Australian Water Recycling
Centre of Excellence

Discussion Paper

Theme 3:
Social, Institutional and Economic Challenges

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1 Introduction

Recent reviews by the National Water Commission (NWC 2009), the Productivity Commission (2008) and COAG (2008) conclude that whilst the Australian National Water Initiative (NWI) reform process has made substantial progress in addressing the constraints and tensions associated with mature rural water economies, the reforms have had limited influence on the management of urban water systems. In the five years since the formulation and ratification of the NWI, the context stimulating urban water reform has altered substantially (NWC 2009, Radcliffe 2007). Guided by the changed context and the recent biennial assessment, the National Water Commission (2009) contends that the NWI provisions, commitments and evaluation metrics for urban water reform are necessary but insufficient to meet the challenges of contemporary urban water reform. Recently articulated key principles by the Productivity Commission (2008) and COAG (2008), argue for similar modification to the NWI to achieve a more ambitious urban water reform agenda that is coordinated across managing agencies and sectoral interests.

Recycled water has assumed a recognised and important role in the portfolio of urban water management strategies. The social, economic and institutional challenge of recycling is pivotal to achieving water sustainability in Australia. The contemporary challenge for the urban water sector is one of meeting community and political expectations for a reliable supply of fit for purpose water in a cost effective manner, in the face of increasing and diverse water demand, extended drought, climate change and new technology (WSSA 2009). Australian Governments have responded by committing to urban water recycling initiatives, as part of a wider transition to water sensitive cities and total water cycle management (NWC 2007, PMSEIC 2007).

As the level of water recycling increases, the choice and implementation of alternative policy instruments, governance arrangements and incentives to assist in the promotion and coordination of water recycling also assume increasing importance. Instrument and governance frameworks will need to provide for the rights of access, rights to exclude, rights of ownership, rights to manage source and treated water in a changing world and the obligations of final use of recycling operations. The acceleration of implemented and intended recycling projects, made more acute with increasing drought frequencies, has warranted a systematic and comprehensive analysis of alternative policy options and frameworks. These in turn require a systematic analysis of social, institutional and economic factors. Policy and commercial initiatives that fail to recognise and account for the site specificity and diversity of technical constraints and opportunities, economic characteristics and public attitudes are unlikely to make substantial contributions to water recycling objectives.

NWC (2007, 2009) and COAG (2008) appraisals of the state of urban water reform, inclusive of recycling, stress the research deficits in social, institutional and economic factors and contend that improved understanding in these research areas is central to increasing the levels of recycling production and acceptance.

The primary objective of this discussion paper is to identify and articulate by way of literature-based insights and practitioner experience, the main social and economic research themes to be considered by the Water Recycling Centre of Excellence in the development of its Strategic Research Plan. In a coordinated approach with the Technology, Risk Analysis and Sustainability themes, application of the suggested body of research is intended 1) to enable a rigorous, evidence based appraisal of the current state of water recycling practice; 2) to identify necessary social and economic research questions to improve both practice and implementation; and 3) to identify and sequence the most appropriate research tasks and methodologies.

2 Background to the current state of practice of urban water recycling

The NWI (COAG 2004) remains the primary and enduring national blueprint for Australian urban and rural water reform. Despite considerable change in Australia's urban and rural water circumstances in the five years since the NWI was ratified, the policy prescriptions and objectives continue to be widely accepted as salient and appropriate for Australia.

In accord with the National Water Initiative paragraph 92 (iv), The Australian, State and Territory Governments committed to a review of institutional and regulatory models for achieving integrated urban water cycle management. In principle there are three fundamental objectives of Integrated Water Cycle Management and Water Sensitive Urban Design (NWC 2007). *First*, to minimise the impact of urban development on regional water balances inclusive of the claims of dependent ecosystems and the natural environment. *Second*, to address water scarcity in cities by diversifying supply options to include all components of the urban water cycle. *Third*, to maximise urban water "metabolism" by retaining, reusing and recycling water entering the urban water management cycle for as long as possible.

Most Australian cities are subject to increasingly variable rainfall patterns, acute water stress and increasing populations. As a corollary they are experiencing mature urban water economies, originally described by Randall (1981) and characterised by limited opportunities for future water impoundments, rising incremental supply and impoundment costs, intensified competition between diverse users including the environment and increased interdependencies amongst water uses. In response, urban water utilities and governments have extended existing water supplies through demand management and sought new water supply options that both buffer against climate uncertainties and are independent of traditional storages.

Recycled water has assumed a recognised role in mature water economies as one element in the portfolio of urban water management strategies. Recycled water augments existing urban supplies, buffers seasonal shortages, partially remedies inter-drought water stresses, potentially replaces potable supplies to maintain environmental flows and defers the development costs of new water resources. Future supplies of recycled water are able to cost effectively satisfy diverse water demands through water quality differentiation; *viz*. supplying users requiring varying grades of water quality, often characterised by lower treatment costs. By augmenting existing urban supplies, the resource characteristics of recycled water are rapidly changing from one of a waste stream requiring disposal to one of economic and commercial value.

In addition to increases in urban populations and densities, increasing concern about climate uncertainties; increasingly stringent effluent disposal options and extractive opportunities; supply shortages leading to prolonged and more severe water restrictions; and opportunities to access Commonwealth water funds are identified as primary motivators in the increased recycling of urban water Radcliffe (2007).

In concert with mature urban water economies these influences have increased the interest and levels of innovation in water recycling and reuse undertaken and investigated by urban water agencies, private operators, community groups and individuals. Despite these efforts and the substantial advances made in the scientific understanding and technologies associated with recycled water, Australian cities remain net exporters of water.

The Strategic Urban Water Plans developed recently in Australian cities point to an increase in the provision and consumption of recycled water, which will assume a crucial role in diversifying the portfolio of urban water resources (see Ward and Dillon 2009 for a summary). The Commonwealth Government set a national target for recycled water of 30% by 2015, a commitment reached at the 2007 Australian Labour Party's National Conference and taken to the federal election of that year. The volume of recycled water from 2002-2006 has increased for Australian states except NSW (Radcliffe 2007a, p.388). Marsden Jacobs (2008) estimates 23% of urban effluent (25% inclusive of stormwater) will be recycled by 2015.

3 Previously identified priorities for urban water research

The NWC (2007, 2009) reviews of the progress of integrated urban water reform in Australian States recommended and emphasised an institutional and economic analysis of water quantity management, incorporating augmented supplies through water recycling. The institutional analysis was intended to complement the development of a set of Australian Guidelines for the risk management of water quality associated with recycling. Focussing on public health and the environment, guidelines for recycling, stormwater harvesting and use and managed aquifer recharge have been released (EPHC 2008 a,b,c).
Summary analysis of research requirements articulated by water agencies, industry and statutory bodies concerned with monitoring the progress of the NWI reveal consistent social, economic and institutional research themes for urban water recycling (see Ward and Dillon (2009) for summaries of the NWC biennial audit 2009; Productivity Commission report into urban water pricing 2008; the COAG update on urban water reform 2008; and industry research challenges identified as part of this discussion paper). The themes are summarised as:

1. Improved whole of system urban water supply planning, focussing on diversification towards less climate-dependent sources of supply, inclusive of recycling and manufactured water;
2. Design alternatives to Governments (operating as water planners, suppliers, distributors and retailers) making supply investments and managing available water with only limited knowledge about the value that users place on water;
3. A review of institutional, market and charging/pricing arrangements such that full cost pricing is consistent regardless of source: pricing should be timely, transparent, accurately reflect scarcity and account for externalities. Specific to water recycling, pricing needs to reflect fit-for purpose water supply: i.e. variable water qualities suitable for a range of alternate water demands;
4. Clearer community transparency regarding the risks to water supplies, rationalisation of water restrictions and levels of supply security;
5. Adopt a partnership approach so that the community is able to make an informed contribution to urban water planning, including consideration of the appropriate supply/demand balance;
6. Efficient water supply decision-making needs to be based on cost–benefit frameworks that result in cost effective water service provision at agreed levels of security and reliability. assess the relative merits of the various augmentation options in ways that better address climate-related uncertainty and which can adapt to improved understanding of future needs and supply options; and
7. Reform needs to address the monopoly provision of urban water that impedes opportunities to develop alternative supply sources. Reform has been confined to governance arrangements rather than the structural changes necessary to achieve more efficient outcomes.

Institutional inertia (Brown 2008), a lack of or poorly defined entitlements (Radcliffe 2007, Ward et al. 2008) and failure to differentiate the contestable and non-contestable aspects of

the urban water system (Productivity Commission 2008, Ward and Dillon 2009) have also been identified as key impediments to water reform processes.
In deliberating the status of urban water reform, the NWC and Productivity Commission relied on metrics generally defined in terms of optimality and concordance: that is, economic efficiency, revenue adequacy, flexibility of supply deployment, administrative simplicity and concordance with existing governance. Transparency of decision processes and distributional equity, levels of agency trust, prospects of ongoing innovation, meeting environmental targets and the capacity to balance the costs of supply security with assignment of risk represent additional performance metrics that correspond with and help coordinate these more ambitious reform agendas.

The proposed modifications to the NWI and subsequent performance metrics flag the corpus of economic, social and institutional research identified as necessary precursors to successfully fulfil future urban water recycling aspirations and objectives.

4 Proposed Social, Institutional and Economic Research Topics

To promote a coordinated approach to research and sectoral priorities, the review has reclassified social, institutional and economic research needs. The proposed research topics are intended to 1) promote correspondence within the Centre of Excellence research themes, 2) to align sectoral needs with research foci and 3) to integrate disciplinary analyses into functional and operational outcomes. Topics are described as: **Decision Support** in policy design and implementation; **Prioritised Investment** in alternate water supply portfolios and **Implementation and Evaluation** to ensure community and industry acceptance coupled with ongoing monitoring and water reform assessment.

The research topics are interdependent and while they represent tractable research components, they should not only be considered in isolation: for example data and analyses from both the Prioritised Investment and Implementation and Evaluation phases provide critical inputs to Decision Support by way of design updates, performance and analytical feedback and identifying points of probable failure.

1. The body of recycling research is primarily guided by the principle and necessity of a **whole of system** management approach to the terrestrial urban water cycle: in general terms that implies minimising water inputs into the urban water cycle, maximising water retention and reuse within the system and minimising water and recyclate exports.

2. **Decision Support** in policy design, instrument testing and implementation:

a. Careful consideration of the conflicted nature of current water agencies that act as the sole supplier, conveyor, seller and conserver of potable urban water and waste streams;
b. Careful consideration of whether centralised, decentralised or hybrid water systems are in the best interests of the water constituency (i.e. suppliers, consumers and citizens);
c. Identify potential solutions and adjustments to guide the resolution of contradictory and fragmented urban water policy frameworks;
d. Differentiate and evaluate apposite instruments, incentives and analysis for water quantity and water quality;
e. Design and test institutional arrangements, governance and instruments that encourage supply alternatives that are independent of the uncertainties of climate and match the preferences, motivations and attitudes of final users; and

f. Identify methods to build public confidence in the science, decision-making and decision-makers to help coordinate priority water reform agendas.

3. **Prioritised Investment** in water supply portfolios:

a. Evaluate supply options based on scarcity reflective pricing of urban water supply, including recycled and manufactured supply augmentations, to reveal accurate price signals enabling appraisals of investment viability and to coordinate supply and demand;
b. Develop and apply a portfolio approach to the investment viability of supply options inclusive of scale effects and the costs of security and asset idling coupled with uncertainty;
c. Identify, differentiate and evaluate the contestable and non-contestable elements of urban water delivery, supply and removal that is encouraging competition where feasible;
d. Increased use of recycled water will require investor confidence of security and freedom to operate. This will require a formal investigation of alternative entitling, allocation and use licensing arrangements of source and treated water in addition to the prescribed management of treatment residues;

4. **Implementation and evaluation** to ensure community and industry participation and performance criteria:

a. Assess institutional integration strategies to ensure the communication and translation of information across scales and management regimes in a strategic manner. Performance metrics for knowledge transfer include legitimacy, credibility and salience;
b. Assess information integration strategies to match available knowledge with decisions, purposes and responsibilities at multiple levels of action, including households organisations and policy;
c. Continual appraisal of a) and b) as inputs into the Decision Support phase;
d. Review and assess communication strategies focussing on:

i. The identification of perceptions, acceptance and barriers to the uptake of decentralised recycling systems;
ii. An assessment of community perceptions towards water recycling schemes in the context of a portfolio based framework for water resources planning;
iii. The development of contextualised scenarios to investigate how different states of water supply security can influence community perceptions of risk; and
iv. The establishment of a program of experimental research to test the effectiveness of different methods and modes of communicating a suite of water recycling schemes to the public.

e. Evaluation of the interaction of prescribed water commodification and the potential erosion of existing voluntary demand management responses that contribute to the public good (i.e. crowding-out and crowding-in effects); and
f. Develop a comprehensive suite of performance metrics to assess NWI compliance and water recycling management. Performance metrics, in accord with the NWI, are likely to include optimality (dynamic efficiency, flexibility), concordance with existing structures, participation, transparency and accountability; inter-organisational collaboration and communication; and the institutional ‘fit’ of chosen technologies.

5 Social, economic and institutional research strategy

The following sections summarise insights from the social, institutional and economic literature associated with urban water recycling. The Australian and International review of the current state of knowledge and practice of water recycling is inclusive of institutional and governance aspects, economic dilemmas and social psychology.

5.1 Decision Support (Institutions and Governance)

5.1.1 Key Research Issues and Challenges

The social and institutional challenge of recycling is pivotal to achieving water sustainability and urban water reform in Australia (Senate Committee 2002). Institutional capacities and characteristics are key elements of this transition. Institutional factors, such as the rules and regulations governing water use and the organisational arrangements for water management, are important in determining whether, when, and how recycling programs develop and perform.

Despite the unified commitment to a diversified water supply approach, the widespread adoption of water recycling initiatives has yet to be realised in practice. Consultation with water experts and practitioners, and review of industry and government statements, reveals a range of systemic and institutional challenges to the successful adoption of new water recycling technologies and practices. Barriers sit under two broad themes:

1. Lack of public confidence in water governance institutions.
2. Inadequate policy and institutional capacity to foster the adoption and diffusion of technical innovations in water recycling.

The overarching research challenge is to identify and clarify the relationship between institutional arrangements and water management outcomes, and the institutional and policy conditions for continuous improvement so as to adapt to changing social and environmental circumstances:

… there is a need to open the "black box" of institutional processes and effects, to provide explanations of how institutions matter – how they prompt people to try to change management practices, how they ease or hinder those changes, how they shape the management alternatives water users and organizations consider and adopt, and how they affect the outcomes that result (Blomquist et al 2004: 927).

Industry needs and trends

1. Building public confidence in water governance institutions.

Public support is key to the success of water recycling because, regardless of technical and environmental considerations, it remains a key determinant of investment in particular schemes (Mooney and Stenekes 2008). Vigilance will be required to maintain public confidence in the quality of drinking water, regardless of its source (WSSA 2009). Understanding the bases of community confidence is thus a key industry priority.

Public confidence and institutional capacity are interrelated. Public concerns about regulations and responsibility for the day-to-day management of recycling schemes are inextricably linked with levels of public confidence in the organisations charged with running and regulating such schemes (Leviston et al. 2006). Addressing community concerns about ongoing management and ownership of water schemes is a central challenge for the successful implementation of water recycling initiatives. Standards and compliance are of pivotal importance to maintaining public confidence in the water industry and in recycling technologies.

2. Building institutional capacity for innovation.

Successfully meeting water industry challenges will only be possible if policies are built upon innovative technological developments, and innovation in regulatory management (Radcliffe 2006). Systemic and institutional barriers to the transition to a diversified water supply approach include:

- practitioner skills,
- organisational resistance,
- fragmented organisational arrangements,
- regulatory regime, and
- limited institutional capacity.

Retaining skilled staff, and building capacity and expertise to meet future skills demand and emerging skill needs, is recognised as a key challenge across the water industry.

Organisational resistance to the adoption of a diversified water supply regime is a second industry challenge. Such resistance stems from the traditionally risk-averse nature of the water industry (Environment Business Australia 2002). A recent survey of over 1,000 public and private decision makers and experts across the Australian water sector found that practitioners[1] are reluctant to adopt diverse water supply technologies, particularly on-site and third-pipe technologies and potable reuse schemes (Brown et al 2009 p. 20-21). Responding to this challenge will require the cultivation of an innovative business culture to support technology diffusion and productivity improvement (Queensland Government undated).

The fragmented organisational arrangements that have traditionally characterised urban water management are at the heart of implementation problems associated with water recycling initiatives (Senate Committee 2002). There is a need to align regulatory and statutory regimes to maximise the efficient use of recycled water, and to to allow water sensitive urban developments and other innovative water solutions (WSAA 2009).

Changes are also needed to the regulatory regime to provide incentives for investment in research and development, and to provide rewards for innovative solutions. The existing regulatory regime has a structural bias against research and development solutions (Environment Business Australia 2002; UK Council for Science and Technology 2009). There is a clear need for effective regulatory incentives and sanctions to achieve a high level of compliance with standards and guidelines, and to encourage innovation and continuous improvement.

Finally, water and sewerage utilities companies need to demonstrate their capacity for incorporating the latest technological solutions. In general, innovation within the water industry is fragmented and focused on short-term needs, with sub-optimal sharing of information. The timely availability of high quality 'fit for purpose' data and information for decision making remains a key challenge (Claydon 2007). There is a need to develop networks and partnerships to provide access to information and facilitate the exchange of ideas (Queensland Government undated).

[1] Overall, practitioners supported the concept of fit-for purpose use, with receptivity to non-traditional sources decreasing with increasing opportunities for personal contact. For example, respondents supported using rainwater and groundwater for drinking (40-59% of respondents), but indicated low (20-39%) to very low (less than 20%) support for using greywater, stormwater, sewage and seawater as drinking sources. For use in public open spaces, respondents considered stormwater and sewage were of high importance (60-79%), greywater, rainwater and groundwater were of average importance (40-59%) and seawater was of low importance (20-39%). Seawater received a low rating for all uses except for industrial purposes.

5.1.2 Current Research

The role of social institutions in the response to water governance challenges has received dedicated effort by the international research community over the past decade (Young et al in press). Formal laws and regulations, as well as informal procedures, govern the distribution of benefits and costs and set the ground rules for conflict resolution. Further, by facilitating and ordering the interactions between multiple actors in complex situations, institutions are especially significant when a task requires coordination (Blomquist et al 2004).

1. Building public confidence in water governance institutions.

Conflicts around the introduction of water recycling schemes reveal the disconnect between water users and the technological solutions devised by experts. With the shift to water cycle management (rather than water supply) and fit-for-purpose (rather than pure drinking water), new skills and new ways of thinking about risk are needed (Colebatch 2006). The institutional fit of a chosen technology in a particular circumstance becomes a matter of deliberation and choice by the range of users involved (Blomquist et al 2004).
International research confirms the importance of institutional arrangements that facilitate inclusive and transparent governance alongside the adoption of best practice technology (Marks and Zadoroznyj 2005). Given the majority preference for government run-and-owned systems (Leviston et al. 2006), the increasing trend toward private sector management and operation of water utilities is an additional concern.

2. Building institutional capacity for innovation.

Research priorities to improve the adaptive capacity and performance of water institutions in Australia include (NWC 2007):

- understanding the conditions for information generation and transfer,
- understanding the conditions for coordination across water organisations,
- attention to the appropriate scale of implementation.

The ability of water institutions to transfer and translate knowledge across organisational boundaries is fundamental to the improvement of adaptive capacity and performance in the water industry (Wallington et al 2009; Senate Committee 2002). Research has shown that boundary organisations (research organisations, housing associations, stakeholder committees, etc) facilitate the communication and translation of information in a strategic manner (Owens et al. 2006; Robinson et al. 2009). Boundary organisations are also critical to the innovation process (Guston 2001). The implementation of technical innovations requires institutional and policy changes to foster their adoption and diffusion (Ingram and Bradley 2006).

A key role of boundary organisations in water planning in Australia and California has been to facilitate the transfer of relevant and useable knowledge between scientific and policy domains (Robinson et al. 2009; Ingram and Bradley 2006). In Europe, boundary organisations have played several roles in water management (Moss et al 2009): in bridging the boundaries between utilities, consumers and regulators (e.g. by building up a knowledge network for sustainable water management); in working across scales (e.g. by translating national agendas into everyday household practice); and in translating technology into particular social contexts (e.g. by matching innovative technological solutions to the business of water management).

Scale issues are related to risk and equity concerns at three levels of action: household, organisational, and policy levels. The need is to match available knowledge with decisions and purposes at the appropriate scale, where responsibilities include:

1. Household level: changes in consumption practices. The controversial nature of water reuse projects at the household level requires that issues of process and outcomes are adequately dealt with. Procedural justice is particularly important for centralised recycling schemes (e.g. greenfield developments), while issues of distributional justice such as cost sharing are important for decentralised schemes (Gardner 2003).

2. Organisational level: relationships between producers, distributors and regulators. At this level, the institutional context constrains decision-making about water recycling due to the fragmentation of regulatory arrangements across a number of agencies (Senate Committee 2002). A key success factor here is the work of champions (Mooney and Stenekes 2008; Taylor 2009).

3. Policy level: relationships between citizens and political authority, where the benefits and risks of any new technology are debated. At the policy level, institutional frameworks can alienate the public by constraining the definition of the problem and acceptable solutions, a situation which results in feelings of a lack of agency and an active distrust of state and expert institutions (Stenekes et al 2006).

3. Property rights regimes and entitling water interests

Property rights are one of the elements of the institutional framework, which subsequently enables opportunities, places thresholds and defines restrictions on the specification, distribution and manipulation of rights for social and economic purposes (Randall 1987). Bromley (1991) states that negotiable water entitlements must therefore be specified in terms of secure, enforceable rights, articulating the duties of the right holder, the obligations of those excluded from the right and the duties and obligations of the managing authority.

Property rights or entitlements are social constructs that rely on the recognition by society of the legitimacy of the individual claim to a benefit that is gained by using a water resource. Society is then prepared to forgo any claim and enter into a contract of compliance to enforce the rights to that claim (Bromley 1991). Individual entitlement holders can therefore anticipate state sanctioned enforcement against those that choose to lay claim without consent. Schlager and Ostrom (1992) propose that private property rights are comprised of a complete bundle of property rights, which consist of rights of access, withdrawal, management, exclusion and transfer. The rights of access and withdrawal grant the individual the authority to access and make use of property. The right of management grants the individual the authority to decide the manner in which the property is used. The right of exclusion allows control of access to the property with expectation of state enforcement when required. The right of transfer allows the individual to sell, lease, rent, bequeath or otherwise dispose of the property.

Water is characterised by multiple economic benefits and constructed social values, hence it has been defined by different notions of property. Depending on the economic characteristics and the parameters of scarcity, water as a shared resource has been managed according to state, market, community and open access property regimes (Quiggin 1986, Randall 1987, Ostrom 1998, Radcliffe 2007, Ward *et al.* 2008, 2008a). Different regimes confer comparative advantages in achieving specific policy objectives, for example, efficiency, equity, distributional justice and the scale of water diversions. Specific policy instruments are more likely to achieve policy objectives when they correspond with specific resource characteristics and diverse community attitudes and values. Formal evaluations and case study.

The NWI promotes market based transfers where appropriate. Fully specifying the entitlements and obligations of water interests are pivotal to the effectiveness of recycling schemes that rely on the voluntary exchange of individual transferable rights. Radcliffe (2007 p.322) exemplifies these considered opinions in arguing that: "*If greater remediation and use of recycled water is to occur, investors will require adequate provisions of security and freedom to operate. The same principles of entitlement allocation and use licensing should be adopted as already apply to suppliers and users of water from surface catchments and groundwater basins. The issue of title in the management of sewage and recycled water has received little attention*".

5.1.3 Future research needs

1. Institutional analyses are required to identify the institutional bases of public confidence, and the drivers and barriers related to adaptive capacity and improved performance, as perceived by customers, regulators and industry practitioners.

2. Building public confidence in decision-making and decision-makers is a key challenge for the water sector. Performance metrics to help coordinate reform agendas associated with optimality (efficiency, flexibility) and concordance with existing structures, include:

- Public participation, transparency and accountability, related to public trust;
- The institutional 'fit' of chosen technologies, and the risks and responsibilities associated with these technologies.

3. Understanding the conditions for information transfer and institutional coordination at the appropriate scale of implementation is required to build institutional capacity for innovation in the water industry. Managing the boundaries between science and decision-making, and between regulators, producers and consumers, is necessary to provide a means of addressing these coordination challenges. Research priorities include understanding:

- Institutional integration via boundary organisations to facilitate the communication and translation of information in a strategic manner.
- Information integration via multi-level analysis to match available knowledge with decisions, purposes and responsibilities at the level of households, organisations and policy.

4. Implementations of alternative property right arrangements for urban water in general and specifically for recycled water remain relatively unexplored. Recycled water is characterised by several operational elements, where water from each element is likely to be described by discrete economic and resource characteristics. Multiple water sources waste water, stormwater, retention ponds, water treatments, aquifers and receiving environments of recovered water vary in resource characteristics and warrant exploration as to the challenges and opportunities of appropriate policy responses, property right regimes and subsequent instrument design.

5.2 Prioritised Investment (Economics of Water Recycling)

Hatton MacDonald and Proctor (2007) articulate the need for a comprehensive economics of water recycling influenced by and embedded within the institutional arrangements and social norms that constrain and enable individual and societal choices. Urban water economics requires 1) full cost pricing, reflective of scarcity and multiple uses, regardless of source; 2) needs to account for the costs of variable water delivery configurations contingent on infrastructure scale; and 3) include the values of externalities (both positive and negative) as the environment must be considered as a legitimate claimant to water. Imputing the risk of supply failure, the costs of energy inclusive of carbon emissions and the assignment of the risk of reduced investment returns due to asset idling (for example (mothballed desalination plants during high rainfall periods) are additional economic factors requiring consideration.

Although recycling is likely to play an important role in future urban water supply, a comprehensive understanding of the economics of water recycling cannot be achieved in isolation from the economics of the other water supply options. Both the Productivity Commission (2008) and NWC (2009) suggest that the key principle that should guide future decisions about urban water supply including the role of recycling is a portfolio analysis approach. This section outlines an overview of the current state of literature based economic knowledge and practice to evaluate water recycling as a part of the portfolio of options considered in urban water investment decisions.

5.2.1 Key Research Issues and Challenges

1. Develop and deploy portfolio based frameworks for evaluating water recycling investments that account for the security cost-reliability trade-off;
2. Develop pragmatic methods, applicable by industry, to estimate system supply reliability inclusive of water recycling in the context of increasingly variable rain-fed sources, with the in the water.
3. Evaluate and compare methods for jointly assessing the supply reliability benefits of water recycling and the effective control of risk/uncertainty associated with extreme unanticipated shortages. More specifically, this will require consideration of:

- key elements of a robust urban water supply system including assessment of all plausible-yet-extreme scenarios;
- the extent to which diversification in water supply sources including water recycling would reduce the variance in water availability.

State of knowledge

Water planning to avoid and manage shortages is an active and expanding area of water supply management (Wilchfort and Lund, 1997; Jaber and Mohsen, 2001; Thomas and Durham, 2003; Pallontino et al., 2005; Wolff, 2008). As an alternative to traditional rain reliant storages, there is increasing attention on future investments in water recycling, inclusive of desalination plants, water reuse managed aquifer storage and conservation measures (Chung et al., 2009). At the vanguard of urban water supply economics is portfolio analysis; an approach that considers a combination of traditional sources with new investments in unconventional sources (Beuhler, 2006). It is in this context that a complete understanding of the relative merits and role of urban water recycling compared to investments in traditional storages can be gained.

Water recycling in comparison to various water shortage management alternatives will incur disparate costs, and yield different benefits. To comply with the public interest doctrine, water planners making investment decisions about whole of system supply options are required to make comparative evaluations of the merits of recycling relative to other supply options to determine the most appropriate combination (Jenkins and Lund, 2000; Rosenberg et al., 2007).

Several evaluation methods for determining the role of recycling as part of the appropriate combination of water supply sources are documented in the water planning literature. Traditionally, there has been great reliance on engineering and hydrological models in decision support for water supply planning. Alternative investments for increasing water supply system reliability have thus been evaluated using relative effectiveness in terms of additional system reliability benefits as revealed by basin simulation hydrological models (Hirsch, 1978; Vogel and Bolognese, 1995; Andreu et al., 1995; Zongxue et al., 1996; Andreu and Solera, 2006; Chung et al 2008; Andreu et al., 2009). In most of these studies, hydrologic uncertainty is addressed by generating yield reliability curves from system simulation models using historical and synthetic/modelled data.

Whilst the significance of economic analysis is acknowledged in most of these studies, it is only the relative effectiveness of investment alternatives at mitigating the risk of water shortages and water restrictions that is mostly reported. The coincidence of disparate costs and benefits of recycling in comparison to alternative investments to enhance water supply system reliability coupled with a budget constraint signals the obvious role for financial and economic analysis.

Wilchfort and Lund (1997); Jenkins and Lund (2000); Jaber and Mohsen (2000); Thomas and Durham (2003) and Aulong et al. (2009) report studies that explicitly incorporate economic analysis in the evaluation of alternative investments for increasing water supply system reliability including water recycling. These studies combine traditional engineering and hydrological water supply yield simulation modelling with the relative cost of investments to estimate a more comprehensive measure of cost-effectiveness. The main objective is to minimize the expected total direct cost of increasing water supply system reliability.

However, in addition to evaluating how recycling can contribute to improved reliability, and weighed against the cost of achieving it, frontier science in this area involves:

- broader inclusion of environmental costs;
- accounting for consumer responses to value reliability; and
- consideration of the correlation between water recycling and other available water supply sources.

Investment decisions in water recycling and other supply alternatives based entirely on direct costs and benefits alone may lead to inefficient investment decisions. Failure to incorporate spill-over or external costs and benefits associated with recycling may lead to sub-optimal investments that are likely to prove costly in the long run. For example, Bryan and Kandulu (2009) found that failure to consider key environmental costs effectively (under) overvalues alternatives that produce important additional (cost) benefits other than the one(s) being considered.

One shortcoming of the cited analyses of water recycling is the singular consideration of the cost-effectiveness of individual and isolated supply options. However, integrated water management dictates that water recycling is not independent of other water supply options. One cost of excluding correlations between recycling and other water supply sources from a shortage management model would be that the model would not give due weight to the risk-reducing benefits of diversification. A traditional view is that diversification is a key risk management strategy ((Yamout et al., 2007). By supplying urban water from several sources including un-correlated recycling returns, water managers can improve the reliability of water availability.

5.2.2 Current state of practice

The joint need for a portfolio analysis approach and accounting for externalities when considering water recycling as part of an optimal mix of urban supply investments are widely acknowledged (Productivity Commission 2008, Grafton and Kompas 2006). However, industry practice has primarily considered options individually and not accounted sufficiently for externality costs and benefits.

Minimal practical application of these key elements reflects substantial divergence between the state of the art in published academic literature and both agency practitioners and industry analysts. Incorporating these factors into evaluation and interactive research bridges this gap and introduces opportunities to advance industry practices. Key opportunities exist to better communicate and thus increase the adaptation of portfolio type approaches, measures and assessments that consider uncertainty.

5.2.3 Future Research Needs

1. Establish rapid and comprehensive methods to estimate the relative cost effectiveness of recycling relative to other water supply investment options when GHG emissions and other externalities are accounted for.

2. Determine whether more comprehensive portfolio analyses improve the assessment capacity of urban water planners when evaluating the mix of investment options available. More specifically, consideration of flexibility aspects, including:

- investment sequencing;
- the value of preserving the option to delay irreversible investments; and
- the value of securing the option to implement timely and effective contingency plans in the event of extreme water shortages.

3. Estimate the relative costs and benefits to the water constituency of alternate institutional arrangements for urban water supply: e.g. alternatives to water agencies that act as the sole supplier, conveyor, seller and conserver of potable urban water and waste streams; and centralised, decentralised or hybrid water systems.

5.3 Implementation and Evaluation (Social psychology research into water recycling)

The NWC (2009) and COAG (2008) recognise that observed societal behaviour of recycling use cannot be reliably parameterised. That is, recycling implementation efforts based on a narrow conceptualisation of "the public" is unlikely to promote widespread adoption. Variable individual attitudes and preferences expressed as recycling choices and levels of acceptance are multi-factorial, sensitive to spatial and temporal scale, subject to changes in risk perceptions and influenced by and embedded within prevailing social perceptions and norms. The success or failure of recycling implementation is frequently attributed to the attitudinal variance of key factors including the relative effectiveness of engagement with affected communities.

5.3.1 Key Research Issues and Challenges

- Identify key community engagement strategies that have been demonstrated to provide mutually desirable outcomes in water use planning.
- Establish a program of experimental research to test the effectiveness of different methods and modes of communicating a suite of water recycling schemes to the public.
- Contextualise scenarios to investigate how different states of water supply security can influence community perceptions of risk.
- Identify perceptions, acceptance and barriers to the uptake of centralised and decentralised recycling systems.
- Conduct longitudinal water use studies incorporating various experimental intervention techniques to investigate actual recycling behaviour and the role of habit formation.
- Assess community perceptions towards water recycling schemes in the context of a portfolio based framework for water resources planning.

Two research gaps have been identified in the review process that are not generally articulated.

First, in a review of existing social research in water supply management, Hurlimann et al. (2009) found a marked predilection for supply-side research – usually focussing on personal characteristics and intended behaviour – at the expense of demand-side water behaviours. To this end, longitudinal water use studies incorporating various experimental intervention techniques could be an important complimentary research priority.

Second, while the vast majority of research into water recycling has been geared towards large-scale recycling schemes, limited research is available on the social dimensions of decentralised systems such as greywater systems and rainwater tanks (Mankad and Tapsuwan, 2010). Direct investigation of people's use of decentralised water recycling systems will be important in identifying the social psychological drivers of actual behaviour. Research directions in the decentralised space could encompass household profiling of willingness to adopt such systems; the identification of policy mechanisms that enable the uptake of decentralised systems; the role of water shortages and water security in uptake; and perceptions and attitudes towards management and maintenance.

Levels of Water Recycling Acceptance

The body of research investigating community attitudes and community acceptance of recycled water schemes has increased throughout the last decade (*inter alia* Dolnicar and Schafer, 2006; Hurlimann, 2007; Hurlimann et al. 2008; Hurlimann and McKay, 2006; Leviston et al., 2006; Marks, 2004; Marks, Martin and Zadoroznyj, 2006; Marks and Zadoroznyj, 2005; Nancarrow et al., 2007; Po et al., 2004; Po et al., 2005).

The pivotal role played by community acceptance is evidenced by implementation failures of numerous water recycling schemes (Stenekes et al., 2001; Khan and Gerrard, 2006). A recent example is the rejection of a proposed indirect potable recycled water scheme by residents of Toowoomba in a referendum that gained international attention (van Vuuren, 2009; Stenekes et al., 2006). Similarly, growing public opposition to attempts to incorporate purified recycled water into drinking-water supplies in South East Queensland has been cited as prompting the government to modify the circumstances under which wastewater injection would occur (Price et al., 2009). Internationally, the San Diego water reuse initiative and proposed indirect potable reuse schemes in Florida and California failed to be implemented due to community opposition (Hartley, 2003). Other attempts to include potable recycled wastewater into new water infrastructure schemes have met with similar public opposition (e.g., Gibson and Apostolidis, 2001; Lamble, 1998; Roberts, 2008). In contrast, a number of successful water recycling projects exist, most notably in Singapore, Namibia and the United States (Johnson, 2009; Landers, 2008; Public Utilities Board, 2008). Many of these reuse schemes were implemented in arid areas associated with significant water security issues.

Levels of support for recycled water schemes appear to be contingent on a number of factors. Numerous Australian studies have shown that acceptance of recycled water (especially that incorporating wastewater) decreases as the intended purpose becomes closer to human contact; that is, it is more acceptable for uses such as clothes washing and open space irrigation, and less acceptable for uses such as ingestion and personal washing (Jeffrey and Jefferson, 2003; Marks, Martin and Zadoroznyj, 2006, 2008; McKay and Hurlimann, 2003; Po, et al., 2003). The original source of water being used also influences acceptance. Community reactions towards wastewater schemes are less favourable than to those schemes not harnessing toilet water waste, such as stormwater and greywater harvesting (Hurlimann, 2007; Marks et al., 2006, 2008).

Macpherson and Slovic (2010 pers. comm.) argue that coherent, united and unequivocal support by the water sector, coupled with understanding the water quality mental models of consumers are key primers for recycled acceptance. They argue that recycled water is generally stigmatised by its source history (i.e. water subject to natural processes versus reuse) ignoring its current quality and safety status. Further, they state that any discussion on water recycling should start with knowledge of water and, in particular, how wastewater can be treated for various forms of reuse.

Despite the challenges of implementation, research into attitudes towards recycled water in Australia reveals generally high levels of acceptance and community support, including schemes involving water reclaimed for indirect potable use (Dolnicar and Hurlimann, 2009; Marks, 2004; Leviston et al., 2006; Leviston et al., 2006; Price et al., 2009; UMR, 2007). In addition to recycled water schemes enjoying majority (in principle) support, there is evidence to suggest that what the community is prepared to accept in terms of urban water futures is more innovative than those currently proffered by water authorities (Nancarrow et al., 2002).

Predicting recycling acceptance and behaviour

Generally, research has yielded few significant correlations between social and economic variables and levels of acceptance (Dolnicar and Saunders, 2005; Marks, 2004; Nancarrow et al., 2007). Leviston et al. (2006) and Miller and Buys (2008) found gender differences in acceptance levels for aquifer storage and recovery in Perth and trust in scientific and technological recycling information in South East Queensland respectively. Dolnicar and Saunders (2005) report that high levels of education and belonging to a younger age category were associated with increased acceptance of recycled water.

Additional factors include the environmental impacts of microbial pathogens (Higgins et al., 2002; Browne et al., 2008; Browne et al., 2007), perceived compromises to water quality (Marks et al., 2003), anticipated increases in the cost of water (Marks et al., 2003), risk to human health posed by pharmaceuticals (Higgins et al., 2002), and a preference for alternative water supply options including increased emphasis on a reduction in consumption (Browne et al., 2008; Browne et al., 2007).

Psychosocial variables have been identified as significant predictors of community acceptance of proposed or hypothetical recycled water schemes (Nancarrow et al., in press; Nancarrow et al., 2008):

- **Emotions** influence the way people process information (Constans and Mathews, 1993; Johnson and Tversky, 1983) and emotional appraisals and cues affect the rating of environmental and recycling risks, potential damage, fairness and acceptability (McDaniels et al., 1995, Loewnstein et al., 2001). Historically, the key barrier to successful implementation of potable recycled water schemes has been attributed to emotional responses labelled the 'yuck-factor' (Dishman et al, 1989; Higgins et al. 2002; Lazarova et al., 2001; Po et al., 2005). A number of researchers however (e.g. Browne et al, 2007; Russell and Lux, 2009), argue that the concept represents an over-simplification of people's decision-making.

- The concept of **subjective norms** supposes that one is influenced and pressured by what other people think and do. Cialdini (2003) and Goldstein et al. (2008) have confirmed social norms as predictors of environmental conservation behaviours. Dolnicar and Hurlimann (2009) report that friends and relatives would be most influential in preventing respondents drinking recycled water as opposed to scientific information influencing their decision to drink recycled water.

- Perceptions of **fairness and equity** are a major predictor of community acceptance of, and compliance with, a wide range of urban and rural water management and policy issues (Alexander et al., 2008; Syme et al., 1999). Research on recycled water use in an urban Australian context has demonstrated that the perceived fairness of processes is positively related to satisfaction with recycled water use (Hurlimann et al., 2008) and negatively related to risk perceptions associated with recycled water use (Hurlimann, 2007). Further, an individual's reaction to decisions made by authorities are influenced by how fairly they perceive the decision-making *process* to have been, independent of how desirable the outcomes of that process may be (Thibaut and Walker, 1975).

- **Risk perceptions** and their importance in understanding attitudes and decision making about water recycling is coming into increasing focus. Technical experts exhibit a predilection for probabilities of adverse health outcomes, but for the majority of people, risk perceptions are more intuitive (Renn, 2004). While the lay community have trouble understanding probabilistic risk statements (Jaeger, Renn et al., 2001; Johnson et al., 1993), intuitive risks are based on how information regarding a technological solution is communicated; psychological mechanisms for dealing with uncertainty; and previous experience with and exposure to associated dangers (Renn, 2004).

- Risk assessments made by the general community in the absence of specific knowledge are largely informed by cues regarding the **trustworthiness** of the responsible authority and sources of information (Siegrist and Cvetkovitch, 2000). The relationship between trust in authorities and attitudes towards policies has been consistent. Research suggests that trust in government authorities and scientific investigations to provide safe recycled water plays a crucial role in determining public acceptance of recycled water schemes, with greater trust translating into more favourable risk perceptions and increased acceptance (e.g., Hurlimann et al., 2008; Hurlimann and McKay, 2004; Kaercher et al., 2003; Nancarrow, 2007; Ross, 2005).

Socio-cultural approaches

Research has identified significant determinants of public acceptance of recycled water, although correlations with the beliefs and values that underpin people's risk perceptions and trust evaluations remain poorly defined (Russell and Lux, 2009; Russell and Hampton, 2006). The following points outline a number of cultural and theoretical approaches designed to elicit the socio-cultural aspects of water recycling:

- **Cultural Evaluator Theory**, (Kahan, 2008) attempts to explain why the provision of information has failed to correlate consistently with more positive attitudes towards recycled water. It may also help explain the tendency for attitudes to become polarised as people have more time to reflect on a recycled water scheme (Price, 2009).

- Perceptions of risk can also be thought of as responses to cultural and social context (Beck, 1992; Giddens, 1991). In **Risk Societies**, Beck (1992) argues that modern society has become accustomed to expressing anxiety emerging from loss of institutional trust in terms of risk. Questions of system 'fail-safes', the consequences of system breakdowns, and transparency in communication of the technical are vital ingredients in the maintenance of institutional trust.

- The concept of **Big Water** (Allon 1994) posits that the history of water infrastructure and institutions influence peoples' perceptions of water supply and contamination. A key part of modern nation building in Australia has been the large scale development of water infrastructure, involving immense engineering feats to bring water to a dry and vast country. Such feats have contributed to the development of a heroic and metaphorical 'Australian way of life', and false perceptions that water supplies are endless and immediately accessible.

- **Cultural theory** focuses on the relationship between social values, worldviews, risk perceptions and behaviours. Four basic worldviews are presented in the literature as patterned ways in which different groups perceive the world and rules governing societal structure: hierarchical, fatalistic, individualist and egalitarian (Peters and Slovic, 1996). Cultural theorists argue that each worldview encompasses different ideals about society which results in different risks perceptions and policy preferences.

5.3.2 Future Research Needs

1. **Recycling acceptance strategies.**

The prevailing approach to engaging communities in recycling transitions involves the adoption of various techniques designed to dampen ambivalence and gain consensus and acceptance (e.g., Moss, 2009; Mouffe, 2005; Walker and Shove, 2008). The dominant framework of communication has been criticised for too narrowly conceptualising 'the public' (Davies, 2008). It is commonly assumed that infrastructure projects involving recycled water fail due to a lack of capacity on the part of the broader community to comprehend detailed scientific information and risks (ACIL Tasman, 2005; Gibson and Apostilidis, 2001; Stenekes et al., 2006), with an aversion to sewage being invoked as the major psychological stumbling block in people's considerations for wastewater in particular (see Russell and Lux, 2009 for an overview).

The solutions to water crises are often framed in technological terms, with a history of engaging the public at the level of information-provision about technology as a means of garnering acceptance of a proposed scheme (Stenekes et al., 2006). The utilisation of a science-based risk assessment approach is often used in conjunction with an assumption that emotion, irrationality and opposition (particularly in regards to health risks) underlie existing community opinion and potential future opposition (Renn, 2004). As a result, agencies involved in water provision generally attempt to alleviate concern and bolster public support to technological water augmentation solutions by expressing its suitability in terms of probabilistic health risks, which is problematic for a lay audience. The less frequent approach is one of participatory engagement with the community to identify and address broader areas of community concern about technological developments, despite evidence that such a method is instrumental in successfully implementing potable reuse projects (Po et al., 2003).

2. **Communication**

An attempt to increase objective levels of knowledge among the community resides at the heart of much government policymaking (Hartley, 2006). Numerous studies have suggested, however, that knowledge (both real and perceived) of water sources and existing recycling schemes has no significant influence upon acceptance and intended behaviour towards proposed water recycling schemes (Leviston et al., 2006; Nancarrow et al., 2007). As Davies (2008) identifies, little work has been conducted on the ideas and assumptions behind scientific assessments of public communication and engagement. Current strategies focussing on public acceptance of technological innovations to water security may simplify the complexity of the institutional issues surrounding water recycling by misappropriating the concerns of the community to the realm of emotionality, irrationality, and personal health risks.

Compounding the matter, there is evidence to suggest that heightening awareness of the particulars of a water recycling scheme can entrench opposition, intensify extremes of opinion, and politicise and polarise debate (Hartley, 2006; Price et al., 2010). An example such as the Toowoomba referendum illustrates how support for potable recycling schemes can change as its introduction becomes more real and immediate, and as emotions heighten in response to political campaigns and media coverage (Hurlimann, 2009; van Vuuren, 2009). Further, research has suggested that heightened awareness is a poor predictor of actual changes in behaviour (Barr, 2003; Lam, 2003).

3. Education and Communication Techniques

The risk perception literature provides evidence that the manner in which information is presented, or framed, can significantly influence how information is received, yet almost no research has investigated different framing techniques with reference to recycled water schemes (Arvai, et al., 2001; National Research Council, 1996; Slovic, 2000). A concerted program of empirical investigation, utilising an experimental approach, will shed significant light on which messages and communication modes are most effective and least prone to distortion and misinterpretation. Care should be taken that such research is driven by a desire to optimise knowledge transfer and understanding, rather than to manipulate and coerce. The research has the capacity to inform the recycling sector to better align production and delivery with prevailing community attitudes; targeted and tailored communication pathways responsive to community heterogeneity; and the development of recycling interpretative centres adapted to local context.

6 Contributors

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