost efficiency and environmental value.

The building has delivered on many benefits identified in the green building literature. The green building rating was critical in attracting a long term high value client (Sydney Water). Monitoring has shown that the building uses 60 per cent less water than a comparable building (Green Building Council of Australia 2013a). Staff satisfaction studies also show staff are happier in the new building and consultants have estimated this translating into approximately three per cent productivity increases (Green Building Council of Australia 2013a).

In terms of overall green building features, they all ranked fairly highly in terms of being impressive (Figure 38). The recycled water plant had the most diversity in responses. While having the most responses for the extremely impressive feature (55/142) it also had the most responses for very unimpressive, even though this was a small number (9/142).

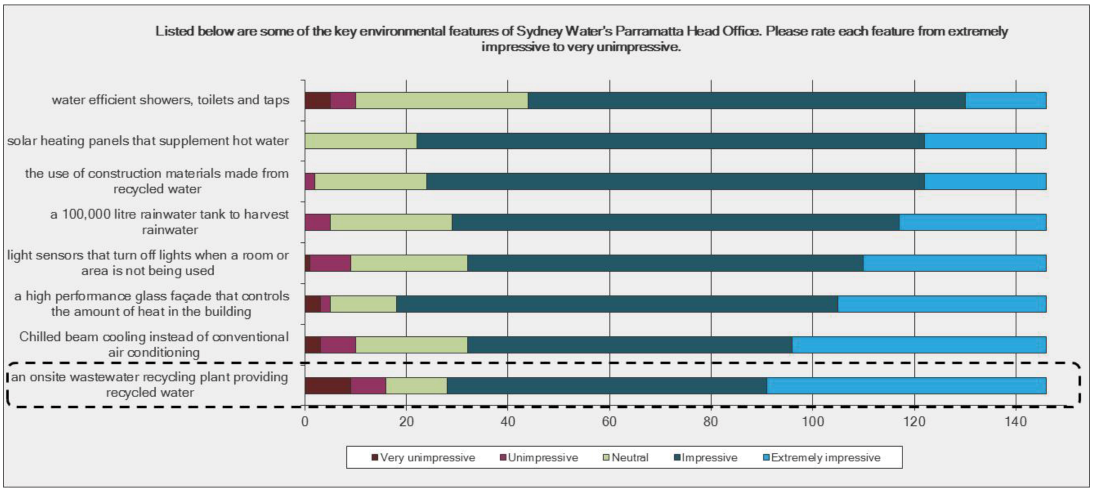


Figure 38: How does recycled water relate to other green building features

Over 60 per cent of the survey respondents indicated that having a recycled water plant on-site made them feel proud individually (see Figure 33). In conjunction with many participants viewing the recycled water plant as an impressive part of the green building package, this suggests that the recycled water plant contributes in some way to the overall green building value for employees and employers (namely employee satisfaction and associated productivity increases). However, there was an even stronger feeling that the plant was critical to Sydney Water's image in the wider community. Respondents felt Sydney Water needed to lead by example and recycle water wherever possible. They see the plant as demonstrating Sydney Water is willing to lead by example and believe more should be made of the fact Sydney Water has a recycled water plant in its building.

In this survey we also asked how respondents would describe the plant to a friend. This question was placed after the awareness and use questions and before any questions on issues, values or perceptions. The placement attempted to avoid prompting of thoughts from the other questions (on cost, risk, safety etc.). There were a small number of responses that didn't really answer the question but overall this question gave an informative unprompted insight into views on the plant.

- Nearly half the responses were very positive (43%). This group including comments about water savings (16%), leading by example (13%) and green credentials (10%). For example, 'must be promoted across the world so people understand how precious water is', 'should be in all buildings', and 'way of the future'. There were also some comments that were positive but slightly misguided. For example: 'Sydney Water has a high energy rating and the recycled water plant is one of the main features', 'saves water and money' and 'it's modern and energy efficient'.
- A further 15% of comments suggested that the plant was good but there are some issues, for example 'it saves water but there are odour issues'.
- 13% of the comments were neutral and informative, for example 'recycled water is ok', 'the toilets use recycled water made in the building'
- 5% of the responses questioned the value of the plant. For example 'don't know..it saves water, but I think it will cost more, so I am not sure if it is win win'
- 18% of the responses were quite strongly negative. These included some extreme responses such as 'it makes me sick I wish we didn't have it' and 'highly inefficient way to make water'.

Overall the responses were generally positive or at least informative, and reinforced the perception of plant providing value through leading by example, delivering water savings and contributing towards green credentials.

The negative responses were more diverse. It was suggested that odour, noise, environmental impact and cost concerns negatively impacted the value of the plant.

There was also concern the plant could have a negative impact on Sydney Water's reputation. If the plant was not providing value for money and good environmental outcomes, it could be seen that Sydney Water was promoting inefficient options. In addition, visitors to the Sydney Water building would not be aware that Sydney Water did not operate the plant. There was some concern that odour, colour and other performance issues could undermine customer confidence in Sydney Water's ability to provide safe and efficient water services.

The majority of responses indicated the plant provided value as an educational tool and to demonstrating Sydney Water's leadership and forward thinking. The plant also provides many individuals with a sense of pride, which could contribute to their overall satisfaction of working in the building and for Sydney Water as an employee. This value is not universal. A small group (about 5%) indicated they were not proud of the plant. Most of these responses also had concerns about safety and odour. This group also rated the recycled water plant poorly in relation to other green building features. Although this is only a small group, it does show that operational and environmental performance, specifically odour, safety and cost, can have a significant bearing on the perceptions of value.

10.4 Conclusion

The survey findings are limited as they only cover one building and the occupants all worked in the water industry. However, it did show that for this building there was a high awareness of recycled water, particularly for toilet flushing, but limited awareness of the other uses. Even though there had been initial problems with the operation of the plant causing odours, the majority of survey respondents believe that the plant is a positive initiative, both from a personal perspective and as a reflection of the company's values.

The responses indicate that the implementation of a series of simple measures would raise awareness of the uses of the recycled water and help to address a number of key concerns. For example, clearer signs, offers of a short tour and information fact sheets with simplified treatment and distribution process.

This survey is easily reproducible and could quickly give other building owners operating recycled water systems an insight into perceptions of recycled water in relation to other green building features and occupants’ awareness perceptions and concerns with recycled water use.

Chapter 11 Conclusions

Part D: Conclusions	Chapter 10: Conclusions

The research in this thesis has investigated the full range of impacts (benefits, disbenefits and risks) of local recycled water systems, the role these systems have in urban water servicing and the role they could have in sustainable urban water servicing into the future. It is anticipated that this research will assist practitioners in the field to make better-informed investment decisions.

This research also identified the conditions that drive (and limit) recycled water investment, thereby providing a useful starting point to determine whether the policy, regulatory and institutional settings are driving the desired short and long term outcomes. The analysis provides some useful insights for local recycled water investment in Sydney, and it also reveals the critical influence generally of these interactions in shaping who invests, the type of investment (end use, source, treatment) and the timing of investments. This research provides guidance to assist policy makers and regulators to develop strategies to revise existing institutional structures to address unintended consequences, and encourage investment that will support a resilient and adaptable water industry into the future.

This research has been conducted in two distinct but interconnected parts. The first part identified the full range of costs and benefits of local recycled water systems. The second part used Sydney as a case study to investigate decisions to invest in local recycled water. By using a comprehensive catalogue of investment in a single location, namely Greater Sydney, the research identifies key trends and unravels the complex interactions between environmental conditions and the social, political, regulatory and institutional contexts. These interactions shed some light on the very different types and timing of the local recycled water investments made by different groups. Focusing on a single jurisdiction, rather than on a set of distinct case studies, revealed how changes in environmental conditions, social perceptions and regulatory and institutional arrangements over time impact on both the types of investments that are made and how the projects are later evaluated. This section highlights the key conclusions of this thesis and provides recommendations for future work. Finally, it documents the specific contributions to knowledge made by this thesis.

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11.1 Local recycled water's role in sustainable urban water services – conclusions and recommendations

This thesis has demonstrated local recycled water has the potential to provide effective and efficient solutions to many of the key issues facing the water industry. The capacity of distributed systems to provide efficient servicing at the urban fringes, and in constrained areas, its potential to increase the resilience of the centralised system and provide customers with differentiated services is well recognised in the literature. This thesis has also revealed private investment in this sector has the potential to enable competition in a monopoly industry, foster innovation and decrease the public funds required for infrastructure augmentation. In the current setting in Sydney, both public and private investment is occurring. Yet the ongoing role of these systems and their long term value at both a site level and as a long term strategy to extend the value of existing centralised infrastructure, is still disputed.

This thesis concludes that uncertainty around the efficiency and effectiveness of local recycled water continues because agreeing on the value of local recycled water is often challenging. Many of the impacts identified in this thesis either rely on expensive evaluation techniques, are site specific and difficult to transfer between sites, are difficult to identify, are part of a broader benefit of which recycled water is only a small component, vary depending on how the centralised system is managed or environmental conditions, or some combination of the above. Even when impacts are easy to identify and measure (for example capital and operating costs), there is limited verifiable data available. The challenges in measuring and including impacts in assessment processes are compounded by their flexibility, making it difficult to compare costs and benefits between systems.

This thesis has identified areas where the industry would benefit greatly from better data (specifically actual capital and operating costs of local recycled water systems, public health and social benefits) and better evaluation techniques (specifically how to measure and evaluate resilience, reliability, flexibility and adaptability). In particular, evaluating developing local recycled water systems as a broader strategy to augment the existing centralised system will remain challenging until flexibility and adaptability can be accounted for in a fair and robust manner. It is recommended that further work be undertaken to identifying simple, practical and broadly accepted methods to include the full range of impacts in decision-making processes. It is also recommended that the concept of resilience and security criteria is re-examined in the context of a mixed supply sources and adaptive planning.

This thesis has demonstrated recycled water was able to provide a rapid response to drought driven supply shortages. This substantial and rapid contribution to the supply demand balance would not have been possible without the groundwork of steady, regulatory driven investment in the preceding years. The investment in recycled water prior to the drought period provided the technical, social and regulatory foundations fundamental to supporting increased recycled water investment. Undertaking the important is therefore critical to being able to respond to the urgent.

In Sydney, local recycled water systems as a differentiated product have been emerging due to strong environmental and social drivers, despite the sometimes complex and conflicting regulatory environment. However, this thesis has concluded that the ability to deliver truly integrated services continues to be challenging, due to the siloed nature of the regulatory and institutional arrangements. Rather than creating new institutional arrangements it is recommended that the industry work to provide linkages and forums that promote collaboration and cooperation between public agencies, the community and the private sector.

As illustrated in Figure 7, the use of the IAD framework this thesis has further demonstrated that identifying, valuing and including impacts in the decision-making process is only one piece of the puzzle when it comes to understanding what investment has occurred and predicting what investment may occur in the future. Through the use of Sydney as a case study, this thesis has shown that the interactions between three factors are a complex but critical component of explaining what investment occurs, and therefore what role local recycled water systems (or any alternative) can have in urban water servicing. These factors are: the impacts of the system; the environmental, social, regulatory and institutional setting; and who is making decisions. It is recommended therefore that policy makers clearly identify and consider this complex interplay to determine whether current policies and regulatory and institutional settings are appropriately designed to drive investment that meets the broad objectives of the water industry for the future. More specifically for Sydney it is recommended that a broad review of the urban water industry arrangements and the role and regulation of recycled water be conducted.

Within the Sydney region, local recycled water has emerged as an effective site-specific solution in a broad variety of circumstances. However, under the current conditions (including regulatory and institutional arrangements) this thesis concludes that local recycled water will most likely remain a limited, boutique and fringe solution, responding to sites' or users' specific requirements, similar to the investments that have been identified throughout this thesis.

For local recycled water to become a more mainstream strategy for addressing the challenges faced by the urban water sector, a number of changes are likely to be required. It is recommended that a clear regulatory definition of the role and objective of the urban water industry be developed, including the role that different participants can play in achieving those objectives. A subsequent step would be to garner broad agreement on how local recycled water contributes to these objectives. However, as has been shown in Sydney, acknowledging the benefits and calculating their value does not ensure the benefits widespread inclusion in regulatory processes (see for example the discussion in section 6.5.4).

To facilitate particularly private recycled water investment, this thesis recommends change in the regulatory pricing process is required; particularly clear and equitable price signals, and simple and predictable benefit transfer mechanisms are key areas for change. In addition, to assist with developing more robust signals for efficient investment, broader dissemination of the current capacity of centralised infrastructure and investment triggers is needed to provide an opportunity for the market to respond with solutions that benefit the private recycled water providers and their customers as well as the public utilities and their customers. Under current conditions there is very little data available that would signal to external investors where their investment would provide any benefit to centralised systems.

The focus of the current regulatory process in NSW on efficiencies over four-year periods for separate water, wastewater, stormwater and recycled water services, and the least cost ‘just in time’ delivery of significant infrastructure, may miss opportunities associated with integrated infrastructure. Certainly, the stark differentiation between revenue recovery rules for recycled water and those for other water and wastewater services is a significant barrier to recycled water investment. Comparisons with regulations in other jurisdictions are likely to provide further insights (e.g. the state of Victoria, Australia, is proposing one clear objective for pricing that maximises the long term best interests of the customer (Essential Services Commission 2016)).

Finally, and perhaps most importantly, there needs to be broad acknowledgement of the complexity of trade-offs between environmental conditions, community preferences, and institutional and regulatory settings. This explicit acknowledgement will facilitate a broader discussion on how to recognise and align these processes, and it is critical to ensuring local recycled water investment occurs in a manner which best supports the ongoing sustainability of the urban water industry.

11.2 Contributions to knowledge

***Paper I:* Wastewater systems: Decentralised or distributed? A review of terms used in the water industry (Appendix A)**

This paper makes two key contributions to knowledge:

- It reveals the key characteristics of decentralised water services.

- It defines the emerging field of local recycled water.

The paper makes these contributions by comparing and contrasting: definitions of decentralised water services from the literature, from different Australian and international regulatory environments, from Australian and international codes, and from water utilities themselves. It reveals that the range of definitions for decentralised systems is as wide as the systems themselves, and provides guidance as to why it is so difficult to make generalisations and comparisons in this area.

The paper identifies the key characteristics of decentralised wastewater systems and highlights the importance of authors clearly stating the parameters covered by their work, rather than assuming that a constant definition is understood.

Finally, the paper reflects upon emerging trends in terminology and definitions as decentralised systems are installed as complements or competitors to existing centralised networks. In doing so it defines the emergence of the term local recycled water systems, setting the scope for this research.

***Paper II*: How sustainability assessments using multi-criteria analysis can bias against small systems (Appendix B)**

This paper contributes to knowledge by revealing the potential biases in the 'Multi-criteria analysis' decision tool's process and application that could involve bias against local recycled water systems, in comparison to more traditional alternatives. It goes on to suggest ways to account for the bias. It will aid decision-makers to make fair and robust comparisons between smaller alternatives and larger centralised options.

***Paper III*: Review and synthesis of the diverse impacts of local recycled water systems (Chapter 4)**

This paper makes the following contributions to knowledge:

- defining the characteristics of local recycled water systems
- cataloguing the full range of impacts of local recycled water systems

- establishing how impacts can be measured and capturing examples of where they have been measured in the past
- revealing that many of the impacts are less familiar than those of more conventional options
- establishing that the impact distribution varies from more conventional options
- revealing many of the benefits are difficult to identify, hard to value or uncertain
- proposing that understanding the broader regulatory and environmental context is vital in determining the type and scale of impacts.

The paper develops a catalogue of the full range of impacts, and identifies where in the literature you can find research and data on similar impacts. This will enable practitioners, researchers and students to have a firm foundation for considering which impacts are relevant for particular situations and decision frameworks. In analysing and characterising the impacts, the paper reveals why assessments of local recycled water systems have been problematic to date, particularly when those assessments involve comparing them to centralised augmentations and extensions. When compared to more conventional options, the differences in the scale and distribution of impacts (as well as uncertainty regarding the measurement and timing of those impacts) make the inclusion of the full range of impacts challenging, contentious and potentially costly. By identifying how the impacts vary from those found in centralised schemes this paper not only helps to explain the lack of agreement on their long term sustainability and viability, but also identifies areas for future research.

***Paper IV:* Local recycled water decisions – ensuring continued private investment (Chapter 5)**

This paper contributes to knowledge by revealing regulatory, policy and institutional barriers for local recycled water investment. It differentiates between the factors that limit investment for the private sector and those that limit investment for the public sector. The paper proposes that for continued sustainable private investment in recycled water, it is important to ensure regulatory and institutional barriers are minimised and methods are developed to compensate private investors for the value they provide to existing centralised systems.

Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers, firstly to understand the scale of the impacts of recycled water schemes, and secondly to begin to develop strategies to address them, assuming there is a desire to support the private recycled water market in the long term.

***Paper V:* Local recycled water investment in Sydney: who, when and why (Chapter 6)**

This paper makes several specific contributions to knowledge as it:

- provides a comprehensive catalogue of recycled water investment in the Greater Sydney Region over time
- provides a multi-faceted analysis of the investment through scale, source, end use and ownership
- analyses the key trends for local recycled water investment
- reveals and explains the complex interactions between environmental conditions and the social, political and institutional contexts
- reveals how reveals how changes in environmental, social, political and institutional conditions over time impact on project successes and failures.

The analysis in this paper identifies key trends in investment and unravels the complex interactions between environmental conditions and the social, regulatory, political and institutional contexts in which that investment takes place. In doing so it provides important insights into what drove recycled water investment in the past and reveals the important role the wider context has in shaping the who, what, when and why of recycled water investment. It also provides a key starting point for designing and enabling new policy directions with better potential to deliver more resilient and liveable urban domains.

Paper VI: **Policy and regulatory tug-of-war: a case study of local recycled water in Sydney (Chapter 7)**

This paper makes a unique contribution to knowledge by:

- revealing the broad range of policy, institutional and regulatory arrangements that influence investment in and use of local recycled water
- highlighting the complexity driven by the breadth of drivers that influence water sector policy
- demonstrating how policy and regulation both promote and deter investment in local recycled water
- revealing the critical and surprisingly negative role the policy, institutional and regulatory environments have on local recycled water investment in Sydney.

This paper demonstrates that even with the best intentions, past, current and future policy, regulatory and institutional environments have a significant and unexpectedly negative impact on why, where and when investment occurs, and what that means for future investment. Identifying and exploring the oppositional nature of these levers better explains existing local recycled water investment. The generalisable insight which emerges from this paper is that a systematic, systemic, detailed review of these instruments and levers can reveal unexpected contradictions and provide a strong and defensible base from which to develop strategies to address unintended consequences and remove barriers to future investment.

Paper VII: **Local recycled water systems – hard to justify in Sydney, but it's a great place to learn (Chapter 8)**

This paper contributes to knowledge by:

- revealing historical, regulatory, policy and institutional arrangements that limit local recycled water investment
- exposing clear distinctions in the barriers, depending on the scheme size and investor type

- proposing that the same factors that limit opportunities for recycled water investment also provide a unique, low risk environment in which to learn about and test the value of these systems.

Despite a number of drivers that should make Sydney an opportune location for local recycled water uptake, this paper identifies a wide range of limiting factors. These factors are generally based in regulatory, policy or institutional arrangements. They include factors that influence the price differential between general water services and recycled water, factors that influence risk and uncertainty, and factors that hinder efficient decision-making.

Making these limiting factors explicit and acknowledging the interplay between them is critical for developers, operators, regulators and policy makers. Firstly, making them explicit allows the scale of the limitations, and their potential impact on investment, to be assessed. Secondly, by acknowledging the limiting factors it is possible to develop strategies to address them.

Paper VIII: **Impact distribution matters: investment in local recycled water systems is determined by who is positively and negatively impacted, how and when (Chapter 9)**

This paper contributes to knowledge by revealing why consistent and fair assessments of local recycled water systems, particularly in relation to centralised extension, augmentation and replacement, have proved to be problematic. Specifically, it:

- reveals the significant difference in the distribution of impacts between conventional urban water services and local recycled water systems
- suggests that the traditional characterisation of impacts into social, environmental, economic and (at times) technical groupings, misses a key aspect in understanding and assessing the relative costs, benefits and risks of these systems: their distribution across stakeholder groups
- proposes that accounting for the distribution of impacts is critical for assessments that include options of different scales and different levels of responsibility.

This paper argues that accounting for the distribution of impacts is critical for assessments that include options of different scales and different levels of responsibility. Taking account of the distribution of impacts will help practitioners better understand the consequences of varying the impact distribution, particularly when moving from substantially public responsibility and ownership of assets to a mix of public and private responsibility and ownership.

Paper IX: **What do building occupants think of onsite recycled water? (Chapter 10)**

This paper contributes to knowledge in the following ways:

- It presents a simple and easily reproducible survey that could be used to provide building owners operating recycled water systems an insight into perceptions of recycled water in relation to other green building features and occupants' awareness, perceptions and concerns regarding recycled water use.
- It provides a survey which owners of a commercial building can use to conduct a review of occupants' attitudes towards the building's recycled water system. The survey investigates: awareness, safety perceptions, and reactions to the recycled water plant generally. It also assesses the value placed on the recycled plant compared to the value placed on other green building features.

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Appendix A: Paper: 'Wastewater systems: Decentralised or distributed? A review of terms used in the water industry'

Abstract

Decentralised water services have been considered a poor or temporary alternative to centralised water servicing. Recently, a combination of: governments seeking to diversify water sources; community sustainability drivers; and technology improvements have resulted in decentralised systems being considered for urban wastewater treatment and recycled water provision.

However, the terms decentralised wastewater and decentralised water have been used to describe a vastly diverse set of applications. The understanding of the key parameters of a decentralised system varies with the purpose, origin and application of the particular system. This variation makes it difficult to compare, discuss and analyse the performance and acceptance of decentralised systems.

This paper reviews definitions from the literature, different Australian and international regulatory environments, Australian and international codes, and water utilities themselves. It specifically identifies key characteristics of a decentralised wastewater system.

Recognising the broad range of alternatives covered by the term decentralised will help the industry appreciate why it is so difficult to make generalisations and comparisons in this area. It also highlights the importance of authors clearly stating the parameters covered by their work, rather than assuming a constant definition is understood.

Introduction

Since the mid-19th century best practice in water and wastewater has been to centralise services whenever it was economically and technically feasible (Gikas & Tchobanoglous 2009). Centralised servicing collects water, usually far outside the urban area and transports it through a large network of pipes to where it is used. Wastewater is transported out of the urban area, treated and usually discharged into a receiving water body. While this centralisation has produced well documented and essential public health benefits (Gikas & Tchobanoglous 2009; Harremoës 1998) it has also resulted in significant capital investment and large complex systems.

In recent times, the sustainability and resilience of single large systems has been questioned. Community sustainability drivers, supply constraints, water restrictions and technology improvements have led to the consideration of other service alternatives.

Changes in social attitudes, financing arrangements and hydrological regimes are fuelling the drive for smaller more flexible systems.

The term decentralised water systems can cover the entire range of water services, including:

- smaller water sources such as rainwater tanks and local groundwater extraction
- local wastewater treatment including onsite septic tanks and a range of different small wastewater treatment technologies
- non-potable water supply including greywater diversion or treatment, stormwater recycling, wastewater recycling and groundwater recharge.

Crites and Tchobanoglous (1998) describe decentralised systems as ones that collect, treat and use rainwater, stormwater, groundwater or wastewater at different spatial scales, from individual homes, clusters of homes, urban communities, industries, or built facilities, and portions of existing communities either independent from, or as part of, a larger system.

However, within the literature decentralised servicing can mean many different things. This makes it hard to compare and fairly consider decentralised systems in relation to better understood conventional water and wastewater solutions.

This paper recognises decentralised water services cover the whole gambit of water services. However, it focuses on the use of the term decentralised (and later distributed) in the literature, specifically in relation to decentralised wastewater and decentralised recycled water services.

The paper summarises the commonalities and differences in the use of the term decentralised wastewater and discusses the significance of these variations. It also looks at some of the emerging trends in terminology and definitions as decentralised systems are installed as a compliment or competitor to existing centralised networks.

In 2009 Cook et al explored the varying definitions of decentralised systems, outlined the key aspects of a decentralised approach and set a definition specific to the South East Queensland perspective. This paper builds on Cook et al's work, but rather than try to develop a single all-encompassing definition of decentralised systems it looks at key parameters that practitioners can use to clearly define the subset of decentralised systems they are discussing. The paper also seeks to clearly identify an emerging subset of decentralised systems that exist within or close to a large centralised network.

One thing is clear, the range of definitions for decentralised systems is as wide ranging as the systems themselves. This reflects their great flexibility and adaptability to local needs, including demand, end uses, regulations, reliability of other supplies, costs of discharge, topography and population density.

Decentralised wastewater services

One of the most widely used definition of decentralised wastewater systems is taken from Crites and Tchobanoglous (1998).

'*Decentralised wastewater management may be defined as the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of generation'*

This definition is representative of the wide range of terminology was used in the literature when discussing decentralised systems. Terms used include:

- local treatment (Cook 2009; NSW Department of Health 2010)
- on-site treatment (many including Sydney Water, Geisinger & Chartier 2005; The US EPA 2005; WERF 2010)

- allotment (Mitchell & White 2003)
- cluster (many including Geisinger & Chartier 2005; Mitchell, Abeysuriya & Willetts 2008; The US EPA 2005; WERF 2010; Willets, Fane & Mitchell 2007)
- distributed systems (Cook 2009; Mitchell, Abeysuriya & Willetts 2008)
- community (Auckland Council ; NSW Department of Health 2010)
- development scale (Tchobanoglous & Leverenz 2008)
- hybrid onsite (Tchobanoglous & Leverenz 2008)
- satellite treatment plants (Gikas & Tchobanoglous 2009; Tchobanoglous & Leverenz 2008).

In addition to a using a wide range of terms, the definition of decentralised systems can vary depending on the specific immediate context.

Yarra Valley Water's (2009) discussion paper recognised that the terms 'distributed', 'decentralised', 'on-site', and 'cluster' are used interchangeably to refer to wastewater treatment systems that operate outside the reticulated sewage network.

Sydney Water's sewer mining policy (2008) refers to decentralised wastewater treatment as a type of sewer mining that involves extracting domestic wastewater from a private sewer and treating it on site for reuse as recycled water. Sydney Water's EIS for West Camden Sewage Treatment Plant (2001) upgrade and amplification considered three 'decentralised' options including:

- on site systems
- community systems that were not connected to the centralised network
- a combination of onsite and community systems.

Key themes in definitions

Although the definition of decentralised wastewater can vary there are some key similarities in the majority of definitions.

These issues are similar to those found by Ackermann (2001) and Pepermans (2005) when they attempted to define distributed electricity generation. They both found it beneficial to look at the concepts used to describe the systems to better understand their components. Specifically, Pepermans (2005) found that the lack of agreement on a precise definition was due to the concept including many technologies and applications in a range of environments (2005, p. 797), which is also the case for decentralised wastewater systems.

The two most consistent concepts in decentralised wastewater systems were the proximity of the generation and/or treatment to use and smaller size. However, what represented small size and close proximity varied between authors. Other concepts varied in consistency, as will be discussed below. What emerged was not a single concept of decentralised systems, but more a moving continuum, where most agreed on what centralised and onsite systems were, with decentralised being somewhere in between (or including on site). The concept of a continuum somewhere between centralised and onsite was also discussed in Pinkham et al. (2004).

The themes identified in decentralised wastewater definitions include:

- close proximity of wastewater source, treatment and use/disposal
- smaller size and relationship to onsite systems
- perception of improved sustainability
- ALTERNATIVE management and ownership models
- perception of inferior performance
- greater variety in source, treatment and transport technologies and discharge locations
- relationship of decentralised systems to centralised systems

These themes are not dissimilar to Pinkham et al (2004), varying mainly in the inclusion of sustainability and performance perceptions and grouping together of treatment/discharge and sewer type. The final grouping reflects a subtle difference between the American and Australian experiences, particularly in recent years where technological, demand and cost advances have changed the technologies used both in decentralised treatment and centralised transport.[54]

Close proximity of wastewater source, treatment and use/disposal

The Oxford Dictionary states decentralize is 'to undo the centralization of'. The two definitions in Crites and Tchobanoglous (1998) are representative of this concept of decentralised being the opposite of centralised. They use networks to separate the two, with centralised systems having large and long transport networks and decentralised systems having little to no transport network.

The idea of wastewater treatment being close to the waste generation; and the disposal or end use being close to the treatment is well accepted in decentralised

[54] see for example Stanwell Park, Coalcliff, Otford and Stanwell Tops in Wollongong's North attached to the centralised gravity network of Sydney Water's Cronulla System as an example of an alternative sewer attached to a centralised network. Also most decentralised systems installed in Sydney are membrane bioreactors (MBR) as opposed to Pinkham's observation that most centralised systems use activated sludge processes and decentralised systems use alternatives such as sand and trickling filters.

literature. Crites and Tchobanoglous (1998) use *at or near the point of generation'* in their definition of decentralised.

In New Zealand, (Auckland Council) define decentralised systems as:

*The collection, treatment and disposal/reuse of limited volumes of wastewater, generally from cluster(s) of dwellings and/or accommodation facilities that are usually located **relatively close together**, with the wastewater system **relatively close to the source** (also referred to as "community", "neighbourhood" or "cluster" systems).* (my emphasis)

Generally, the overarching concept of proximity for generators to each other, generators to treatment and generators to end use is to keep systems small and local. It is very had to specifically define, and is referred to only in general terms (e.g.: relatively close, at or near).

Smaller size and relationship to onsite systems

While all definitions agree, decentralised schemes are not centralised, many have variations within the 'not centralised' component. Many of these explicitly exclude on site as a separate category (for example see NSW Department of Health 2010 & Tchobanoglous & Leverenz 2008). Others, like Sydney Water (2009) and Geisinger and Chartier (2005), specifically include on site systems under the banner of decentralised. This is perhaps another example of the advances in technology and new applications changing the understanding of terms. In the past 'on-site' would generally refer to a single household, now on-site systems can refer to basement plants in large commercial or residential towers.

Whether decentralised systems are assumed to include or exclude on site systems, they all have an implied smaller scale than centralised systems. Occasionally the scale is specifically defined. This is more frequently done in standards or regulations. The US EPA (2005) definition suggests decentralised systems typically provide treatment on the property of individual homes or businesses.

However, when scale is discussed explicitly in a definition it can vary considerably from only including onsite (The US EPA 2005), to including large recycled water schemes such as Rouse Hill (18,000 homes) in Sydney (Gordon 2008).

The Interim Final Queensland Guidelines for Decentralised Wastewater Systems (2007) (unpublished) were developed for systems with capacity from 21 to 1,000 EP (Cook 2009). In Switzerland, treatment plants for less than 500 residents are considered as decentralized systems. (Adler 2006)

NSW department of Local Government in its guidelines for onsite reuse for single dwellings defines centralised and on-site systems (1998). It suggests centralised systems can be built to service from less than 10 to many thousands of households. This is the exception rather than the rule as usually 10 houses would be considered decentralised.

These examples show the wide range of scales the term decentralised systems cover.

Perceptions of improved sustainability

Nelson (2008) suggests that as integrated water solutions become the preferred way of servicing, decentralised technologies will become more dominant. Certainly, within major Australia water utilities the process of integrated water planning has spurred the consideration, if not the implementation, of decentralised water and wastewater alternatives.

Decentralised definitions often included perceptions of greater sustainability and opportunities for recycling (see Venhuizen 1986 for example). Results from Cook et al's (2009) interviews with industry practitioners in Australia reiterated that the concept of decentralised treatment included being fit for purpose and sustainability objectives, including better integration of services and water sensitive urban design.

This is reflected in current trends in Australia. Voluntary green building codes such as the Green Building Council of Australia's 'Green Star building rating tool' have encouraged the use of decentralised recycled water systems.

Alternative management and ownership models

Occasionally the management and ownership model is referred to. When it is, generally the more decentralised they system the more private the ownership and management structures. The larger and more centralised systems tended to have an assumption of public ownership and management.

The Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT) suggests cluster treatment systems are typically privately owned, community systems are publically owned and onsite systems are owned by individuals (2010).

Cook et al (2009) also suggested onsite systems were predominately individually owned, cluster systems suggested some form of common ownership and distributed systems were operated by specialised utilities.

Perception of inferior performance and increased risk

Decentralised systems, particularly onsite systems have a poor performance perception. They have generally only been used at the fringes of traditional centralised servicing (Nelson 2008) and have often been viewed as a temporary or second class measure.

Governments throughout Australia (see for example Victorian Auditor-General 2006) have identified and responded to the high levels of failing on site systems (mainly septic tanks) through long and expensive centralised sewering programs.[55] This response has reinforced the perception that centralising rather than improved management techniques is the best way to overcome the social (odour, amenity), health and environmental issues associated with these failing tanks.

Advocates for decentralised services dispute decentralised systems present higher risks. Pinkham et al's (2004) review of risks concludes generally, the risk and cost of failure are less for decentralised as the consequences are small and widely distributed.

Greater variety in source, treatment and transport technologies and discharge location

[55] (See Victorian backlog sewer program and Sydney Water Priority Sewerage Program for examples)

The final area where decentralised systems were differentiated from centralised systems was the source and discharge methods. These concepts were not often referred to but when they were decentralised systems were generally seen as more flexible and capable of meeting the local needs and opportunities.

A wide variety of sources for decentralised systems were evident in the literature, including rainwater, groundwater, stormwater and wastewater – either blackwater or greywater. This was most evident in Cook et al (2009) where decentralised systems were identified as being more independent than centralised systems as they did not rely on a single source.

Some descriptions of decentralised wastewater systems were specific about where decentralised systems discharged (e.g. to the ground, irrigation or recycling) as opposed to centralised systems that generally discharged to open water bodies (Pinkham et al. 2004).

(Gikas & Tchobanoglous 2009) suggested that satellite treatment plants often lack solids processing and the solids are returned to the network.

Relationship of decentralised systems to centralised systems

Many definitions excluded connection to the centralised network, either explicitly (for example Sydney Water 2001) or implicitly by using isolation as a requirement or an assumed reason for the systems (see WERF definition).

The assumption that decentralised systems are isolated and remote from centralised networks reflects their historical role. Until recently most decentralised systems, particularly in the United States, were in hard to service or remote places and used septic tanks and ground leaching trenches for disposal. In recent years, decentralised systems have begun to be used in conjunction with centralised systems to save energy and to provide a valuable non-potable water source. Green Building Council of Australia's Green Star Rating system which allocates points for onsite recycling and reuse has helped make onsite systems more popular. This has been made possible by the advances and commercialisation of more small scale treatment systems. More recent literature identifies the potential for decentralised systems to integrate with the centralised network (see Cook 2009 for example).

Some of the benefits, concerns and issues associated with decentralised systems on or close to a centralised network are very different from remote schemes. To try and differentiate these schemes some authors use alternative terms. Gikas and Tchobanoglous (2009) defines satellite treatment plants as being within the network and decentralised treatment plants being off the network.

Since about 2008 the term distributed has been used in Australia (see Mitchell, Abeysuriya & Willetts 2008). This is a term also used in the electricity industry (see Ackermann, Andersson & Söder 2001; Pepermans et al. 2005 for distributed electricity definitions).

Distributed wastewater or recycled water in recent literature has been used to describe small local schemes within or near a centralised network. Chung (2008) considers a distributed wastewater scheme in which multiple satellite WWTPs are located throughout a community with the ability to treat and distribute reclaimed water to nearby users. WSAA guidelines for distributed systems (WSAA 2010), recent CSIRO documents (see for example CSIRO 2008, 2009; Tjandraatmadja et al. 2008), and (Mitchell, Abeysuriya & Willetts 2008) all use the term distributed to refer to small/ local wastewater treatment plants within or close to a centralised network.

The term distributed is useful as it clearly distinguishes schemes with the ability to connect to centralised network or within the centralised service area. These schemes are likely to have different considerations to isolated schemes. It also is consistent with the terminology in the electricity sector. However, writers should acknowledge it is not widely used or recognised yet in relation to wastewater and recycled water, making a clear statement of purpose and definition at the outset particularly important.

Conclusion

This paper has highlighted that the use of the term decentralised system in the water and wastewater context varies as widely as the application. The flexibility of decentralised systems to provide the best solution for the specific local circumstances, (i.e. size, treatment technology, water sources, end uses), makes it difficult to fit them within a concise definition.

Although the use of the term varies widely, most would agree that decentralised systems are used in a local context where the source, treatment and reuse occur close to each other.

As decentralised technology has become more reliable and affordable it has progressed from a second rate system for poor and remote communities to one that is increasingly installed in prestige buildings to meet 'green building requirements' and demands for recycled water.

Perhaps most reflective of the growth and diversification of the industry is the emergence of the term distributed systems, to reflect systems adjacent to and in competition with, large centralised networks.

Some authors have provided simplified (e.g. Crites & Tchobanoglous 1998) or more detailed and inclusive definitions (e.g. Cook 2009). However, the current literature is inconclusive about many details such as size, connection to the centralised network, management and ownership structures and principles of sustainability.

Rather than working on setting an all-encompassing definition, it is suggested that authors be aware of the large range that the term decentralised can cover and be specific and clear when describing the systems they are discussing. As a starting point the size (system, area of service and population), treatment type, location in relation to a centralised network, water sources and sustainability goals and any specific management or ownership structures should be clearly stated.

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Appendix B: Paper: 'How sustainability assessments using multi-criteria analysis can bias against small Systems'

Abstract

Multi criteria analysis (MCA) has emerged as a popular decision making tool in the water industry. However, there are some restrictions with the method and its practical application that can bias against smaller systems in relation to larger centralized alternatives. This paper specifically identifies these biases, in relation to small recycled water systems and suggests ways to account for the bias. This will aid in the fair and robust comparison of smaller alternatives in relation to larger centralized options.

Introduction

For over 100 years centralized water and wastewater services have been best practice across urban Australia and indeed throughout the world. However, continuing to maintain and expand the capacity of systems to manage and respond to aging infrastructure, demand growth, and shifting expectations in terms of sustainability, resilience and security, is proving both expensive and technically challenging.

To meet these challenges, a broader range of options are being proposed, which require broader assessment frameworks. One of the more popular frameworks is multi criteria analysis (MCA). MCA can help decision makers balance multiple objectives from multiple viewpoints. Although MCA provides a range of benefits it can bias against small systems, particularly in relation to the larger and better understood centralized alternatives.

This paper demonstrates how MCA can bias against small systems. It compares the areas of bias to the cited benefits of small systems and notes the similarities between these two. Suggestions are then made on how to acknowledge or minimize these biases to help make MCA assessments of small systems in relation to larger systems more balanced.

What are small systems and why do we consider them?

Until recently small water and wastewater systems have generally been reserved for locations that were remote and difficult and/or too costly to service. In recent times, the cost effectiveness, sustainability and resilience of single large systems has been questioned. This has led to utilities and developers considering the use of small systems in conjunction with the existing centralised system, or instead of extending the existing centralised systems (Etnier et al. 2007; Mitchell et al. 2010; Mitchell et al. 2008; Nelson 2008; Pinkham et al. 2004; Willets, Fane & Mitchell 2007).

These small systems working with or near the centralised system (called distributed systems in this paper) can be very diverse, in their source, treatment methods, discharge locations, end uses and management models (Gikas & Tchobanoglous 2009; Watson 2011; WSAA 2010). Distributed water systems can cover the entire range of water services, including:

- smaller water sources such as rainwater tanks and local groundwater extraction
- local wastewater treatment including a range of different small wastewater treatment technologies
- non-potable water supply including greywater diversion or treatment, stormwater harvesting, wastewater recycling and groundwater recharge.

This paper focuses on the last two types, although some arguments would hold for all three.

Benefits of small systems

It is difficult to define distributed systems, and this generally reflects their flexibility and adaptability to local needs, including demand, available end uses, regulations, reliability of other supplies, costs of discharge, topography and population density.

In addition to their flexibility and adaptability, other benefits of small systems include (Gikas & Tchobanoglous 2009; Pinkham et al. 2004):

Environmental benefits such as:

- opportunities for local integrated water solutions

- reduced resource intensiveness,
- reuse potential → reduced environmental extractions and discharges

Risk and reliability benefits such as:

- risk reduction – safety, security and disaster mitigation
- risk reduction – avoiding excess capacity or underused capacity
- risk reduction – reliability and redundancy for the centralized system

Economic benefits such as:

- reduced financial burden, smaller units of investment
- reduced reliance on networks (which show diseconomies of scale)
- efficiency by matching of treatment to waste stream and end use requirements
- efficiency by matching of investment to demand in space and time
- reduced planning and construction timeframes

Social benefits such as:

- treating waste locally
- reduced issues with network expansion in built up areas
- education
- equitable cost distribution - shifting of the financing burden to direct beneficiaries (user pays)

What is Multi-criteria analysis (MCA) and why use it?

Decisions in the water industry are often complex and require decision makers to consider a wide range of perspectives and alternatives. The range of options and the complexity of tradeoffs has increased as principles of integrated water management, water sensitive urban design and liveable cities have evolved. There are many methods available to compare sustainability impacts of different urban water options and different decision-makers prefer (or require) different methods (Fane, Blackburn & Chong 2010). One method that has gained popularity in the water industry and is supported by the Water Services Association of Australia (WSAA) is multi-criteria analysis (MCA) (Lundie et al. 2008).

MCA is a decision making framework designed to help decision makers balance multiple objectives and multiple viewpoints, particularly when impacts are difficult to value in dollar terms (Asafu Adjaye 2005). MCA ranks options based on a set of criteria developed in conjunction with stakeholders and the relative importance of criteria is represented by weights. A way of measuring against each criterion is agreed, but this does not have to be a dollar value. In fact, it does not have to be a value that can be quantified directly, a subjective, or qualitative assessment can be made. This allows decision makers to consider externalities even when the impacts cannot (or are too difficult to) be measured (Asafu Adjaye 2005). MCA also makes it possible to include impacts that are outside the strict economic definition of externalities.

How do the elements of multi-criteria analysis can bias against small systems

Despite MCA's many benefits it also has its limitations particularly in relation to the fair comparison of large alternatives to small systems. This paper discusses issues that relate to common errors in the application of MCA and decision making in general and issues inherent in the MCA framework, all of which can bias against small systems.

How decision making and MCA application can bias against small systems

MCA is a tool to aid complex decisions. However, like all tools it is only as good as the data used and the way it is applied. Limited data availability, limited knowledge on how to include the measures or common decision making pitfalls can all affect the fair assessment of options in an MCA process. However, these issues can have a greater effect on less well understood alternatives, such as using small systems to complement larger centralized systems. These general issues include:

- common decision making pitfalls
- including risk and uncertainty
- incorporating and valuing flexibility
- ensuring consistent assessment boundaries in terms of e.g., level of service provided, population served, timescales considered, components of infrastructure lifecycle considered, etc.
- identifying, selecting and valuing benefits and externalities
- choosing the most appropriate metrics.

Common decision making pitfalls

Several common decision making flaws can particularly affect the fair assessment of small systems when using MCA. It is recognised that in general, decision making has a strong bias towards preserving the status quo, seeking out evidence that confirms the current norms and making choices in ways that justify past choices (Hammond, Keeney & Raiffa 1998). In the Australian water industry the current planning framework often preferences large centralised solutions (LECG Limited Asia Pacific 2011). Most of the urban water planning is undertaken by the centralised utilities. The planners and engineers in these organisations have a large 'intellectual capital' in centralised systems management and in the engineering community at large there is a lack of technical knowledge on the implementation and performance of smaller systems and limited education or training available (Etnier et al. 2007). For small systems being evaluated against large centralised options through an MCA process, this means that the criteria are more likely to be developed thinking about how it applies to large options. The risk and uncertainty of the smaller options will tend to be over emphasised, while there will be over confidence in the performance and value of larger options.

It has been shown that in infrastructure decisions the benefits are often overestimated and the costs are often underestimated (Commonwealth of Australia 2006a). One study of transport alternatives found that costs were 20-45% higher than originally estimated and benefits were 20-51% overestimated. Similar results were found in other areas of major infrastructure investment (Office of Financial Management 2007). This bias can make large options look better value than they are. This also negates the flexibility and modular benefits of decentralised options.

Including risk and uncertainty

MCA can explicitly deal with risk and uncertainty through sensitivity analysis where key weights or scores are changed to see how the final decision may be affected (Mukheibir & Mitchell 2011). However, perceptions of risk and uncertainty may also be implicitly included in MCA analysis through the early exclusion of options in the screening process, the way options are valued and the inclusion of criteria such as customer acceptance, and this can lead to biases against small systems.

Both federal and state treasury agencies (Commonwealth of Australia 2006; Office of Financial Management 2007) suggest pessimistic values should be used in options evaluation. Using pessimistic scenarios is a particular issue for small systems and newer technologies as there is more uncertainty surrounding their performance, full lifecycle costs and acceptability.

Small systems reduce the consequences of failure and when used in conjunction with centralised systems, could help to reduce vulnerability to natural shocks (Gikas & Tchobanoglous 2009; Pinkham et al. 2004). However, small systems are also more vulnerable to misuse and shock loads (Etnier et al. 2007; Pinkham et al. 2004). Due to the public health aspects of water and wastewater services, decisions tend to avoid risk (Nelson 2008; Productivity Commission 2011; Water Corporation 2011). This risk adversity affects smaller, less well understood options and is compounded as decision makers commonly recall and place more emphasis on dramatic or bad outcomes (Hammond, Keeney & Raiffa 1998). This can lead to the positive risk benefits of small systems being negated by the negative risks and results in the early exclusion of potential small options, or poor acceptability or protection of public health scores.

Selecting lesser known (and potentially riskier) technology could also lead to decisions requiring review by Treasury departments under government procurement guidelines (see for example (NSW Government 2010)). As identified by ACTEW, the more layers of uncertainty added to the process (in this case an extra approval authority) the less likely it is to be favoured (Productivity Commission 2011). This again can lead to the early exclusion of options or poor acceptability scores.

Under current regulatory and institutional frameworks the responsibility for the installation and operation of small systems can be the responsibility of private parties, rather than the utility doing the planning. This can lead to uncertainty regarding the ongoing capacity and capability of the systems, leading to pessimistic demand, revenue or performance scores.

Incorporating and valuing flexibility

Flexibility is a key benefit of decentralised systems (Pinkham et al. 2004). Flexibility is not just about investment in time but also technology choices and treatment levels better matching discharge, end use or waste contamination level. Using small systems allows the best technology and option to be used at each location at different points in time. This can allow the inclusion of integrated solutions, recycled water of different standards, and different sources where appropriate. However, in an MCA process it is difficult to describe, cost and score a non-uniform and adaptable option. This often results in a generic small system option being selected or a series of separate (e.g. demand management option, decentralised recycled water option, stormwater recycling option) being scored, which loses many of the flexibility benefits. The issues associated with rolling up options into generic bundles are discussed in more detail later.

If demand or growth profiles are slower than expected distributed systems are favoured as they use smaller amounts of capital spread over time. This moves capital costs to the future and lowers net present value Mitchell et al (2007).

There is also a poor understanding of how to value the flexibility and lower levels of risk associated with shorter asset lives (Office of Financial Management 2007). Although there are methods[56] to include flexibility into the assessments (Mukheibir et al. 2012), the less well understood the methods and the benefits are, the more likely they are to be ignored or undervalued. This will lead to poorer scores for small systems in cost as well as flexibility.

[56] The NSW Office of Financial Management (2007, p39) suggests using equivalent annual cost to better include the value of shorter asset lives (also useful when technological change is rapid and demand is volatile). Pinkham et al (2004) suggests that economic tools such as options theory or decision analysis can also be used to value flexibility and the avoided risk (for example of overinvestment or investment in redundant technology) flexibility provides (pp. 22-3).

Ensuring consistent assessment in terms of boundaries

In almost all circumstances the costs and benefits will vary depending on system boundaries used, both in space and in time and whose perspective is used to determine costs or benefits (Mitchell et al. 2007). Clearly defining the project objectives is critical to setting boundaries for analysis. For small systems, too narrow a focus will limit the potential benefits, particularly benefits associated with integrated water solutions. For example, if a project objective is to increase water supply the benefits of a distributed recycled water system on the wastewater network, treatment and disposal will not be taken into account. Alternatively, if only a new development is considered in the analysis benefits from providing nearby existing customers with recycled water may be excluded.

Identifying and including benefits and externalities

It is difficult to identify externalities, let alone measure and value them. While there is lots of information on how to evaluate sustainability impacts, there is little information on how to value sustainability impacts in the urban water industry (Fane, Blackburn & Chong 2010).

Although this issue is common to all options it can particularly disadvantage small systems and distributed recycled water options as they are likely to have external benefits such as social learning and improved conditions of open space. As it is unlikely that resources will be available to evaluate every externality for every option value judgements may be used to identify the externalities that are significant and important (Etnier 2005). This means the choice of which stakeholders get to determine these values becomes pivotal to the outcome, and may introduce bias towards better understood solutions and benefits. Often in water planning assessments, the stakeholders are industry and sectoral representatives. Their perspectives on these value judgements are likely to be rather different from representatives of end-users, particularly local end-users.

Choosing the most appropriate metrics and values

How to measure against criteria and how to combine the scores in a fair and robust way is the subject of much debate for MCA. However, the choice of unit for water savings and the choice of demand values used and the number of criteria selected can particularly bias against small systems.

For water savings, a common metric is unit costs of water supplied to water conserved. The three most common techniques to calculate this measure (annualised unit cost, present value per total volume saved or supplied and average incremental cost) can give quite different results (Mitchell et al. 2007).

Annualised unit cost has difficultly accounting for options where yield changes over time, which is the case for staged decentralised options. It also tends to favour large scale options as the ultimate yield (at full demand) is often used, rather than some average over time, providing a low annualised unit cost, even though there will be many years of idle capacity.

Mitchell et al (2007) recommend using average incremental cost or levelised cost. However, levelised cost still favours water supplied in earlier years, i.e. the large lumpy investments.

Some measures use a water demand value in their calculation (for example levelised cost, net present value). Results can vary substantially depending on whether average or peak demand or even ultimate capacity is used. The variation in these numbers is greatest for large centralised investments, and the use of ultimate peak capacity can greatly favour centralised investments over smaller decentralised ones.

Finally, there can be a tendency to use a large number of criteria in MCA. The more criteria that are used, the less impact each criterion is likely to have on the outcome and the more likely criteria will overlap or double count to some extent (Ferguson & Gough 2011).

How the MCA method can bias against small systems

The discussion above examines decision making and MCA application issues that can bias results against small systems in comparison to larger centralized alternatives. There are also some inherent issues with the MCA method that can bias against small systems including:

- Missing distribution of impacts
- Grouping distributed options to realise comparable scale loses the value of individual advantages

Missing impact distribution

The distribution of impacts for small systems and centralised alternatives is often different, and this difference is unaccounted for in many types of analysis. MCA assumes the distribution is the same, yet many small system alternatives rely on individuals or smaller groups for funding and ongoing management. By ignoring the distribution of impacts MCA does not allow the consideration of important differences between the options.

The influence of distribution can sometimes be implicitly included through increased risk profiles or additional criteria to understand willingness to pay or acceptance. However, the introduction of extra criteria increases the chance of double counting, or diluting the importance of other relevant criteria.

Grouping distributed options for evaluations

There are often a large number of options that will meet the project objectives. To make the assessment more manageable options are sometimes grouped into representative categories for the initial evaluation (Office of Financial Management 2007). Centralised options often stand alone, but less well understood decentralised options may be lumped into a generic 'decentralised' option. For example, in the City of Sydney strategic servicing strategy developed by Sydney Water and government stakeholders the 'decentralised' options were not specific about whether they included stormwater reuse, rainwater tanks, sewer mining or only in-building blackwater. Each of these kinds of options has different benefits and limitations, and these differ further according to the context (scale and timing) of each option. Lumping a non-specific group together means that their performance cannot be assessed in a meaningful way against key criteria. The outcome is that at a strategic level, groups of distributed/ decentralised options cannot easily be costed or any specific conclusions be made about benefits or the scale of the benefits.

Why are these biases important

The ways that MCA can bias against small systems either through application or process are all important on their own. However, the factors discussed above rarely act independently. They often combine to compound the influence of the individual biases. For example, if there is difficulty accounting for flexibility in treatment type and investment timeframe this bias is likely to be compounded by grouping options to hide the flexibility small systems provide. As another example, Demand estimates and growth profiles are often overestimated for centralized systems, making them appear more financially favorable than small systems. This financial advantage is compounded by poor cost estimates for small systems due to lack of knowledge and understanding and potentially greater safety factors due to the uncertainty that surrounds the installation and management of small systems in urban environments.

However, perhaps even more significantly, the way MCA can bias against small systems matches closely to the benefits of small systems, as shown in table 1.

Table 1: the benefits of small systems and how they can be negated by biases in MCA process and application

Benefit of small system	**Summary of the influence of biases against small systems**
Sustainability – integrated water solutions	• Roll up of options loses value of locations specific solutions • Value can be minimized by too narrow a boundary focus
Sustainability – reduced	• Value of environmental & social benefits minimized because difficult to identify and measure

extractions and discharges	• Poor choice of demand metrics can undervalue small solutions in relation to larger centralized alternatives
Reduced risk – human health, supply and security	• Negated by over cautiousness and influence by poor past experience and bad outcomes • Negated by focus on bad outcome of one system failure, rather than reduced consequences of failure and small probability of all systems failing concurrently
Reduced risk – providing robustness and reliability for centralized system	• Negated by uncertainty of approvals process, timing of investments and ongoing maintenance • Negated by lack of techniques to identify and measure the value of robustness and flexibility
Economic efficiency - Flexibility in investments in time, space, technology & treatment	• Negated by lack of techniques to identify and measure the value of robustness and flexibility • Generic options reduce the economic and flexibility benefits • Single preferred option negates flexibility/ fit for purpose benefits
Economic efficiency – smaller investment units spread over time	• Negated by optimistic demand estimates favouring large solutions • Risk adversity and lack of experience with small systems results in higher cost estimates
Social benefits – education, equity and greening	• Difficult to identify and value, values are dependent on people not included in the process • The effect of changes in distribution of impacts often is translated to increased risk and reduced acceptability

How can we manage these biases?

Despite the discussion above, MCA is an effective and useful tool to consider complex options for sustainable integrated water solutions.

There are several good guidance documents for applying MCA, setting boundaries, specifying the base case, selecting criteria and effective measurement parameters and conducting sensitivity testing (Department for Communities and Local Government 2009; Fane, Blackburn & Chong 2010; Ferguson & Gough 2011; Lundie et al. 2008; Mitchell et al. 2007; Mukheibir & Mitchell 2011). By applying good practice many of the application biases can be minimized or managed.

The consequences of changes in impact distribution can be assessed once the final options have been identified and can be part of a risk assessment process.

Further biases identified in this paper can be minimized during sensitivity testing & risk assessment. By understanding how the methods and application can bias against small systems and how those biases can compound, decisions of how and what to test can become clearer.

Finally, further research is currently underway which should help improve the way we value recycled water (The economic viability of recycled water schemes – Marsden Jacob Associates), incorporate flexibility, reliability, risk and uncertainty into assessments (Planning for Resilient Water Systems – ISF) and improve the way we identify opportunities for viable small systems in an urban redevelopment (City of Sydney decentralised master plan – GHD; Building industry capacity to make recycled water investment decisions - ISF).

However, forewarned is indeed forearmed. By identifying and understanding the way both the MCA process and its application can bias against small systems practitioners can look for ways to minimize the influence of biases on their decisions.

Conclusion

Multi criteria analysis is a valuable tool for making sustainable decisions in the water industry. However, there are some restrictions with the method and its practical application that can bias against smaller systems in relation to larger centralized alternatives. Current research will help assess the value of the flexibility of small systems and the complimentary value they can provide to centralized system robustness when used as a compliment. Meanwhile, specifically acknowledging these biases and taking them into account when undertaking sensitivity testing will aid in the fair and robust consideration of smaller alternatives in relation to larger centralized options.

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Appendix C: Questions sent to interviewees

Costs and benefits of local recycled water systems

Site survey questions – planning, construction and operation

Introduction

This research aims to identify the full range of costs and benefits of small recycled water systems in an urban environment. By collecting data from sites with operating recycled water plants and collecting data from the planning phase through construction and operation this research aims to inform future industry decisions on:

i) the efficient role for small scale recycled water schemes in the provision of water and wastewater services, and

ii) whether changes to the existing regulatory and institutional rules & frameworks should be considered

The research is being conducted by Rachel Watson, through the University of Technology Sydney. The research has ethics clearance 2011-242A. I have attached a research "Q&A" sheet or you can contact me on 0416 922 799 or Rachel.watson@uts.edu.au if you have any further questions. You can also contact my supervisor, Professor Cynthia Mitchell or the UTS ethics research committee (see Q&A sheet for contact details) if you have questions about the research process or how your data will be used.

I am collecting information in the following areas:

- Project description and drivers
- Reflections on the process, particularly value for money, the approvals process and any improvements/ changes you thing would make these systems more viable and efficient

- Assessment of alternatives and planning
- Regulatory approvals
- Construction costs and benefits
- Operating costs and benefits

I am also collecting information from Sydney Water regarding:

- The drivers for an office with recycled water
- Staff perceptions on recycled water – quality/safety/ sustainability
- Their role as a utility in interacting with/ supporting small private recycled water systems, including any benefits or costs they encountered as a utility from the installation of a recycled water plant in this building.

1: Background and plant description

If this research could answer one question for me it would be......

Please provide a description of the plant including effluent source, recycled water end use, demand profiles (design, ultimate and demand profile if available) and process (equipment, treatment levels, discharge location, sludge handling, flow balancing).

2: Planning

2a) What were the drivers for considering recycled water (e.g. internal sustainability objective, market demand, water security)? Was recycled water specifically required or was recycled water just the best option to meet a broader driver

2b) What alternatives (if any) were considered?

2c) Did you use any particular sustainability assessment process to weight up alternatives? If so what? (e.g.: cost benefit analysis, cost effective analysis, multi-criteria analysis, life cycle analysis, other?)

2d) What type of costs and benefits did you include in your assessment? How did you do this?

2e) Did you feel you had enough information on the range of alternatives and how to compare them? What were the biggest gaps?

2f) Are there any major differences between the design performance and/or costs and the operating performance and/or costs? Do you think this will change in the future?

2g) In retrospect what is the most important consideration when deciding whether to install a recycled water system?

2h) What would you do differently next time? What would you do the same?

Any other comments? Questions?

3: Approvals

3a) What licences/ permits and approvals did you need for the plant? What were the fees associated with these approvals?

3b) What regulatory authorities did you need to speak to?

3c) What ongoing reporting and monitoring requirements do you have?

3d) How long did the approvals phase take? Do you have any comments about these processes?

3e) Were there any benefits in installing a recycled water plant (i.e. planning concessions in greater floor area ratios?)

3f) Do you think having a recycled water plant caused delays in the overall building approval or made it easier? Why?

3g) What were the biggest hurdles to getting the plant installed and operating?

3h) What would you do differently next time? What would you do the same?

3i) Is there anything you would like to see changed in the approvals process?

3j) What are your thoughts on the regulatory process? How easy was it for you to understand who you needed approval from and what their requirements were?

Any other comments? Questions?

4: Construction

4a) Where is the plant located? Why was that space chosen? When in the overall site design was the space for the plant allocated? When in the overall site design was the plant designed?

4b) What was the total capital cost for the plant? What does the total capital cost include? Did this vary substantially from estimates? Why?

4c) Do you have a breakdown of the capital costs, for example:

- Electrical
- Mechanical/ plumbing/ ventilation
- Sitework

- Engineering/ admin

- Equipment installation

- Regulatory approvals for the plant

4d) How was/is the plant funded (subsidies or grants, capitailised into future rents, upfront payment)? Did the green building ratings or the recycled water plant feature in financing discussions?

4e) Do you think the plant was good value for money? Why?

4f) How long did the construction phase take? Were there any significant delays? Did it impact the delivery of the building?

4g) What were the biggest hurdles to getting the plant installed and operating?

4h) Do you think installing a recycled water plant influences your corporate image? Do you think it helps you attract particular customers/clients?

4i) What would you do differently next time? What would you do the same?

4j) Is there anything you would like to see changed in the funding arrangements?

Any other comments? Questions?

Operation

5 General Operation

5a)What is the relationship between who planned the system, who constructed the system, who owns the system and who operates the system? How do you think this has influenced the operation of the plant and ongoing costs?

5b) Who operates the plant? What type of background/ training do they have? How much time do they spend on site?

5c) Who is responsible for monitoring and reporting for the plant?

5d) What has the general response to the plant been? (Staff, customers, regulators, other)

5e) What are your thoughts on the value of the plant?

5f) What do you see as the major benefits of the plant?

5g) Who do you think benefits the most from the plant? Do you think operating a recycled water plant is beneficial to your corporate image? Do you think the recycled water plant has helped you attract a certain type of customer?

5h) What do you see as the major limitations of the plant?

5i) What have been the major operating issues to date?

5j) What would you do (ask for) differently if you could start again? What would you keep the same?

Any other comments? Questions?

6 Specific operating cost questions

6a) How does the operating performance (cost, quality and quantity) align with the expected/design values?

6b) What are the operating costs (per year? per kL?) what does this include? How do you feel about this cost in relation to mains water and sewage charges?

6c) Do you have a breakdown of the operating costs, for example?

- Labour
- Electricity
- General Equipment replacement and repair (not membranes)
- Membrane replacement
- Chemicals
- Regulatory

6d) How do you fund the system? (direct use charge to customers, flat charge to customers, charge in relation to potable water price, rolled into a general building cost?

7 Users

7a) Who are the main users of the system?

7b) What is their level of awareness of recycled water? Do they know they are using it? Do they know what it is used for? What type of programs/ education packages do you have for the users of the system?

7c) Do you think the users have any safety concerns regarding recycled water use?

7d) Do you think the users value the recycled water?

8 Finally

Any other questions? Comments?

UNIVERSITY OF TECHNOLOGY, SYDNEY
CONSENT FORM

I ____________________ agree to participate in the research project Costs and Benefits of Local recycled Water Systems (UTS HREC approval number : 2011-242A) being conducted by Rachel Watson (Level 11 UTS Building 10, 235 Jones Street Ultimo NSW 2007, t + 61 29514 4950) of the University of Technology, Sydney for her degree PhD in Sustainable Futures.

Funding for this research has been provided by Sydney Water.

I understand that the purpose of this study is to understand the costs and benefits of small recycled water schemes in an urban environment.

I understand that I have been asked to participate in this research because I am involved in managing/ planning for/ operating/ using a small recycled water system. I understand that my participation in this research will involve providing information on my experience with the management/ planning/ operating/ using of the small recycled water system at **1 Smith Street, Parramatta** including data on the costs and benefits of the system.

I agree that the interview will be digitally recorded. I am entitled to respond on behalf of our organisation, and will abide by any internal requirements relating to confidentiality.

When responding to the interview questions, I ensure my answers do not cause a conflict of interest or breach any confidentiality with respect to our company, colleagues or clients.

I am aware that I can contact Rachel Watson or her supervisor Cynthia Mitchell if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Rachel Watson has answered all my questions fully and clearly.

[ ] I agree that the research data gathered from this project may be published in a form that does not identify me in any way.

OR

[ ] I agree that the research data gathered from this project may be published. I hereby explicitly express the wish to be identified.

____ ____/____/____
Signature (participant)

____ ____/____/____
Signature (researcher or delegate)

NOTE:

This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 9772 Research.Ethics@uts.edu.au), and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

Appendix D: Sydney Water building survey

Sydney Water staff opinions on in building recycled water

Your opinion matters.

Thank you for giving your opinion on the recycled water plant in the basement of Sydney Water's Parramatta Head Office.

The survey investigates what is good and bad about having a recycled water plant as part of the building and should take less than 10 minutes. The survey responses are anonymous.

As a thank you for completing the survey you can go into the draw for one of 5 double movie passes. To enter the draw you will need to provide your name and email, however these details will not be linked to your responses. The survey will close Monday 3rd June 2013. So make sure you have completed the survey by then to be in the prize draw.

Once the research is complete we will get back to you with the results.

This research is part of a wider research project Sydney Water is sponsoring that investigating the costs and benefits of decentralised recycled water systems in Sydney. The survey has been approved by the UTS ethics committee - 2011-242A. If you have any concerns about the way the research is being conducted please contact the UTS Research Ethics Officer on 02 9514 9772, and quote this number (2011-242A).

If you have any questions about the research, please contact Rachel Watson rachel.watson@uts.edu.au.

Building Features

***1. Listed below are some of the key environmental features of Sydney Water's Parramatta Head Office. Please rate each feature from extremely impressive to very unimpressive.**

	Extremely impressive	impressive	Neutral	Unimpressive	Very unimpressive
The use of construction materials made from renewable sources or containing recycled content	◯	◯	◯	◯	◯
Solar heating panels that supplement hot water requirements	◯	◯	◯	◯	◯
Chilled beam cooling instead of conventional air conditioning	◯	◯	◯	◯	◯
Light sensors that turn off lights when a room or area is not being used	◯	◯	◯	◯	◯
An onsite wastewater recycling plant providing recycled water	◯	◯	◯	◯	◯
A high performance glass facade that controls the amount of heat entering the building	◯	◯	◯	◯	◯

Water efficient showers, toilets and taps	◯	◯	◯	◯	◯
A 100,000 litre rainwater tank to harvest rainwater	◯	◯	◯	◯	◯

Plant awareness

***2. Were you aware, before today, that Sydney Water Head Office building has a recycled water plant in the basement?**

◯ **Yes**

◯ **No**

Tour

***3. Have you been on a tour of the recycled water plant in the basement of the Parramatta Head Office building?**

◯ **Yes**

◯ **No**

Recycled water uses

***4. What do you think the recycled water is used for? Please write your answer below.**

5. If you were talking to a friend about the recycled water plant what would you say?

Reason for recycled water plant

***6. Why do you think Sydney Water has a recycled water plant in the building? You may select up to 3 main reasons.**

☐ To help meet government targets

- [ ] As a demonstration/ education tool
- [ ] To reduce wastewater discharge
- [ ] To save water
- [ ] It is a good thing to do
- [ ] It was a government requirement
- [ ] To reduce stormwater discharge
- [ ] To get a green building rating
- [ ] It is best practice
- [ ] For Sydney Water to lead by example

Other (please specify)

Feelings and attitudes

***7. To what extent do you agree or disagree with the following statements about Sydney Water's Head Office having a recycled water plant on site?**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I feel proud	○	○	○	○	○
It reflects positively on Sydney Water in the wider community	○	○	○	○	○
More should be made of the fact that the building produces and uses recycled water	○	○	○	○	○
As a water utility Sydney Water should definitely use recycled water wherever it can	○	○	○	○	○
It costs too much money to run and maintain	○	○	○	○	○
I worry about the safety of the recycled water	○	○	○	○	○
I worry the recycled water will affect the safety of the drinking water in the building	○	○	○	○	○

Concerns

***8. Do you have any concerns about the use of recycled water in the Sydney Water Head Office building?**

○ **Yes**

○ **No**

Specific concerns

***9. Please tell us about the concerns you have.**

More information

***10. Would you like to know more about the recycled water plant in Sydney Water's Head Office building?**

- Yes
- No

What information is required

***11. Is there anything specifically you would like to know more about?**

Final comments and questions

12. Do you have any other comments or questions about the recycled water plant or the environmental features of Sydney Water's Parramatta Head Office? If not just click next.

General participant information

***13. Do you work in the Sydney Water Head Office building?**

- Yes
- No

*14. How long have you worked for Sydney Water?

- Less than 1 year
- 1 - 5 years
- 6 - 10 years
- 11 - 20 years
- More than 20 years

*15. What division do you work in?

Age and sex

16. What is your age?

- Under 25
- 26-35
- 36-45
- 46-55
- Over 55

*17. Are you....

- Male
- Female

Thank you

Thank you for completing the survey - we will share the results with you shortly. You will now be redirected to the prize entry page.

Appendix E: System operator survey

Decentralised recycled water schemes - capacity building project

Introduction

There has been a rapid increase in small, privately operated recycled water systems in Sydney over the last few years. This survey is designed to see how the systems are operating, identify key issues, determine demand for further training and also review the approvals process from an operational perspective.

This survey is part of a broader project being carried out by Rachel Watson - A PhD student at UTS. Her project is looking at the full range of costs and benefits of decentralised recycled water systems.

The survey will take approximately 20 minutes to complete. Participants will receive a $20 Woolworth's gift card as a small token of appreciation.

Your responses can remain anonymous if you wish. However, the full results of the surveys will be provided to Sydney Water, who has funded the PhD.

If you want to know more about this research you can contact Rachel Watson - rachel.watson@uts.edu.au

If you have concerns about the research, and would like to talk to someone who is not connected with the research, you may contact the Research Ethics Officer on 02 9514 772, and quote this number (2011242A).

***1. What recycled water scheme/ property do you work at?**

***2.Whatisyourrole?**

The Plant - source and capacity

We would like to know more about the recycling scheme and plant you operate.

***3. What type of scheme do you operate?**
Please tick as many as apply.

- ☐ Sewer mining
- ☐ In-building wastewater
- ☐ Stormwater
- ☐ Greywater
- ☐ Groundwater
- ☐ Other, please specify

Decentralised recycled water schemes - capacity building project

***4. What is the capacity of the plant?**

- ◯ Less than 250 kL/day
- ◯ 250 kL/day - 750 kL/day
- ◯ 750 kL/day - 1 ML/day
- ◯ More than 1 ML/day
- ◯ Don't know

***5. How much recycled water does the plant actually produce on an average day?**

- ◯ Less than 250 kL/day
- ◯ 250 kL/day – 750 kL/day
- ◯ 750 kL/day – 1ML/day
- ◯ More than 1ML/day
- ◯ Don't know
- ◯ Other, please specify

Users and uses of recycled water

***6. Who are the main customers for the plant?**

Please choose as many as apply.

- ☐ Residential
- ☐ Commercial
- ☐ Retail
- ☐ Industrial
- ☐ Don't know
- ☐ Other, please specify

Decentralised recycled water schemes - capacity building project

***7. What is the recycled water used for?**

Please choose as many as apply.

- [ ] Irrigation
- [ ] Outdoor watering
- [ ] Toilet flushing
- [ ] Washing machines
- [ ] Cooling towers
- [ ] Industrial use
- [ ] Don't know
- [ ] Other, please specify

The Plant - operating time and performance

***8. How long has the plant been operating for?**

- ○ Under 6 months
- ○ 6 - 12 months
- ○ 1 - 2 years
- ○ 2 - 3 years
- ○ 3 - 5 years
- ○ More than 5 years
- ○ Other, please specify

***9. Is the scheme currently operating?**

- ○ Yes
- ○ No

Plant operation (1)

Decentralised recycled water schemes - capacity building project

***10. Have there been issues that caused the plant to stop operating?**

- No
- Don't know
- Yes, please specify

***11. Approximately how often has the plant shut down?**

- 0
- Once a year
- Twice a year
- 3-5 times a year
- 5+ times a year
- Other, please specify

Plant operation (2)

***12. Please explain why the plant is not operational.**

Operational issues and challenges

These questions will help us understand the issues typically faced when operating decentralised recycled water schemes.

Decentralised recycled water schemes - capacity building project

***13. From the list below, please indicate whether you have experienced any issues or challenges.**

If you answer yes, please describe the issue(s) and how it was resolved (if at all) in the box at the end.

	Yes	No	Don't know
Third party involvement (planning, construction or delivery)	◯	◯	◯
Design phase	◯	◯	◯
Sludge management	◯	◯	◯
Equipment failure	◯	◯	◯
Odour	◯	◯	◯
Noise	◯	◯	◯
Maintenance	◯	◯	◯
Management issues	◯	◯	◯
Lack of space	◯	◯	◯
Water quality	◯	◯	◯
Customer complaints	◯	◯	◯
Other issues	◯	◯	◯

Please describe the issues you have experienced and if they have been resolved, how this was achieved.

Involvement with scheme

Decentralised recycled water schemes - capacity building project

***14. At what stages have you been involved with this scheme?**

Please select all that apply.

- [ ] Planning
- [ ] Design
- [ ] Construction
- [ ] Commissioning
- [ ] Ongoing operations and maintenance
- [ ] Management
- [ ] Other, please specify

***15. How long have you been involved with this scheme?**

- ○ Under 6 months
- ○ 6 - 12 months
- ○ 1 - 2 years
- ○ 2 - 3 years
- ○ 3 - 5 years
- ○ More than 5 years

Training - Formal qualifications

These questions will help us understand if there is a demand for training courses or further skills development.

***16. Do you have a qualification that helps you perform your role?**

- ○ Yes
- ○ No

Qualification details

Decentralised recycled water schemes - capacity building project

***17. What qualifications do you have? Please select the type of qualifications you have from the list below and provide details.**

- [ ] TAFE
- [ ] University
- [ ] Private/ Industry e.g. AWA
- [ ] Other
- [ ] Please provide details of any qualifications you have

Other training and experience

***18. What training have you been given to help you perform your role?**

Please select all that apply

- [ ] None
- [ ] Learn from operating manuals/ guides
- [ ] Technology provider assistance
- [ ] Hand over period from previous operator
- [ ] Learn on the job
- [ ] Other, please specify

***19. Have you operated any other decentralised recycled water schemes?**

- ( ) Yes
- ( ) No

Involvement with other schemes

***20. Please specify which other schemes you have worked on AND how long you operated the schemes for.**

Work related experience

Decentralised recycled water schemes - capacity building project

***21. Have you had any other experience that helps you perform your role (e.g. work in related industries)?**

- ◯ No
- ◯ Yes, please specify

Further learning opportunities

***22. Are there any other courses or learning opportunities that you would like to participate in?**

Please select all that apply.

- ☐ No
- ☐ Visits to other schemes
- ☐ Networking with other operators
- ☐ Coaching
- ☐ Courses, please specify

Decentralised recycled water schemes - capacity building project

***23. Are there any aspects of recycling, plant operations or plant management that you would like to learn more about or gain experience in?**

Please select all that apply.

- [ ] No
- [ ] Recycled water guidelines
- [ ] Water Industry Competition Act
- [ ] Plant management
- [ ] Risk management frameworks
- [ ] Emergency response procedures
- [ ] Reverse osmosis
- [ ] Membrane bioreactors
- [ ] Saving energy
- [ ] Controlling colour and odour
- [ ] Other (please specify)

Approvals

These questions will help us better understand the approvals required for different schemes, in particular the Water Industry Competition Act 2006 (WICA).

***24. Does this scheme have a Water Industry Competition Act (WICA) licence?**

- ○ Yes, a Water Industry Competition Act 2006 (WICA) Network Operator licence
- ○ Yes, a Water Industry Competition Act 2006 (WICA) Retail Supplier licence
- ○ Yes, both a Water Industry Competition Act 2006 (WICA) Network Operator AND Retail Supplier licence
- ○ No
- ○ Don't know

Involvement in WICA licence process

Decentralised recycled water schemes - capacity building project

***25. How have you been involved with the WICA licence process?**

Please select all that apply.

- [ ] Managed the application
- [ ] Assisted with the application
- [ ] Licence reporting
- [ ] No involvement
- [ ] Other, please specify.

Impressions of WICA process

***26. How would you describe the WICA licencing process?**

Please indicate on the scale below.

	strongly agree		neither agree nor disagree		strongly disagree	N/A
The process was quick	○	○	○	○	○	○
The process was easy to understand	○	○	○	○	○	○
The process was inexpensive	○	○	○	○	○	○

What is the reason for your rating? (after each statement)

Issues with WICA licence?

Decentralised recycled water schemes - capacity building project

***27. Are you experiencing any issues in meeting the WICA licence requirements?**

- No
- Don't know
- Yes, please specify

Applying for a WICA licence

***28. Are you currently applying, or do you plan to apply, for a WICA licence?**

- Yes, we are in the process of applying
- Yes, we plan to apply in the future
- No
- Don't know

WICA knowledge

***29. How would you describe your knowledge of the Water Industry Competition Act 2006 (WICA)?**

- I know a lot
- I know a little
- NA - I don't need to know about it.
- Other, please specify

Other approvals

***30. What other approvals were required for this scheme?**

Please select as many as apply.

- ☐ Local Council Section 68 certificate
- ☐ Trade waste agreement
- ☐ Sewer mining agreement
- ☐ None
- ☐ Don't know
- ☐ Other, please specify

Approvals

***31. How would you describe the approvals process?**

Please indicate on the scale below.

	strongly agree		neither agree nor disagree		strongly disagree	N/A
The process was quick	○	○	○	○	○	○

What is the reason for your rating?

	strongly agree		neither agree nor disagree		strongly disagree	N/A
The process was easy to understand	○	○	○	○	○	○

What is the reason for your rating?

	strongly agree		neither agree nor disagree		strongly disagree	N/A
The process was inexpensive	○	○	○	○	○	○

What is the reason for your rating?

Reporting and emergency management

Decentralised recycled water schemes - capacity building project

***32. What reporting requirements do you have?**

Please select as many as apply.

- [ ] Daily reports
- [ ] Weekly reports
- [ ] Monthly reports
- [ ] 6-monthly reports
- [ ] Annual reports
- [ ] Annual client reports to IPART
- [ ] Incident reports
- [ ] Don't know
- [ ] None
- [ ] Other, please specify.

***33. If there is an incident, what is your emergency management procedure?**

Please select as many as apply.

- [ ] Standard emergency procedures as per the site safety manual
- [ ] Standard emergency procedures as per the the plant operations and maintenance manual Shut
- [ ] down / evacuation procedures
- [ ] I do what I think is best at the time based on my knowledge and experience
- [ ] Don't know
- [ ] Other, please specify

Recommendations and suggestions

Decentralised recycled water schemes - capacity building project

***34. What additional support would you like to help you operate/ manage this scheme?**

Please select as many as apply.

- [ ] No additional support required
- [ ] Improved procedures
- [ ] More staff
- [ ] Additional training
- [ ] Other, please specify

35. Do you have any recommendations or advice for OTHER SCHEME OPERATORS that would help make decentralised recycled water schemes more successful in the future?

36. Do you have any recommendations or advice for REGULATORS that would help make decentralised recycled water schemes more successful in the future?

Thank you

Appendix F: Paper: 'Small water and wastewater workshop 2012'

Distributed (i.e. small scale) recycled water systems have plenty of potential, but there are currently significant limitations to investing in such systems. Which limitations matter most, and to whom, was the subject of a highly interactive workshop at the Small Water and Wastewater Systems Conference in Newcastle from 26-28 September 2012. Some innovative elements in the workshop design ensured strong participation and valuable outcomes. The workshop was hosted by **Professor Cynthia Mitchell** and PhD candidate **Rachel Watson** from the Institute of Sustainable Futures at the University of Technology Sydney.

Cynthia began by reflecting on the fantastic range of presentations throughout the previous two days, which focused on the successes of small solutions, their benefits, and their economic, environmental and societal value. She also noted that different examples discussed at the conference encompassed diverse exposure pathways and enormously diverse levels of risk acceptance.

However, even though there is a range of good examples of small recycled water systems there is still a range of cost, risk and institutional barriers that make it difficult for small recycled water systems to compete against other traditional water services. It is only by understanding what these limits are, who they affect and how they limit effective investment that we can begin to take action that will allow small-scale systems to reach their full potential as a valuable part of urban integrated water management.

Rachel then used Sydney as an example to discuss some of the more challenging barriers to an efficient and competitive local recycled water market that exist in the short to medium term. These included limited commercial opportunities for recycled water to be price competitive due to centralised water supply being secured through large-scale supply options (such as desalination), large wastewater networks having existing capacity and centralised ocean discharge of primary treated wastewater with limited environmental impacts.

However, she also identified that these barriers can be seen as creating a perfect environment to test, monitor and develop the capacity of both the systems and the private sector operators, without placing unacceptable impacts on the existing system, the environment or the community.

This introduction provided the background for an interactive debate on the topic: ‘We don’t invest in small systems because they are too risky’. The purpose of the debate was to encourage participation, stimulate structured conversations, and acknowledge the wide range of different perspectives that co-exist).

The debate was structured to allow time after each speaker for people from the floor to interject and provide their perspective on what had just been said. This format successfully encouraged participation from most of the workshop participants. It also provided participants with time to reflect on alternative perspectives and provide back-up or counter arguments. The debate also highlighted the value in getting groups from very different perspectives to come together in a neutral and supportive space – one where there was definitely space for a diversity of viewpoints. The group agreed that more opportunities for this type of debate to occur would be a positive initiative.

Figure 1. Examples of the voting sheets, colour-coded as follows: Blue: regulators/planners; Yellow: private service providers; Red: Public service providers; Green: advocates/researchers.

The final half of the workshop focused on articulating key limiting factors (both those identified through the debate and others) and ranking their importance from different perspectives. The first step was for participants to identify all the key limitations from their perspective. Each limitation was \then categorised as either limits relating to relative cost and centralised pricing; limits relating to risk and uncertainty; or limits regarding institutional and regulatory frameworks.

The limitations were then put up on boards and participants were given 10 votes each to use in whatever combination they chose, to vote for what was most and least important from their perspective (see Figure 1). Voting dots were colour-coded so that different perspectives could be tracked in the voting process. Using a voting process that included both the positive and negative position and reflected the different perspectives within the group provided some interesting and useful distinctions.

Key Outcomes

The following key observations can be made from the debate and voting processes:

Overall:

The economics of small systems is a function of the institutional arrangements and the rules that are associated with them.

As with any emerging industry the uncertainty that exists within so many areas (particularly cost, benefits, public health risks, ongoing performance management, benefits and costs to existing centralised system infrastructure and customers and long-term markets for recycled water) can create barriers and increase risk perceptions.

Planning and Regulation:

The lack of a coordinated process for identifying opportunities for small systems in advance of centralised investment was seen as very important by regulators and private investors in particular, but it scored votes from all groups.

Private investors also thought the efficiency of small system investment could be improved by a better process for identifying what scale of system was appropriate in what circumstances. This would support the most efficient mix of small and large systems within an urban area.

Regulators, utilities and private investors suggested small recycled water investment would benefit from a consistent approach to regulation.

Costs and Price:

- The cost of regulation, both from a regulatory oversight and resourcing perspective and from a system validation and auditing perspective, was seen as important by all groups.

- The limitations of an inflexible price regulation system was seen as important by regulators/planners, sustainability advocates and public utilities, but was not a high priority of private investors.
- Knowing how to allocate and share costs and risks and rewards was a high priority for everyone.

Risk and Uncertainty:

Unsurprisingly, the planners/regulator group was particularly concerned with clearly identifying and understanding how to manage the risks.

The private industry rated capacity building and having a minimum or accepted level for operators and training as highly important; however, this area also received votes from every sector as being important.

The process for ranking both in the positive and the negative provided some useful distinctions. In general there was limited voting in the negative. One of the main areas to attract a negative vote was the potential of the private sector cherry-picking profitable schemes and leaving the expensive ones to the general customer base. This category clearly demonstrated the difference in perspectives because only the private investors rated this as not important, and only the public utilities rated it as important.
Using different colours for the different perspectives was also a useful exercise, as it was very valuable to see where an issue was seen as important from a range of perspectives, and where it was the focus of only one or two groups.

Overall the workshop provided a great opportunity for a range of participants from different backgrounds, interests and perspectives to engage in open and robust discussion on the key limiting factors for investment in small systems. It was agreed that having the opportunity to engage in these forums is rare, but very valuable. As this workshop was held at the Small Water and Wastewater Systems Conference most (but not all) of the participants were advocates of small systems. In this context it was useful for participants to clearly identify what could limit investment in small systems and for whom these limits were most important. This will prove extremely useful in guiding work to overcome these limitations

Appendix G: Supplementary material for Chapter 7: Acts, regulations, policy documents, special reports included in analysis

Supplementary material table: Relevant federal and state regulations and policies used in the analysis

	Policy	Acts/ Regulations	Guidelines	Government documents
Federal	National Water Initiative) National Competition Policy		National Water Quality Management Strategy Guidelines Guidelines for Sewerage Systems – Reclaimed Water (ARMCANZ/ANZECC 2000) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1), 2006 National Plumbing and Drainage Code AS3500:2003	National Water Reform Framework (CoAG 1994) (only included recycled water from 2003) Urban Water Recycling: National Water Commission position (2010), National Water Commission Review of Pricing Reform in the Australia Water Sector, (2011) National Water Commission Competition in the Australian urban water sector (LECG 2011) Urban Water Markets (2008) Frontier Economics Externality Pricing in the Australian Water Sector (2011), Frontier Economics Efficient water resource pricing in Australia: an assessment of administered scarcity pricing in urban areas (2011) Frontier Economics Pricing principles for recycled water and stormwater reuse (CIE 2010)

	Policy	Acts/ Regulations	Guidelines	Government documents
				Access dispute between Services Sydney Pty. Ltd and Sydney Water Corporation Arbitration report (Australian Competition and Consumer Commission 2007) Australia's Urban Water Sector (Productivity Commission 2011) A discussion Paper on the Role of the Private Sector in the Supply of Water and Wastewater services (Department of the Prime Minister and Cabinet 2006)
State (NSW)	NSW Water Conservation Strategy (DLWC 2000) Metropolitan Water Plan (2004, 2006, 2010) NSW Government, Sewer mining policy (2008) Sydney Water Developer Charges The Precinct Acceleration Protocol Sydney Water Trade Waste	Public Health Act (1991) Sydney Water Act (1994) and associated material including second reading speech Sydney Water Operating Licence – (2000-2005,2005-2010, 2010-2015, 2015-2020) NSW Code of Practice for Plumbing and Drainage Environmental Planning and Assessment Act 1979 + regulations State Environmental Planning Policy (Sydney Region Growth Centres) 2006 State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004	NSW Guidelines for Urban and Residential Reuse of Reclaimed Water Use of Effluent by irrigation (2004)NSW Department of Environment & Conservation) Interim NSW Guidelines for Management of Private Recycled Water Schemes, 2008	Prices for special water, sewerage and drainage services for the Rouse Hill development area (IAPRT 1993) Pricing arrangements for recycled water and sewer mining (IPART 2006) Price determinations for water and wastewater services Sydney Water (numerous) Wholesale pricing review (IPART 2016) (and associated public submissions) Urban Water Regulation Review – Discussion Paper: Joint review of the Water Industry (and associated submissions) (NSW Government 2012) Assessment Process for Recycled Water Scheme Avoided Costs – Water Guideline (2011) - IPART

	Policy	Acts/ Regulations	Guidelines	Government documents
	Policy	Protection of the Environment Operations Act 1997 + regulations Water Industry Competition Act 2006 & Regulations (+ reviews) Independent Pricing and Regulatory Tribunal Act Local Government Act (1993) – s68, s60 The Local Government Amendment (Stormwater) Act 2005 and supporting regulation Energy Administration Amendment (Water and Energy Savings) Act 2005		Draft Development Servicing Plan 2016 – Hoxton Park (2016) Sydney Water(Sydney Water 2016) Literature Review – underlying cost and industry structures of metropolitan water industries (2007) IPART Hawkesbury-Nepean Catchment Action Plan 2007-2016 (2008) Hawkesbury-Nepean Catchment Management Authority Water Conservation and Recycling Implementation Report (various) Sydney Water

Appendix H: Appendix to Chapter 4: Review and synthesis of the diverse impacts of local recycled water

Supplementary material: Examples of studies identifying and measuring the impacts of local recycled water systems

		Impact	Who is impacted	Examples	Location	Comments
Efficient urban water services – the interaction between centralised and distributed	Infrastructure investment	**Efficiency though flexible investment**	Utility, community	(Deng et al. 2013)	Kent Ridge Campus, University of Singapore	Modelling process demonstrated additional value to outcomes and changing preferred outcome when flexibility of options is explicitly included in the decision-making process.
			Utility, community	(Mukheibir et al. 2012)	Melbourne	Scenario analysis - Modelling process flexible integrated approach investing opportunistically in demand management and integrated water solutions provides large benefits over just in time large infrastructure investment
			Utility, community	(New South Wales Government 2006)	Sydney	Options approach to develop the best suite of options that provided an optimal supply and demand mix, including diversification, for Sydney, and considered 'the cost of the whole portfolio of measures, not just the cost of each option in isolation'
		Inefficiency through duplication	Owner, customer, utility, community			
		Inefficiency through loss of economies of scale (management and treatment)	Owner, customer, utility, community	(Clark 1997)	Adelaide, SA	Similar overall costs for 500 – 1 million services Economies of scale for larger treatment plants are offset by diseconomies of scale in networks.
				(Fane, Ashbolt & White 2002)		Economies of scale around 1000 connections Found that the economies of scale in sewage treatment are balanced by the diseconomies of scale of pipe networks at around 1,000 connections
				(Mitchell		Economies of scale for IUWM around 1,000-10,000 connections

		Impact	Who is impacted	Examples	Location	Comments
				2004)		
				(Friedler & Hadari 2006)	Israel	Finds on-site MBR-based system becomes economically feasible when the building size exceeds 40 storeys. Cluster MBR-based systems, incorporating several buildings together, became feasible when the cluster size was four buildings or more (each 10 storeys high). Details assumptions underlying cost calculations
		Gains in wider system reliability/ resilience	Utility, community	(Wolff 2008)	Theoretical model	Modelling method for calculating constant-reliability unit costs that adapts some concepts and mathematics from financial portfolio theory. Comparison on a constant-reliability basis can significantly change the relative attractiveness of options. That is: surface water (which is often cheap) is less favourable when reliability is taken into account and options that are uncorrelated (recycled water) or inversely correlated (outdoor water conservation) with existing supply sources will be more attractive than they initially appear. Notes options should be evaluated and chosen as packages rather than individually
		Individual system vulnerability to shocks, loss of reliability	Owner, customer			
		Infrastructure capital and operating costs	Developer, owner, customer	(Yamagata et al. 2003)	Tokyo Japan	Economies of scale after 100m^3/day (1ML./day). Survey of 325 buildings with onsite recycled water, where reuse and onsite systems a regulatory requirement
				(Zhang, Wang & Wang 2010),(Liang & van Dijk 2010)	Beijing, China	Costs range from 0.1-0.42 Yen*10^4/m^3 Noted economies of scale are important with halving of the $/kL from 200kL/day to 1ML/day plant size. However, also noted the importance of utilisation, showing a rapid decrease in efficiency with utilisation rates under 80%.
				(Asano 2002)	California USA	$0.50/m^3 capital - overview of previous work
				(Hurlimann & McKay 2005), (Marsden	Rouse Hill	$3-$4/kL ($2004) At the time recycled water was charge at $0.28 and potable water was $0.98

		Impact	Who is impacted	Examples	Location	Comments
				Jacob Associates 2006)		
				(Radcliffe 2004), (Marsden Jacob Associates 2006)	Sydney Olympic Park WRAMS	Direct operating cost : $1.60/kL Recycled water subsidised – as sold at $0.83/kL
				(Butler & MacCormick 1996)		Theoretical modelling NPV savings of 30% for communities of up to 3000 people requiring advanced nutrient removal for decentralised reuse over conventional treatment.
				(Giurco et al. 2010)	Port Melbourne, Victoria	Cost effectiveness modelling exercise for industrial reuse. Cost per kL for around 250-300kL/day MBR is about $8-9/kL About $2.5 million capital and $420,000-550,000 opex. Suggested that increasing water and trade waste prices may make water recycling opportunities more cost-competitive with the price of water from the centralised mains water supply. However, under current scenario only becomes cash positive after 10yrs either with a subsidy or interest free loan
				(Ogoshi, Suzuki & Asano 2001)	Fukuoka City, Japan	Reported production cost $2.01/m^3
				(Chanan & Ghetti 2006)	Beverley Park, NSW	$1.81/kL with 15 year capital payback
				(DeCarolis, Hirani & Adham 2009)	USA	4ML/day MBR cost around $0.50-$0.65/ML (p. A-9) Presents cost break downs for MBR plants of 4ML/day and 20ML/day so larger plants. (1MGallon and 5 MGallons).
				(Daigger et al. 2005)		3.8ML/day MBR plant cost around $0.48–0.58/m3.
				(Côté, Masini & Mourato		Modelling - Suggest costs of $0.40/m^3 for MBR total lifecycle cost at capacities over 75,000m^3/day (75ML.day)

		Impact	Who is impacted	Examples	Location	Comments
				2004)		
		Avoided centralised system costs (augmentation, transport, treatment)	Utility, community	(Butler & MacCormick 1996)	Earring, NSW	Capital savings due to delays of pipe and treatment augmentation in range of $5 million Notes wide range of reported costs and the importance of understanding components of reported costs.
				(Anderson & Iyaduri 2003)	Finley, NSW	Capital avoided costs of 50% over traditional water and wastewater augmentations Inland city so potential for savings through load based licence costs. But no numbers published or discussed.
				(Anderson 2006)	Western Sydney, NSW	Modelling for greenfields release areas in western Sydney Provision of a third-pipe recycled water system is estimated to reduce potable water reticulation costs by about $640/ house
				(Anderson 2006)	Western Sydney, NSW	Modelling for greenfields release areas in western Sydney Energy of recycled water approximately 0.9MWh/ML compared to Shoalhaven transfers of 2.4MWh/ML
				(NSW Independent Pricing and Regulatory Tribunal 2007)		Biological oxygen demand (BOD) is substantial driver of secondary wastewater treatment costs. BOD can also impact transport costs, via corrosion of pipelines. The cost of combating BOD impacts can range from minimal to almost 20 per cent of capital costs and 25 per cent of operating expenditure.
				(Water Services Association of Australia 2007)	Set of theoretical case studies based on Australian data	Models a set of theoretical case studies to examine the cost breakdown of wastewater treatment and transport and the impact of calculating avoided costs based on different methodologies. The cost of existing assets in all of the case studies was dominated by the cost of transmission, which is common for water and wastewater systems. This cost is dominated by wet weather flows. Treatment and disposal costs were 22%-37% of total costs and are driven by volumes, BOD and SS.
				(Independent Pricing and	Sydney	Methodology for calculating avoided costs for recycled water schemes – has been applied to Rouse Hill

		Impact	Who is impacted	Examples	Location	Comments
				Regulatory Tribunal 2006)		
		Avoided water and wastewater charges	Owner, customer	(Sydney Olympic Park Authority 2006)	Sydney Olympic Park	Cost of recycled water is set $0.15 below potable water price. Notes this does not reflect cost of service provisions.
			Customer	(Zavoda 2005)	Solair building New Your	New York City Department of Environmental Protection Comprehensive Water Reuse Program, which offers a 25% reduction in water and sewer charges for buildings with reuse systems that reduce potable water consumption by at least 25%.
				(World Green Building Council 2013)		actual savings in green buildings only about 3% were attributed to water (p. 56). Not all of these are attributed to recycled water as some are water efficiency.
				(Gomez 2014)	Tahmoor Coal, NSW	the water recycling system offsets potable water purchase such that the operating cost of treatment plant is less than water purchasing by about $150,000/yr This number will vary depending on water, wastewater and tradewaste price structures and the amount used.
		Centralised system lost revenue	Utility	(Independent Pricing and Regulatory Tribunal 2015)	Sydney	Current discussion on how centralised common assets should be funded and what level of revenue entitlement is appropriate in a competitive market.
		Stranded and unfunded assets	Utility	(National Water Commission 2011)	Murray Darling Basin	Termination and exit fees used to exist in the Murray Darling Basin area but exit fees were found to be an impediment to trading and made illegal. The price structure was changed to fixed infrastructure charges based on delivery shares rather than water access entitlement has facilitated efficient trade. Since the abolishment of exit fees there has been a substantial increase in entitlement trade out of private irrigations districts.
		Degraded centralised assets due to low	Utility	(Sydney Water 2010),	Sydney, NSW	Policies, processes and modelling for managing waste discharges and minimising low flow damage from local recycled water

		Impact	Who is impacted	Examples	Location	Comments
		flows		(Sydney Water 2006)		systems.
		Degraded recycled water assets due to water quality	Customers	(Institute for Sustainable Futures 2013)	Australia	It was shown that some customers bore costs due a different standard of water, while others benefited.
		Social health benefits associated with healthy open space	Community	(Do & Grudnitski 1995)	Ranchero Bernardo, San Diego, California	Hedonic pricing study.717 sales transactions. Golf Course adds 7.6% to property's value.
				(Sugiyama et al. 2008)	Adelaide, South Australia	A mailed survey collected the following data from adults (n = 1895) in Adelaide, Australia: People who perceived their neighbourhood as highly green had 1.37 and 1.60 times higher odds of better physical and mental health, respectively, compared with those who perceived the lowest greenness.
	Reliable irrigation in times of surface water shortages		Community	(Orchard 2002)		Increase in injuries on hard, dry playing surfaces and artificial surfaces.
			Community	(Otago et al. 2007)	Australia and America	Reviews studies linking injuries to sports ground conditions particularly hardness and grass cover. Appears there is a correlation between injuries and increased ground hardness and reduced grass cover associated with dry conditions. Studies are correlational & epidemiological and are all football related.
			Community	(Jonker et al. 2014)	The Netherlands	Linear regression model. The quantity and particularly quality of urban green are positively associated with quality and length of life. A 1SD increase in the quality of green leads to 0.3-year higher life expectancy and healthy life expectancy. Suggests that urban green reduces stress, stimulates physical activity, improves the microclimate and reduces ambient air pollution.
			Community	(Marsden Jacob Associates 2014c)	Theoretical	$14/person/year when no potable water is available. Theoretical analysis where value of keeping a park green to health was equal to: 1.8%*$782*catchment population*(frequency of restrictions) The 1.8% was from Corti (2003) where it was assumed the attractiveness of an un-irrigated park during drought reduces from

		Impact	Who is impacted	Examples	Location	Comments
						average attractiveness to the lowest quartile of attractiveness, $782 was estimated cost of physical inactivity.
		Valuing healthy open space		(Hurlimann & McKay 2005)	Mawson Lakes, SA	Willingness to pay of $17.80/ customer/yr. Contingent valuation study of randomly sampled residents living in recycled water area. Women, 30-50yr olds and people with high concern for environment all had higher willingness to pay.
				(McConnell & Walls 2005)	Various (literature review of over 60 studies)	Review more than 60 published articles that have attempted to estimate the value of different types of open space. Both the revealed and stated preference studies generally show that there is value to preserving most types of open space land uses, but the values tend to vary widely with the size of the area, the proximity of the open space to residences, the type of open space, and the method of analysis. Property values generally increase the closer they are to golf courses, large natural areas and certain types of wildlife habitat and open space is particularly valued in higher density and smaller block size developments.
				(Mulley, Simmons & Maheshwari 2007)		Finds the value of open space is hard to quantify but provides environmental, social and economic benefits including environmental pollutant filtration, improved community health and social development, revenue generation.
				(Anderson & West 2006)	Minneapolis-St. Paul	Hedonic price study. The value of an average home increases with proximity to parks, special parks, lakes, and rivers. 0.0035% of sales price for every one per cent decrease in the distance to the nearest park; 0.0342% for every one per cent decrease in the distance to the nearest lake. The value of proximity to open space is higher in neighbourhoods that are dense, near the central business district, high-income, high-crime, or home to many children.
				(Bowman, Thompson & Colletti 2009)	Cedar Rapids, Iowa, United States	Transactional analysis: compared capital appreciation on properties in a standard subdivision and one designed to include conservation features (integrated waterways and forested areas) & three times as much open space, hedonic pricing and contingent

		Impact	Who is impacted	Examples	Location	Comments
						valuation The 5 year appreciation rate was double for houses in conservation development. It also appeared they sold faster (half the time) although the sample was not statistically significant. Hedonic pricing showed proximity to open space/ conservation features provided price increase between $462 - $17082, average $882 for standard and $8688 for (conservation subdivision). Biggest increase was proximity to a stream gave a 9.6% property increase Contingent valuation showed average willingness to pay of $US4343. 66% of all respondents indicated willingness to pay for additional open space/conservation features. Of those expressing willingness to pay, 70% indicated that they were willing to pay at least $2000.
				(Blamey, Gordon & Chapman 1999)	Canberra, Australia	Choice modelling experiment with 294 participants skewed slightly towards older more educated males Willingness to pay $18/household/year for an improved greening of Canberra (from brown).
				(Marsden Jacob Associates & Brisbane City Council 2011)	Cabbage Tree Creek, Australia	Willingness to pay $1.20/household/year for a 1% increase in healthy green parks. No methodological details provided.
		Avoided field rehabilitation costs by having adequate irrigation	Community	(Carrow 2006)		Water efficiency can be used to a point, but better results with secure water supply. Without adequate water, declines in turf quality implies a potential for reduction in recreational use, environmental/functional capabilities, and economic use/value of the site, which in turn may adversely affect the direct customer, owners, local economy, and local environment.
				(GHD 2007)	Dandenong,. Australia	Cost of repairing and reinstating fields due to inadequate irrigation ranges from $8,000 - $30,000 with an average of $18,000 Examines ways of valuing the water used for playing fields. (pp14-

		Impact	Who is impacted	Examples	Location	Comments
						15) Suggests triple bottom line value of the water used to keep playing fields viable is financial: cost of water plus cost of repairing or reinstating unused grounds, decline in economic flow on - ABS has income from people associated with volunteer sport social: alternative meeting place costs - antisocial behaviour (worse in rural areas & with youth) (pg4) environmental: reduced nutrients needed to fertilise, reduced nutrients to waterways - if recycled water used. A reduction in grassed areas will also affect their ability to act as sources of oxygen, help to control erosion and influence temperature extremes. Notes even slightly restricted watering regime can impact on the quality and durability of playing fields increasing operating costs.
		Avoiding loss of business due to inadequately or costly irrigation	Customer	(GHD 2007)		Suggests for golf courses you can assume all of revenue is from irrigation so return = $/ML Given some key assumptions, a semi private club with a water consumption of 100 ML and an income of $800 000 would generate a gross return of $8 000/ML.
		Air quality, water quality, beautification enhancements through healthy green space	Community, environment	(Chen & Wang 2009)	China	86,380 Yuan/yr Used opportunity cost method to estimate value of environmental improvements (greening and beautification) via the equivalent cost to clean up a polluted local area.
		Habitat enhancement/ preservation	Environment	(Blamey, Gordon & Chapman 1999)	Canberra, Australia	Willingness to pay $5/household/species (up to $24 for 5 species) to preserve habitat Choice modelling experiment of 294 participants.
		Property value increases with open space and integrated conservation features	Community	(Acharya & Bennett 2001)	New Haven County, Connecticut.	A willingness to pay of $75 for a percentage increase in open space, (p. 234) hedonic property value analysis.
				(Do &	Ranchero	Golf course location adds 7.6 per cent to a property's sales price

		Impact	Who is impacted	Examples	Location	Comments
				Grudnitski 1995	Bernardo, San Diego California, USA	Hedonic pricing study.
				(Lutzenhiser & Netusil 2001)	Portland USA	Hedonic pricing study. Natural area parks increase sales price by $10,648 in $1990, Golf courses $8,849, specialty parks $5,675 urban parks $1,214. Generally, increase in house price with proximity to open space varies with distance and the type of open space. Natural area parks have the greatest increase, compared with. Golf courses, suburban parks and specialty parks.
				(Cho, Bowker & Park 2006)	Knox County, Tennessee	Moving 1,000 ft closer to water bodies increased prices globally by $331 although big range ($12 to $4,232) locally for individual water bodies. Moving 1,000 feet closer to a park was estimated to be $303 in the global model, but ranged from $59 to $1,809 for individual parks. In some areas there was found to be a negative value associated with the park or the waterway - perhaps indicating other factors at play. They suggest perhaps the quality of the park or waterbody or perhaps some other feature is the cause but do not investigate.
		Property value increases with recycled water or green services	Customer	(Marsden Jacob Associates 2014a)	Rouse Hill Australia	Hedonic study approximately $5000 or 0.72% price increase for home with recycled water over similar homes without recycled water.
		Different service standards for similar customers	Customer			
		Different cost impacts for similar customers	Customer, community	(Marks et al. 2003)	Florida USA, South Australia	Residents like cheaper recycled water supply. These earlier schemes provided recycled water at a subsidised rate. Survey of 80 people across 4 recycled water sites.
	Equity		Customer, community	(Po, Kaercher & Nancarrow 2003)	Literature review	Residents generally expect to pay less for recycled water as lesser quality and to encourage uptake.

		Impact	Who is impacted	Examples	Location	Comments
			Customer	(Zavoda 2005)	Solair building, New York	New York City Department of Environmental Protection Comprehensive Water Reuse Program, which offers a 25% reduction in water and sewer charges for buildings with reuse systems that reduce potable water consumption by at least 25%.
				(Menegaki, Hanley & Tsagarakis 2007)	Crete, Greece	Farmers state that they are willing to pay on average 0.15€/m3 of recycled water, which is 55% of the average fresh water price Willingness to use and willingness-to-pay study
		Keeping impacts local	Community			
		Improved water quality through reduced surface water extractions	Environment, community	(Yamagata et al. 2003)	Tokyo, Japan	Average potable water savings of 30%. Survey of 325 buildings with onsite recycled water.
				(Blamey, Gordon & Chapman 1999)	Canberra, Australia	Willingness to pay $42/household/yr for increased river flows for some rivers, up to $62/household/yr for increased river flow for all rivers. Choice modelling study of 294 participants. Compared options for water supply/demand.
Environmental interactions	Reduced extractions / disposal		Environment	(Marsden Jacob Associates 2013, 2014b)	Sydney Australia	Willingness to pay $0.96-$1.35/kL for recycled water to go to the environment Choice modelling.
		Improved water quality through reduced wastewater discharge	Environment, community	(Cooper 2003)	Picton, NSW	Picton reuse project prevented 1,390 kg of phosphorus and 1,685 kg of nitrogen from being discharged to the Hawkesbury-Nepean River system.
			Environment	(Melbourne Water)	Melbourne	Value of nitrogen removal estimated at $6,645 per kg of TN removed Abatement cost
				(Hurlimann & McKay 2005)	Mawson Lakes SA	Willingness to pay: $29.20/customer/yr Contingent valuation study of 139 randomly selecte4ed residents living in recycled water area. (45% response rate) Women, 30-50yr olds and environmentally concerned willing to pay more.

		Impact	Who is impacted	Examples	Location	Comments
				(Mattinson & Morrison 1985)	Peel Harvey Estuary, W.A.	Willingness to pay for improvements $1.41 for visitors, $27.00 for residents (per person per year) Contingent valuation study to identify willingness to pay for improved water quality (reduction in blue-green algae) survey of 45 visitors, 57 residents – doesn't state unit of improvement
			Environment	(Chen & Wang 2009)	China	25,550 Yuan/yr. Benefit of wastewater discharge reduction was estimated as equivalent to a saving of pollution discharge fee.
			Environment	(Liang & van Dijk 2010)	China	3 Yuan/m^3 shadow price of water as proxy.
			Environment	(Molinos-Senante, Hernández-Sancho & Sala-Garrido 2010)	Valencia, Spain	Ranges of value of nutrient removal of 0.0099 - 1.0039 euro/m^3 Estimates environmental benefit of nutrient removal by using shadow prices. Over 22 WW plants included in the study there is a high variability in the value of nutrient removal.
			Environment	(Marsden Jacob Associates & Brisbane City Council 2011)	Cabbage Tree Creek, Australia	Willingness to pay $1.16/household/yr for a 1% increase in healthy creeks and rivers. No information on method provided.
				(Marsden Jacob Associates & Brisbane City Council 2011)	Cabbage Tree Creek, Australia	Estimates environmental benefits of phosphorous removal at $76,000 to $200,000/ tonne of phosphorus/yr. Proxy used as cost of removal through traditional treatment.
		Reduced nutrient use for crops	Customer, environment	(Cooper 2003)	Picton, NSW	Picton uses nutrients that would be discharged to Hawkesbury-Nepean River to help grow crops.
				(Marks et al. 2003)	Florida USA, South Australia	Residents in Altamonte Springs (Florida) and New Haven (SA) are very aware of the nutritional value of reclaimed water for plant growth, with some acknowledging that this cheaper resource improves residential properties. Survey of 80 people across 4 recycled water sites.

		Impact	Who is impacted	Examples	Location	Comments
	Nutrient capture / disposal			(Toze 2006a)		Some crops (e.g. rice, salad) have been shown to be more productive when irrigated with treated effluent. Fertiliser requirements have been shown to reduce over time due to accumulation of nutrients in the soil particularly nitrogen when crops are irrigated with treated effluent.
				(Hurlimann & McKay 2007)	Mawson Lakes, SA	Willingness to pay $0.02/kL for reduced saltiness for garden watering Conjoint analysis of 136 randomly selected residents of Mawson Lakes. Results indicate that for garden watering having 'low salt levels' is the most important attribute of recycled water, for clothes washing 'colourless' is the most important attribute, and for toilet flushing a 'low price' was the most important attribute.
		Reduced crop yields and soil quality due to salinity	Customer, environment	(Toze 2006a)		Nutrients- some can be good (decrease fertiliser demand and increase crop yield) but too much particularly of dissolved organic carbon and in some instances nitrogen can affect the soil structure. (p. 154) Sodium is particularly hard to remove. can affect ability of soil to carry water, affects some crops yields more than others.
				(Raveh & Ben-Gal 2016)	Israel	Prolonged irrigation with recycled water with a high salt content has change soil conditions, and increased salt content in plants themselves. While soil conditions can be managed, salt levels in plants are not toxic and salt levels in edible produce are within health safety levels the upward trend is thought to be concerning Comparative study with samples taken over 1993-2012.
		Reduced water quality due to salinity and nutrients from recycled water use, runoff or discharge	Environment	(Estévez et al. 2010)	Spain	Found that golf courses were being excessively watered with recycled water. While it stopped salt build up it meant there were associated water quality issues with run-off.
		Dynamic competition	Owner, customer,	(Independent Pricing and	Sydney, NSW	Discussion that private supply of recycled water has introduced dynamic competition although its value is not quantified.

		Impact	Who is impacted	Examples	Location	Comments
			community	Regulatory Tribunal 2015)		
		Leverage private funds	Community			
A changing urban water industry	Existing services – new options	**Servicing new developments outside of planning horizon**	Developer, customer			
		Develop and maintain regulatory regimes	Regulator			
		Last resort/ failure contingencies	Owner, utility, regulator	(OFWAT 2003)	UK	Identifies need to plan and provide revenue for planning for costs associated with supplier of last resort in competitive market for essential services.
		Individual reliability (avoid restrictions)	Customer	(Howe et al. 1994)	Colorado, USA	Reviews willingness to pay (save) for increases (decreases) in system reliability. Contingent Valuation in three Colorado Towns. Results depend on current reliability and scale of change.
			Customers	(Hurlimann & McKay 2005)	Mawson Lakes SA	Willingness to pay of $8.60/customer/yr. Contingent valuation study of 139 randomly selecte4ed residents living in recycled water area. (45% response rate) Women and 30-50yr olds willing to pay more.
			Customers	(Hurlimann 2009)	Bendigo, Victoria	Willingness to pay $7.66/kL for recycled water delivered to their house. (in comparison to $1.33 for potable water which was restricted). Contingent valuation study of 305 office workers, during extreme drought conditions where water cartage industry (costs much higher than potable water) already in existence.
			Customers	(Hensher, Shore & Train 2006)	Canberra, ACT	Generally customers had low willingness to pay for avoiding low level restrictions, or even infrequent or inconsistent high level restrictions (i.e. not year round). Willingness to pay 31.26% of bill water bill ($239) on average, for a reduction from continuous restrictions to virtually no chance of

		Impact	Who is impacted	Examples	Location	Comments
						restrictions. Similarly WTP from 1 in10 years to 1 in 20 years is $11.95 on average or from 1 in 20 years to 1 in 30 years, is $3.98 on average. Compensation of $227 would be required to accept an increase in the frequency of restrictions from 1 in 20 to 1 in 30years. Stated Choice experiment in Canberra with 211 residential customers, and 205 businesses. Three restrictions levels were discussed, one month, all summer and all year. Businesses and residents had about same willingness to pay.
				(Tapsuwan et al. 2007)	Perth, Australia	Choice experiment with 414 responses. Willingness to pay 22% more to be able to use sprinklers up to 3 days a week. Willingness to pay 50% more for new water source vs. restrictions
			Customers	(Marsden Jacob Associates & Brisbane City Council 2011)	Cabbage Tree Creek, QLD, Australia	Willingness to pay $2.84/household/yr for an increase in years without restrictions (1 in 50 to 1 in 100). No details given on method or sample size.
		Green building benefits	Developers, owners, customers	(Green Building Council of Australia 2005)		Benefits include lower development control costs, improved risk mitigation and management, higher tenant retention, lower renovation costs, faster lease-up periods, lower overheads, higher returns, more flexible space planning, more productive and healthier environments, access to financial incentives and tax credits, a baseline measure to earn carbon credits, lower insurance costs, increased interest by Ethical Investment Funds, a better industry image.
			Developers, owners	(Fuerst & McAllister 2011)		Hedonic pricing study demonstrated a rental premium of approximately 5% for LEED certification and 4% for Energy Star certification (p.67). Sales price premium of 25% for LEED-certified buildings and 26% for Energy Star (p.68).
	Serv ice new	**Branding**	Developers, owners,			

		Impact	Who is impacted	Examples	Location	Comments
			customers			
		Servicing customer preference for recycled water & sustainable services	Customers	(Dolnicar & Schäfer 2009)	Australia	Online survey of 1000 Australians. Shows preference for recycled water for non-body contact uses over desalination.
				(Blamey, Gordon & Chapman 1999)	Canberra, Australia	Willingness to pay $47/household/yr for recycled water for outdoor uses, but a negative $55/household/yr for recycled water for all purposes. Choice modelling study of 294 participants in Canberra, skewed slightly towards older, more educated males. Looks at participants preferences for a range of supply options. High preference for water savings and recycled water.
				(Marsden Jacob Associates 2013, 2014a)	Sydney, Australia	Sydney households are on average willing to pay between $2.65 and $48.38 per year for an additional 10---40GL per year of recycled water by 2030 This equates to: $0.45-$1.22/kL for recycled water supplied to Western Sydney Homes $1.49-$1.51 for recycled water to be supplied to councils $2.06-$3.80 for recycled water to be supplied to industry Choice modelling, where participants indicated a willingness to pay, even if they didn't directly get the recycled water themselves, and were willing to pay now, even though it was recognised it would take some time for the projects to come on line.
		Health risks	Customer	(Marks et al. 2003)	Florida USA, South Australia	Questions cost of toilet flushing as end use for residential as accounts for only 14% of water use, but 50% of plumbing costs and increased risk of cross connections. Survey of 80 people across 4 recycled water sites. Interesting how this perception has changed slightly.
				(Toze 2006a)		Microbial pathogens which enter the environment through faecal contamination. (e.g. viruses, bacteria, helminths, protozoa) these are usually of greatest concern to public and health regulators. Viruses usually need human host and do not impact animals. Bacteria (e.g. legionella - minimal risk but possible), Helminths (e.g.

		Impact	Who is impacted	Examples	Location	Comments
						round worm and hook worm) high risk in untreated sewage, but limited in treated sewage. Pharmaceuticals - EDCs (endocrine disrupting chemicals) low risk in treated sewage due to low concentrations and low half-lives, no risk to crops but some risk to animals in constant contact with water (e.g. alligators). (p. 152) PAC (pharmaceutically active compounds) little risk to humans but can affect soils by potentially creating antibiotic resistance. (p. 153) Heavy metals - generally removed by treatment - untreated can be taken up by crops and could pose some risk if primary dietary item, treated wastewater application shows no noticeable difference in crops to background levels.
				(Toze 2006b)		Membrane filtration has shown to have 7 log removal for faecal coliforms and 6 log removal for Giardia. Table 2 shows log removals for pathogens and different treatment processes.
		Perceptions and aesthetics	Customer	(Marks et al. 2003)		All customers of New Haven noted odour, colour or sediment issues. Survey of 80 people across 4 recycled water sites.
			Customer	(Po, Kaercher & Nancarrow 2003)	Review international and local	Acceptance for recycled water generally does not translate to local acceptance to use Interestingly this perception is still reflected in preference in MJA study in Sydney (see below) where higher willingness to pay for industrial over residential.
			Customer	(Watson 2014)	Parramatta, NSW, Australia	Qualitative online survey of 146 building occupants. Sydney Water building survey, demonstrates aesthetic problems can influence perceptions of scheme negatively. Found a high positive response to in-building recycled water despite some initial problems.
			Customer	(Hurlimann & McKay 2007)	Mawson Lakes, SA	Willingness to pay of 7c/kL to reduce colour, 6.5c/kL to reduce salt and 6c/kL to reduce odour for washing machine end use. 1c/kL reduce odour in toilet flushing. Conjoint analysis of 136 randomly selected residents of Mawson Lakes. Results indicate that for garden watering having 'low salt levels' is the most important attribute of recycled water, for clothes washing

		Impact	Who is impacted	Examples	Location	Comments
						'colourless' is the most important attribute, and for toilet flushing a 'low price' was the most important attribute.
		Education	Community, regulator, utility, customer	(Dolnicar, Hurlimann & Nghiem 2010)	Australia	Increase in acceptance with education and process information Random survey of 1000 people.
			Community	(Liang & van Dijk 2010)	China	Cost of an equivalent public awareness campaign to reach the same number of people as are using the schemes.
		Contributing to liveability in the urban landscape	Community, environment	(Hurlimann & McKay 2005)	Mawson Lakes SA	Willingness to pay for proximity to wetlands is \$8.60/customer/yr Contingent valuation study of 139 randomly selected residents living in recycled water area. (45% response rate) Women, 30-50yr olds and environmentally concerned willing to pay more. Lots of people stated not willing to pay for wetlands which is contrary to stated reason for living in area (i.e. top reason is wetlands).
				(Roseth 2006)	Adelaide, Darwin, Melbourne, Perth, Sydney	70% of respondents consider having a healthy, green garden as important and half believe it is their right to use water to keep garden healthy phone surveys of a random sample of 3,500 residents, 700 each of Adelaide, Darwin, Melbourne, Perth and Sydney. In addition, face-to-face interviews were conducted with a random sample of 56 of the phone survey respondents.
	liveabili ty	**Contributing to urban cooling through retaining water in the environment**	Community, environment	(Jacobs & Delaney 2015)	Penrith, NSW, Australia	Heat mapping Health issues associated with heat. Urban environment can increase heat effects. Retaining water and healthy green space, particularly with tree cover can reduce temperatures by 8^0C.
		Providing opportunities for integrated water management	Environment	(Anderson & Iyaduri 2003)	Finley, NSW	Potential for stormwater integration noted but not explored. Minimal due to most rainfall in winter (limited irrigation requirements).

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