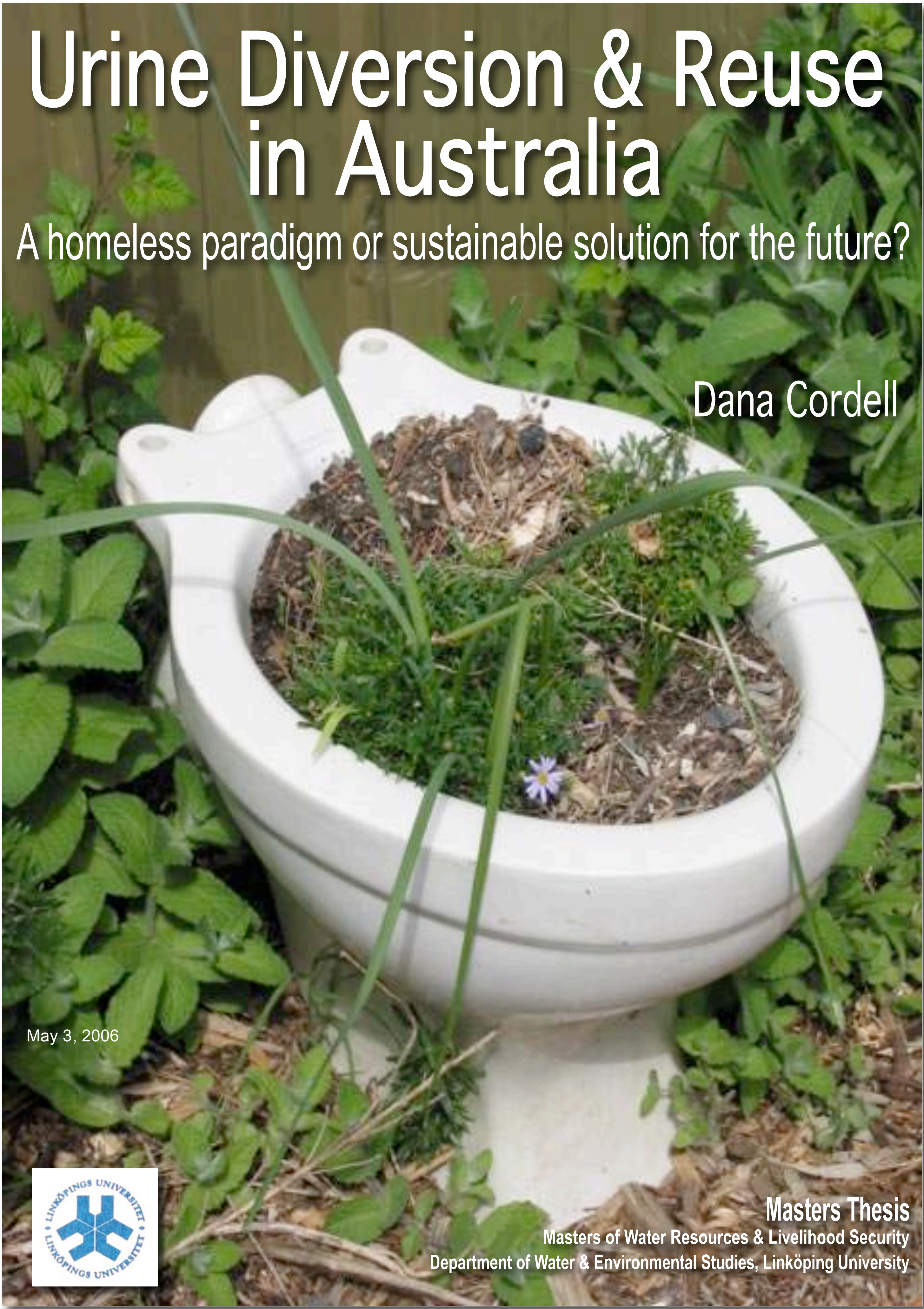
Urine Diversion & Reuse in Australia

A homeless paradigm or sustainable solution for the future?



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May 3, 2006

Masters Thesis
Masters of Water Resources & Livelihood Security
Department of Water & Environmental Studies, Linköping University

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Glossary of terms*

Algal bloom An algal bloom refers to the sudden abundance in growth of aquatic algae. There is still some uncertainty as to the exact factors which trigger a bloom, however excess nutrients such as phosphorus (P) certainly contribute to the intensity of blooms (Mitrovic, 1997).

Anthroposphere Analogous to the natural systems of the biosphere or atmosphere, the *anthroposphere* is the social system involving materials, goods and processes that satisfy the biological and cultural needs of humans. (Moore & Brunner, 199?).

Backcasting Backcasting is a method used for planning for the future. Compared to forecasting, which involves projecting from a point or scenario in the present, backcasting involves working backwards from a specified desired future end-point to the present. This allows the determination of the physical feasibility of that future and what policy measures would be required to reach that point (Robinson, 1990)

Bioavailable A material such as a nutrient which can be absorbed by biological organisms. For the purpose of this thesis, it refers to the chemical form of P when it is available for uptake by plants.

Biodiversity Biological diversity. The variety of all life forms, comprising genetic diversity (within species), species diversity (across all species) and ecosystem diversity (EPA NSW 2000b).

Biogeochemical cycle These describe the natural cycles of such nutrients as Phosphorus, Carbon and Nitrogen. They are so named because these chemicals cycle through both the biological and the geological world.

Biological Nutrient Removal (BNR) An end-of-pipe nutrient removal process used to remove the high level of nutrients from wastewater at the wastewater treatment plant.

Catchment The area of land drained by a river and its tributaries (EPA NSW 2000b).

Closing the loop A phrase typically referring to closing the currently unstable linear biogeochemical cycles that industrial society has opened for resource exploitation purposes. In this study it mainly refers to phosphorus (P). Unsustainable P management results from opening the loop of a closed circular system to extract and process P from the lithosphere. This linear process means that industrial methods of agriculture now require continual application of phosphorus-rich fertiliser. However, unlike the natural biochemical cycle, which recycles P to the soil 'in-situ' via dead plant matter, industrial agriculture harvests plants prior to death and decay, transporting them all over the world for food production and consumption. The P within the food is then consumed and eventually discharged via the sewerage system into our waterways, where it can initiate toxic algal blooms (ISF, 2003). This pathway occurs mainly via agricultural runoff (during periods of high rainfall), effluent from sewage treatment plants, and urban runoff (NSW EPA, 1995).

End-of-pipe A term referring to solutions to pollution that focus on managing solid, liquid or gaseous waste at the end of a process, rather than targeting the problem at the start or source of a system. This contrasts to 'at-source' solutions.

Eutrophication A state of growth in plant primary productivity which can in turn lead to algal blooms, which block sunlight, reduce dissolved oxygen (DO) upon death and decomposition and release toxic compounds. These combined stresses can result in fish kills and leave the water undrinkable for humans and other terrestrial animals (Mitrovic, 1997)

Exchange pool The parts of a biogeochemical cycle where the nutrient is temporarily stored for relatively short periods of time (McShaffrey, 1999). For Phosphorus, this is in the biotic community where P can be recycled within days through an organism's consumption and excretion of other biotic material.

Flux The rate of flow of fluid, particles, or energy. For the purpose of this thesis, flux refers to a material load per time, usually in units of kg/annum.

Food security "A world free from poverty, hunger, malnutrition, and unsustainable natural resource management." (p.iv IFPRI, 2002)

Hawkesbury-Nepean A significant catchment area in Australia that supplies water to over 4 million residents of Sydney and surrounds. This catchment also produces most of the state's agricultural and economic goods and services including fishing, recreation and tourism.

Integrated Resource Planning (IRP) Integrated resource planning allows resource conservation options (or demand-side options) to be compared to supply-side options, such as in the provision of water services. It originated in the electricity industry in the US though is now used extensively in the water and other industries (Mieir et al., 1983; Howe and White, 1999).

Material Flux Analysis *Also known as Material flows analysis (MFA*) or *Substance Flows Analysis* (SFA). A quantitative material accounting technique to account for all the material flows of goods and processes involving a particular material of environmental significance. From such a tool, preventative measures can be taken, goals and targets set and monitoring enforced.

Meaningful scenario For the purpose of this study only, a 'meaningful scenario' is a target that if met, will lead to significant positive change towards the ultimate aim of the target. This could be ecological change or political change for example. This compares to a 'tokenistic' target that is more a gesture or symbol rather than actually creating any real change. This term was introduced in this thesis when a distinctive gap was discovered between what it would take to introduce urine diversion and reuse into Australia per se versus and what it would take to create significant change through urine diversion and reuse.

Non-point source A diffuse source of pollution coming from many small sources over a large area. Not a discrete point source of emission.

Nutrients Nutritional substances required by all living organisms for growth and reproduction. Unnaturally high levels of nutrients, such as in a river below a sewage treatment plant, can encourage abnormally fast and prolific growth of algae in the water, or weed growth in the bush.

Phosphorus (P) One of the 4 most important nutrients identified. P is fundamental to the growth and reproduction of all living organisms. P flows occurs naturally in the environment, though excess loads of P can pose environmental stresses on surface waters resulting in eutrophication.

Respondent Those Stakeholders interviewed in either Sweden or Australia for the purpose of this study.

Source separation	A term typically referring to approaching pollution management at the start or source of a process, rather than focussing on managing the waste products at the end of the process (see *end-of-pipe*). Diverting urine at source is an effective way of source separating nutrients rather than end-of-pipe nutrient removal at a sewage treatment plant prior to discharging the effluent.
Stakeholder	a Stakeholder includes those who: benefit, lose, are voiceless, are representatives, are responsible, mobilise against, make more effective/ less effective, contribute to financial/technical resources, or create behaviour change. (Jonsson, 2005;The World Bank Group, 2001).
Urine diversion	Diverting urine from faeces at source via a wet or dry urine-diverting toilet. This is no longer termed 'urine separation' as 'separation' implies an extra action of separating parts from a mixture, where as urine is never mixed with faeces or other parts of the wastewater stream in the first place.
Urine reuse	In this study, urine reuse refers to the reuse of urine as a fertilizer in agriculture, either for edible or non-edible crops.

* unless otherwise referenced, definitions provided here have been defined by the author for the purpose of this thesis, based on her research and prior understanding of such concepts.

Acronyms

The following acronyms have been used in this report:

ANZECC	Australia and New Zealand Environment and Conservation Council
DEC	NSW Department of Environment and Conservation
DIPNR	NSW Department of Infrastructure, Planning and Natural Resources
DPI	NSW Department of Primary Industries
EA	Australian Environment Agency
EAWAG	Swiss Federal Institute for Environmental Science and Technology
Ecosan	Ecological sanitation
EPA	Former NSW Environment Protection Agency (now DEC)
EU	European Union
IRP	Integrated Resource Planning
LCP	Least Cost Planning
MFA	Material flux analysis (also know as Substance Flow Analysis, SFA)
NSW	New South Wales (the Australian State whose capital is Sydney)
P	phosphorus
SLU	Swedish University of Agricultural Sciences
WHO	World Health Organisation
TUHH	Technical University Hamburg-Harburg

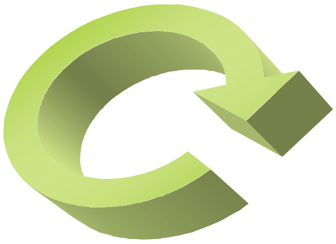
Acknowledgements

I would like to acknowledge the plethora of stakeholders involved in urine diversion and reuse both in Sweden and internationally that were contacted for this study, particularly the seven Swedish respondents interviewed in this study. I would also like to acknowledge the Australian respondents interviewed in this study who were identified as potential stakeholders if urine diversion and reuse was introduced in Australia and those who participated in this study through other personal communication. Together they represent a key source of knowledge and new thought that this thesis was based upon. Their enthusiasm, cooperation and knowledge sharing was highly appreciated.

I would also like to thank my supervisor and mentor, Assoc Prof Jan-Olof Drangert for his inspiration, support and boundless enthusiasm for sustainable sanitation solutions, 'closing the loop' and sustainable livelihoods and for always encouraging critical thinking. At Linköping University's Tema Vatten where this Masters thesis took place, I would like to thank all the friendly faces who provided a very supportive and stimulating environment. I would like to individually thank Dr Julie Wilk, Assoc Prof Åsa Danielsson, Prof Jan Lundqvist, Susanne Eriksson and Ian Dickson who were involved in the direction, coordination and assistance of Tema Vatten's 'Water Resources and Livelihood Security' Masters Programme and who each provided me with invaluable support in different ways. A special thanks to Dr Helena Krantz for translating my stakeholder letters into Swedish and for being a constant source of advice and assistance in conducting social research in the field of ecological sanitation.

On the Antipodean side, I acknowledge the ongoing creative and intellectual support of my Australian colleagues, mentors and friends at the Institute for Sustainable Futures, University of Technology, Sydney, particularly Prof Stuart White, Andrea Turner, Dr Cynthia Mitchell, Dr Simon Fane and Dr Juliet Willetts. Last but not least I thank my parents, Marilyn and Stephen Cordell and sister Miri Fridman, for both supporting and challenging me.

*" **Waste** is nothing more than a **resource** in the **wrong** place.
It is not waste that we should **dispose** of, rather the **concept** of waste "*
(Esrey, 1998)



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VOLUME III: CONCLUSIONS & RECOMMENDATIONS

Abstract

Diverting urine from faeces or mixed wastewater and reusing it to fertilize crops, is a traditional method used in Asia. It is also a contemporary approach to sustainable nutrient and water management in Scandinavia and other parts of Europe. Urine diversion and reuse is a proven socio-technical system that has significant potential benefits on both a local and global scale, such as recirculating scarce plant nutrients like phosphorus back to agriculture, reducing eutrophication of waterways and improving water and sanitation systems. This thesis explores the nature of these benefits in Australia and the global context and what barriers would need to be overcome if a urine diversion and reuse system were implemented in Australia to achieve significant environmental benefits. These questions are investigated through stakeholder interviews in Sweden, to identify the 'lessons learnt' from the Swedish experience with urine diversion and reuse, and, through interviews with relevant stakeholders in Australia to identify possible barriers and opportunities, costs and benefits, and roles and responsibilities in the Australian context. Findings from both the stakeholder interviews are triangulated with other sources of knowledge, such as the literature, personal communications and a qualitative assessment of costs and benefits.

This thesis found that while urine diversion is likely to benefit the Australia situation and warrants further research, these benefits are fragmented and spread across a range of discourses and separate institutions. Its acceptance and effective introduction into Australia might therefore be challenged by its lack of a single obvious organisational home. To overcome this and other identified challenges, several recommendations are made. For example, an Australian demonstration trial of urine diversion and reuse is recommended where clear drivers and opportunities exist, such as: in new developments adjacent to agricultural land; in regions where algal blooms are a critical problem and are predominantly caused by municipal sewage discharges; and where synergies with waterless urinals are being considered for water conservation value. This thesis does not promote urine diversion and reuse as the 'silver bullet' to Australia's water and nutrient problems, however it does recommend that it be considered on an equal basis next to other possible options. For example, if reducing nutrient loads on receiving water bodies is a key objective, then a cost-effective analysis of urine diversion and reuse, compared to other options to reduce nutrient loads, could be undertaken, ensuring all relevant costs and benefits to the whole of society are included in the analysis.

Keywords: urine diversion and reuse, phosphorus, agriculture, sanitation, stakeholders, institutions, management.

VOLUME I: CONTEXT

Why divert & reuse urine?

CERES, Melbourne, *photo: Dana Cordell*

1 Introduction

Urine diversion and reuse is an age-old practice in parts of Asia and there is significant potential in other growing urban centres around the world to return displaced urban nutrients back to agriculture. Currently practiced in a range of regions, from Sweden to Mongolia, the process of diverting urine from the household wastewater mix is offering substantial benefits to modern water and sanitation systems by preventing nutrient pollution of receiving water bodies. These, together with a plethora of other benefits, means it is time urban Australia began exploring options of urine diversion to help solve it's battle with the provision of sustainable water and sanitation services.

The primary research questions this thesis explores are: *In what ways can urine diversion and reuse contribute to sustainable management of nutrients and water in Australia and at the global level?* And, *If urine diversion and reuse systems were to be introduced in Australia at scale, what challenges would it face and how could these challenges be overcome?* In order to explore these questions, a transdisciplinary approach has been taken, involving stakeholder interviews both in Sweden, to learn from the Swedish experience and in Australia, to identify the barriers and opportunities, roles and responsibilities, costs and benefits according to key stakeholders. Intermediate objectives of this thesis are to advance knowledge in this area in Sweden and internationally, particularly in previously untouched research areas.

This thesis does not advocate urine diversion as the default solution to improved planning for the provision of water, sanitation and/or food services in Sydney and surrounds. However due to a 'urine-blindness' in most modern cities of the Western world (Drangert, 1998), the potential of urine diversion and reuse in urban Australia is currently unknown and there is a need to fully explore its possibilities both in its own right and compared to other potential sustainable options.

The structure and purpose of each volume in this thesis is as follows:

Volume 1 acts as a discussion starter. It introduces key literature in related fields and addresses the questions: *Why consider urine diversion in an Australian and global context? and What does a urine diversion and reuse arrangement look like?* Volume 1 also identifies and summarises the key theoretical frameworks and tools drawn upon in this transdiciplinary study.

Volume 2 justifies the chosen methodology and identifies potential limitations of this study. It presents an in-depth qualitative analysis of the Swedish and Australian interviews, which is then compared and contrasted to the literature according to the major themes that emerged from the interviews. Volume 2 goes on to discuss the nature and magnitude of costs and benefits of urine diversion and reuse.

Volume 3 synthesises the entire analysis - providing conclusions from each stage of analysis, reporting on overall key findings and then making recommendations for policy and further research. Finally, a comprehensive reference list of resources and key contacts is provided.

The primary audience for this thesis are the key stakeholders in Australia who could influence, or be influenced by, a urine diversion and reuse system in and around Sydney. For this reason, this thesis has been structured with these key stakeholders in mind. However this report has also been structured to provide information to other audiences, including the Swedish and international water and sanitation community, so that the analysis and discussion can contribute to the international body of knowledge on this topic. In this way, this report is relevant to municipalities, water service providers, community groups, researchers, industry and governments who manage or are concerned with sustainable water and sanitation provision, protecting waterways and/or securing a sustainable supply of fertilizer for the future.

2 Why think about urine diversion and reuse?

There are so many reasons to think about urine diversion and reuse. This section develops the case for diverting and reusing urine separate from faeces or mixed household wastewater. This is relevant in both the Australian and global context.

Urine diversion and reuse has a wide range of short to long-term benefits spanning several different discourses[1]. Due to the diversity of its benefits, urine diversion and reuse can be advantageous by complementing the areas of operations of several institutions, including those responsible for sustainable water and sanitation service provision, nutrient management, food production, and river health (within the broader context of catchment management). Some of the key arguments for diverting and reusing urine are summarised in Box 1 and expanded upon in the following sections 2.1 to 2.4.

Box 1: Why divert and reuse urine?

- Diverting nutrient-rich urine to land instead of water, can reduce excess nutrient pollution of such water bodies and hence reduce the occurrence of toxic algal blooms.
- Reusing urine as a source of phosphorus fertiliser will preserve the world's limited geological sources of phosphorus.
- Reusing the nutrients in urine instead of importing new mineral nutrients will slow down the rate at which our cities consume resources (such as mineral nutrients) and generate waste. This in turn will reduce the rate at which our cities consume energy, chemicals and water
- The nutrients in our urine come from the food we grow and then eat. If we return those nutrients back to agriculture, we can continue to produce food in a more sustainable way into the future.

2.1 Managing eutrophied waters

Diverting nutrient-rich urine to land instead of water, which typically receives society's treated wastewater, can reduce excess nutrient pollution of such water bodies.

Most experts, governments and community groups would agree that excess nutrient loads or eutrophication[2] of inland and coastal waters in Australia, Sweden and many other parts of the world is a significant environmental problem (HNRMF, 2004; DLWC, 1999; Naturvardsverket, 2002; Cloern, 2001; HELCOM, 2005). Eutrophic waters can lead to algal blooms, resulting in substantial fish kills and reduction of aquatic biodiversity (EcoSanRes, 2003; ISF, 2004). In addition to critically threatening aquatic ecosystems, toxic algal blooms also result in significant economic and social costs, in the form of losses to fishing and recreational industries and gravely threatening drinking water sources (Hawkesbury–Nepean River Management Forum, 2004).

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[1] These benefits are summarised in section 9 and related discourses introduced in section 4.

[2] A state of growth in plant primary productivity in turn can lead to algal blooms, which block sunlight, reduce dissolved oxygen (DO) upon death and decomposition and release toxic compounds. These combined stresses can result in fish kills and leave the water undrinkable for humans and other terrestrial animals (Mitrovic, 1995)

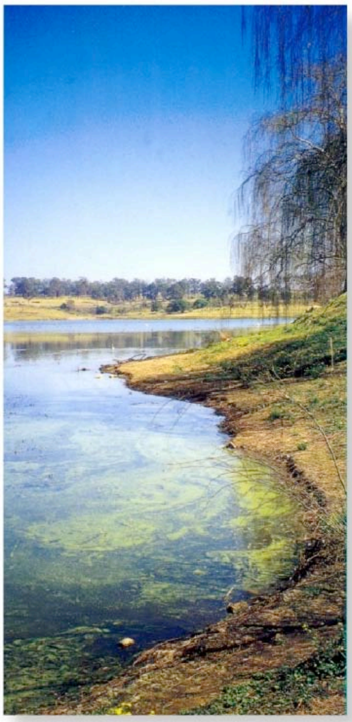

Figure 1. Blue Green Algal bloom in a reservoir, NSW
(source: Mitrovic, 1995)

While eutrophied waters can occur naturally, their increased frequency and intensity in global hot spots is a result of anthropogenic[3] activities releasing excess nutrient loads into water bodies and modifying river flow regimes (Naturvardsverket, 2002; HELCOM, 2005). In most developed areas, including Sydney and surrounds, there are typically several key anthropogenic sources of nutrient loads, including non-point sources such as agricultural runoff, and point sources such as human excreta and detergents found in municipal wastewater (Tangsubkul et al, 2005).

Options to manage key sources of nutrients can intervene at source where nutrients are generated, at end-of-pipe[4], or somewhere in between. Biological Nutrient Removal is an example of an end-of-pipe treatment, as it extracts nutrients from mixed municipal wastewater once it arrives at a sewage treatment plant prior to the discharge of the effluent. Urine diversion is an example of at-source treatment because it diverts the pollution at its source of generation – the toilet.

2.2 Managing dwindling phosphorus resources: 'Governing the Commons' revisited

Reusing urine as a source of phosphorus fertiliser will preserve the world's limited geological sources of phosphorus.

Perhaps an even more critical natural resource problem than eutrophication facing us this century that is the emerging phosphorus crisis. That is, the dwindling global supplies of this non-renewable, irreplaceable resource[5]. By replacing mineral fertilizer with nutrient-rich urine, we can substantially reduce the demand on mining non-renewable phosphate rock from reserves in West Sahara, Morocco, China and a limited number of other locations (Rosmarin, 2004). Phosphorus, like water and healthy soils, is a critical ingredient for the production of food crops. Yet at current extraction rates, we are likely to deplete known phosphorus reserves in the next 50-100 years (Cordell, 2005; White, 2000; Rosmarin, 2004; UNEP, 2005). This emerging phosphorus crisis is largely ignored in today's dominant discourses on food security.

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[3] human society. Analogous to the natural systems of the biosphere or atmosphere, the *anthroposphere* is the social system involving materials, goods and processes to satisfy the biological and cultural needs of humans. (Moore & Brunner, 199?).

[4] 'end-of-pipe' refers to treatment/management of pollution at the end of a treatment train or production process, rather than intervening earlier on in the process, where greater benefits can typically be realised.

[5] For further figures and discussion on phosphorus supplies and demand for food production and consumption, see: EFMA, 2003; IFIA, 2005; Hagerstrand et al, 1990; Gumbo & Savenije, 2001; FAO, 2004a; FAO, 2000; FAOSTAT,2005; Fresco, 2003; Mokwunye, 2004; Cordell, 2005a.

Management of phosphorus and other essential global resources (such as oil) or ecosystem functions (such as biodiversity), typically fall victim to the 'Tragedy of the Commons'[6] syndrome. That is, there are public resources that are fundamental to our survival, yet do not fit discretely and unambiguously in the realm of responsibility of a single sector of society. Such resources have historically not been managed in a timely and appropriate manner. However, in her book 'Governing the Commons', Elinor Ostrom built on this notion of the Commons by suggesting that such natural resources suffering from human overexploitation (coined 'common pool resources') should be *deliberately* managed by cooperatives comprised of the resource users themselves (Ostrom, 1990). Sweden is one country that has to some extent formally recognised the need for appropriate management of common pool resources. This was exemplified by their political decision in the mid-1990's to trial closing the loop on phosphorus through urine diversion and reuse schemes involving multiple institutions and stakeholders. The quote in Box 2 is indicative of this acknowledgement by the Swedish Environmental Protection Agency.

Box 2: Closing the loop on phosphorus: a case of 'governing the commons'?

"An important job was to be carried out and everybody was convinced that somebody else would do it. Anybody could have done it, but nobody did. Everybody thought that anybody could do it, but nobody realized that nobody would. It all ended up with everybody blaming somebody, when nobody did what anybody could have done."

(*Unknown author*, cited in Naturvardsverket, 2005)

2.3 Managing urban metabolism of water and food

Reusing the nutrients in urine instead of importing new mineral nutrients will slow down the rate at which our cities consume resources (such as mineral nutrients) and generate waste. This in turn will reduce the rate at which our cities consume energy, chemicals and water[7]*.*

More than half the world's population are now living in urban areas and this trend is set to increase (FAO, 2002; Lundqvist, 2001). How we provide essential services like water, sanitation and food to our cities, while efficiently assimilating or recycling its waste products (wastewater fractions and organic solid waste) will be crucial for future urban planning Günther,1996).

Many of the world's urban areas are already facing insufficient water supplies to meet the needs of their expanding populations (SEI, 2004; Mitchell & White, 2003; SIWI-IMWI, 2003). Further, existing water and sanitation systems are placing stress on the environment and society through ongoing water pollution, unsustainable energy and chemical use[8] and high operating costs.

It is now internationally agreed that more sustainable management of our urban water systems is required (Mitchell and White, 2003; SEI, 2004; IWA (homepage); WHO WatSan (homepage); WSSCC (homepage). Contemporary discourses in this field have shifted thinking in a number of key ways, such as: from managing water as a commodity, to water 'service provision' and looking for the least cost options for providing the desired service (Howe and White, 1999); 'backcasting' from a preferred future goal to the present to determine necessary actions required now (Mitchell and White, 2003); internalising environmental and social costs in economic analyses; looking for synergies that integrate related services such as water, wastewater, stormwater, nutrients, food production, energy; distributing or decentralising such services; and ensuring participatory processes that engage

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[6] 'Tragedy of the Commons' was coined by Garrett Hardin in 1968 referring to the clash between individual interests and the common good (Hardin, 1968; Wikipedia, 2005).

[7] Substantial energy, chemicals and water is required both for the production and transport of fertilizer, and the transport and treatment of solid waste and wastewater.

[8] Energy and chemical use in the transport and treatment of water and wastewater.

citizens and other stakeholders. These concepts and key references are discussed in section 4.3. Urine diversion can compliment this new approach, facilitating reuse and appropriate treatment of wastewater fractions.

2.4 Returning urban nutrients to agriculture

The nutrients in our urine come from the food we grow and then eat. If we return those nutrients back to agriculture, we can continue to produce food in a more sustainable way into the future.

As cities continue to consume copious amounts of nutrients in the form of food grown outside the city boundaries, there is a growing need to both manage the resultant organic waste and return those valuable nutrients from whence they came, so that the cycle of food production and consumption may continue in a sustainable way. Urban agriculture, that is, growing crops and raising livestock within and bordering urban settlements (Esrey et al, 2001), can be fertilized partially or wholly by the reuse of nutrients from human excreta (Gumbo & Savenije, 2001; Drangert, 1998). This already occurs to some extent with the reuse of sewage sludge, however there is increasing concern about the heavy metal content of combined industrial/municipal sludge. Some countries like Sweden, have banned or boycotted sludge reuse in food crop production (Krantz, 2005). Separating urine at source and reusing it can be a much more efficient way of recirculating those nutrients with lower toxic risk.

Of all the sources of nutrients in household wastewater, human urine is the largest contributor. Urine contains approximately 80% of all Nitrogen, 50% of Phosphorus and 60% of Potassium found in household wastewater (Esrey, 2000; Cordell, 2004; Jonsson, 2001). This is illustrated in Figure 2. While excreta output varies by age, type of diet (such as vegetarian versus meat-based), climate and lifestyle (Esrey et al, 2001), urine it is typically sterile and a readily available source of phosphorus. For example, urine alone provides more than half the phosphorus required to fertilize cereal crops (Drangert, 1998).

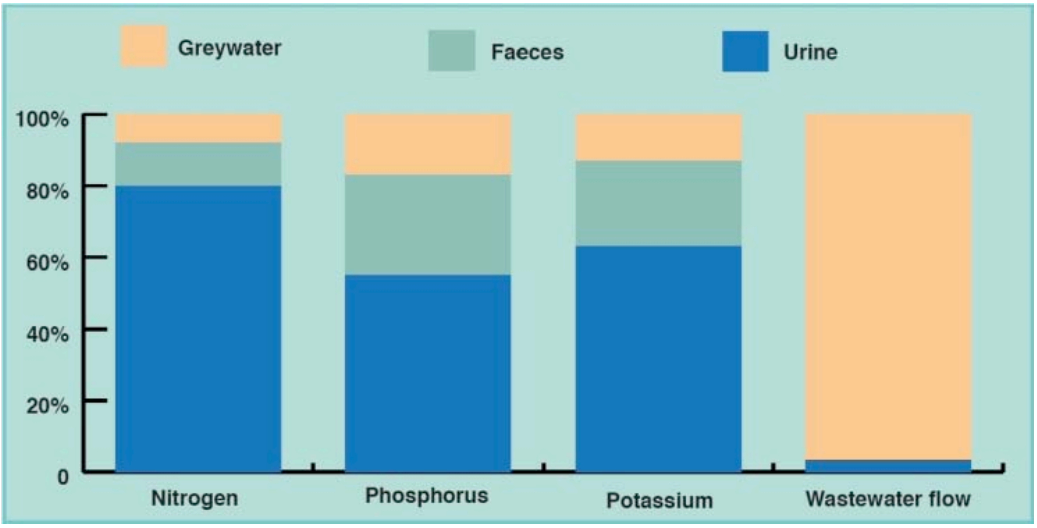

Figure 2: Proportion of each key nutrient coming from urine and other household wastewater fractions (source: Johansson et al, 2000)

However, Drangert suggests a ‘urine-blindness’ has prevented modern societies from tapping into this bountiful source of plant nutrients.

By diverting urine from the toilet bowl into a storage tank for up to six months, the stored urine can then be reused in agriculture, replacing the need for artificial fertilisers. As a fertiliser, urine is effective and has very low levels of heavy metals (Jönsson, *1997*).

While the area of land surrounding the urban fringe required to take up nutrients from human excreta is currently unknown, Johansson *et al* (2000) suggest urine can be transported up to 100km by truck, while remaining a more energy-efficient method than conventional systems of mineral fertilizer production, transportation and application. Drangert has also developed a preliminary relationship between the land area required for food intake, amount of nutrients in human excreta, soil capacity to absorb urine, plant requirement for nutrients and the population density in peri-urban areas (see Drangert, 1998).

2.5 Urine diversion in practice

While some Asian countries like China, Japan and Vietnam have practiced diverting urine and returning it to agriculture for centuries (Winblad, 1997), Scandinavia and other parts of Europe have today developed a variety of modern urine-diverting toilets that are currently on the market[9] (Jönsson, 2001). The urine diverting toilet range includes dry, single-flush or dual-flush toilets (see Figure 3). These systems have been well documented by both manufacturers and independent sources (see WRS Uppsala, 2003; Johansson 2000; West, 2003). Several large demonstration projects have been undertaken in the past decade while at least 2 municipalities in Southern Sweden have mandated urine diversion in new developments (see Box 5).

Figure 3: There are several commercially available urine diverting toilet systems available in Sweden. These range from dry urine diverting toilets like *Wost Man Ekologi*[10] (A-1) and *Separett*[11] (A-2); to dual- or single-flush urine diverting models like Gustavsberg's[12] 393U (B-1), *Wost Man Ekologi WM-DS* (B-2), and *Dubbletten*[13] (B-3); to the unique post-toilet centrifugal separator like the *Aquatron*[14] (C-1).

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[9] However the practice of urine diversion in Scandinavia did start as early as 1800's in Stockholm, for practical reasons, as discussed in section 6.1.1.

[10] See www.wost-man-ecology.se

[11] See http://www.ecovita.net/products.html and http://www.separett.com/default.asp?id=1109

[12] See www.gustavsberg.se (however this does not contain specific information on the 393U urine diverting model)

[13] See http://www.dubbletten.nu/english-presentation/WCdubbletteneng.htm

[14] See www.aquatron.se

Today, urine diversion has been largely unexplored in Australia. Although there are some individual demonstrations of urine-diversion[15] (see GHD, 2003; CERES in Cordell and Turner, 2004), currently, there is no available independent study or publication that explores the potential of urine diversion and reuse on a large scale in Australia. This thesis aims to explore the potential of urine diversion and reuse at a significant scale in Australia through stakeholder interviews in Australia and by researching the latest developments of urine diversion in Sweden (and internationally), and their potential contribution to sustainable water and nutrient management in Australia. Australia is currently, and is likely to be even more so in the future, facing the critical issues of eutrophication, water scarcity and unsustainable water and sanitation provision and a linear consumption of urban nutrients.

While the key drivers for using urine-diverting toilets may range from excess nutrient loads to water scarcity, the potential benefits are numerous. On a broad level, the principle of urine diversion and reuse traverses numerous discourses on sustainable management of water, sanitation, nutrients and food. It is only by addressing these multiple benefits that the true potential of urine diversion may be realised.

3 What does a urine diversion and reuse arrangement look like?

Like other source separation systems in sanitation arrangements (including greywater and blackwater diversion and reuse), there are numerous ways urine can be collected, stored, transported and used. One arrangement typically seen in Sweden is depicted in Figure 4. The optimal configuration for a particular area will depend on numerous factors, including cost, management arrangements, the key objective of diverting urine, housing density, responsible institutions and the final end use of the urine.

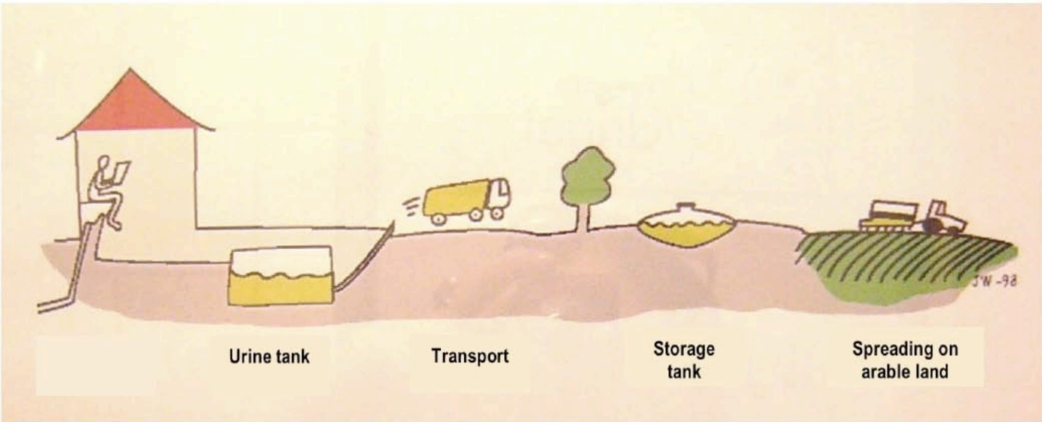

Figure 4: Typical system arrangement in Sweden (source: Nacka Naturskola).

Urine diversion systems can compliment a range of existing sanitation arrangements, including: wet or dry toilets; onsite[16] sanitation systems, community scale[17] sanitation systems or centralised piped wastewater systems. The optimal system will depend on the factors mentioned above in addition to what the region's main drivers are for considering urine diversion. In the long term, from a sustainability point of view, onsite or community scale systems may be most appropriate for a majority of situations, due to lower life-cycle costs, reduced risks and improved environmental outcomes compared to centralised systems.

[15] GHD (2001) undertook a feasibility study of dry urine-diverting toilets in an apartment block in inner-Melbourne; CERES Community Environment Park in Melbourne added simple urine diversion technology to their public composting toilets to reduce the excess urine loads on the toilet, reduce odour and improve the composting process.

[16] Such as many summer houses in Tanum Municipality, Sweden (Tanums Kommun, *webpage*1,2)

[17] Such as Kullön in Vaxholm, Stockholm Archipelago (VERNA, 2005a,2005b)

Synergies of urine diversion and reuse and other organic household waste streams, such as food waste should also be considered to maximise the overall sustainability outcomes. That is, if a natural resource objective is to recycle urban nutrients back to agriculture, a holistic decision-making framework may allow urine to be compared with other options such as sludge or a low-water vacuum piped system where all wastewater fractions, possibly including kitchen organic waste, are sent to agriculture via a decentralised network. This latter system has been trialled in Germany[18] (Otterpohl et al, 2003; Otterpohl, 2002). Some of these trials have further integrated energy recovery into the system by using methane recovered from anaerobic decomposition of wet faeces to generate energy for space heating.

[18] project details and interim reports of ongoing project evaluations can be found at http://www.kompetenzwasser.de/Sanitation_Concept_for_Separate_Tre.22.0.html?&L=1 and http://otterwasser.de/homee.htm

4 Theoretical frameworks and key concepts

This section describes the theoretical frameworks and key concepts used in this thesis. It also describes why a transdisciplinary approach has been adopted and justifies how research quality of this transdisciplinary approach can be assured.

4.1 Transdisciplinary research

In this thesis, multiple methods are integrated to address multiple aspects (technical, institutional, social and so forth) of a multi-faceted problem[19].

Both the theoretical basis and practical application of urine diversion and reuse traverse numerous disciplines and discourses. Some of these are described in the following sections. Thus to conduct effective research on this issue, a transdisciplinary approach has been adopted. As Sommerville and Rapport note: "*A transdisciplinary perspective is an essential requirement of real-world problem solving*" (Somerville and Rapport, 2000 p. XV). This research focuses largely on opportunities and challenges posed by the practical application of urine diversion and reuse in the 'real world' and is therefore inherently and purposefully transdisciplinary.

Opportunities and barriers to the implementation of innovative sustainable systemstypically span a plethora of areas. These characteristically include: technical, institutional, health, social, economic and ecological aspects (Livingston et al, 2005; MISTRA, 2000; Malmqvist, *forthcoming*). The research question posed by this thesis could not be fully answered if all key aspects were not addressed to some extent. Carew defines transdisciplinary research as: "*An holistic process of exploring and resolving problems in their context through the iterative integration and application of theory and practice" (p52, Carew, 2004)*. Nelson et al (2005) suggest transdisciplinary research (as opposed to multidisciplinary research) attempts to not only understand an issue or methods across disciplines, but also to integrate these different types of knowledge and approaches to form a new method that more appropriately addresses the research question. In suggesting this, he refers to Molteberg and Bergstrom's articulation that the "totality of the transdisciplinary study would be greater than the sum of the parts" (Molteberg and Bergstrom, 2000a, 2000b, cited p3, Nelson et al, 2005). This is true of my research in the sense that the multiple aspects of urine diversion and reuse are explored through interviews with a diverse range of stakeholders from disciplinary backgrounds in both the Swedish and Australian situation. This is triangulated through analysis of existing literature, in addition to a qualitative analysis of costs and benefits of urine diversion and reuse.

Carew's analysis of transdisciplinary research (mentioned above) explores how research quality can be demonstrated and validated. She suggests that transdisciplinary researchers tend to spend a disproportionate amount of time and resources on breadth as they traverse multiple disciplines and attempt to integrate these disciplines into a single framework. It is therefore important that this breadth is managed in a scholarly way. However, defining and measuring quality in transdisciplinary research is perhaps harder and more complex than in disciplinary research as it differs from the traditional measures of research quality used to assess disciplinary research. Boyer (1990, cited in Carew, 2004) suggests that the narrow definition of what constitutes research quality is not necessarily appropriate or sufficient in the context of university transdisciplinary research. He defines four key modes of scholarly activity that he believes are of equal weighting: the scholarships of a) discovery (pursuit and generation of new knowledge); b) integration (synthesis of new ideas from existing theories, knowledge, disciplines); c) application (resolving 'real world' problems) and d) teaching or 'communication'[20] (facilitation of knowledge transfer by providing accessible findings). My research has endeavoured to cover each of these four modes by: a) seeking new knowledge

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[19] This multi-faceted problem is described in section 2.

[20] Carew modified Boyer's 'scholarship of teaching' to 'scholarship of communication' to better reflect the two way nature of learning between all relevant parties.

on opportunities and barriers of urine diversion and reuse (particularly in the Australian context where it is untried); b) integrating several key discourses relating to urine diversion together with several key methods into a single framework in which to analyse the research question; c) focusing my research on what would need to occur in Australia for urine diversion to be applied and making policy recommendations; d) structuring my research in such a way that the information is accessible to a wide range of audiences, in addition to providing an extensive resource list in the form of references and key contacts list.

4.2 Key concepts: discourses and methods

Key contemporary concepts and strategies for managing sustainable water and nutrient cycles relevant to this study are discussed in this section. Methods from several disciplines are drawn upon to analyse the research question in this study and for the purpose of describing how they have influenced the approach to this research, they are classified as either discourses or methods/tools.

These discourses and methods include:

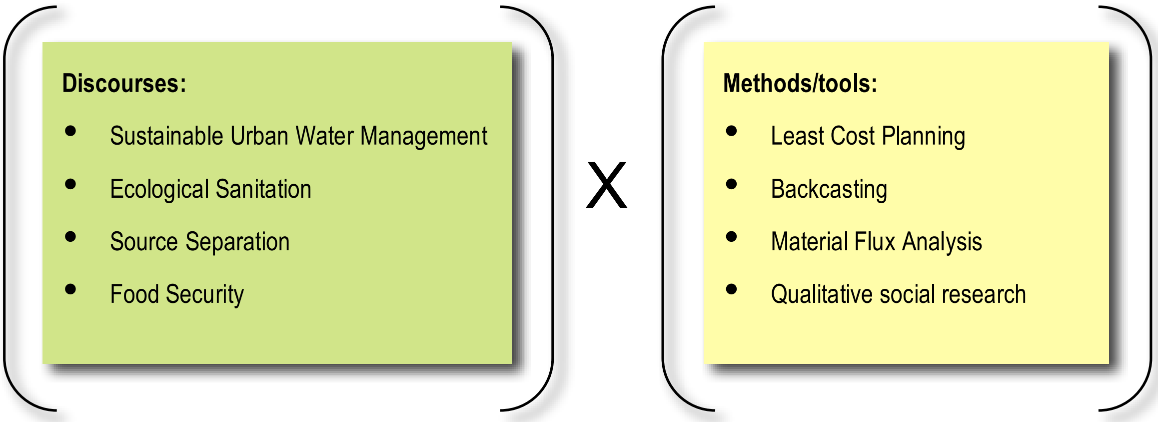

Figure 5: The four key discourses and four methods drawn upon in this transdisciplinary research study.

4.3 Sustainable urban water management

There are numerous interpretations and conceptualisations of sustainable urban water management as noted recently by Livingston et al (2005), such as 'Water Sensitive Urban Design'[21] (Mouritz, 1991) and 'Integrated Resource Planning'[22] (Howe and White, 1999). However, there are some generally accepted principles, such as taking a 'systems approach' and planning for water, wastewater and stormwater in an integrated manner. Some other approaches include synergies with nutrients, energy and food systems, such as Integrated Resource Management in figure 6. Sustainable urban water management can compare alternative options across the whole life cycle and consider environmental and social costs

[21] Water sensitive urban design involves integrating water quantity, quality, and water consumption into land use planning, design and management of the urban environment (Mouritz, 1991). A significant part of WSUD has typically been integrating stormwater issues into urban design.

[22] Integrated resource planning allows resource conservation options (or demand-side options) to be compared to supply-side options, such as in the provision of water services. It originated in the electricity industry in the US though is now used extensively in the water and other industries (Mieir et al., 1983; Howe and White, 1999).

and benefits in economic analyses, where possible. The MISTRAUrban Water Program[23] views sustainable urban water systems as broader than simply physical infrastructure. They include the organisational infrastructure and the users in addition to the technological infrastructure (MISTRA, 2000) (see also Fane 2004; Spears, 1999; Mitchell and White, 2003). Urine diversion and reuse forms a component or 'piece of the puzzle' of the sustainable urban water systems and is therefore considered in this context as well as other discourses discussed below. Sanitation services are typically included implicitly in sustainable urban water management. West (2000) prepared a detailed report on best-practice sanitation systems in the context of sustainable urban water systems based on a 9-month study tour around Europe and the US. In this review, urine diversion and reuse systems in Scandinavia are highlighted as one best practice system for recirculating nutrients from wastewater.

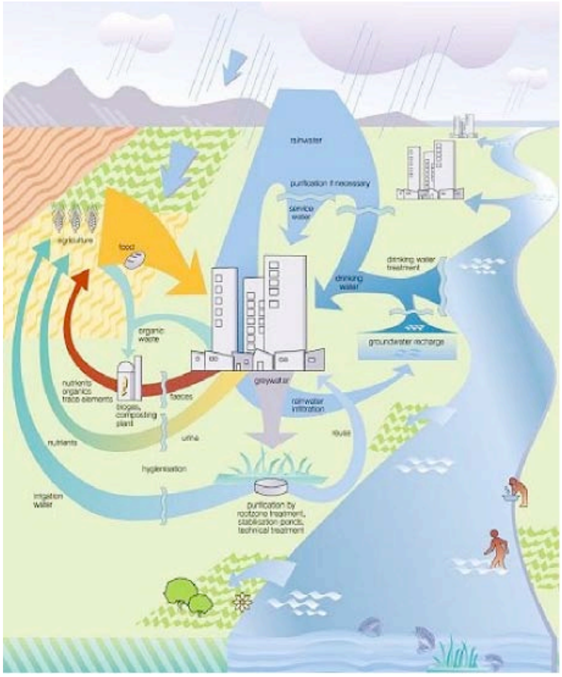

Figure 6: Integrated resource management depicting appropriate sourcing of water fit for purpose and recycling of wastes as resources (www.ecosan.org)

4.4 Ecological Sanitation

Ecological sanitation, or 'ecosan', refers to the containment, sanitization and recycling of human excreta to arable land (EcoSanRes, 2005). It overlaps partially with sustainable urban water systems, as both endeavour to find sustainable approaches to sanitation provision whilst protecting the environment and public health. However ecosan principles extend beyond this and are based on the principles of: 1. source separation and pollution prevention rather than end-of-pipe treatment; 2. sanitizing urine and faeces; and 3. the safe reuse of urine and faecal products for agricultural purposes (SEI, 2004). Other important objectives are the reduction of water use in sanitation systems and reducing the demand for mineral fertilizers in agriculture by recycling nutrients from human excreta. There are numerous documented practical examples of ecological sanitation around the world in places such as Southern Africa, China, Vietnam, Mexico (Gumbo & Savenije, 2001; Drangert, 1998; SEI, 2004), and in the developed world in Scandinavia, particularly Sweden (Johansson & Kvarnström, 2005; Kvarnström et al, 2006). There are two key international discourses on ecological sanitation: EcoSanRes (see www.ecosanres.org) and EcoSan (www.ecosan.org). The forthcoming World Health Organisation 'Guidelines for Safe Use of wastwater, excreta and greywater'[24] may in some respects legitimise the application of urine diversion and reuse in the eyes of some politicians (Jan-Olof Drangert, pers. Comm. 2005).

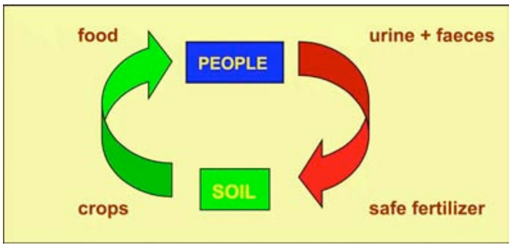

Figure 7: principles of ecological sanitation: contain, sanitise and reuse excreta on arable land. (source: ecosanres.org)

[23] The MISTRA Urban Water Programme is a Swedish 3 year research programme to develop criteria for assessing urban water and wastewater systems (see http://www.urbanwater.org/dyndefault.asp?p=2479)

[24] Scheduled for release early 2006.

The application of urine-diversion addressed in this thesis is grounded in the ecological sanitation principles, however simultaneously addresses the other key concepts raised in section 4.

4.5 Source separation

In environmental management terms, source separation typically refers to approaching pollution management at the source of a process where waste is generated, rather than focussing on management of the waste products at the end of the process (often referred to as *end-of-pipe* solutions). In solid waste management terms, it refers to the household sorting of waste streams to facilitate recycling or reuse (French, 2002). In the context of sanitation, source separation is closely linked to ecological sanitation. 'Source separation' refers to separating the different household wastewater fractions at source and treating them separately (Jönsson, 2003). These fractions have very different characteristics, including volumes generated, nutrient content, presence of pathogenic material, and when kept separate from one another these fractions can be more appropriately treated and more readily reused (Otterpohl, 2000; Otterpohl et al, 2003). This tends to be more environmentally beneficial, cost-effective and efficient than chemically, biologically and/or mechanically separating the different wastewater fractions at end-of-pipe. Diverting urine at source via a urine-diverting toilet is an example of an effective way of collecting the majority of household nutrients in wastewater rather than expensive end-of-pipe nutrient removal at a sewage treatment plant. This is exemplified in recent studies in Germany (Otterpohl, 2000), China (Huang et al, *in press*), Sydney (Tangsubkul et al, 2005) and the Baltic Sea (Johansson & Lennartsson,1999). These studies indicate that source separation of municipal sewage is one of the key options for physically reducing point source pollutant loads (such as nutrients) discharging into waterways.

4.6 Food security

Future food security has increasingly become of global significance (FAO, 2000; SIWI-IWMI, 2004; UN, 2000; IFPRI, 2002; Runge-Metzger, 1995; WorldWatch Institute, 2000). According to the UN's Food and Agricultural Organisation (FAO), food security exists "when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs for an active and healthy life" (p1. FAO, 2005). The FAO is a key institution in the global food security debate. The FAO's annual State of Food Insecurity (SOFI) reports, IFPRIs reports and UN Millennium Development Project, all stress that food insecurity is a consequence of numerous inextricably linked factors, including frequent illnesses, poor sanitation, limited access to safe water, lack of purchasing power and various other issues. They highlight connections between the Millennium Development Goals (MDGs) on hunger, poverty, water and sanitation. (FAO, 2004b; Braun et al, 2004; UN Millennium Development Project, 2005). More recently it is understood that water provision will be a critical issue for meeting the future nutritional demand of a growing and undernourished population. Experts suggest that a radical shift in the way we think about and manage water is required in order meet this demand (Falkenmark & Rockström, 2002). However, just as the challenge of food security faces 'hydroclimatic realities' (p.5 SIWI-IWMI 2004) of limited water availability, so too does it face the 'geochemical realities' of limited phosphorus reserves (Cordell, 2005). Currently, there is little or no mention of phosphorus as a key factor limiting future food security in the dominant discourses, despite its key role in the growth of food crops. This could be attributed in part to what Falkenmark (2001) calls 'paradigm locks'. That is, over time, different fields develop their own set of language and concept, even if they are working towards the same overarching goal. The dialogues on 'water for food security', and 'ecological sanitation' (or 'closing-the-loop') for food security each developed separately, though a significant part of each address the same question: how can we achieve global food security in a sustainable way? Figure 8 indicates that phosphorus, along side water, food accessibility[25] and nutritional

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[25] Institute For Agriculture And Trade Policy, 2004; Smaller, C. *personal communication* (5/6/05); Cordell, 2005a; Kent, 2001; Johnson,1998; IFPRI, 2003; WorldWatch Institute, 2002.

absorption are essential ingredients for global food security. One way of securing phosphorus for the future is reusing urine.

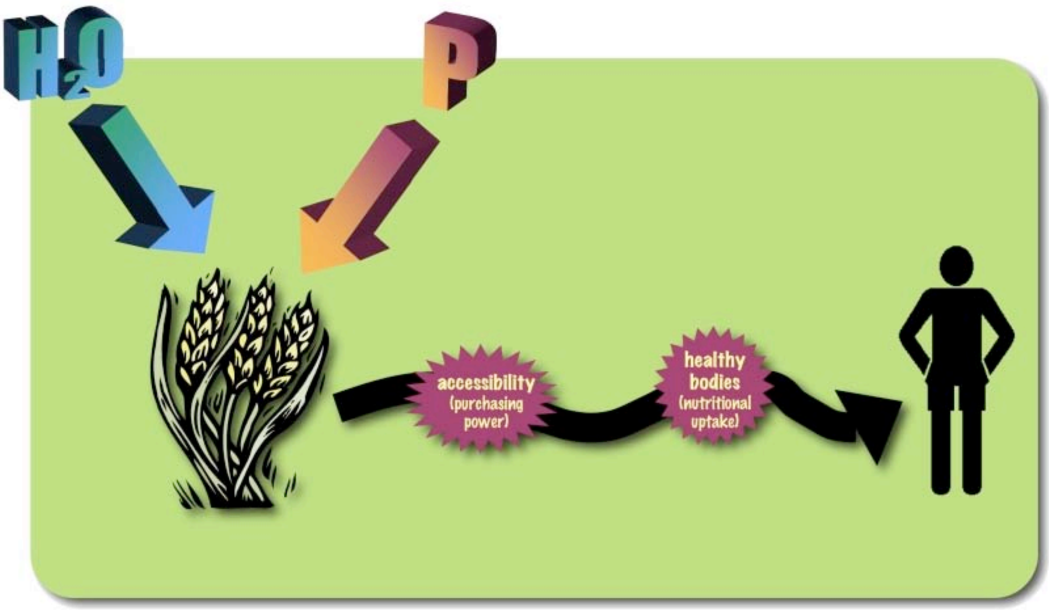

Figure 8: Four issues seen as key to addressing global food security: water, phosphorus, access to food, and nutritional absorption (source: Cordell, 2005).

4.7 Least Cost Planning (LCP)

Least Cost Planning, which originated in the US energy industry, is a resource management framework for determining the least cost options for achieving the greatest benefit to society for a given resource. In terms of sustainable water provision, it is based on the principles of providing a service, not a commodity - that saving a kilolitre is the equivalent of supplying a kilolitre. It allows comparison of supply, source substitution, reuse and demand management options on an equal basis (see Fane et al, 2004; ISF, 2004;).

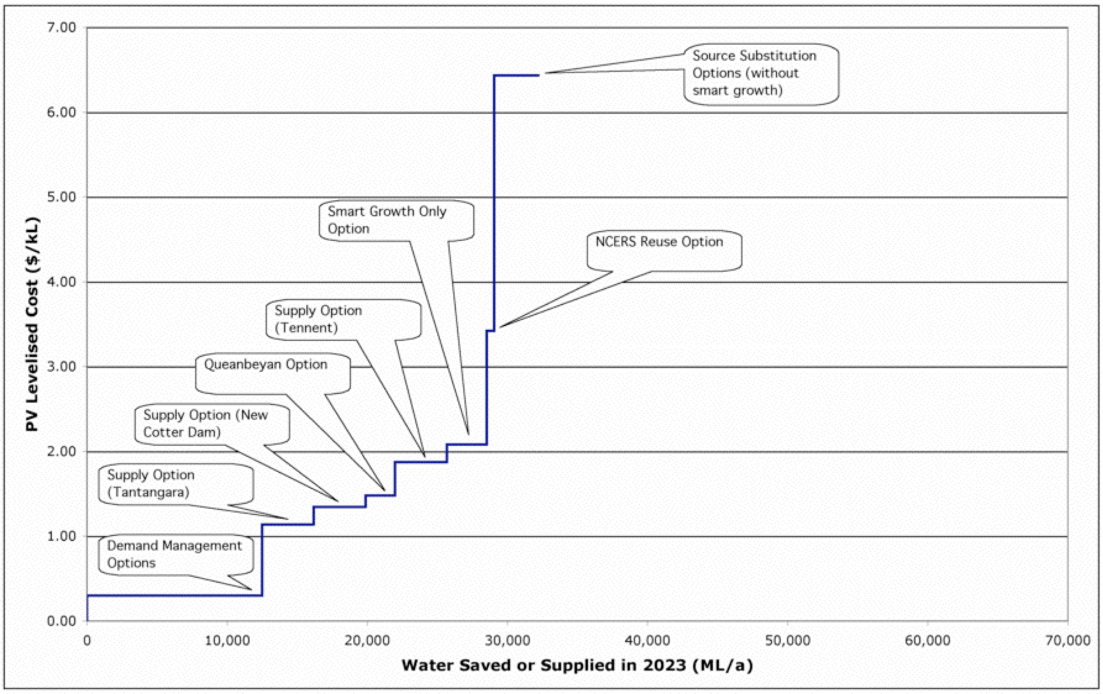

Figure 9: An output from a Least Cost Planning study in Australia, allowing various water supply, demand and reuse options for meeting the regions water needs to be compared on an equal basis, based on each options unit cost, ie. $/KL of water they yield (Y-axis), and, the total amount of water each option can yield (x-axis). Based on cost-effectiveness, the options with the lowest unit cost (furthest to the left) are recommended for implementation first.

Least cost planning thinking was intended as an underlying tool in this thesis. That is, to determine the cost-effectiveness of urine-separation in Australia, to move towards sustainable nutrient management. The unit cost (often defined as $/kL water saved) could be defined as $/Tonne of phosphorus avoided from entering the catchment and compared to alternatives such as $/tonne of equivalent algal bloom clean up, allowing comparison on an equal basis. Whilst it was decided against a detailed analysis in this thesis, the use of LCP is still recommended as a next step to this research (see section 10).

4.8 Backcasting

Backcasting is a policy tool used for planning for the future. Compared to forecasting, which involves projecting from a point or scenario in the present, backcasting involves working backwards from a specified desired future end-point to the present (see figure 10). This process allows for the determination of the physical feasibility of that future and what policy measures would be required to reach that point (Robinson, 1990). (see also Dreborg, 1996; Mitchell and White, 2003).

According to Hojer and Mattsson (2000), backcasting is a particularly powerful and useful tool where great change is needed. In this thesis, it is assumed that a great change or shift in current practice will be needed to reach the goal of recirculating nutrients within human waste back to arable land and no/low eutrophication. Urine diversion and reuse is one means of reaching these goals. Backcasting from these goals, we then ask: how much could urine diversion and reuse contribute? and, what are the current barriers and opportunities to achieving these future goals? This backcasting approach was used to formulate part of the research question in this thesis, that is, what would it take to reach a meaningful ecological target through urine diversion and reuse.

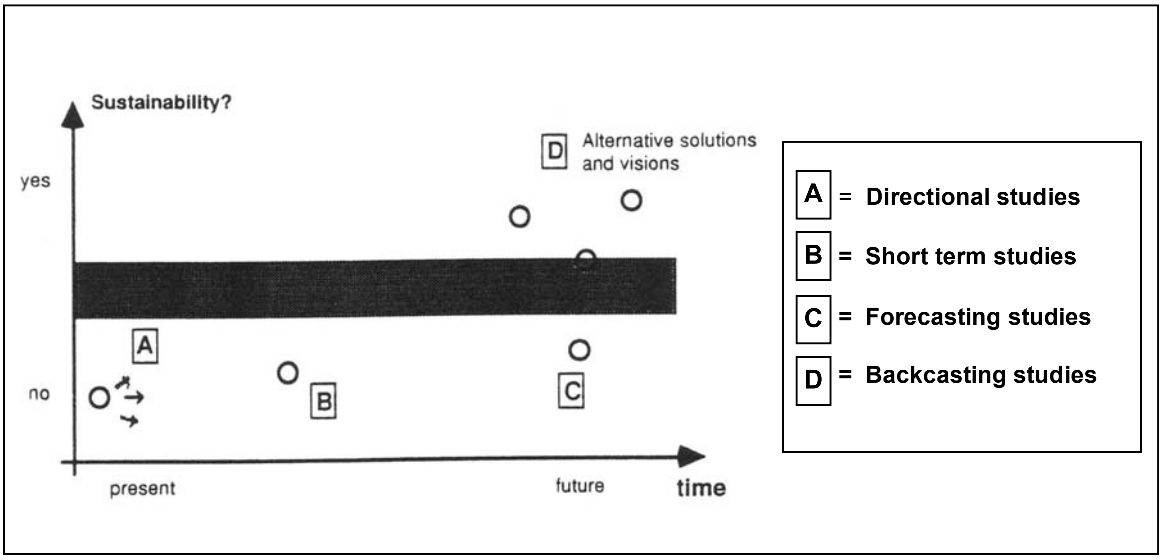

Figure 10. Application of backcasting to sustainability studies. The diagram indicates that some studies, such as forecasting or short term studies may not be sufficient or powerful enough to reach a desirable level of sustainability, as they are more appropriate for marginal change, where as backcasting is useful when step or radical change is required. Source: (Dreborg, 1996).

4.9 Material Flux Analysis

Brunner and Baccini developed the methodology of Material Flux Analysis (MFA) in the early 1990s. MFA is a material accounting tool that helps us assess and understand the sustainability of a particular material in the environment whose quantity and flow paths have been altered by human activity. It involves examining the inputs, outputs and accumulation of the material through a defined system boundary, such as a city, catchment, household or region (Brunner and Baccini, 1991). In relation to managing nutrients, MFA allows analysis of the fluxes of nutrients (such as nitrogen or phosphorous) through a specific catchment, to determine which human activities are responsible for the main sources of the excessive nutrient flows into the catchment's waterways (such as agricultural practices or effluent discharges) (Brunner and Baccini, 1991; Cordell 2000; ISF, 2004).

An MFA of phosphorus through a catchment like the Hawkesbury-Nepean (in NSW, Australia), would identify wastewater (primarily urine), as one of the key sources of nutrients into the catchment (see figure 11) (ISF, 2003). MFA can further measure the load per annum and any changes over time. MFA can also be used as a tool to model scenarios of the impact of urine-separation compared to other options for reducing nutrient loads into the catchment.

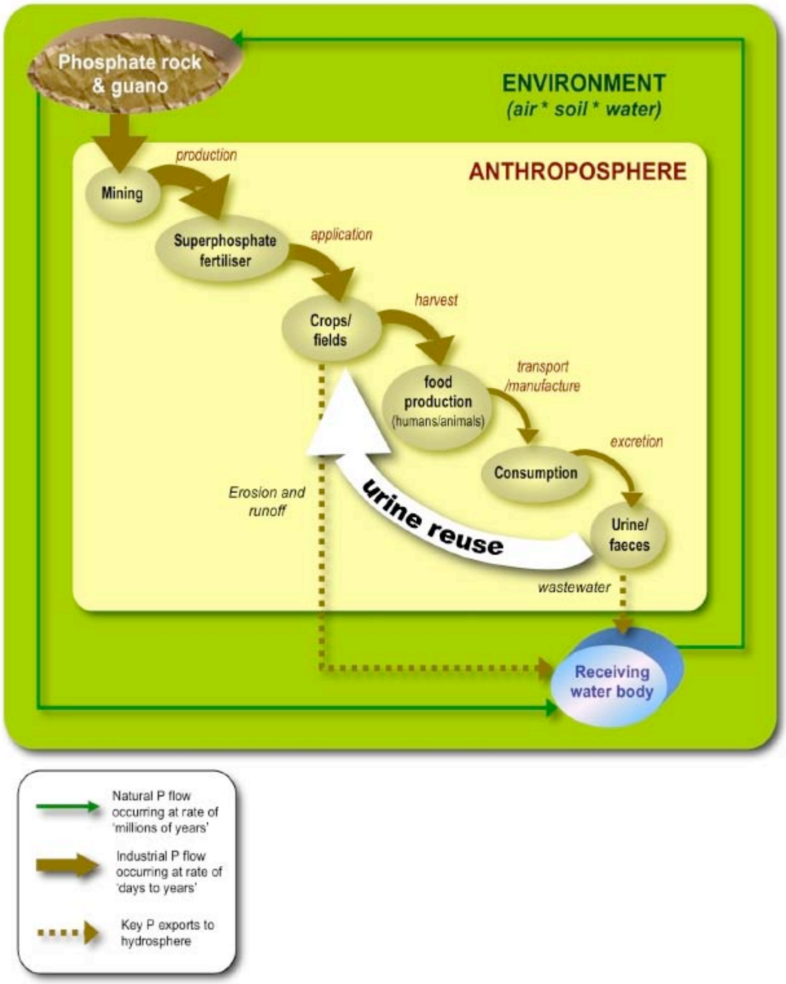

Figure 11: The P-cycle altered by industrial society for food production. This shows the unsustainable 'open-looped' system compared to the natural biogeochemical 'close loop' cycle. The 'anthropogenic' flows represent those undertaken by industrial society at the rate of 'days to years', whereas the lines are naturally cycled at a rate of 'millions of years'. It is much more resource and energy intensive (and hence more costly) to recover P further down the path, due to its decreasing concentration. This is particularly the case for the receiving water body, due to the high level of dispersion which occurs once the P-containing good reaches the water.
(*adapted from Cordell, 2000 and ISF, 2003*)

Several recent studies have used MFA to model phosphorus and nitrogen flows through an urban centre, with reference to wastewater flows and food production (see Tangsubkul, et al, 2005 and Schmid Neset et al, 2005; Cordell, 2000). For example, the impact of diverting and reusing urine on phosphorus and nitrogen imports into an urban centre can be readily modelled both for a given year and over time.

MFA can also be used as a preventative tool to anticipate and modify environmental stresses caused by unsustainable interactions between human activities and the natural environment (Moore and Brunner, 1996). A downside of the MFA tool is that it is time and resource intensive, as extensive research is required to gather sufficient information.

4.10 Qualitative social research

Qualitative social research involves inductive analysis to develop theories or explanations of the social world, including why we behave the way do (Trent Focus Group, 1998). Qualitative data collection methods, such as semi-structured interviews, are useful when the research question at hand is complex and/or not widely understood. This was the situation for the subject of this research. It was anticipated that awareness of urine diversion would be limited or negligible among various stakeholder groups coupled with its benefits and opportunities being complicated and difficult to explain and grasp. Further, it was anticipated prior to undertaking this research, that the largest gaps or barriers in this field were non-technical, hence social research methods were considered highly appropriate to capture these non-technical issues. Qualitative data can be analysed quantitatively or qualitatively. Qualitative content analysis, that is, organising interview transcripts into categories and sub-themes and interpreting the responses under each theme (Trent Focus Group, 2001) was considered most useful and appropriate for the research question(s) in this study.

Other social research methods, such as participatory processes, were not employed within the scope of this thesis, however they are acknowledged as highly important and perhaps useful for follow-up research emerging from this study. Participatory decision-making means involving the community and stakeholders at the start, middle and end of the decision-making process. Outcomes generally incorporate the public's values into decisions that affect their lives. Participatory methods can also act as an early warning system for public concerns and needs and to reduce costly project delays further down the track (Carson and Gelber, 2001). Studies such as White et al (2001) undertook extensive community consultation and stakeholder engagement to complement the cost-benefit analysis on the feasibility of an environmental policy. Whilst this thesis will not undertake primary research to engage citizens (due to time and resource restrictions), it will engage stakeholders through stakeholder interviews, which form the basis for the research. This will complement the cost-benefit component of this thesis.

Figure 12: Group deliberations in a participatory process to unpack views on best-practice sanitation systems. (photo: Dana Cordell)

4.11 Relationship between discourses

The following diagram (figure 13) conceptualises the interrelationship between four of the key discourses this thesis is based upon. It shows that some discourses overlap (such as ecological sanitation and sustainable urban water). The theory and application of urine diversion and reuse traverses all four discourses to some extent and fits in the intersection of all four. This, broadly speaking, entails the cost-effective sustainable use of resources by humans that facilitates their reuse, while protecting public health and the environment.

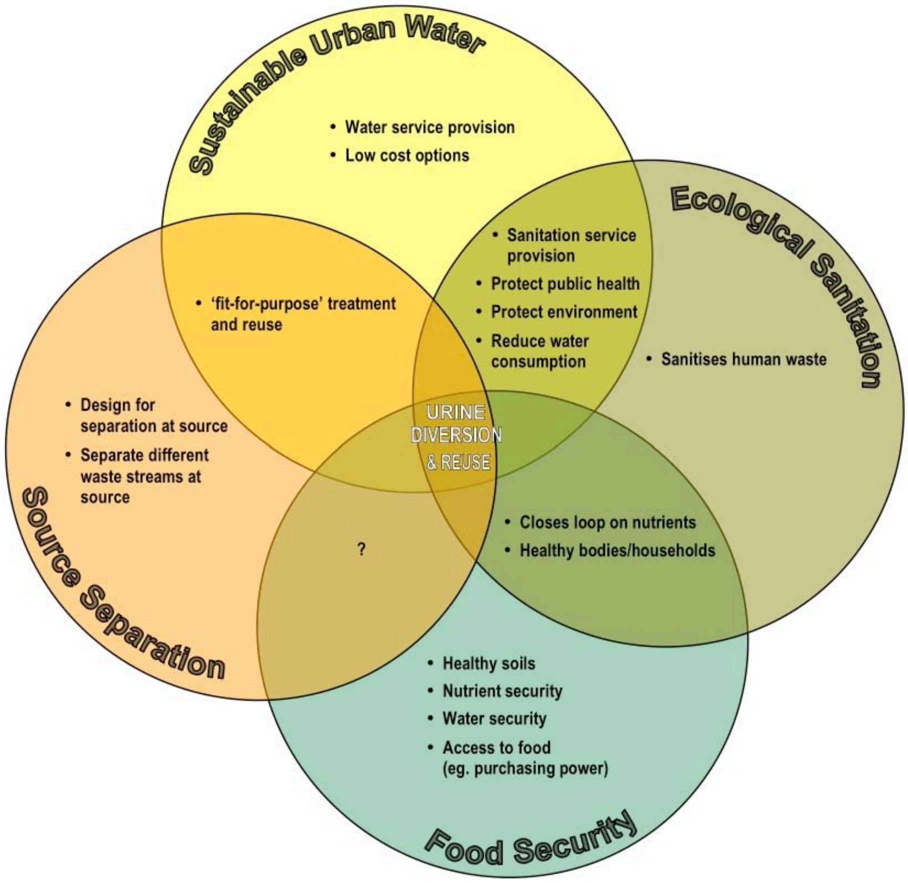

Figure 13: The interrelationship between the four major discourses drawn apon for this thesis: Sustainable urban Water, Ecological Sanitation, Source Separation and Food Security. Urine diversion and reuse is based in the overlap between all four discourses.

VOLUME II: ANALYSIS

What are the barriers and opportunities?

The roles and responsibilities?

The costs and benefits?

“There's no synergy between town and country, there's no synergy between the nutrient cycle that is generated by a city moving back into a country environment… Sydney is a massive consumer of natural resources. We haven’t found a way of recycling some of those resources back in to the areas that produce them... And the farmers understand this...the nutrient cycle, because that's their livelihood. They send all these nutrients to the city in the form of vegetables and timber and things like that, but they're not getting it back... We just call it 'waste management' in the city...its not culturally understood by governments"

[p4, Catchment Management Authority respondent, Australia]

5 Methodology

5.1 Research question and objectives

The key research questions addressed in this thesis are:

1. *In what ways can urine diversion and reuse contribute to sustainable management of nutrients and water in the Australian and global context?*

2. *If urine diversion and reuse systems were to be introduced in Australia at scale, what challenges would it face and how could these challenges be overcome?*

Both research questions are exploratory in nature, as this topic has not yet been researched in Australia. More narrow research questions may have limited the scope of findings. However, due to the diversity of the environmental, demographic and political contexts within Australia, where relevant, this research has focused on a specific part of Australia: Sydney and surrounding land, and, the Hawkesbury-Nepean Catchment[26] that provides water to Sydney.

The first question asks what are the benefits of urine diversion and reuse and how can it address the pertinent nutrient and water challenges facing Australia and the global environment. Identifying the costs of urine diversion and reuse is also implied in this question.

The second research question is more complex. It asks what are the barriers and opportunities to introducing urine diversion and reuse systems in the Australian context, be they institutional, technical, behavioural or other. However this question is not simply referring to the introduction of a new technology on the market in Australia, it refers to implementing a socio-technical system at a scale that will significantly improve Australia's nutrient and water problems. That is, what are the challenges and what changes would need to occur in Australia in order to reach a meaningful scenario. A 'meaningful scenario' was not explicitly defined while undertaking this study, because the purpose of the stakeholder interviews was to explore stakeholders' perception of the main benefits of urine diversion and reuse would be for Australia and not to presuppose what this scenario was without prior research to support such a scenario. If this main benefit was seen to be the recycling of urban nutrients back to agriculture, then an example of a meaningful target could be ensuring 50% of nutrients in wastewater are recycled back to arable land by 2025[27]. This is similar to a recently proposed target under Sweden's National Environmental Objectives[28] to recirculate 60% of phosphorus from wastewater back to land (of which 30% must be to agricultural land), by 2015[29]. Both these approaches are based on the principles of backcasting, as described in section 4.8.

Box 3: A meaningful scenario?

For the purpose of this study, a meaningful scenario is a target that if met, will lead to significant positive change towards the ultimate aim of the target. For example this could be ecological or political change. This compares to say a 'tokenistic' target that is more a gesture or symbolic rather than creating any real change. This term was introduced in this thesis once the distinctive gap between what it would take to introduce urine diversion and reuse into Australia versus what it would take to create significant change through urine diversion and reuse became apparent.

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[26] See section 5.2.4 and Appendix C for justifications for selecting this catchment.
[27] These two figures – 50% and 2025 - are purely used by way of example and are not based on research of appropriate figures.
[28] See Sweden's National Environmental Objectives at http://www.miljomal.nu/english/english.php
[29] This target was recommended to the Swedish government by a Swedish EPA Action Plan and the decision was in Parliament at the time of this research.

This thesis is intended to achieve multiple objectives within the broader research questions to maximise benefits and contribution to the Australian, Swedish and international research community.

The key objectives within these two research questions are:

- to document the latest ‘grey’ knowledge areas and lessons learnt from the Swedish experience of urine-diversion and reuse (i.e. what works, what doesn’t and why?);
- to collate the latest published knowledge on urine diversion and reuse internationally;
- to identify current opportunities and barriers (or perceived barriers) to implementing urine diversion and reuse systems in Australia;
- to identify the potential roles and responsibilities if urine diversion and reuse were introduced into Australia;
- to identify the potential costs and benefits of urine-diversion and reuse in Australia;
- to make policy recommendations based on the findings of this thesis; and
- to facilitate research collaboration between Sweden and Australia in this field.

5.2 Methods and motivations

This thesis topic is inherently transdisciplinary and hence research methods draw from a spectrum of theories, concepts and methods. Figure 14 depicts the research methods and steps, including data collection, analysis and synthesis, conclusions and recommendations. Explanations of each step and justifications for the chosen methods are provided in the proceeding sub-sections and Table 1.

In order to best address the research questions, methods were selected based on optimising research quality versus scope and time. For example, compared to gathering data through a quantitative questionnaire, conducting interviews restricts the number of respondents and demands significant analysis time. However, the depth and type of information achievable through interviews is seen as crucial to this study and outweighs the disadvantages. Table 1 defends the choice of each method.

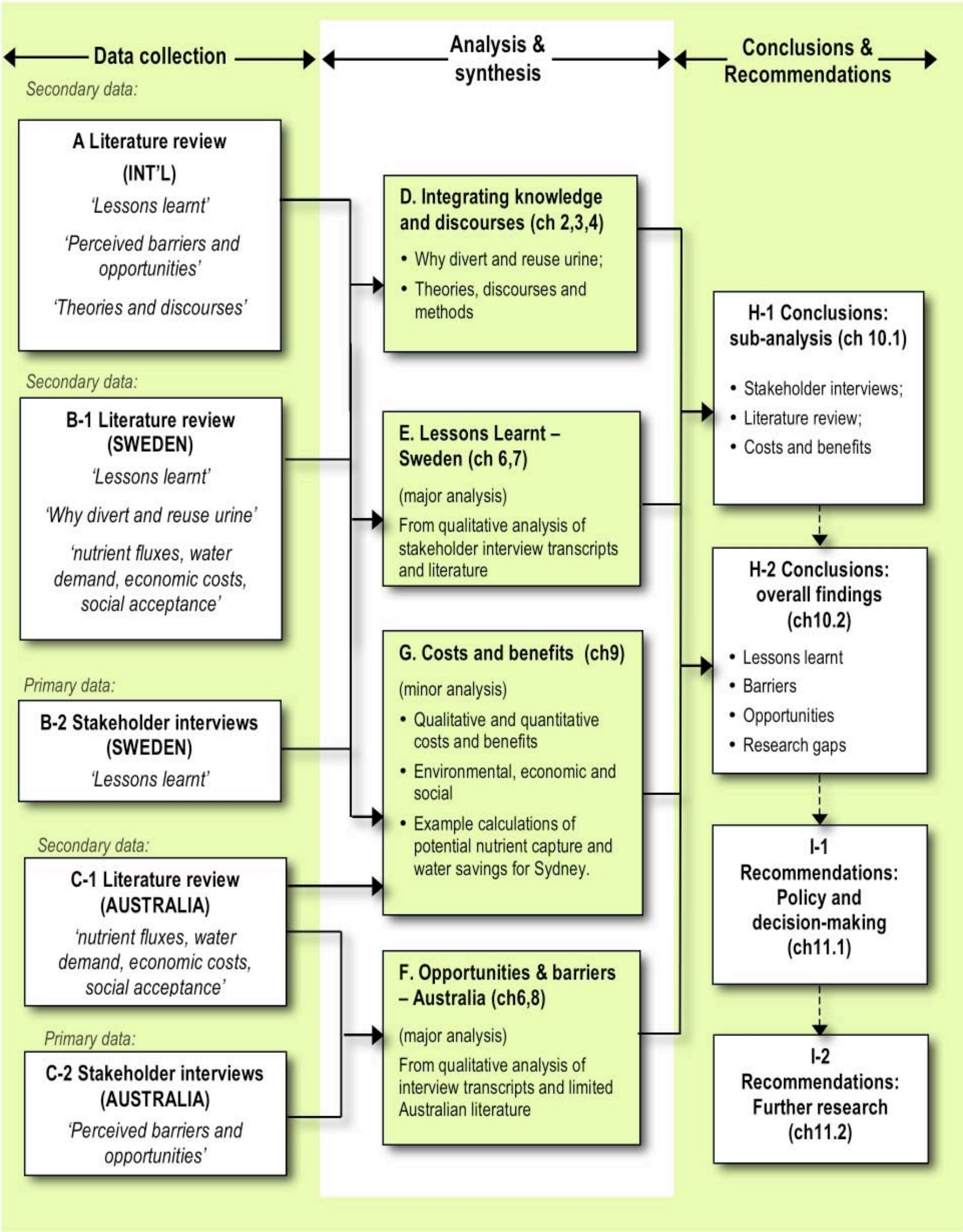

Figure 14: Method flow chart. Three phases are depicted – the data collection phase, the analysis and synthesis phase, and the conclusions and recommendations phase.

Table 1: Methods chosen for addressing the research question and justification for choices.

Method*	Motivation for choice of method
Semi-structured, face-to-face Interviews **(B-2, C-2)**	• *Primary* data collection method chosen because some or all of the key research issues are currently unpublished knowledge; • *Qualitative* method because issues relate to institutional perceptions which are more readily qualified rather than quantified; • *Interviews* rather than questionnaire to enable probing and to explore issues in more depth; and • *Semi-structured* as the author has partial knowledge of issues and themes, however does not want to exclude addition or related emerging themes. • *Face-to-face* to better establish trust; build a relationship for potential future research; to enable reading of unspoken queues such as body-language; to minimise risk of communication problems assuming Swedish interviews will be conducted in English.
Qualitative analysis of interviews and text **(E, F)**	• To determine opportunities and barriers by theme, which will in turn be used as a basis for policy and research recommendations; • To allow comparison with issues and views emerging in the literature. • *Quantitative* analysis was considered inappropriate because the number of respondents was not intended to be statistically significant, nor was any emerging numerical data considered reliable or complete enough to use as the basis for any serious quantitiative analysis of of nutrient flows, water flows or costs and benefits.
Literature review **(A, B-1, C-1)**	• To gather any existing knowledge on this issue, minimising need for further resource-intensive primary data collection; and • To triangulate: to supplement data emerging from interviews, to obtain as much information and perspectives on the issue as feasible.
Qualitative assessment of costs and benefits **(G)**	• To identifying the nature of costs and benefits of urine diversion, particularly as they traverse numerous areas and have not been fully assessed before. • *Quantification* was not considered appropriate due to lack of data availability and reliability, however is recommended for future research.
Case-study **(D,G, F)**	• When appropriate, to allow tangible, applied analysis, rather than basing argument in theory; and • To contribute to solutions for sustainable nutrient management of a catchment of significance in Australia.
Policy recommendations **(I-1)**	• To ensure analysis is applied and targeted at decision-makers able to affect change.

* Codes in brackets refer to steps in Figure 14.

5.2.1 Stakeholder interviews and analysis

Further to the justification provided in Table 1 for selecting stakeholder interviews as a key method, the Swedish interviews were seen as beneficial over other methods because the enabled a more complete knowledge set to be gathered, rather than relying on the more fragmented information available in the literature. Further, they could document knowledge on more informal perceptions of urine diversion and reuse, which could be the basis for further research. This is discussed further in reflections on methods in Section 9.9.1. Justification for stakeholder interviews as a data collection technique in the Australian context is much less complex, as Australia has had very little experience with urine diversion and reuse and there is certainly no existing substantive body of research available to work from.

The procedure for undertaking and analysing the stakeholder interviews was as follows:

1. Identify key relevant Swedish and Australian stakeholders (based on advice from experts in this field)
2. Send introduction letter to targeted stakeholders (Swedish and English version sent to Swedish stakeholders, English version sent to Australian stakeholders)
3. Follow-up phone call to clarify any questions/concerns and make time for interview if stakeholder is willing.
4. Undertake face-to-face interview (1-2hrs duration), record using
5. Transcribe interviews
6. Analyse transcriptions into categories and themes (draw quotes that demonstrate views within each theme)

According to Jonsson (2005) and The World Bank Group (2001), a Stakeholder includes those who: benefit, lose, are voiceless, are representatives, are responsible, mobilise against, make more effective/ less effective, contribute to financial/technical resources, or create behaviour change.

Some comparison between Swedish and Australian interviews was possible, however the Swedish interviews were assessing lessons learnt in addition to barriers and opportunities for the future, while Australian interviews were predominantly exploring an essentially untouched field. Hence there was a slight difference in focus and purpose of the interviews. Initially the intention was to interview a representative in the same roles to make comparison easier, however it was more important to speak to relevant persons in the local context. For example, State government have a larger role in Australia, where as National or municipalities take more of that role in Sweden. Stakeholder categories interviewed in the respective countries included:

Sweden: 'Lessons Learnt' stakeholder interviews with:	Australia: 'Barriers and Opportunities' stakeholder interviews with:
• Municipality • Plumber • resident and practitioner at Gebers ecovillage • Sanitation consultant/researcher • Urban water company • Academic/researcher • Toilet manufacturer	• Municipality • Government (agriculture) • Government (infrastructure, planning, natural resources) • Catchment management Authority • Academic/researcher • Toilet manufacturer • Urban water utilities (national association)

In both Sweden and Australia, other stakeholders were consulted for specific issues, including other municipalities, farmers, researchers, state government departments, water utilities and health department. This was via informal snowballing – that is, I gathered names that primary respondents suggested I contact, and when several respondents suggested I contact the same person or organisation, I prioritised contacting them for more information. Information used from these secondary communications is referenced as 'personal communication' in the text.

The information gathered from interviews was used in a number of ways, as appropriate, including:

- Direct quotes reporting on an issue/theme,
- An issue or idea to follow up on in the literature or with other experts, and/or
- Supporting or contrasting information in the literature.

For example, if a primary respondent raised an important issue outside the scope of his/or professional field of expertise, I would be more inclined to research that issue further either in existing literature or consult other experts in the relevant field.

5.2.2 Literature review

Analysis of the Swedish stakeholder interviews is presented by first summarising the stakeholder views, followed by a comparison and contrast with literature. This multi-method of investigating a topic from different perspectives enables a greater understanding.

This structure was not mirrored for the section on Australian stakeholder analysis because there is too little published information from Australia on issues relating to urine diversion and reuse. Instead, a small section identifying and comparing three relevant discrete sources from Australia is provided.

Useful information emerging from the literature review was presented in several places in this report:

Volume 1: background (section 2), theoretical frameworks (section 4),

Volume 2: analysis of Swedish interviews (section 6), analysis of Australian interviews (section 7) and discussion of costs and benefits (section 8).

5.2.3 Analysis of costs and benefits, water and nutrient balances

Whilst the initial intention was to quantify the costs and benefits, during the literature review and stakeholder analyses it became apparent that data availability and data reliability were limited and the costs and benefits were likely to be highly sensitive of to the specific context. Further, methods to analyse costs were seen as flawed and irrelevant in this circumstance. For example, a simple CBA could be used demonstrate that benefits of urine diversion outweighed costs or vice versa, depending on assumptions and data used in the analysis. For these reasons, a quantification of costs and benefits would not be considered meaningful as a second outcome of this study. Rather, a discussion of the type and nature of costs and benefits was considered more meaningful, particularly given the qualitative nature of some of them.

For the same reasons (data availability, reliability and sensitivity) an overall quantitative analysis of nutrient and water flows was not undertaken. Rather, by way of example, a single quantification for a given context was undertaken to demonstrate their potential order of magnitude. Further data collection and analysis of costs and benefits, water and nutrient balances has been recommended in Section 10.

5.2.4 Case study – Hawkesbury-Nepean Catchment

The initial plan was to focus the Australian research around a case study of the Hawkesbury-Nepean catchment, for reasons provided in Table 1 and Appendix C. However, as most stakeholders had limited prior understanding of urine diversion and reuse, it was more appropriate to refer to Australia (or the state of NSW) in general and only refer to the specific catchment where relevant, such when discussing algal blooms. It was not relevant for example, when discussing the benefit of recirculating nutrients back to agriculture, particularly with the representative from NSW government agriculture department who was based far from the Hawkesbury-Nepean cathcment.

In addition to using the Hawekesbury-Nepean catchment as a point of reference in the Australian stakeholder interviews, it was intended to be the system boundary for any quantitative analysis. As discussed in section 5.2.3, such a quantitative analysis was not considered useful and hence was replaced by a qualitative discussion of costs and benefits with several calculations for indicative purposes only.

5.3 Advancing the current body of research

This thesis aims to progress rather than duplicate the current knowledge and application of urine diversion and reuse in Australia, Sweden and internationally and to identify research gaps and needs. Specific advancements on current research are addressed below.

Urine diversion and reuse in Sweden

Research to date on this emerging solution has predominantly focused on health issues, including microbial risks and safe handling and reuse of urine (see Schönning and Stenström, 2004); nutrient value of urine (see Maurer et al, 2003), and some social surveys (see Pahl-Wostl et al, 2002). At the time of commencing this thesis, there was little or no documented understanding of institutional barriers and opportunities for urine diversion and reuse, including whole-of-society costs and benefits and roles and responsibilities[30]. It was anticipated that some of this knowledge may be in the grey literature and also with those stakeholders who have had recent or ongoing experience with urine diverting systems and not documented these aspects (Cordell and Turner, 2003, 2004; Jan-Olof Drangert, pers. comm. 2004). Preliminary identification of this knowledge gap was the motivation for exploring such institutional challenges through the semi-structured stakeholder interviews in this thesis.

Urine diversion and reuse in Australia

There are several individual urine-diverting toilets in Australia in both residential and non-residential contexts (see CERES cited in Cordell and Turner, 2004). A feasibility study for urine-diverting composting toilets in a multi-residential building in Melbourne has also been undertaken, however the actual demonstration has not been installed to date (GHD, 2003; S. West, pers comm. 22/7/05). This thesis uses findings from these examples and takes the study of urine diversion and reuse in Australia to the next level by looking at catchment scale, institutional issues, whole-of-society costs and benefits and provides policy recommendations.

A related emerging innovative technology in Australia is waterless urinal systems. Their consideration and introduction in urban Australia has predominantly been due to their benefit of significantly reduce urban water consumption in the commercial and institutional sector (ISF, 2004). However their installation would provide a significant opportunity for the collection and reuse of urine as minimal or no water is flushed through a waterless urinal. No serious research into the synergies between waterless urinals, water conservation and urine diversion and reuse has been undertaken in Australia, however recommendation that this synergy be explored has been suggested by the author in both a national radio interview and Independent review of waterless urinals in Australia (Cordell, 2004b; ISF, 2004).

[30] However during the course of this thesis, a study on sanitation regulatory frameworks in Sweden and three other countries has been published (see Johansson and Kvarnström, 2005).

5.4 Limitations of the study

This section discusses a number of limitations of this study that became available during the course of this research.

5.4.1 Reflecting on methods used

There were a number of possible limitations of the stakeholder interviews method used which could affect the responses from stakeholders. These are reflected on below.

Level of intervention

The interview methodology was intended to be semi-structured and essentially exploratory, however some intervention by the interviewer was carried out *ad hoc*, as it seemed appropriate at the time. For example, on topic of whether pharmaceutical residues were perceived as a barrier or opportunity for urine diversion and reuse: One Australian respondent stated near the start of the interview that urine diversion and reuse would not be possible because it contained harmful micropollutants. There was a sense that this perception was going to block any further constructive exploration of the potential of urine diversion and reuse for Australia. Hence I intervened and offered my understanding that some of the Swedish respondents and preliminary study results suggested the converse: that diverting urine to land was advantageous over treating it with mixed wastewater and discharging to water bodies.

Another ad hoc decision to intervene came about as I wanted to make interviewees feel as relaxed as possible and willing to share their thoughts, hence I felt it important for me to 'participate' at times and share my knowledge on certain points (for example, some Swedish respondents were interested to know the level of activity in this field occurring in Australia). A more 'formal' interview structure may have stilted conversation and flow of information. My level of intervention in this regard was more evident in the Australian interviews as they were exploring a largely undiscussed topic, hence I felt they required more probing following comments or statements made by interviewees. It was evident that some stakeholders were thinking through concepts and ideas for the first time during the interview, and hence it was useful to probe initial thoughts (eg. around roles and responsibilities) to encourage deeper thinking on the issue within the limitations of the interview time period. Or simply, for example, to explain more factual knowledge, like how urine-diverting toilets used less water than conventional toilets and hence could conserve water.

Action research

An unexpected outcome of the Australian interviews was seeding ideas in some stakeholders' minds about trialing such a system. For example, when asked respondents were asked about their organisation's possible role if such a system were to be introduced in Australia, some interviewees began enthusiastically talking through logistics of a demonstration project. Although this could be seen as a positive reaction and beneficial to this research area in the longer term, it was not an intention of this thesis research.

Perhaps this unexpected shift in views during the course of the interivew can be compared to the difference between instant polls and deliberative polls. The former searches for a snapshot opinion, the current perception or level of understanding held by the respondent, where as deliberative polls seek *informed* opinions (Carson and Gelber, 2001). The intention of my interviews in Australia is more aligned with the latter. I did not feel the former (snapshot views) was as useful for the purpose of my study. I was anticipating an initial sceptical reaction from some stakeholders and that would not be so useful for working through potential opportunities and barriers.

Impartiality of the interviewer

One important difference between deliberative polls and my 'deliberative interviews' is that polls typically require impartial information/facts (eg. pros cons) of the issue and the interviewee to also be impartial. In my study, I am not entirely impartial as my study is based on the premise that I think urine diverting and reuse systems could benefit Australia and therefore warrant further research. I do believe I made respondents aware of my opinion and did not give any false impressions that I was entirely impartial.

Language

Another possible limitation of the Swedish interviews was language as the interviews were conducted in English by an Australian interviewee. I perceived the level of English proficiency among stakeholders ranged from sufficient to fluent. Although there were no obvious signs of miscommunication, it does not mean some miscommunication did not occur.

Gender

It is possible that the gender dynamic in the interviews may have affected the interview discussion and responses. Around 90% of respondents were male, while I am female. For example, when discussing the issue of 'cross contamination' of the urine bowl and hence urine tank, no respondent raised the issue of menstrual blood, only children's faeces and diarrhoea were discussed. This may or may not be attributed to the gender dynamic.

5.4.2 Scope limitations

Due to the size and time restrictions of this Masters research, scope boundaries needed to be drawn, hence excluding some items. While not considered essential, some of these items may have further enhanced this research though were excluded due to size restrictions. This included:

Stakeholders interviewed

While careful planning was undertaken to ensure selection of an appropriate cross section of stakeholders in each of the Swedish and Australian contexts, if more time was available, a second round of interviews with the following stakeholders would have been pursued: In Sydney other stakeholder groups that may have also been useful for additional views could include: the state environmental regulator: NSW Department of Environment and Conservation, the state health regulator: NSWHealth; and the water and sanitation service provider in Sydney: Sydney Water Corporation. In Sweden the Swedish EPA would have been interviewed.

Other waste streams

Although prior to commencing this study it was acknowledged that urine diversion and reuse may be most beneficial (and particularly cost-effective) when considered in the same framework as other domestic waste streams (including blackwater, greywater and organic solid waste), scope boundaries needed to be set, and thus only urine diversion was actively studied. However, incidental information on synergies between the waste streams has been documented (including in the stakeholder interviews analysis). A further justification for only addressing urine in isolation from faeces and other household organic waste is that it has been given little to no attention in the sanitation and nutrient debate in Australia to date. Hence part of the purpose of this study was to bring urine into the dominant discourses on sustainable water, sanitation and nutrient solutions.

New literature

During the latter stages of completing this thesis, several new reports relating to urine diversion and reuse were being finalised for release. Access to some of these reports at the start of this thesis research may have streamlined a substantial amount of some sections. This included a report capturing the Swedish experience of urine diversion to date. Whilst aware of the development of this report, it was not possible to obtain and compare preliminary findings prior to its release. Three other important documents due for release around the time of this thesis included: new guidelines (both WHO and Australian national guidelines) on reuse of wastewater were being finalised; and a comprehensive manual produced as an output from the MISTRA Urban Water Programme (see Malmqvist, *forthcoming*). It was not possible to include an assessment of all documents in this thesis, however they have been referred to in relevant sections of this thesis.

Cost analysis

Due to the lack of reliable data, it was not considered meaningful to undertake any sizable cost-benefit analysis. Rather, a qualitative discussion on issues relating to the types of costs and benefits was considered more useful and hence pursued. A cost calculation has been used by way of example to indicate the potential order of magnitude

Literature in Swedish

It is likely that further literature pertaining to urine diversion in the Swedish context exists written in Swedish, however the author does not have a sufficient understanding of the Swedish language to interpret such literature.

6 Swedish experience: Lessons learnt

This section documents findings from interviews undertaken with key Swedish stakeholders. At the end of each section, findings from other sources (such as literature and personal communications) are compared and contrasted with findings from the interviews.

6.1 Drivers and benefits

This section provides an indication of the key historical drivers and current benefits of urine diversion in the Swedish context, as reported by respondents. Section 8 highlights spectrum of potential benefits of urine diversion more fully. The key benefits are seen as capturing and returning valuable nutrients to arable land, followed more recently by reducing eutrophication of receiving water bodies. Key drivers acting as a catalyst for change have been the political environmental movement of the mid-1990's and having a single change agent in a position of power.

Most stakeholders considered the mantra of 'closing the loop' on nutrients, particularly phosphorus, a powerful driver and the key overarching reason to divert and reuse urine:

> "*you need to use phosphorus carefully in the long term perspective*" [p2. Technical Director, water company, Sweden].

> "*the recovery of urban nutrients and reusing it in crop cultivation*" [p3. Academic/researcher, Sweden].

Another more recent benefit is reducing nutrient loads to waterways. Increasingly, eutrophication of Swedish lakes and coastal waters is seen as a key reason to divert urine from municipal sewage that typically ended up in such water bodies. Particularly as human settlements in sensitive areas expand and lead to increased volumes of wastewater (and hence nutrients) generated and discharged to water bodies. This was the case for Tanums Kommun, a municipality located on Sweden's rocky West Coast with little absorption capacity for effluent. In 2002 Tanum mandated that all new toilets should be urine diverting to protect the coastal waters.

> "*Phosphorus and Nitrogen…To catch it up so you don't have so much in the sea. Yes, that's the biggest reason*" [p3, Plumber, Sweden]

> "*what is coming up as more important now…is that diverting the urine and making sure that we don't emit it to the water, then we decrease the polluting emissions to water. And that is something that I don't think has been that important previously, but it is becoming more important*" [p3, Academic/researcher, Sweden].

While respondents felt the above two environmental arguments were strong reasons in favour of urine diversion and reuse, they also suggested the implementation was helped by the recent environmental movement of the last decade. Almost all respondents mentioned Sweden's political context in the mid-1990s as a significant driver behind the trials and installations of urine diversion and reuse systems:

> "*We had a boom, for environmental issues in Sweden that had its peak around the mid 90s, 94-98. So this development was part of that... But since then it has not developed*" [p.6 Ecovillage resident and practitioner, Sweden]

> "*there was a political will to go for sustainable systems or environmentally sound systems, saying we should have urine diversion*" [p3. Sanitation researcher and consultant, Sweden]

> "*..it kind of became a symbol to many of the ecovillages – if you want to do anything environmentally sound when you build your house – which everyone were up to in*

the mid-1990s – you ought to have one of these. It kind of became a symbol" [p2. Sanitation researcher and consultant, Sweden]

"*It is something that sort of speaks very well or has a resonance of a lot of Swedish culture*" [p3. Academic/researcher, Sweden]

Some respondents also mentioned a key driver for the installation or trial of urine diverting toilets in their case was a single change agent in a position of power, pushing for that specific environmental solution. In several cases reported by respondents, this has been a local politician in a municipality, a manager in a water company or a building developer.

"*Changes are often made by a single person….and this person should be very very strong*" [p6. Technical Director, water company, Sweden]

While the aforementioned benefits and drivers were given the most weight by respondents as a whole, other benefit for diverting and/or reusing urine include urine's properties as a fast-fixing organic fertilizer. One respondent told that prior to Sweden joining the EU, ecological farmers in Sweden were promoting urine as a fast-fixing N fertilizer for winter wheat which:

"*needs readily available N very early in the spring, and it was very hard to get that for the ecological farmers…source diverted urine would be an excellent source of such N which would mean not only that they would get a higher harvest, but also that the protein level would become high enough so that the grain would pass as wheat for bread. One problem that they had was that protein level was often too low so it was often discarded as fodder". And "you can hardly find a better fertilizer than urine*" [p6. Academic/researcher, Sweden].

A few respondents also believe that diverting urine to land/soil is likely to be more risk adverse compared to both: a) diverting sludge to arable land that may also contain industrial heavy metals, and b) discharging urine (which may contain pharmaceutical residues) to water via treatment plants. This is discussed further in Section 6.4.2 on Health-related opportunities.

6.1.1 Analysis: comparing and contrasting with the literature

This section explicitly compares and contrasts the above respondents' views on drivers and benefits with the literature and other sources.

The Swedish literature was found to be consistent with stakeholder responses in relation to the *key* benefits of urine diversion and reuse. That is, returning valuable nutrients to agriculture and reducing nutrient emissions to water bodies (SEPA, 2002; Johansson *et al*, 2000; Jönsson 2001). The literature however is more diverse in describing the range of other benefits.

Maurer et al (2003) further suggests that capturing and reusing nutrients from source-separated urine is more energy efficient than production from virgin resources. Unlike the stakeholder responses, Drangert (2005) and Schmid-Neset & Drangert (2005) discuss the historical drivers of diverting urine from faeces was improving functionality of dry toilets. For example, urine-diversion was first introduced in Stockholm in the late 1800's when it became too cumbersome for householders to frequently empty mixed dry toilet waste from apartment buildings. Small-diameter sewer pipes were fixed to building exteriors, allowing the large volumes of urine (but not faecal solids) to divert down the pipe. This meant householders need only carry small volumes of dry solid waste down the stairs monthly rather than daily. In addition to removing the largest fraction (by volume), diverting urine from dry toilets is also known to reduce odour[31] (Drangert, 2005; Smidt-Neset & Drangert, 2005).

[31] It is believed much of the odour in dry toilets comes from the reaction of urea in urine and faecal solids.

A significant proportion of the literature also discusses the benefits of urine diverting systems over conventional wastewater management in terms of both recycling nutrients back to arable land and reducing nutrient emissions to water (Jönsson, 2001). If it is assumed that nutrients should be returned to arable land, recycling urine independent of faeces is reported as advantageous over recycling mixed human excreta because: a) it captures a large proportion of the nutrients with minimal losses due to evaporation, b) odour can be reduced; c) urine is essentially sterile therefore bears less pathogenic risk; and d) diverting urine from faeces improves the dehydration phase of composting faeces (Krantz, 2005; Johansson et al, 2000; Schönning and Stenström, 2004). This comparative benefit of urine diversion and reuse over other forms was not raised in the stakeholder interviews.

Findings from Johansson et al (2000) also suggests that the environmental benefits from urine diversion at the household will depend on the situation of collection and treatment of the other wastewater fractions, percentage of urine captured and the proportion of time householders actually spend at home.

In addition to describing the benefits of diverting urine for crop production, Steinfeld (2004) also notes a multitude of other historical uses and benefits of diverting urine: "*Urine has been used throughout human history for a variety of purposes, from religious rituals and rites of passage to medicinal, culinary, and industrial purposed. And of course, its been used to fertilize food crops*" (p10).

Two additional drivers were also suggested in the literature: According to Krantz (2005), the boycott on using sludge on arable land (due to chemical contaminants) was a driving force for considering new ways of returning urban nutrients back to farmland, such as urine diversion and reuse. Furthermore, traditional onsite systems in Sweden (typically septic tanks and leachfields) are failing environmental performance requirements because they are not removing enough phosphorus. This has been another driver to look at alternative sanitation solutions, like urine separation, to remove nutrients (Johansson, 2005; Pahl-Wostl et al, 2003).

While the Swedish literature does not conflict with the stakeholder responses, it does add several further benefits and motivations of urine diversion and reuse. As some of the key authors (Johansson and Jönsson) were also stakeholders interviewed, these other explanation may not have been raised due to time or relevance during the interviews.

6.2 Roles and responsibilities

This section highlights the current roles and responsibilities of urine diversion and reuse in Sweden according to the respondents. It also addresses how respondents thought these current roles and responsibilities could be improved.

Urine diverting systems in Sweden typically involves the following roles:

- Product design and development;
- Installation;
- Collection;
- Application to land;
- Maintenance and monitoring (ad-hoc and scheduled);
- Liability (if environmental or health hazard occurs);
- Management, including overall coordination;
- Education, communication and awareness;
- Financing (eg. subsidising if not a cost-recovery system).

The responsibilities for these roles can be distributed among stakeholders in a number of ways. The following describes some actual or recommended arrangements reported by respondents.

Existing legislation states urine diverted from the wastewater stream is the responsibility of the municipalities[32]:

> "*today the Swedish legislation says as soon as you have installed urine or whatever comes from the wastewater fraction into the holding tank like this, its considered household waste, and that's the municipality is part responsible for collecting it and disposing of it in an environmentally sound way. That is, if they collect urine they should try to put it back on farmland not take it to the STP*". [p3. Sanitation researcher and consultant, Sweden]

However, according to the Swedish sanitation researcher and consultant there is still some confusion and only a handful of municipalities are actively managing the installation of urine diverting systems. One such municipality, Tanums Kommun, mandated urine-diverting toilets for new installations.

The respondent from Tanum municipality explained that the municipality ensures its residents install a urine diverting system when they apply to build a new house or undertake major renovations. However the policy is realistic in recognising the motivation of its residents:

> "*you don't have to change to urine separation if you are just upgrading a bad/failing onsite systems. Because it would discourage people from calling the council*". [p2. Municipal Staff, Sweden];

The municipality provides a checklist to the householder of what toilets can be installed and a contact list of farmers who are prepared to collect the urine generated. However the municipality has the actual contract with the farmer and:

> "*if someone doesn't want to use one of these farmers, the municipality has the responsibility to empty the urine tank, because the municipality has the responsibility for sewage*". [p2. Municipal Staff, Sweden].

If the supply of household urine outweighs demand from farmers, the municipality has the responsibility to collect it:

> "*first maybe we can spread it on some land that is ours, like energy forests. Then at worst you go to the sewage plant.. So each household doesn't have to think about it*". [p2. Municipal Staff, Sweden].

The Swedish municipal staff member considers the Tanum municipality management model successful for its given situation. When asked if management at the municipal level is most appropriate if urine diversion became more widespread among Swedish municipalities, the response was:

> "*At the practical level it must be that the municipal level I think, you have to have direct contact with all the farmers and all the people, at he National level you should have maybe more legislation and how you should deal with sewage system in the rural areas that are not connected*" [p2. Municipal Staff, Sweden].

While most stakeholders agreed that the municipality had a key role to play managing/coordinating urine diversion systems, their view on the degree of householder responsibility varied from very high householder involvement to moderate.

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[32] See section Johansson and Kvarnström (2005) for reference to legislation.

The respondent from Tanums Kommun suggested an inherently substantial level of involvement:

> "*the responsibility is almost always on the one who is doing something. There's not so often that we tell them exactly how to do it. Its always a responsibility to be careful and to have knowledge, as a property owner. There's a big responsibility in Sweden…"* [p2. Municipal Staff, Sweden].

While Tanum residents in rural summer houses are typically responsible for maintaining and reusing their own dry composting urine-diverting systems, more permanent or semi-permanent Tanum residents with a dry or wet toilet diverting urine to a large (eg. $3m^3$) urine storage tank, the householder is typically responsible for contacting a farmer (from a list provided by the municipality) to collect the urine once a year for an annual fee of 800Kr/yr (AU$136/yr[33]):

> "*And maybe you* [householder] *can use that 3 cubic metre tank for 2 years, but then you have to talk to the farmer yourself… maybe he can't come while he's out farming"* [p2. Municipal Staff, Sweden].

At Gebers ecovillage bordering Stockholm, it has been purposefully written into the house regulations that residents are responsible for their own urine diverting dry toilets. This level of householder responsibility is one reason the collective chose simpler dry toilets systems over more 'high-tech' vacuum flushing toilet systems [p3. Ecovillage resident and practitioner, Sweden]. The ecovillage is outside the area of responsibility of the municipality, hence the ecovillage's apartment owners are each responsible for ensuring appropriate management and operation of their system. The only requirement from the municipality was that the compost had a concrete floor and roof, to ensure no leakage down and no flies in.

The respondent from Stockholm Water Company felt it was not actually necessary to give householders such a high degree of responsibility, particularly with ongoing maintenance:

> "[an academic and urine diversion enthusiast] *goes in and cleans his own toilets – the thin pipes when they are blocked with urine residues, but you can't* [expect householders to] *do that*" [p4, Technical Director, water company, Sweden].

Householder involvement can range widely, from simply using the toilet (similar level of responsibility as for most centralised systems) through to being responsible for the entire chain including reuse in household garden food production. If however, the urine is reused offsite, then farmers will need to be involved to some degree. In Sweden, it is even the farmer who typically comes to each house to collect and reuse of urine on their land, or other agricultural land.

In the Stockholm area, urine from diverting toilets is transported to agricultural land surrounding Lake Bornsjön, which is owned and managed by Stockholm Water Company. All urine is stored in 100 m^2 bulbs before application on the surrounding land. According to the Swedish Ecovillage resident and practitioner the urine is 'dumped' if the bulbs are full (at the sewage treatment plant). [p9].

According to the Swedish sanitation researcher and consultant, there's no problem finding a farmer who wants to take the urine:

> "*I haven't seen in one single place a problem finding a farmer, if there is a strong actor involved (and a competent actor, normally a municipality)"* [p2].

However he also stresses the importance of cost-recovery for the farmers:

[33] Exchange rate as at 1st October 2005 (www.xe.com).

"*most people say well the farmers they are willing to pay. No they're not. You must pay the farmer, then he will come, and smile*" [p9].

Municipalities, householders and farmers are important actors at the practical level. At the strategic and political level, the national government play a key role. While many respondents felt this was an important role, they felt there was more opportunity for participation by Swedish government and that they hadn't taken enough initiative in recent years (see also section 6.3.1 Barriers):

"*at the national level you should have maybe more legislation and how you should deal with sewage systems in the rural areas that are not connected*" [p2. Municipal Staff, Sweden]

The Swedish EPA which reports directly to the Environment Minister, does have the responsibility to develop an action plan for how wastewater fractions should be reused in the future. There are currently 15 (soon to be 16) National Environmental Objectives with numerous sub-objectives[34]. A recent policy development in Sweden occurring at the time of this thesis has been the proposal of a National Environmental Objective target for recycling 60% of phosphorus from sewage to land. According to the Swedish sanitation researcher and consultant at least 30% of this must be to arable land [p1.].

Box 4: municipality policy on urban nutrient reuse

In addition to the rural municipality Tanum on the West coast, Norrköpings Kommun, is one municipality in Sweden's south which has also made a policy decision to mandate this installation of urine diverting systems or equivalent in new dwellings to prevent further eutrophicaiton of its water courses. That is, new sanitation systems in households must meet minimum performance requirements for public health protection, protection of water courses and recirculation of 50% of wastewater nutrients back to Agriculture. The municipality has organised for 6 local farmers to collect the urine annually

Norrköping has recently taken this policy one step further; now requiring that urban nutrients also be recirculated to local farmland via urine diversion in new urban developments. This is a significant motion, given the size and density of Norrköping urban centre.

(J. Hjelmqvist, pers comm., 2/9/05; Johansson and Kvarnstrom, 2005)

In addition to strategic coordination by the national government, the regional water service provider plays a coordination role.

The water service provider is typically part of the municipality in Sweden, yet can act as an independent body, such as in Stockholm. Stockholm Water Company (Stockholm Vatten AB) owns Lake Bornsjön, the reserve drinking water catchment, and is:

"*totally responsibility for the area around this water source and so there we had the possibility to make experiments and use the urine for agriculture and a study.*" [p1. Technical Director, water company, Sweden].

Another important actor, yet one not discussed as frequently is industry. The development of any new technology must involve industry. In the case of urine diversting systems, this includes toilet manufacturers and plumbers. In Tanum, the local plumbing outlet sells three different models urine-diverting toilets to Tanum residents and provides 2-year guarantee on parts [Plumber, Sweden].

The toilet manufacturer interviewed suggests design, installation and maintenance of components of urine diversion and reuse systems are more complex than householders may think:

"*you have the manufacturer for the tank, that's one part, and then for the pipe, you know… everything is not connected.*" [p3. Toilet manufacturer, Sweden].

[34] see also www.internat.naturvardsverket.se

However the Swedish toilet manufacturer felt householders who purchased their urine-diverting toilet model would still often call the toilet manufacturer if there was something wrong, regardless if it was the toilet or other parts of the system. The pipes, tanks and other parts may be the responsibility of other manufacturers or the plumber who installed the system components.

In the examples discussed in the stakeholder interviews, the roles and responsibilities reported tended to vary within a limited scope. For example, farmers are almost always involved in the truck collection of urine to their farms. Respondents typically felt the current roles and responsibilities worked well though there was room for improvement. Such suggested improvements are discussed in the next section.

6.2.1 Elements of successful institutional arrangements

Most respondents offered possible improvements on current institutional arrangements and responsibilities. These recommendations varied from the need for an overall coordinating body through to roles of specific stakeholders.

Both the Swedish toilet manufacturer and the Swedish sanitation researcher and consultant expressed a need to ensure a single actor is concerned and responsible for the nutrients throughout the whole cycle – from urination to plant uptake. The Swedish toilet manufacturer cautioned that otherwise, for example, too much water might be used to flush the urine, rendering it useless to the farmer or the urine collector. Hence someone needs to ensure the toilet manufacturer and householders:

> "[we need to] *know that if we use too much water, then we can't use the urine*" [p7, Toilet manufacturer, Sweden].

On the same theme, the Swedish academic/researcher felt there were too many authorities involved along the chain of urine diversion and reuse. This was perceived as partly a consequence of the current laws and acts being somewhat conflicting, ambiguous and complex:

> "*There's so many authorities all over the place.. (who actually decide over a small part of the system)"* [p8, Academic/researcher, Sweden].

If urine diversion and reuse were to be expanded on a mass scale in Sweden, several respondents recommended that a professional or community organisation could be responsible for provision of a fee-based service:

> "*you should have professionals running the system like they do everything else. I mean you have professionals emptying rubbish bins, professionals running the electricity…. And you (the user) would pay for it of course)"* [p11. Ecovillage resident and practitioner, Sweden].

> "*if you have a car, every year you have it checked you know certified specialist. Having their scheme and then they control it, then they charge you for it…But we don't have that in Sweden, We should have, and that's one of the things that needs to be set up"* [p4. Sanitation researcher and consultant, Sweden]

> "*be organised on a community base, so a common organisation in some way, so not a personal responsibility. For instance, Stockholm Water could be the party responsible for picking up the urine and doing the transports and so on*" [p4. Technical Director, water company, Sweden].

Further, the Swedish sanitation researcher and consultant adds that householders should be paying more for their decentralised sanitation services:

> "*today they are paying very little. They emit more harmful substances, and pay less. People have been paying almost nothing for 20-30 years*" [p4] ….“*they should pay something but maybe not all*” [p6]

The Swedish sanitation researcher and consultant and the Swedish academic/researcher both suggested municipalities:

> “*ought to be responsible for this* [managing and financing] *aswell… and this should be included in law of water and wastewater because this is a wastewater fraction*” [p7, Sanitation researcher and consultant, Sweden]

> “*HAVE to be the responsible party, for example for the handling systems, for the reuse... making sure there is a system in place that actually can collect it [urine] that can see that it gets reused and so on. That has a set framework with rules in which you have to work... But of course they should have a strong support from the central government, and that is something that has been lacking*.” [p9, Academic/researcher, Sweden]

Perhaps the underlying message of the elements of successful institutional arrangements is encompassed in the Technical Director of the Swedish water company suggestion that regardless of which stakeholder is ultimately responsible for which role, clarity is most important:

> “*you need to make borders for responsibility in the system*” [p4]

Respondents tended to agree that while their experience with functionality and feasibility of urine diversion and reuse was essentially a positive one, there was certainly a need to improve organisation aspects of the system, particularly if it were brought to scale in Sweden, beyond demonstration projects.

6.2.2 Analysis: comparing and contrasting with the literature

This section explicitly compares and contrasts the above respondents’ views on roles and responsibilities with the literature and other sources.

Most respondents had clear ideas and views on roles and responsibilities of the various actors in the Swedish model of urine diversion and reuse, particularly the key role the municipality must play. This sense of clarity was also reflected in the literature. In *Urine Separation – Closing the Nutrient Cycle*, Johannson et al (2000) sets out explicit roles and responsibilities for actors in a urine diversion and reuse system, emerging from several R&D projects in the Stockholm area. Johansson et al identify key responsibilities for householders/house managers, local politicians and farmers. However this prescribes a particular scenario that worked for the Stockholm area, and may not necessarily be transferable to other areas, such as Sydney. Hjelmqvist, who works at a Swedish municipality that is actively implementing urine diversion and reuse systems, also reminds us that differing expectations of whom should be responsible for which roles is an important interplay that could affect the systems’ functionality. She uses the community’s expectation of municipalities by way of example:

> “*some people think that the [local] government should do everything for them, even though the government should also stay out of their business*” (J. Hjelmqvist, pers comm., 2/9/05).

Johansson and Kvarnström (2005) reviewed the sanitation regulatory frameworks of four countries including Sweden and stressed the importance of tailoring the roles and responsibilities, or regulatory frameworks to fit the specific context. Johansson & Kvarnström, also provide a detailed account of the sanitation regulatory frameworks in Sweden, including the legislation and requirements at the national, county and municipal level. Sanitation arrangement like urine diversion and reuse involves a number of sectors at the national level, including those responsible for environmental protection (the Swedish Environmental

Protection Agency), food and drinking water quality (The National Food Administration), agriculture (The Swedish Board of Agriculture), public health (The National Board of Health and Welfare), urban development and spatial planning (The National Board of Housing, Building and Planning). An Australian account of Swedish organisations in the water and sanitation sector and their roles is provided by Sarah West[35]. West provides a profile of each relevant organisation and their roles in relation to wastewater services, management or research, following an extensive international tour of best practice sanitation systems (West, 2003).

Johansson & Kvarnström also identified opportunities for improved regulatory and institutional structures for ecological sanitation systems. Besides Johansson & Kvarnström, the literature in general did not make any such suggestions of possible organisational structures for the future if urine diversion and reuse were to go to scale, beyond demonstration projects. This contrasts to respondents, who were encouraged to vision how roles and responsibilities could best be configured in a future where urine diversion and reuse is more commonplace.

Other insights into good organisation arrangements emerging from the literature and personal communications included Hjelmqvist's suggestion that trust and good relations within and between institutions are very important (Hjelmqvist, pers comm.). For example she felt good working relationship between the politicians and departments and between departments has been a critical element to their recent sanitation policies involving urine diversion. While Jönsson (2001) reminds us that the R&D projects in and around Stockholm were aided substantially through the financial contributions from a supportive housing and agricultural sectors. This is an important reminder as financial responsibility is a necessary element for a sustainable system and an Australian demonstration or broader implementation of urine diversion and reuse will need a designated financer or group of stakeholders responsible for financing the system – both capital and ongoing costs.

6.3 Current barriers and future challenges

Any sanitation system will have both advantages and limitations. Identifying existing barriers and future challenges enables planning how they may be overcome, minimised or avoided in the future (for example if Australia were to invest in urine diverting systems). This section identifies both real and perceptual barriers reported by respondents. Key themes included: a) Regulatory, institutional and management-related barriers; b) Health challenges; c) economic challenges; d) education and awareness; e) technical and operational; and f) challenges in agriculture industry.

6.3.1 Regulatory, institutional and management-related barriers

Respondents raised a range of regulatory and institutional barriers that spanned the international through to local level. Some also discussed a general lack of coordination.

A barrier at the international level is that the EU directive on ecological farming currently prohibits reuse of human excreta on ecological farms:

> "*The anthroposophic farm system… you have these different dimensions and that if you should mix human and animal kingdom and vegetable kingdom (that energies should not be mixed. Something like that.*" [p6, Ecovillage resident and practitioner, Sweden].

On this issue, the Swedish sanitation researcher and consultant, adds:

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[35] Sarah West is an Australian researcher and practitioner in the field of sustainable water and sanitation arrangements (see http://sarahwest.cjb.net/).

"*and Sweden and Denmark and Norway are working to get these fractions* [urine] *on the list, but that takes time you know. Its so slow. But…when that comes out it will go very quickly you know, so it's not **the** problem*." [p10, Sanitation researcher and consultant, Sweden].

While this was the key barrier at the international level, on the national stage, several respondents noted a decline or stagnation in the development of urine diversion since the environmental boom of the mid 1990s. They also suggested the environmental agenda was being replaced by a predominantly economic one:

"*because of the political climates, that environmental issues are going down and economic issues are going up*" [p6, Ecovillage resident and practitioner, Sweden],

"*you have the wrong period. You have this dip in the environmental interest and all politicians only speak about is money. Money money money*" [p7. Technical Director, water company, Sweden].

Further, the Swedish sanitation researcher and consultant suggests there was a 'backlash' in the late 1990s against urine diversion:

"*there was a lot of problems with the urine diversion, the farmers weren't standing there with cash wanting to buy the urine, which was obviously the case, if you just had been asking the farmers they would say 'of course, but we can't PAY you for this', as the mineral fertilizers are soooo cheap*" [p2. Sanitation researcher and consultant, Sweden].

This mid-1990 environmental boom that saw the push to develop and install sustainable sanitation systems, including urine-diverting systems, meant municipalities had to take the initiative. However according to the Swedish sanitation researcher and consultant, some of those municipalities were not convinced of urine diversion systems as a solution or did not want to take responsibility, hence the systems were more likely to fail:

"*many of those products failed because the people working in the municipalities they were supposed to solve the problem but they didn't like this… so they built it kind of homptus-promptus and said 'ok, see, it failed'*" [p3. Sanitation researcher and consultant, Sweden], and,

"*Today a lot of the municipalities they are like ostriches, they put their heads in the sand and they try to get away from this. But they cannot – it says so in the law. They cannot hide from it*" [p10. Sanitation researcher and consultant, Sweden].

Perhaps some of these difficulties facing municipalities are due to the ambiguity regarding which department within the municipality is responsible for urine fraction once it is diverted from other wastewater. According to the Swedish sanitation researcher and consultant, Sweden:

"*the plumbers are responsible for water and wastewater services, and the waste department are responsible for the waste. And this* [urine] *is considered a waste… its very complicated… they say 'no you should do it', 'no you should do it'. And if you read in the law it's the Waste department, but of course it would be good of it was the Water and Wastewater department because it is part of the system*" [p6. Sanitation researcher and consultant, Sweden].

In addition to these specific challenges for municipalities, the Swedish academic/researcher suggested there is a need to ensure someone is concerned about the coordination the entire process, as:

"*there are so many authorities all over the place…who actually decide over a small part of the system*" [p8] … "*I mean, its not just the technology, you need to have an* *organisation taking care, transporting, reusing the urine and so on*" [p10. Academic/researcher, Sweden].

Finally, the Technical Director of the Swedish water company raises the issue of institutional change as a barrier to shifting from conventional centralised systems to more sustainable decentralised ones:

"*We have one big problem: You have a well developed system, this conventional system. And the CHANGE is always very expensive*" [p7]. "*if you don't have any interest of all those parties [stakeholders] then you will not be lucky to change, because the conventional system it is very well established and so on, so its quite difficult to put up something new and to put up interest for that*" [p5. Technical Director, water company, Sweden].

These regulatory and institutional challenges varied widely in terms of administration level and topic. Some appear more straight forward to overcome, like ensuring a coordinating body body for institutional home for urine diversion and reuse, while others challenges are so complex, they might require managing around, such as the changed political climate towards a more economic agenda.

6.3.2 Health challenges

The key health-related challenge raised by respondents was the presence of pharmaceutical residues and endocrine disruptors in urine:

"*Today the greatest drawback is the question about medical residues…And its very important to go deep in the problem and put all the questions on the table*" [p3. Technical Director, water company, Sweden]

Whilst also sharing this concern, the Swedish sanitation researcher and consultant reasons this will be a problem for all wastewater:

"*if we find very nasty things in the urine, like pharmaceuticals, this is really a dangerous wastewater fraction. That might be a problem…in the future. But that will also be a problem for all different kinds of wastewater, not only urine.*" [p9, Sanitation researcher and consultant, Sweden].

Several respondents even acknowledged this challenge could be a future opportunity:

"*There is research suggesting if you spread it on land rather than water it will break it down better, but that's all we can say. We don't know.*" [p7, Municipal Staff, Sweden]

A second perceived health-related challenge to progressing the reuse of urine on arable land is, a resistance to reusing urine in agriculture due to its association with sludge (which is often avoided due to the presence of heavy metals):

"*the food industry has always been playing it safe, and they have seen, well it's a wastewater fraction (urine) therefore it equals sludge*" [p2, Sanitation researcher and consultant, Sweden].

The Swedish Ecovillage resident and practitioner notes 3-4 years ago there was a proposal that 75% of P in wastewater should be recycled to agriculture, however the sanitation researcher and consultant reasons that due to the stigma associated with sludge and hence urine by default, the Swedish EPA:

"*didn't **dare** to take that* [proposal], *because that would be the main question in the sludge issue – and the farmers and food producers say **no** to the defecation of sludge on agriculture. Since 1998 there's been a really infected debate and the government didn't have the courage to litigate to say yeah we take this 75% for* *reuse. Because this means the sludge must be recycled*" [p1, Sanitation researcher and consultant, Sweden].

It is likely that the first health-related barrier will be a significant challenge for the future of all wastewater reuse and even safe disposal. The latter barrier will not entirely prevent the diversion and reuse of urine, as it may still be applied to non-food crops such as energy forests, however if the ultimate goal of urine diversion is to return nutrients in urine back to arable land, then this barrier will need to be overcome eventually.

6.3.3 Economic barriers

Two key economic obstacles to urine-diverting systems were raised by respondents: 1. Cost-effectiveness compared with existing sanitation systems; or 2. Complexity of valuing environmental benefits.

According to several respondents, urine-diverting systems need to compete with existing systems - either as sanitation systems or as a source of fertilizer. The drawback here is that some major benefits of urine diversion are often not considered in economic terms, let alone acknowledged in qualitative terms. For example, as noted by the Swedish municipal staff member, only the environmental benefit of BOD removal is being considered in new sanitation options. While nutrient removal is also of significant benefit to aquatic health it is not included as a benefit, therefore urine diversion and reuse does not measure as a desirable option.

Further, environmental costs of conventional sanitation systems are often not quantified, as Technical Director, water company, Sweden exemplifies:

"*the problem is if that if you don't put a value on what you save in the receiving water for instance. That's not a money value, that's an indirect environmental value and you have no good economic model for putting a value in real economic terms on it. And that's always the difficulty, so when you come to the end it will tend to be a question of counting money, and then you say its x% more expensive to build a system with urine separation than to build a conventional system, and then we choose a conventional system*" [p3. Technical Director, water company, Sweden].

"*its very very difficult to go further and really develop this technique because its costs a little bit more. Not so much, but a little bit more. So if you don't have other driving forces… such as algal blooms, and water scarcity…then its very difficult to get a decision that you should go further with it. Just now that's the situation in Sweden*" [p3. Technical Director, water company, Sweden].

Perhaps due in part to the lack of including true costs, urine-diverting toilets are not currently commercially viable to warrant marketing aggressively by toilet manufacturers. This was highlighted as an economic barrier:

"*you need to produce much more toilets to get this development of the toilets…Its too small. You need to produce 100s of 1000s…today its not of interest to develop this kind of toilet because its too small. They are not asked for*" [p7. Technical Director, water company, Sweden].

"*It doesn't give us any money. I mean that's the problem. But…if we have an order like 500 each month, or even 300 each month, then we start to put some power behind it*" [p5, Toilet manufacturer, Sweden].

"*I mean their sales number has been so small that its surprising that they have survived*" [p10. Academic/researcher, Sweden].

The cost to householder is also more than a conventional toilet, according to some respondents, assuming there is no regulation or subsidy encouraging installation/purchase.

This was raised by the Swedish plumber, while the Swedish ecovillage resident and practitioner noted:

> "*you have the economic incentives too, which we don't have… we only get 10% discount for doing this* [urine diversion and dry compost toilet], *which is far too low*" [p10, Ecovillage resident and practitioner, Sweden]

However the Swedish sanitation researcher and consultant argues that householders are currently paying too little for conventional water and sanitation services, that they:

> "*emit more harmful substances, and pay less*". [p4, Sanitation researcher and consultant, Sweden].

So while there is no conclusive suggestion that urine diverting systems cost more in absolute terms, respondents are suggesting that their perceived cost-ineffectiveness (compared to other systems) if environmental costs are excluded may hamper commitment to their development and application.

6.3.4 Awareness and education

Several respondents stressed that the system does not work if users or other stakeholders aren't aware, motivated and educated in the 'how' and 'why' of the system. The whole system could fail on a number of levels if awareness and motivation levels are not sufficient.

> "*the big problem is that we are not so aware. The motivation in different levels is too small*" [p7. Ecovillage resident and practitioner, Sweden].

In a very direct way, the actual nutrient uptake will depend on motivation levels and behaviour of users to a large degree. According to some respondents, men must sit to urinate because if they stand, it is unlikely that all urine will be collected in the urine compartment.

The specific education challenge of urine diversion in public toilets was raised as a barrier by the Swedish municipal staff member:

> "*We have this museum where there is a lot of tourists from all over the world, that has urine separation. There we have had some problems, especially in the Ladies Bathroom. We think because the ladies, the mothers, have these children and then they go to the wrong pipe* [bowl]" [p4, Municipal Staff, Sweden]

These responses suggest education and awareness and hence motivation to participate in a role in urine diversion is a key factor to ensuring the effectiveness of such systems. It is important to recognise this needs to occur at all levels, from users through to politicians.

6.3.5 Technical and operational challenges

All emerging technologies face technical challenges, or 'teething problems' during their early stages. Odour and clogging of the urine pipe were the most frequently raised technical problems. However these problems typically occurred in the first trials of urine diversion systems and later rectified and understood to be preventable. One idea for prevention is to have double U-bend, another to have an oil seal. The Swedish municipal staff member and the Swedish plumber also mentioned crystal build-up in the siphon as an initial technical problem.

> "*another problem is small crystals in the urine will get bigger and bigger*" [p1, Plumber, Sweden].

Other technical barriers referred to lack of design for a wide audience:

> "*then there are other technical problems…to develop the toilets in details so that the function will be very very good and not a problem in any way for the user. So that it can be used by all different persons.* [if you find it] *difficult to move…you should be able to use this*". [p4. Technical Director, water company, Sweden].

The Swedish toilet manufacturer felt very strongly that a key barrier was the absence of a Standard for all urine diverting systems:

> "*I mean otherwise its like the Wild West you know. This area they do like that…and this area they do like this… I mean it's a mess. Its not the same and it should be the same…that's why we don't have successful urine separated toilets in Sweden. I mean that's the problem. Because you don't have any instruction how to dimension or lay out a pipe. For instance, I mean if you're four person at home, in a house. They want to know how big tank do I need? Should I ventilate a tank or which dimensions should I have? Which materials? Could I use PVC or iron? It's a question like that*" [p2, Toilet manufacturer, Sweden].

Another operational drawback raised was more of a logistical nature of collecting and distributing the urine within dense urban areas. The Swedish ecovillage resident and practitioner suggested that whilst in large urban areas reaching rural or peri-urban agriculture was a challenge, reusing urine on some local urban green spaces like football fields was not necessarily viable either.

> "*I heard someone say all the big areas (for example football fields) would be great. But then I got to know the level of N is very low, because you drink a lot of beer and its mostly water that comes out. It's the morning urine that has the best effect/concentration*" [p8, Ecovillage resident and practitioner, Sweden].

These technical challenges are perhaps the most straight forward to address relative to say regulatory or institutional challenges. In some respects they might be more appropriately termed 'lessons learnt'.

6.3.6 Challenges in the food and agricultural industry

The key objective of urine diversion is to return nutrients to agriculture. Therefore it is not surprising this presents several challenges to the food and agriculture industry. One respondent in particular was very vocal about such challenges. The Swedish sanitation researcher and consultant stressed that the food industry drives demand to a large degree, therefore if they do not accept food fertilised with urine or sludge then farmers in turn will not accept urine from households, as highlighted:

> "*if they* [the farmers] *use the sludge, they won't be able to sell the products to the one that gives the best prices. And therefore they say "No", and then they use chemical fertilizer*" [p2, Sanitation researcher and consultant, Sweden].

Arla (the largest producer of dairy products in Sweden) does not allow urine fertilization on cow pastures:

> "t*he food industry has always been playing it safe, and they have seen, well it's a wastewater fraction (urine) therefore it equals sludge*" [p2] …"*There is so much money in the value of their brand name, so one bad TV program or article in the news… will cost them very much, and then its not worth, it doesn't really cost them anything to say no, at the moment, which is really stopping this development*. [p9, Sanitation researcher and consultant, Sweden].

However the Swedish sanitation researcher and consultant puts this in perspective by adding:

> "*I don't believe that's the big problem. Not at least in the next 5 years. There is a lot of farmland that is not Arla… and there's always energy crops, and we grow things*

that the cattle eat, so that's not the really short term barrier" [p9, Sanitation researcher and consultant, Sweden].

Another factor pushing farmers towards chemical fertilizers is their relatively low price, hence there is little economic incentive to use urine. The Swedish sanitation researcher and consultant provides further insight into ensuring sufficient demand from farmers:

"*I don't believe that the farmers will be the problem. As long as you realise that they wont go in this and take costs. They need to at least get out even*" [p8, Sanitation researcher and consultant, Sweden].

Perhaps the type of key driver of urine diversion and reuse will implicate the degree of importance of successfully engaging the food and agricultural industry and hence the magnitude and critical nature of this challenge. For example, if the key driver is reducing algal blooms, then ensuring farmers and the food industry will accept the urine is a secondary issue, where as if returning nutrients to arable land is the key driver, than effective participation is critical.

6.3.7 Analysis: comparing and contrasting with the literature

This section compares and contrasts the literature on barriers and challenges with stakeholder responses. The literature does not conflict with stakeholder responses, however does provide further information.

Some respondents did suggest fully integrating urine diversion and reuse into every day practice and policy was certainly a different thing to demonstration projects. However Hjelmqvist took this barrier one step further by suggesting pilots are often promoted as 'ecological' or 'flashy/premium' and thus there is a need to pilot these systems in realistic or ordinary dwellings/buildings to facilitate a smoother translation into a policy (J. Hjelmqvist, pers comm., 2/9/05).

Although much of the Swedish regulations are enabling rather than restrictive of urine diverting systems, Johansson and Kvarnström (2005) notes that the Public Water Supply and Wastewater Systems Act is inconsistent with the Environmental Code, and prevents the implementation of closed looped sanitation systems in urban areas. As a general comment, they reflect that sanitation policy formulation and passing legislation appears relatively easy and it is *"much more difficult to change informal institutions such as attitudes, human and organisational behaviour, codes of conduct and behavioural patterns*" (p39, Johansson and Kvarnström, 2005). Another barrier of ecological sanitation raised by Johansson and Kvarnström is that the concept does not fit neatly into one existing regulatory framework, as it traverses many sectors of society.

Johansson et al (2000) suggests a current limitation of urine diversion systems is the significant expense associated with installing new pipes (both in the ground and in buildings).

While the average householder might prefer dual flush urine-diverting toilets because they tend to flush both bowls clean every time, as suggested by the Swedish toilet manufacturer, this 'luxury' is at the expense of increased volume of urine collected. This means there is twice the volume to store and transport, which in turn increases the overall cost of collection (Kvarnström, 2005).

Box 5: Drip irrigation for urine reuse?

While drip irrigation of urine may seem relatively straightforward compared to greywater or other effluent reuse (due to lack of particulates), some experts suggest urine dispersal using drip irrigation could be problematic due to sludge build up and mineral precipitation. While build-up in dripper lines from greywater is typically attributed to aerobic or anaerobic bacteria, build up from urine would be mineral-based and difficult to clear once precipitation occurs. Further, if water was added to the urine mix, this could increase the potential for mineral build up due to the Mg and Ca in water (therefore greater risk in hard water). (Hakan Jonsson, pers comm. 31/8/05).

Though some respondents warned of the limitation of bulking up the urine volume with excess flush water and the implications for transport, none discussed the bulky volume of urine itself. Schönning & Stenström (2004) note that while attempts have been made to concentrate nutrients in urine, storage at ambient temperature in tanks still remains the only viable technique today. Drying urine has also been tested, however results in loss of nitrogen.

Regarding societal norms on urine, Sawyers (2005) and Drangert (1998) suggest faecophobic societies are closely related to modern urbanisation, typically sewered with centralised systems. Drangert calls this phenomenon 'urine blindness'. He suggests both the professionals managing urban water and sanitation systems and users of these systems avoid thinking about the character of individual fractions within wastewater and rather continuing the legacy of 'flush and discharge' (p157). Sawyers' contrasts this to the East, where many countries have been reusing human excreta for centuries and are thus more accepting of modern interpretations of reuse systems.

6.4 Lessons and opportunities for the future

In addition to reflecting on roles and responsibilities and barriers and limitations, there are other lessons learnt from the Swedish context that can contribute both to improving the Swedish experience and guiding the Australian experience should Australia decide to invest in urine diversion. These essentially fit under the same themes as barriers, that is, a) Regulatory, institutional and management-related barriers; b) Health challenges; c) economic challenges; d) education and awareness; e) technical and operational; and f) challenges in agriculture industry.

6.4.1 Regulatory, institutional and management-related issues

Similar to barriers, regulatory and institution opportunities were raised on the international and national level, in addition to a general coordination role.

On the international level, the Swedish academic/researcher raised the EU Water Directive as a window of opportunity to install urine-diverting systems:

> "*What's happening with Sweden now is that we are slowly getting the EU Water Directive into place. Which means that many of the waters in Sweden, they have to improve the ecological state of these waters. And that will cost money. And some municipalities will, I'm sure, see urine diversion as a cost-effective measure of improving the ecological state of the water*" [p10, Academic/researcher, Sweden].

In contrast to several other respondents, the Swedish sanitation researcher and consultant viewed the EU restrictions on using human excreta in ecological farming (as discussed in Section 3.3.1) as:

> *"not a barrier but an opportunity we haven't realised*" because once this restriction was corrected, ecological farmers might be willing to pay for urine "*because this is fast N and plant nutrients. Its lots of what they need. They would increase their crops*" [p10, Sanitation researcher and consultant, Sweden].

The Swedish academic/researcher also noted that the International Ecological Farming Society (IFOAM) does accept urine as an ecological fertiliser, so:

> "*there's a fair chance that it would be allowed as an ecological fertilizer in Australia*" [p6, Academic/researcher, Sweden].

Another important future opportunity at the national level, raised by most respondents, was the pending national targets for nutrient reuse. Without such regulation combined with economic incentives, most felt there would be little further development of urine diversion:

"*the Swedish EPA proposed a goal for 2015 that 60% of P in the wastewater fraction should be recycled to some sort of land/crops and 30% of that should be to agricultural crops… we have been waiting 4,5, 6 years for this National Objective for recycling. Currently there is no real limits (it just said we should aim to recycle more… So it gives all of us, whether we work with urine diversion or recycling sludge or whatever, that this is the rules of the game now. Lets start working to meet this objective. And this is sort of a platform that we've been waiting for a long time. Which I believe will be one of the key drivers for…seeing more closed loops in the future*" [p1, Sanitation researcher and consultant, Sweden].

The Swedish academic/researcher felt that these national targets would legitimise urine diversion as a serious option for sustainable sanitation:

"*previously the urine diversion has been sort of wild ideas from environmental freaks – there has been no official support. There was for 2-3 years, but then the advisors to the government changed (even if the government did not change) which meant that urine diversion lost a lot of the support from the government*" [p8. Academic/researcher, Sweden].

The Swedish academic/researcher also mentioned another national initiative that he felt would further legitimise urine diversion:

"*There's also a new* [national] *regulation that will come in to place I think the same time period. That states the hygienic state of urine – how long you have to store it before you reuse it, that sort of thing. Which gives it an official status*" [p7. Academic/researcher, Sweden].

The Swedish academic/researcher suggested this official support at the national level would be key to stimulating new developments and actors in urine diversion in Sweden:

"*First you need support on the national level so that municipality actors they are to go in and start larger scale project. But those larger scale projects, one of the most important benefits of those might be that we might get some more money in the business so that we get product development and new actors. And that is essential I think, for it to get widespread acceptance*". [p10, Academic/researcher, Sweden].

"*The first step on the way to broad scale introduction is that we get new actors in the different devices – on the toilets, on the pipes, on the tanks and so on. So that we get some development of those gadgets*." [p10, Academic/researcher, Sweden].

He also suggested the need for an organisational structure to manage the system:

"*I mean its not just the technology. You need to have an organisation taking care, transporting, reusing the urine and so on. So its very much an organisational issue"* [p10, Academic/researcher, Sweden].

Several other respondents also stressed the importance of managing and coordinating the entire chain to ensure a successful urine diversion system that efficiently and effectively returns nutrients to arable land. Suggestions included householder feedback to demonstrate how their involvement in urine diversion affects what happens to the nutrients and crops further down the chain:

"*and you would have to have a farmer coming to visit every autumn with potatoes. Do something around it, or have a picture of the farmer in the staircase where he's entering the house*" [p7, Ecovillage resident and practitioner, Sweden].

Other suggestions included ensuring someone is managing the entire nutrient balance, the logistics of timely collection and transport and thinking about opportunities for new actors:

"*it has to work: the urine has to find its way to the tank and shouldn't be stopped or anything, like problems with the pipes and when it gets full, someone must come and collect it. If it doesn't work - these practical things for the householder - it will be a problem*" [p8, Municipal Staff, Sweden].

"*that's what I find…when trying to solve the chain…then saying 'oh yeah and we need the farmer, we need that guy in the tractor*" [p2, Sanitation researcher and consultant, Sweden].

"*If you've got a lot [of urine] if you could make them* [the farmers] *an entrepreneur and they could get money from transporting this and other big companies own a lot of tank trucks… And maybe in the future…they could also be the entrepreneur building the system, so they could in the future build the onsite systems. They're local, they're engineers, they're skilled in many things. Also the transport entrepreneur they could also be….They're multi-skilled*". [p9, Sanitation researcher and consultant, Sweden].

However the Swedish sanitation researcher and consultant later notes from a nutrient balance perspective that demand from all farmers is not required:

"*even if we take aaaallll the nutrients from all Swedish people back to farmland, we will only cover 25% of the total nutrient fertilizer supply to our farmers. So we only need to convince 25% in the very future to take that. So that's' not the problem, we don't need to convince all the farmers*" [p8, Sanitation researcher and consultant, Sweden].

There were a significant number of institutional and regulatory opportunities respondents identified, that ranged from short-term to longer term, occurred at all levels – international through to local and were both formal (such as Directives) and informal (household feeback) opportunities.

6.4.2 Health-related opportunities

Interestingly, one of the most significant barriers raised by respondents, that is the presence of pharmaceutical residues and endocrine disruptors in urine, was also raised as an opportunity or benefit by the Swedish academic/researcher:

"*one big benefit already now and might become even more important in the future is that we have most of the pharmaceutical residues in the urine. And the advantage of this, the ordinary wastewater treatment plant, is not efficient enough for many of the pharmaceutical residues. And there is an increasing concern about this*" [p6, Academic/researcher, Sweden].

The Swedish academic/researcher further elaborated:

"*We know that if we put these substances on an agricultural soil, the risk of uptake is minimal. We know that because there have been lots of studies of other substances from sewage sludge, and if you look at organic substances the uptake by the crop is essentially non-existent. And therefore the risk of pharmaceutical residues when you put them on agricultural soil, is also very small. But the advantage is if you put it on an agricultural soil, it will be in a microbiologically very active environment for a very long time for several months before there's a big rain to flush it down. And that's a big difference compared to the wastewater treatment where you only have treatment for some 6 hours, and therefore there will be a far larger degradation of the pharmaceutical residues in the field*" [p6, Academic/researcher, Sweden].

The Technical Director of the Swedish water company suggested that in the longer term, this issue is a responsibility for the medical industry:

> "*At the end it's a question for the developer and producer of the medicals. They have to produce environmentally safe medicals... They must be degradable in nature, for instance, not toxic*" [p4, Technical Director, water company, Sweden].

Whether this issue is viewed as a barrier or opportunity, it is certainly a critical one that requires further attention.

6.4.3 Economic opportunities

Respondents described economic-related opportunities for farmers, householders, housing industry and generally when comparing urine diversion to the conventional sanitation systems.

Farmers could increase their income generation by supplementing farming activities during the winter months:

> "*we've got a lot of small, most people that are sitting on tractors and machines taking away the snow from our streets – that's the farmers – that's their extra income and the farmer and farming association they are looking for new opportunities for being an entrepreneur*". [p8, Sanitation researcher and consultant, Sweden].

The respondent from Tanum municipality suggested that householders outside the municipalities area of responsibility could benefit:

> "*if you're not in this area* [of municipal responsibility] *then you can connect to it and then if you install urine separation you will have a reduction of fee. So that's one way*" [p4, Municipal Staff, Sweden].

The Swedish sanitation researcher and consultant highlighted how adding urine diversion to new developments could be a marginal cost and hence insignificant:

> "*the project manager could not see the extra costs for urine diversion. Of course there's an extra costs, some more pipes, more consultants, but seeing the houses were sold for 3 million SEK each…if … sneezed that would change the economics of the system more than if you added urine diversion*" [p6, Sanitation researcher and consultant, Sweden].

Further, according to some, water prices are too low and don't reflect the true cost of water (particularly environmental costs). Hence increasing price would open up opportunities for urine diversion to be cost-competitive:

> "*I think generally that the water prices in this city is much too low. And that's because we have so much water here. I mean that's what I would like, that you at least double the price, THEN there is economical room to have a lower price on the environmentally friendly solutions, and still that you do pay for it*" [p11, Ecovillage resident and practitioner, Sweden].

Whilst not suggesting environmental costs and benefits should necessarily be included in water pricing, The Technical Director of the Swedish water company did state the importance of including the environmental benefits in the overall decision-making framework:

> "*You need to have good environmental arguments… So that you can really show that this system is much more environmentally friendly than the conventional system. It will decrease the algal blooms for instance in the receiving water, in that way, for example. Or you will save water in that and that way… [If] they are strong, then you can get the change, but you need the good arguments*" [p7, Technical Director, water company, Sweden].

The Swedish academic/researcher and the Swedish sanitation researcher and consultant were both of the opinion that urine-diverting systems could be cost-competitive with other decentralised systems, particularly with new performance standards that will be required:

> "*If you put up the coming guidelines, the performance that will be required, it will not cost more having a source separating or a urine diverting system than having a small package treatment plant, SBR plant or the kind of new filter beds or whatever. It wont be more expensive, which means you could say that you should go for it, and in many cases it will be less should this not be expensive, especially if you go for a urine diverting dry system, the best for the environment, it costs less*" [p7, Sanitation researcher and consultant, Sweden].

> "*if you compare with something that actually treats the wastewater to a large extent, then I'm pretty sure we can make it cheaper or maybe much cheaper* [for new or renovated dry systems]"[36] [p3, Academic/researcher, Sweden].

The Swedish academic/researcher believes:

> "*the large benefits from a cost point of view will occur when we take care of the faecal matter also*" [p3, Academic/researcher, Sweden].

6.4.4 Attitudes, awareness and communication

Most respondents raised or discussed the importance of education, not only for the user but the entire chain of stakeholders, at all levels.

Effective and appropriate communication both in public places and households was viewed as essential to influencing user behaviour and hence ensuring the system functioned correctly:

> "*if you install in places like that* [public places] *you have to have good signs. And now before they had this text 'you have to sit down and this is urine separation toilet..'. But now they have pictures instead*" [p4. Municipal Staff, Sweden].

> "*That's the same as to know that you shall clean your hands when you have been to the toilet… You absolutely need to understand and know and have it in here WHY you have this system and how to use it and what the different steps is of great importance. You can't jump it over, then it will be inappropriately used*" [p5, Technical Director, water company, Sweden].

In addition to effective education and communication on functionality, most stakeholders also linked motivation levels of users to success of urine diverting systems. According to the Swedish academic/researcher, whilst initial urine-diverting toilet behaviour required men to sit down to urinate, he acknowledges that perhaps it is wise to consider how enough urine can still be captured if men stand. If not, the system risks failure if men resist the technology because are required to sit, or, if they do stand perhaps sufficient proportion of urine, and hence nutrients, will not be captured.

> "*What we have discovered after those studies that some of those toilets function fairly well even when the men are standing. So actually I think that they can be encouraged to try that also. In that way we don't receive as much resistance from the men… Most of these have a large enough bowl in the front so that even if you miss some in the beginning you can sort of zoom in on your target, if you're concerned about it. And the men should be told this so that they don't get resistant against the technique. Because standing up when peeing, that is something that men do in Asia, in Africa, all over the place.*" [p5. Academic/researcher, Sweden].

[36] This last statement refers to managing both urine and faeces.

The Swedish academic/researcher also commented on findings from a study he was involved in, highlighting the importance of people's attitudes and behaviour for the amount of nutrients captured:

> "*we saw that when the urine is not reused, people lose their motivation to actually uphold and maintain the system. Because these types of systems need more maintenance than an ordinary system. And when the urine is reused, that's enough motivation for people to put in that extra maintenance. But if its not reused, then people after a few years say 'what the hell, we don't want to have this bother with the urine pipes when no body is going to use the urine anyway. So then they pull it out*'" [p8, Academic/researcher, Sweden].

Similarly, the amount of water conserved is highly sensitive to user behaviour, as demonstrated by the Swedish academic/researcher. Therefore if water conservation is an objective from installation of urine diverting toilets, user attitudes should be accounted for and managed accordingly:

> "*What we have seen for water saving for example is that you have to point out to the people that they can save water and the people have to be aware and see water as a scarce resource for urine diversion to actually save water. Otherwise they flush just as they normally would and they hardly save any water at all… We saw the difference between two different areas. One which was an ecovillage where they were a little concerned about water and one which was an ordinary living district, where they didn't really care about water. And one where they didn't care about water or haven't thought about the use of water, they saved very little. I mean when you do the calculations you can save some 80%, I think that if I recall correctly, the ordinary living here they saved something like 10-20% of the water*" [p4, Academic/researcher, Sweden].

Box 6: Influencing user behaviour

The importance of effective user feedback in optimising the system is suggested by Ecovillage resident and practitioner, Sweden.

"*Maybe the farmer should say: this urine that I got in November, had a very high level of cadmium. I wonder if any of you might have put a battery in your toilet. Maybe doing the connections that way rather than working with urine pipes… I don't know how much connection you actually experience by brushing your urine pipes. I get that connection because I have the whole context. But if you don't have that, you just have a filthy pipe that you have to work with, but you don't see the meaning of it. So I think you do need to connection*" [p11, Ecovillage resident and practitioner, Sweden].

The Swedish academic/researcher is fairly confident that user attitudes are changeable in the future,

> "*it seems to me that the attitude of people, they are so flexible, within 10-15 years time I'm pretty sure that people would change their acceptance*" [p2. Academic/researcher, Sweden]

the Swedish ecovillage resident and practitioner extends this notion and suggests a mechanism to influence user attitudes and behaviour through creation of a mental feedback loop involving farmers:

> "*In residential areas…you need to have good information. Both how you should run in – the toilet. And also the meaning of it. At least in Sweden people are willing to do things if they really trust... if people believe that its working then you tend to do it, here. So that's why I would like to have a picture of this farmer in the entrance "thanks" for this… or "last year we got 125 cubic metres which was enough to cover these 3 fields, and I didn't get 4 million tonnes of potatoes. Or something like that. Good feedback. And yeah the average size was only 1% less than the next field. …or 1% more! …Then you really get 'Oh really, gosh, that sounds good'. I think you have to be really practical with it*" [p8, Ecovillage resident and practitioner, Sweden].

To further encourage the uptake rate of urine diverting toilets and appropriate usage, the Swedish toilet manufacturer stresses customer satisfaction and hence design is of utmost importance:

> "*if the customer is not satisfied, then you can forget it. I mean that's the most important of everything, they MUST be satisfied… And the customer thinks about the hygiene, the bowl must be clean when they use it, and no smell, and quiet and everything like that, like a normal toilet"* [p2, Toilet manufacturer, Sweden].

In addition to user awareness and motivation directly affecting physical system functionality, The Swedish ecovillage resident and practitioner also drew the connection between user awareness and motivation to political processes:

> "*the political drive is based on the processes happening within people. Cause if you don't have the drive within the people then the politicians don't respond to it. So the real issue is that raw environmental consciousness*" [p6, Ecovillage resident and practitioner, Sweden].

Stakeholder responses in this section suggest effective education and awareness is not so much an opportunity, rather another critical element for maximising capture and recycling of nutrients back to arable land.

6.4.5 Technical and urban planning

Whilst many respondents acknowledged the importance of influencing consumer attitudes and behaviour to ensure the system functioned properly (as per the previous section), several also noted various design improvements that could also lead to better system functionality. These included enhancing design of the toilet bowl and pedestal for easier usage by a range of users, changing pipe design to minimise clogging, crystal build up and odour, through to streamlining design and installation, urban planning and improved maintenance.

The Swedish toilet manufacturer, suggested a clean bowl is important to users:

> "*the bowl must be completely clean, every time you flush. If you flush with the small one or the big one. It should be ALWAYS clean. And when I say clean, I mean… it must be completely clean*" [p2, Toilet manufacturer, Sweden].

For this reason, the toilet manufacturer designed their dual flush urine-diverting toilet such that the small flush (2.5L) discharges 0.25L to the urine bowl and the remainder to the back, while the full flush (4L) flushes 0.3L to the urine bowl. Other urine diverting toilets might flush nothing to the back for the small flush, while others again are only single flush toilets. The Swedish toilet manufacturer admits if the toilets were to become commercially viable, they would look into improving design, for instance designing a floor-standing toilet rather than wall-hanging. This is partly because floor-standing is more economical.

Furthermore, the toilet manufacturer is also looking at a having a separate urinal to allow men to stand in either domestic or public situations. This would facilitate greater collection of urine and hence nutrients:

> "*if…it* [nutrient recovery] *must be up to 90% then you have to have the toilet AND a urinal, then you can achieve what you want to. But if you integrate the urine separation [only] in the toilet, its impossible to achieve that goal you have*" [p5, Toilet manufacturer, Sweden].

> *And if there's a possibility urinals should be installed actually…But it takes half an extra square metre of building area, and in that way its costly*" [p5. Academic/researcher, Sweden].

Improvements to seat design, such as a children's seat, was also a suggested improvement:

Another technical issue at the user interface is odour. According to the Swedish toilet manufacturer, "*the customer thinks the smell in the bathroom is the worst*" [p6, Toilet manufacturer, Sweden]. Several respondents raised points as to why odour problems may occur, and how they could be addressed to minimise the problem:

> "*maybe if you have this siphon and if you flush maybe 1dL the concentration of urine might be quite high, so maybe its urine not water standing there….and that's also a problem with the smell. And some people they actually say they install one extra* [siphon] *and then the smell disappear… But there is a lot of problem with smell with this double flush toilet system than with this dry toilet system. Maybe one should install a fan on this*" [p9, Municipal Staff, Sweden].

> "*The problem is the smell of the urine, that's the problem, I don't know if it's the model of the toilet or something else, but it happens. [If] if happens its empty and we have to put 2 water locks, and then it works*". [p1, Plumber, Sweden].

> *"when you punch the hole manually…, and its not straight,…then you might have some tension here in the wall…if its bended, so the pipe tends to press the seal in that way, then you have the smell*" [p4, Toilet manufacturer, Sweden].

Other technical refinements offered by respondents included using larger pipes and trial and error process with troubleshooting:

> "*Larger pipes are typically more fail safe, contrary to what the Swedish Plumber believes most people think and "not so much difference in price, small or big pipes*" [p8, Plumber, Sweden];

> "*we had these problems with flies, and clogging of the urine pipes and didn't know really how to run it. Now we sometimes have the same problems with flies and clogging, but we know how to run it…it was trial and error, and experts combined.*" [p8, Ecovillage resident and practitioner, Sweden].

The Swedish municipal staff member and the Swedish toilet manufacturer discussed further system design 'lessons learnt' for ensuring adequate nutrient recovery:

> "*the urine tank…maybe you should have urine getting out to the bottom of the tank and not flushing on top.. The ammonia will get up if you have it like this, but if you have it below..."* [p9, Municipal Staff, Sweden].

While the Swedish plumber felt the installation process functioned fine:

> "*I think they* [the installation plumbers] *know what they have to do...that works…Often they come here before they have built the house and I have a little map or they see the system.*" [p2, Plumber, Sweden]

The Swedish toilet manufacturer's strongest recommendation for future advancement of urine diverting systems was development of a standard to ensure consistency and coordination of systems, including the installation process:

> *"If you have a Standard you know exactly what you want. Then perhaps if we* [the toilet manufacturer] *know, we can leave some information, you can buy a tank from that manufacturer, or we recommend you use this pipe, and so on…* A *SIMPLE book, for urine separated systems. How you dimension and how much water you can use, etc… also so a customer could read it in a very simple way*" [p7, Toilet manufacturer, Sweden].

The Swedish academic/researcher went as far as to suggest opportunities to learn from overseas developments of urine diverting systems, like those in China:

"*China claim they have installed more than 1 million urine diversion dry toilets….within 10 years or 5 years they might also develop wet urine-diverting toilets that might also be of interest to Sweden*" [p10, Academic/researcher, Sweden].

At the urban planning level, opportunities for wider-scale installation of urine diverting systems in new developments was raised by the Swedish municipal Staff, Sweden:

"*And also maybe if there's coming a time- more cities that don't have a sewage plant today they and they're growing quickly, maybe there will come some ay and hopefully if you then decide to install urine separation that will be easier*" [p7, Municipal Staff, Sweden].

Respondents covered an array of technical improvements and opportunities for the future. Such 'lessons learnt' could be used by Sweden, or Australia when designing and/or planning for urine diversion and reuse systems.

6.4.6 Appropriateness of urine diversion

Respondents were also asked if there were any situations in which urine diversion arrangements might be more appropriate or less appropriate. Responses varied in interpretation of the word 'appropriate'.

The Swedish plumber suggested urine-diverting systems were appropriate in households though not public toilets:

"*In the family it works...But in a big* [building] *when you have many different people who use it. I think it's a problem. If you have example here [referring to public toilets in the museum]. It doesn't work –there was a problem – there was paper in the urine and different things. That was a problem. There is the only 'black' side where I don't think it works*" [p3, Plumber, Sweden].

The Technical Director of the Swedish water company thought urine diversion could be appropriate for both rural and urban settings, however there would likely be a greater opportunity for new developments:

"*I think its possible to manage it in the city, in the dense city as well as on the country side…* [If you] *build a new part of a city, its much easier to take this decision from the beginning, to build for urine separation, and its much more cost-effective and easier to make it cost-effective*". [p7, Technical Director, water company, Sweden].

In one densely populated municipality in Stockholm urine diverting systems are mandated because:

"*its very hard to build a central treatment system because its very rocky ground so you have to blow your way through. So therefore this municipality they support the installation of urine diversion in the houses... Its cost-effective compared to central treatment… it will be more common to have it regulated like that. And the reason for that is that the EU becomes stricter on the nitrate regulation, Which means that we have to decrease the Nitrate emissions also from smaller municipalities than we normally did in Sweden*" [p9, Academic/researcher, Sweden].

The Swedish academic/researcher was also of the opinion that urine-diverting systems were relatively more appropriate in rural rather than urban areas:

"*I think it's a good thing to do in all areas, but the largest advantage is… in rural areas where you have onsite treatment. Because that's where we can get the largest benefits for the environment. So that's where it should be introduced first. But I think in the long run it is something that is appropriate for essentially most systems*" [p10, Academic/researcher, Sweden].

Whilst the Swedish sanitation researcher and consultant felt urine-diverting systems were generally applicable, it does depend on the context:

> "*I would start by saying source separating systems will compliment and make better performance of the wastewater systems in almost any situation…But this is an idealistic way… If the farmers don't want urine you shouldn't go for urine diversion, really... It also depends on what's the structure that's already in the ground*." [p7, Sanitation researcher and consultant, Sweden].

While respondents felt urine diversion and reuse was generally a good approach, there were certainly more opportune situations in which to install such systems whether that be due to geography, institutional structure, awareness, urban planning.

6.4.7 Analysis: comparing and contrasting with the literature

This section compares and contrasts the stakeholder views of opportunities for the future and lessons learnt with the literature and other sources. Lessons and opportunities in relation to health aspects, particularly microbial and chemical risks of urine diversion and reuse have thoroughly investigated and documented through Swedish and Swiss funded research. General findings from such studies are that urine diversion and reuse is essentially safe and hygienic if basic precautionary measures are taken, such as a minimum storage time in case any cross contamination with faeces has occurred. Similarly, basic precautions for reuse and application on crops are described. For details of such studies and risk management strategies and guidelines, see: Schönning (2001), Schönning and Stenström (2004); Fane (2005), Malmqvist et al (*forthcoming)* and the Swiss Federal Institute for Environmental Science and Technology (NOVAQUATIS, 2003). More recently, researchers are investigating the nature of risks relating to pharmaceutical residues and endocrine disruptors. There is little conclusive documentation based on thorough investigations, however preliminary research suggests that disposal of pharmaceutical-containing urine to land rather than water poses a much lower risk, as there are two extra barriers: 1. Months of residence time in soil to breakdown, compared to hours in a wastewater treatment plant, 2. The soil-root barrier is more efficient against larger molecules (Jönsson, 2005). Further, Jönsson suggests that we are typically exposed to higher amounts of hormones secreted from the fertilizing manure of pregnant cows. Other research centres in Switzerland (EAWAG) and Germany (TUHH) also also investigating these risks and management options of micro-pollutants in urine, hypothesize that diverting urine from wastewater to soil is likely to be more risk adverse than allowing the micro-pollutant-containing urine to pass through the conventional wastewater treatment system and into a receiving water body (NOVAQUATIS, 2003; Martina Hammer, pers. comm).

Technical lessons learnt for effective collection, storage and reuse of urine nutrients have also been documented in various publications and courses, particularly by one of the respondents. Some of the key lessons are summarised in Box 7 below. A technical assessment of commercially available urine-diverting toilets (as at 2001) has been published by WRS Uppsala (2001). This market survey profiles the function, water consumption, design, maintenance, price, contact details and short comments of several models. While the stakeholder responses overlap on some issues, they were not as exhaustive as the literature. However, most of the toilet manufacturer's perspectives and suggestions for improvements were undocumented in the literature and may prove useful for future toilet design.

Evaluations of urine diversion in demonstration villages or buildings in and around Stockholm have found that typically 50% - 85% of the urine was diverted. The amount diverted was highly sensitive to motivation level the user (Jönsson, 2001).

Box 7: 'Technical Tips' Lessons learnt

The toilet:

- Hair and fibres in the urine bowl should be flushed away by water when cleaning the toilet, as blockages can otherwise occur.
- Blockages in the urine pipe U-bend, can be cleared by inserting a mechanical snake or caustic soda solution. However acid may also need to be used every second time in case the caustic soda precipitates.
- The urine bowl should allow men to stand up while urinating (otherwise the percentage of urine collected will be less).
- The flush for the urine bowl should use as little water as possible (<0.1L/use), other wise there will be a larger volume of urine to store and collect.
- No part of the toilet system exposed to urine should contain metal.

The pipes and tanks:

- The system should be watertight to ensure no infiltration of rainwater or groundwater.
- Horizontal pipes should have a slope of 1-2% to ensure urine sludge build up is flushed away.
- The pipe/tank system should be pressure neutral: positive pressure may result in odour in the bathroom, while negative pressure or ventilation will allow some N (in the form of ammonia gas) to escape from the system. A 2-5mm hole in the inlet pipe to the tank was found to be optimal.
- The inlet pipe to the tank should allow urine to be filled from the bottom

Reuse:

- Drip irrigation is not recommended due the potential for mineral precipitate from the urine to clog the pipes and fine holes. This can be particularly problematic if urine is mixed with water, which will increase the precipitation with Calcium and Magnesium in the water.

(sources: Jönsson 2001, 2005, pers comm.)

There have been few serious studies addressing the full economics of urine diversion and reuse. While some studies refer to specific costs and benefits such as the maximum distance urine can be transported before it becomes cost-ineffective (Johansson et al, 2000). There has been no full analysis of whole-of-society costs and benefits (including environmental, social and economic to all key players) or cost-effectiveness of urine diversion and reuse compared to others. Costs and benefits are discussed more fully in Section 8.

On the topic of user acceptance and attitudes, the literature generally mirrors the breadth of opinions of the respondents. That is, literature also suggests there are mixed views in the professional community regarding user attitudes and preferences towards decentralised sanitation systems like urine diverting toilets. It is easy to believe users will not widely accept these alternative toilet systems (including composting toilets) where the toilet interface might look, smell and function differently to a standard flush toilet, in addition to possibly requiring a higher degree of interaction and responsibility by the householder. However, as White (pers comm.) suggests, users of the WC were 'toilet trained' initially, that is, our preference for the flushing porcelain toilet is a social construct of recent decades, hence there is potential to 'toilet train' flushing societies towards other toilets, including more environmentally friendly solutions. This view is strengthened by findings from a Swiss study that used focus groups of ordinary citizens to assess consumer attitudes towards urine diverting toilets (Pahl-Wostl et al, 2003). Pahl-Wostl et al found a significantly high acceptance among the study group, as long as there was no increased cost to the user. Further, the study found a willingness to eat vegetables fertilised by urine, a finding also echoed by Schmidtbauer (1996, cited in Pahl-Wostl et al). Johansson (pers comm.) points at the case of a swedish ecovillage, where the children were brought up using dry urine diverting toilets, and were found to not be using the toilets at their school, as they were not urine diverting. This strongly indicates the toilet training phenomena.

Politically, several lessons have been recently documented. In line with recommendations offered by some respondents, Karlberg (2005) suggests political will is possibly more important for successful implementation of sustainable sanitation arrangements than technology choice. The importance of political will and political entrepreneur as one of seven key criteria to be considered during the urban water or sanitation planning process has emerged as a recommendation from the MISTRA Urban Water program (Malmqvist et al, *forthcoming*). In chapter 8.1 of this forthcoming publication, Söderberg and Johansson discuss the importance of integrating aspects of institutional capacity early on in the planning process. The criteria are provided in Box 8.

Box 8: Institutional capacity in planning for urban water and sanitation systems

Seven criteria for integrating aspects of institutional capacity into planning (Malmqvist et al, *forthcoming)*:

1. The presence of policy entrepreneurs, i.e. initiators as well as implementers;
2. The sphere of action, such as legislative and political support;
3. A value coalition of shared world views, problems and goals among crucial actors;
4. Access to resources such as knowledge and money;
5. Explicit division of responsibilities and risks among actors involved;
6. A defined arena for participation and conflict management; and
7. Communication with users

exert from p2, *8.1: Institutional capacity: The key to successful implementation,* Henriette Söderberg and Mats Johansson.

7 Australia: Opportunities and barriers

This section documents responses from stakeholder interviews undertaken in Australia. The semi-structured interviews were focused around the question of whether urine diversion and reuse systems could benefit Australia; who should be responsible; what would be the barriers to overcome and how can potential opportunities be harnessed.

Respondents existing understanding of urine diversion systems ranged from extensive to negligible:

> "*I wasn't even aware of that. I've dealt with blackwater/sewage as a whole, all my life, I've never divided it up into the two streams and looked at the quality of either side*" [p2, Municipal staff, Australia]

> "*I'm doing* [urine diversion] *as a demo of technology and learning more about it*" [p1, Academic/researcher, Australia]

7.1 Potential benefits

While there is a range of potential benefits of urine diversion and reuse (as discussed in section 8), the relative importance of these benefits will vary from context to context. The key potential benefits of urine diversion in the Australian (or more specifically NSW) context raised by the Australian respondents were: 1. Closing the loop on nutrients, by returning valuable nutrients in urine back to arable land, 2. Reducing risk of algal blooms; 3. Improvement on current wastewater treatment and reuse; and 4. Water conservation.

The majority of respondents mentioned recycling valuable nutrients from wastewater back to agriculture as a benefit of urine diversion:

> "*Fertiliser. You're not sending it to the ocean… You're reusing it. You're not wasting a good valuable resource. In 50 years time, I think you might have said it, that we're going to run out of phosphate. So as that happens, its going to become even more important*" [p1, Toilet manufacturer, Australia].

> "*The value is sort of in the nutrients you're going to sort of keep in the system. I mean that's the bottom line of it. I mean the current STP*[37] *set up basically get rid of most of your P and N out of the game. So if you can manage to capture some of those and reuse them there is a benefit for agriculture*". [p1, State Government staff (agriculture sector), Australia].

> "*Harvesting a resource, in my simple terms, instead of mixing a resource up with water and sending it to a treatment plant, it was diverting and harvesting something that was usable*" [p1, Urban water utilities (national association), Australia].

> "*With out energy sources we can always get atmospheric N and ammonia. P is more challenging… Over all for society its an extra cost by not recycling*. By importing [mineral fertilizers]. *Particularly once we start getting shortages of P*" [p7, Academic/researcher, Australia].

However the Australian academic/researcher acknowledged that whilst this is a critical issue for the future, it may not be a politically strong argument in the shorter term:

> "*It can only be seen as a secondary benefit, I think, under the current time frame. But it will be part of the ideology of why or how do you move towards a sustainable*

[37] Sewage Treatment Plant

society. This is just one component of how you do that: you don't consume non-renewable resources" [p6, Academic/researcher, Australia].

Perhaps a more politically persuasive reason is their potential to reduce the risk/incidence of toxic algal blooms. Most respondents noted reducing nutrient loads to sensitive waterways around Sydney as another key potential benefit and driver of urine diversion and reuse. Many of these waterways have or are still suffering periodic algal blooms:

"*For Sydney they'd reduce the nutrients going in to the river…So that's the main benefit…its still huge in Sydney, I mean you know we've got a river that's choked with weed, the Darling River that had the blue-green algal bloom for 1000km prompted a lot of our water reforms… I'd say its still an issue. And a big one. And not just in the Hawkesbury-Nepean. For Australia generally*" [p2, State Government (infrastructure, planning, natural resources), Australia].

"*if you're near the Nepean, then obviously you're more interested in that, but parallel with the other end, its doesn't have to be treated and go to the ocean*" [p1, Toilet manufacturer, Australia].

"*Well in Australia…we know we have cyanobacterial pollution problems. And we have coastal dinoflagell algal problems from time to time. This is the country that first discovered them and reported them globally*" [p6, Academic/researcher, Australia].

The respondent from the Australian Catchment Management Authority, Australia also highlighted the economic burden of current management of algal blooms:

"its costing the local councils, the farmers, and certainly the government agencies at the federal level, its costing them money to take the weed out, manage the blue green algae. And it's also cost the Fishing industry and the Tourism and recreation industry. And they're big industries" [p6, Catchment management Authority, Australia].

In addition to recycling nutrients and preventing algal blooms, several respondents suggested urine diversion and reuse systems would be an improvement on current wastewater management. They referred to different aspects, including nutrient removal, wastewater service costs and reuse.

For farmers fertilizing with sludge, the Australian State Government staff member in the agricultural sector suggested working with urine could be easier than gritty sludge clogging pipes:

"*People handling the effluent would probably think it was Christmas... One of the problems they've got in the dairy world is that it still comes with a few lumpy bits and that tends to clog up fine jets….so this sort of stuff* [urine] *would be miles ahead from that point of view*" [p4, State Government staff (agriculture sector), Australia].

Diverting urine from the blackwater stream could be an advantage for onsite wastewater disposal and reuse. A current limitation of onsite disposal of mixed household wastewater in Sydney is the capacity of the soil type and land space available to absorb nutrients, let alone water. However the alternative, pump out, is costly.

Similarly, source separation of nutrients in urine (and the associated volume of flushwater) could be simpler than complex separation and treatment processes at the treatment plant:

"*They [water and wastewater service provider] would be interested in less waste to treat. Less pumping, less overall costs. So they could get a benefits out of the technology*" [p4, Toilet manufacturer, Australia].

"*it gives you a fairly simple way of controlling at least half of N (80%) and half of P, and between the two for K, rather than trying to pull it out at a wastewater works…*

Looking at advanced nutrient removal from wastewaters, and what are they doing: they're sending the N back in to the atmosphere, and the P if you're lucky into a biomass that's semi-recoverable or in a combination with chemicals where its not very biologically (or plant) available" [p3, Academic/researcher, Australia].

"*…just on the weighted evidence we could probably agree that soil disposal or recycling is actually a real plus for urine diversion*" [p3, Academic/researcher, Australia]. "*My view on that is most evidence of pharmaceutical compounds are when they get into the water so we're actually doing a favour by taking the urine out of the sewage which we end up discharging in to water ways, where we haven't removed those compounds anyway by traditional sewage treatment. So we're actually doing a great service by urine diversion and soil treatment*. [p2, Academic/researcher, Australia]

Reducing the large volumes of 'freshwater' effluent through use of urine diverting toilets could benefit Hornsby Shire's estuary in addition to reducing nutrient loads. In the Shire, the quality and quantity of large amounts of treated sewage effluent discharging into the estuary is destroying the estuary by restricting flushing and increasing nutrient loads, together resulting in more frequent algal blooms.:

"*Reducing the volume of the household users* [wastewater] *is a good thing. So a big advantage is to reduce water consumption*" [p10, Municipal staff, Australia].

The Australian municipal staff member also felt water conservation was a secondary benefit in its own right, not only to reduce generation of wastewater:

"*water conservation is a benefit, for sure… From an environmental perspective, from a conservation perspective, from a social and social cost perspective*" [p9, Municipal staff, Australia].

Finally, the Australian municipal staff member suggested urine diversion is beneficial as it is inline with the theory of source separation:

"[urine diversion], *that's right at source, and we're all sold on that concept – the closer to source you are that you take out the pollutant, the better, so that logic flows, and you're concept is definitely much closer to source than any of the things we're throwing at*. [p13, Municipal staff, Australia].

There was general agreement among most stakeholders that urine diversion and reuse would return valuable nutrients to where they first came and reduce incidence of algal blooms. Suggested other benefits appeared to range widely and refer to stakeholders' specific area of work. No stakeholder suggested there were no benefits, however perhaps they felt pressure to suggest possible benefits as the research topic was centred around opportunities for urine diversion and reuse in Australia.

7.2 Roles and responsibilities

This section identifies potential roles and responsibilities according to respondents, if a urine diversion system were to be implemented in NSW.

Potential NSW stakeholders could include:

- Householder
- Water utility/ service provider
- Municipality
- Regulator – Health (eg. NSW Health), Environment (eg. DEC), Planning (eg. DIPNR), Utilities & sustainability (DEUS), Food (NSW FA)

- Federal Government (eg. EA)
- Plumbing industry (eg. Toilet manufacturer, plumbers)
- Agricultural industry (eg. fertilizer manufacturer, food industry)
- Farmers
- Housing developer/planner
- Community/citizens
- Consultant (eg. environmental)
- Catchment organisation (eg. HN CMA)
- Private industry/ new actors

Some Australian respondents, when asked about responsibilities, initially suggested the householder should be responsible for taking the initiative to install such systems:

> "*well the householder has to be responsible to the community… The community needs to control the system, so it's like any recycling system, it has to be local government that verifies that the system is operating correctly ,say once a year*" [p2, Toilet manufacturer, Australia]

Box 9: Citizen responsibility

"it would be nice if every citizen took their citizenship more seriously and got more involved" [p8, State Government (infrastructure, planning, natural resources), Australia]

According to the Australian municipal staff member:

> "[if council were to introduce urine diversion and reuse] *then its up to the householder to broker agreements with anybody else, to use it* [the urine]*… we probably wouldn't be part of that system*" [p15, Municipal staff, Australia]

However, after further discussion on whether if left to consumer preferences (without any economic or regulatory instrument as a catalyst) householder uptake would be sufficient to result in meaningful environmental outcomes, then other stakeholder roles were discussed. For example, perhaps parties benefiting from urine-diversion/reuse might take on a greater financial responsibility (which may then trigger greater householder uptake through economic incentives/subsidies):

> "*if there is significant value for the government and the general community, then they should subsidize the system*" [p2, Toilet manufacturer, Australia]

Following an implication and discussion of householder responsibilities, many respondents commented on roles and potentially responsible institutions, in terms of regulating/managing environmental and public health risks. There was a view by some that while Health Department public were responsible for the public health aspects, they would not necessarily be warm to the idea of urine diversion and reuse:

> "*I mean the EPA (DEC) …they're the regulators of that sort of stuff*" [p4, State Government staff (agriculture sector), Australia]

> "*The health department are a little worried because business is not as it used to be. They have to be a little bit more knowledgeable about different barriers and how do you measure barrier function*" [p5, Academic/researcher, Australia]

> "*All this stuff is taking it back one or two steps and putting people in contact with their waste again: changing filters, turning taps, bucketing stuff…And health don't like the idea, because its going backwards, as far as they're concerned. SO the Health view is a conservative one based on empirical evidence. So from a very broad perspective its not unreasonable. However, even though the risk is real, it is*

also extremely low, and that is also from empirical evidence" [p8, State Government (infrastructure, planning, natural resources), Australia]

In relation to the specific health risk of potential pharmaceutical compounds and endocrine disruptors, the Australian academic/researcher suggests this will be more of an issue for the environmental regulators rather than health:

"*The Health department…realise there aren't the human health impact through that sort of discharges, but there are ecological, and therefore its an EPA issue not a Health Department issue*" [p6, Academic/researcher, Australia]

In addition to identifying specific roles, respondents also discussed the present nature of institutional arrangements. For example, several respondents suggested more coordinated roles would be required between currently disconnected institutions managing water and sanitation.

"*I get annoyed...totally disconnected between water/stormwater/wastewater and those who deal with food way down the chain*" [p7, Academic/researcher, Australia]

"*I think there is around 5 regulators responsible for plumbing in NSW… So all these people have a responsibility… NSW can't get its act together to adopt a decent regulatory model like Victoria has done*" [p3, Urban water utilities (national association), Australia]

The complexity of this institutional structure has limited the development of onsite sanitation systems. Some respondents suggested bypassing difficult players. Thus, although not technically legal, the Australian respondent from the national urban water utilities association suggested it might be simpler for householders to install a system without approval of the regulators:

"*the regulators just don't know how to handle it. So you just ignore the regulation and do it, but be very mindful that fact that you are accepting the risk that if you cause problems to people in the building or cause a health problem, then you will probably bare the brunt of that decision*" [p4, Urban water utilities (national association), Australia].

"it wont be the water utility. The water utilities have gone back to managing pipes" [p7, Catchment management Authority, Australia],

"*The Department of Health...they take the precautionary principle to extremes.. they have to be dragged, kicking and screaming...."* [p5, Catchment management Authority, Australia],

However State Government (infrastructure, planning, natural resources), Australia felt that the complex and convoluted regulatory system suggested by others is not as bad as its made out to be and that:

"*having a single agency responsible for water quality is like having a single agency responsible for quality of life… the environment and water are not neat – they are complex and messy, and their management is also likely to be so*" [p2, State Government (infrastructure, planning, natural resources), Australia]

The Australian academic/researcher suggested the introduction of urine diverting and reuse systems could provide an opportunity for new actors, or new roles for existing actors:

"*So our local companies that produce superphosphate and so forth, rather than buying in rock phosphate for example, buying urine and using fertilizer from that… So that's perhaps staying with the traditional agencies that deal with that*" [p7, Academic/researcher, Australia]

The Australian respondent from the national urban water utilities association suggested a shift towards the increasingly popular discourse on centralised management of decentralised systems[38] as an opportunity for more effective management of urine diversion and reuse systems and highlighted that many features of existing regulatory system could then still remain:

> "*I think there's an understanding now that if you have centralised management of decentralised systems then they can work very well and quite often that gives you the best compromise, the best set of outcomes… You know you must have that proper framework in place so they continue to work the way they're designed to work and they're operated and maintained in a proper way, and people understand the do's and don'ts of working with these systems*" [p2, Urban water utilities (national association), Australia]

A shift to decentralised systems (even with centralised management) would involve a redistribution of costs (otherwise the costs might be more skewed towards the householder. This would be relevant issue for urine diverting systems and considers:

> "… *I think it needs to be built into the overall billing structure of how people pay their water service charges and usage charges, and there may need to be some cross subsidy to get these things rolling to show to the community that they can work, to encourage people to make those investments*" [p2, Urban water utilities (national association), Australia]

The non-homogeneous views from respondents about which stakeholders should be responsible for which roles if urine diversion and reuse were introduced in Australia hints somewhat at the ambiguity and complexity of current institutional structure in NSW, which is raised again in the following section on barriers.

7.3 Limitations and barriers

This section discusses potential limitations and barriers perceived by respondents to introducing urine diversion and reuse systems in NSW (or Australia generally), so they may be addressed or avoided accordingly.

7.3.1 Regulatory, institutional and management related barriers

There were a substantial number of regulatory and institutional issues raised by respondents as likely barriers to the development of urine diversion and reuse in Australia. This ranged from complex and potentially conflicting and ambiguous institutional arrangements, to inappropriate regulation and standards, institutional perceptions and mind-sets.

A first limitation noted was the lack of capacity of urban councils to manage decentralised systems like urine diversion and reuse. In rural NSW, councils have the responsibility for water and sanitation provision. While in urban areas of NSW, typically the centralised water and sanitation system is the responsibility of the water utilities, which generally accounts for most water and sanitation arrangements. Urban councils are therefore less equipped to manage water and sanitation systems due to lack of necessity. However under the current regulatory system, they are responsible for decentralised systems. This lack of resources and capacity – both in terms of experience, skills and time has been acknowledged as a limitation of increasing decentralisation of water and sanitation services in many urban councils, and, by the Australian municipal staff member and the respondent from the State Government (infrastructure, planning, natural resources) in this study:

[38] See West (2001) for discussion on the case for centralised management of decentralised water and sanitation systems.

> "*The other problem you've got with councils in Sydney where they're not sewage providers or water providers, so our knowledge of sewage treatment systems and water reticulation systems is low*" [p7, Municipal staff, Australia]

> "*They're* [urban councils] *not water utility managers in the urban area, like the councils are outside of Sydney, so they don't have water engineering experts so much*" [p3, State Government (infrastructure, planning, natural resources), Australia]

Limitations of current regulation included the restriction on effluent reuse in the Sydney catchment area, which could pose a logistical barrier to cost-effective reuse of urine, in addition ot generally complex and convoluted plumbing regulation and legislation:

> "*they've got this funny rule where you're not actually allowed to put it in the catchment. So you've gotta take it over the hill to someone else's backyard, and apply it over there. Which is probably you know, not a bad thing in essence, but its just a bit odd in terms of the level of trust and stuff*" [p4, State Government staff (agriculture sector), Australia]

> "*NSW has the most convoluted plumbing regulation. If you look at plumbing, I think there's around 5 regulators responsible for plumbing in NSW*" [p3, Urban water utilities (national association), Australia]

> *"you've got legislation that is just soooo far out of date that its going to prevent you doing things... most legislation is preventing innovation, preventing adaptability"* [p4, Catchment management Authority, Australia]

In addition to existing regulation restricting decentralisation and reuse systems, several respondents stressed Sydney's current institutional arrangements were a barrier to holistic and sustainable management of our water and sanitation systems.

> *"in Australia we have very poorly structured regulation for the built environment. That's just my personal view… A classic example is stormwater which is managed by totally different set of regulators to water and sewage"* [p2, Urban water utilities (national association), Australia]

> *"there's always going to be a problem until we get both the water flow regulator and the water discharge regulator singing from the one song sheet"* [p3, Catchment management Authority, Australia]

Box 10: Fragmentation of water and sanitation institutional arrangements

"We're splitting up the industry: the sewer providers the drinking water supplies are being split into various agencies, just looking at small parcels, and as soon as you start splitting up a system, you lose the trade-offs across the whole system" [p4, Academic/researcher, Australia]

A weakness of the recently restructured NSW State departments was also offered as a barrier to leadership on new sustainable water and sanitation solutions such as urine diversion and reuse:

> "*They've been destroyed, rebuilt and put together in a haphazard way, so there's very weak leadership coming out of those organisations at the moment because the government has just turned it upside down*" [p6, Academic/researcher, Australia]

> *"DEC doesn't regulate on flow, so you can discharge as much nutrients in the river as you like, as long as it meets their guidelines on discharge. But they don't look at the environment on the river…"* and *"IPART is driven by a view of doing things by submission… if you don't go along* [to public hearings] *and argue that the policy*

> *needs to change, it wont change"* [p4, Catchment management Authority, Australia]

Australian State Government staff member in the agricultural sector, the respondent from the State Government (infrastructure, planning, natural resources) and the Australian respondent from the Catchment management Authority indicated conservatism among the regulators regarding wastewater reuse, potential micro-pollutants and health risks:

> "*they get pretty conservative about it…and they avoid it like the plague*" [p4, State Government staff (agriculture sector), Australia]

> "*in NSW* [we] *would prefer the rainwater tank option because there are fewer risks, its more reliable, so for example with government subsidies - there isn't much enthusiasm for subsidies on greywater diversion. Because it's less controllable and requires a greater commitment to ongoing operational management*" [p5, State Government (infrastructure, planning, natural resources), Australia]

Views and perceptions of specific institutions were also sited as possible limitations to reuse and decentralised systems. The Australian respondent from the Catchment Management Authority also notes a serious disconnect within governments of importance of returning urban nutrients back to farmland:

> *"We just call it 'waste management' in the city...its not culturally understood by governments"* [p4, Catchment management Authority, Australia]

Both the respondent from the State Government (infrastructure, planning, natural resources) and the Australian academic/researcher were of the perspective that those making decisions preferred large centralised systems:

> "*It's simply the engineers who make the calls on this. They use the big plumbing systems, that's their comfort zone… We don't have the right people and we don't have the right institutional incentives to change. In fact we have disincentives*" [p4, Academic/researcher, Australia]

A number of respondents addressed other limitations associated with the current NSW regulation and institutional structure. From an industry perspective, the toilet manufacturer, Australia, who has had extensive experience in commercialisation of toilet systems in Australia, suggested Australian Standards (AS) would need to be changed. According to him this can be a difficult process, as the AS board need to be convinced of the technology, which takes time. Therefore possible time delays need to be considered:

> "*Standards, the Plumbing Code… That's a big one. Time delays – the regulators will want to see the result of a trial of the technology. They will not accept the technology unless they have had experience with it. So you have to factor a field trial in to the time line… this process could take 2-3 years to finalise*" [p8, Toilet manufacturer, Australia].

The respondent from the State Government (infrastructure, planning, natural resources) warned of potential industry backlash if wide uptake was required and thus mandated and made other sanitaryware and/or plumbing fixtures defunct:

> "*Apart from anything else you may put all the other toilets out of business. So there'd be a possible industry backlash"*

Two respondents discussed the extent of user involvement required in management and maintenance of urine diversion as a limiting factor to wider acceptance of the systems:

> "*I'd say if –the system is simple to operate, and will not be too inconvenient for the householder, then I'd say yes I would be interested in installing such a system But if the system requires the householder to check the tank and manually adjust the*

system if required then you're going to say, well hang on I am not interested…." [p2, Toilet manufacturer, Australia].

"*people don't maintain their* [onsite] *systems. They have their sludge tanks that are meant to be dewatered and desludged every X period of years… Doesn't happen, they don't do it*" [p5, Municipal staff, Australia].

Finally, as an overall comment on barriers, the Australian respondent from the national urban water utilities association reflected that the main challenge was in how to successfully implement the strategy:

"*That's where the challenges are I think: not in the technology or proving that the technology is a benefit, its how you roll the technology out into a community*" [p2, Urban water utilities (national association), Australia]

Limitations associated with regulation, institutional structure and institutional perceptions, were the most widely reported type of barrier limiting urine diversion and reuse. Furthermore, it is likely that these barriers will provide the greatest challenge to overcome, particularly in comparison to education or technical barriers.

7.3.2 Health challenges

While two respondents raised possible health-related challenges to the introduction of urine diversion and reuse, this did not feature as a significant challenge as a whole. The Australian toilet manufacturer, Australia compared potential public health challenges to those facing other onsite sanitation systems:

"*I think they* [the authorities] *look at it like that* [onsite systems] *as they have issues with such systems that is mainly related to maintenance…. If you've got a problem in the system and someone dies, then, well that's a major issue for the community and that is what governments and authorities are worried about and rightly so*" [p6, Toilet manufacturer, Australia].

Endocrine disruptors were discussed as a potential health risk:

"*Some of the problems though…is that some of the endocrine disruptor products are more toxic than the primary chemical*" [p12, Municipal staff, Australia]

However the Australian municipal staff member also admits:

"*the people of Sydney are eating stuff from Market gardens now which have had biosolids disposed on them for the past 15-20 years. And no one seems to complain about it. But maybe the knowledge out there isn't that great that that's what they are doing*" [p12, Municipal staff, Australia]

Those that did raise health issues, didn't strongly perceive the risks as high themselves, rather suggested other actors, such as the 'authorities' or 'public' might.

7.3.3 Economic barriers

Two respondent raised a foreseeable economic barrier. According to the Australian municipal staff member, the price of water and fertilizers are so cheap, there is little economic incentive to use other sources. He suggested the same economic barrier that exists with recycled water would occur with urine:

"*the price of water is really cheap. The price of <u>fertilizer</u> is very cheap… they [the irrigators] say no its not worth it to us. I can get it for $1/KL from Sydney Water. The infrastructure is already there I've got nothing else to worry about, why would I?... Nutrients are cheap we've got our own system in place for nutrients already, and we don't need it either*" [p7, Municipal staff, Australia]

On the sensitivity of user preferences to costs, the Australian toilet manufacturer suggests:

> "*If you've got the option of purchasing a really good looking toilet, and if the cost is as much as your urine separating toilet, I believe the average consumer would rather purchase the stylish one, than the one that's a bit strange visually with the collection area detail in the front of the bowl and the associated fittings. So you'd want to make it so that its financially attractive to for the average consumer to purchase a urine separating toilet so a subsidy or some form of government support would be required to establish the concept, particularly in the early market introduction phase.* " [p4, Toilet manufacturer, Australia].

This suggests without the creation of economic or other incentives, neither the purchase of urine diverting toilets nor the use of urine as a fertilizer would be an attractive option based on cost-effectiveness alone.

7.3.4 Attitudes and awareness

Two barriers associated with attitudes and awareness of urine diversion and reuse were raised. While the Australian State Government staff member in the agricultural sector warned of psychological resistance to reusing human waste:

> "*there's a whole pile of practical and psychological barriers you have to work your way through.. even just the 'erk' factor*" [p4, State Government staff (agriculture sector), Australia]

Though the Australian respondent from the national urban water utilities association rationalised that:

> "*we do that with chickens and cows and lots of other things, so there's no reason why we [humans] can't be lumped in there. We're a mammal the same as everyone else, aren't we?"* [p1, Urban water utilities (national association), Australia].

From a marketing perspective, the Australian toilet manufacturer was adamant that Australian males will not sit down to urinate. According to him, there is a saying in the 'Aussie' culture regarding men who sit down to urinate:

> "*Australian men wont sit down…There's a saying 'well he sits down to urinate, that means he's not manly*" [p3, Toilet manufacturer, Australia].

The latter issue may be more straightforward to rectify, particularly if toilet design can be modified to allow men to stand. The first issue is perhaps more deeply engrained in Western culture and thus may take longer to create chain.

7.3.5 Technical, infrastructure and urban planning issues

There is a range of technical and logistical barriers to introducing urine diversion in Sydney/NSW, according to almost all respondents. Most barriers referred to broader infrastructure, urban planning and logistical challenges.

Respondents suggested retrofitting existing buildings with new technology will always be more difficult both physically and economically. However the Australian respondent from the national urban water utilities association suggested it might be necessary to reach a 'meaningful' environmental target:

> "*I think the greatest challenge is what you do in the existing built environment. Because although we're getting told Sydney is growing so fast, when you actually look at the facts and the figures, the existing built environment – that's where all the usage is and the growth areas are only minor compared to the existing areas. So how do you retrofit these systems into an existing environment. That's your main .challenge. As soon as you start to look into putting in new piping systems,*

even if you use trenchless technology…its still very expensive" [p5, Urban water utilities (national association), Australia]

Several respondents suggests logistics, land space and accessibility could be a challenge in dense urban areas:

"*In suburbia where land is scarce, where we're going up now more that we're going out… the concept would seem harder to apply to find somewhere to put the tank, to set up the whole infrastructure of having people coming around and collecting it from the tanks*" [p1, Municipal staff, Australia].

Box 10: Logistical and infrastructure challenges:

"It's a bloody big ask to get across Sydney…Even if people were still excited about it, you still have to put in 4 or 6 million loos" [p7, State Government staff (agriculture sector), Australia]

Minimum flows in the sewerage system was raised by the respondent from the State Government (infrastructure, planning, natural resources) as an increasing problem today due to greywater diversion which could be exacerbated by further diverting urine from blackwater. The more water efficient, and reuse/diverting a household is, the less resultant flow in the sewers and hence increased likelihood of blockages:

"*we've got the same problem with greywater – if households capture all the greywater, then there's much less flushing of the property sewer pipes. So there's anecdotal evidence already from some plumbers that they're going to be a lot more blockages as people have been starting to capture greywater. They are blocking up*" [p4, State Government (infrastructure, planning, natural resources), Australia].

Another technical barrier could be that most houses built on concrete slabs therefore it's not possible to put tank under house, unless design for it prior to building:

"*well tanks under the house really aren't an option because most of the houses are built on concrete slabs…. If you bury the tank below the ground then the urine would need to pumped out for collection consuming energy. Best solution is to use gravity to transport the urine to the household collection area* " [p5, Toilet manufacturer, Australia]

However one respondent, the respondent from the State Government (infrastructure, planning, natural resources) raised an unlikely but possible technical/design issue of corrosion:

"*there might be some problems if you've got copper plumbing, cause you've got uric acid and that can apparently cause corrosion problems*" [p1, State Government (infrastructure, planning, natural resources), Australia]

The Australian toilet manufacturer and the Australian respondent from the Catchment management Authority, Australia noted that the nutrient balance needed to addressed if urban nutrients were to be returned to agriculture via urine diversion:

"*But with all these systems, if you only get 1% of the population installing them then it makes little difference* [to nutrient removal and reuse] *The system must be taken up by a large percentage of households to realise the full potential of the technology nationally."* [p1, Toilet manufacturer, Australia].

"the volume issue is always going to get you…Its just a matter of getting enough of the stuff…making sure enough is coming through. That's a pretty big infrastructure issue I think. And when you look at where Sydney is sitting, its struggling with its infrastructure sort of issues pretty big time at the moment as far as effluent goes. Most of it, 70%, goes whooshing out into the ocean" [p6, State Government staff (agriculture sector), Australia]

> *"there's no synergy between town and country, there's no synergy between the nutrient cycle that is generated by a city moving back into a country environment… Sydney is a massive consumer of natural resources. We haven't found a way of recycling some of those resources back in to the areas that produce them*" [p4, Catchment management Authority, Australia]

The Australian municipal staff member also identified challenges if onsite disposal/reuse of urine was desired due to the land space and lack of absorption capacity of the soils:

> "*the majority of Sydney is sitting in sandstone…so you are irrigating on to sandy sites that cant take up nutrients, that are leached to groundwater*" [p5, Municipal staff, Australia]

The spectrum and degree of responses suggest this is a complex challenge that requires further analysis and planning particularly in relation to urban planning and logistics.

7.3.6 Challenges to the food and agricultural industry

Reusing urine to prevent algal blooms and return nutrients to arable land could present the agricultural industry with challenges. Convincing local farmers to take urine as fertilizer could be a barrier, given their resistance to using effluent – due to cheap price of water and nutrients. The Australian municipal staff member warns it might not be realistic to expect existing farmers to switch over to taking urine in his municipality, given they are resisting effluent:

> "*I guess I'm a bit sceptical about farmers wanting to use it in Hornsby… like I've been flat out selling them recycled water, not even selling it, I'd be giving it away*" [p7, Municipal staff, Australia]

The Australian academic/researcher felt that whilst capturing nutrients and returning them to agriculture was critical, to reduce algal blooms in Hawkesbury Nepean would also require a significant improvement to agricultural practices to prevent nutrient runoff into the catchment's waterways:

> "If that was from urine versus rock phosphate sources, it still may end up in the ricers if there is poor agricultural practices" [p6, Academic/researcher, Australia]

Both points take a different perspective on challenges to the agricultural industry, yet equally recognise any holistic approach, urine diversion and reuse or other, to manage phosphorus, will need cooperation of farmers and agriculture.

7.4 What would need to happen?

This section addresses what would need to happen in Australia to reach a meaningful scenario of urine diversion and reuse, according to respondents. This was seen as a critical question because there is significant gap between introducing this technology on the market to freely compete with other alternatives for the consumer's eye, and actively ensuring enough systems are installed and functioning successfully in the appropriate places to make a meaningful positive impact on Australia's environment (in terms of the urban nutrient and water cycle). Respondents suggested the following were key to reaching a meaningful scenario: a) proven technology and technical improvements; b) demonstration projects; c) political willingness and institutional arrangements; and d) behaviour and user preferences.

7.4.1 Proven technology and technical improvements

From a local government perspective, council would need proof that the technology works, is safe and is likely to result in environmental benefits, then it can simply put the technology into a Development Control Plan (DCP) as a recommendation. The Australian toilet manufacturer also suggested a prerequisite was a proven technology:

“ *The technology must be fool-proof so that it will not have any adverse impact on public health*” [p6, Toilet manufacturer, Australia]

“*probably before council went down that route, they’d want some confidence in what it was and how it worked…If anyone were trying to sell me this concept I would need data on the breakup of nutrients and…pollutants between the two streams [urine and faeces]*” [p1-2, Municipal staff, Australia]

“*like if we could quantify…pulling out 99% of the nutrients that are ending up in the sewage treatment plant and ending up in the river. We might put more resources into developing a whole bureaucracy to manage that system through time*” [p15, Municipal staff, Australia]

In addition to demonstrating the technology could meet its claimed benefits design and technical aspects would need to be improved, such as allowing men to stand to urinate. New urine diverting toilets would also have to pass performance requirements to get a watermark, and, the standards would need to change:

“*The toilet would have to comply with the current standard AS1172, part 1 and part 2, which provide the performance requirements for a toilet. To achieve watermark accreditation the toilet must comply with the performance requirements in the standard. Perhaps for this type of toilet the standards may have to be amended. Also it may be necessary to amend the Plumbing code in Australia*” [p5, Toilet manufacturer, Australia]

7.4.2 Demonstration projects

From the extensive experience with design and commercialisation of mainstream environmentally friendly toilet systems across Australia, the toilet manufacturer. Hence he provided several insights into to motivations and process for conducting field trials of new toilets, such as ensuring the user is satisfied, convincing the government and community at large:

“*I have found that unforeseen problems usually come out in the results of a field trial. This provides vital data to make corrections to the technology prior to commercialisation. If problems occur in a field trial, if not solved then, they will occur when the technology is introduced into the market, but on a much larger uncontrolled scale which could lead to the failure of the system in the eyes of the consumer and governements. Hence the field trial is very critical*” [p3, Toilet manufacturer, Australia]

“*It is essential to trial exactly the technology you’re proposing… We’d develop something that we think is right, then we’d go in and trial it, and find unforeseen consumer problems such as ‘this is not big enough’ or ‘I’m having trouble doing urinating in that area in the bowl’, so work with the actual user to come up with something they are happy with before the technology is finalised*”. [p8, Toilet manufacturer, Australia]

“You need that to convince the government and authorities that it is acceptable for the wider community. They don’t want to force technology onto the community that is not going to be generally accepted” [p3, Toilet manufacturer, Australia]

“Good demonstration projects, so people can see it works” [p6, Urban water utilities (national association), Australia]

The Australian State Government staff member in the agricultural sector and The Australian municipal staff member agreed a trial was appropriate and were quite confident that a demonstration trial would be possible:

"*there's always people who are prepared to give it a go, pilot it, see if it's a goer…There's a reasonable sort of culture of research in the whole NSW universe I think… Otherwise there would never be a new drug developed, would there?*" [p6, State Government staff (agriculture sector), Australia]

"*there's all sorts of ways of promoting these sort of technologies and these ideas and having a trial demo within the Council is a good study like with waterless urinals is a good starting way for giving council some feeling as to whether its worth pushing in through the development process for instance*" [p1, Municipal staff, Australia].

Demonstration trials are typically the logical step between desktop or lab research on a new technology and implementation. Respondents not only affirmed this but suggested there could be sufficient interest by at least several parties in trialling urine diversion and reuse.

7.4.3 Political willingness and institutional arrangements

Most respondents suggested lobbying key political bodies would be critical to lifting urine diversion systems off the ground in Australia. That is, convincing the government of the significant environmental benefits. Some further suggested finding a 'champion' to drive its implementation could be of benefit.

"*you need to put a really good case of the impact of urine diversion systems are going to have on the environment and all other important*" [p2, Toilet manufacturer, Australia]

"*Its only when...you've really got a big time crisis that you're going to get change"* [p6, State Government staff (agriculture sector), Australia]

"*If there are significant proven benefits to the government and the community, then they will support it, possibly provide subsidies and incentives for for the consumer to install the technology. If there is not government support for the technology then it would be an issue and then it it would have to rely on environmental enthusiasts to promote the technology keeping it out of the mainstream market*" [p7, Toilet manufacturer, Australia]

"*there are many* [State] *departments managing the water cycle so you'd have to convince several. You could find a champion minister to take it to the others*" [p6, State Government (infrastructure, planning, natural resources), Australia]

"*Its hard to see how it would get started without some sort of mega enthusiasm at some level. Either government or a private industry*" [p3, State Government staff (agriculture sector), Australia]

"*Firstly the government would have to adopt that as policy, and then to get compliance with the policy you can either educate, regulate or give incentives… Now for the government to regulate there would have to be a really clear benefit*" [p5, State Government (infrastructure, planning, natural resources), Australia]

"*It would require the Commonwealth to take this up. They would have to see that there is a benefit in doing this. And I guess if the Commonwealth continue to see the nonsense that's going on in Sydney they might be starting to reach a view that urban water is something that needs to be managed at a Federal level rather than at a State level, and they may decide to do that now. They'd have a real fight on their hands to take away the responsibility from the States and Territories but sometimes if the bucket of money is big enough and they see that the benefit is there they may be more willing to look at this*" [p3, Urban water utilities (national association), Australia]

The Australian municipal staff member also stressed that specific and appropriate institutional arrangements would need to be put in place:

> "*it NEEDS some sort of bureaucracy, unfortunately, to manage the system through time, to say where it goes and what the urine is used for*" [p6, Municipal staff, Australia]

The Australian respondent from the national urban water utilities association agrees:

> "*at the end of the day if your going to make those things work they just don't happen by themselves unfortunately. So you've got to bring a whole lot of people on side, unfortunately…at the end of the day I think having good regulation is a good support structure to these changes*" [p1, Urban water utilities (national association), Australia]

Finally, the respondent from the State Government (infrastructure, planning, natural resources) noted a redistribution of costs would need to occur:

> "*there's that issue that is true of all management. What is the user share of all costs, and what's the public goods share. So you'd have to do some serious economic analysis before changing policies or institutional arrangements*" [p67, State Government (infrastructure, planning, natural resources), Australia][39]

Convincing the government of urine diversion and reuse benefits to society is therefore considered a key step to substantial introduction of the system.

7.4.4 Behaviour and user preferences

Some respondents felt user preferences were also important considerations to ensure effective uptake. According to the toilet manufacturer, the technology should not differ too much otherwise you will not get uptake/acceptance:

> "*whatever you do it has to be accepted by users. The dual flush toilet which is now the norm in Australia was successful because it was easy to use for everybody, effective and allowed the user to make a simple decision to select between two push button options to conserve water*" [p1, Toilet manufacturer, Australia].

> "*I think people would like to see it really works in a community…young families, with teenage children, with young children, adult children…so its going to work for the whole mix of the population*" [p6, Urban water utilities (national association), Australia]

The Australian toilet manufacturer suggested a "consumer survey" should be undertaken to understand community preferences and views. While the respondent from the State Government (infrastructure, planning, natural resources) agreed, he also noted there is no such thing as a homogenous community and a single view:

> "*there's no single community. The community is wide. You know you get some people over here who will go and do it tomorrow and will pay $10 000, and some others who won't even do it if they're made to*" [p5, State Government (infrastructure, planning, natural resources), Australia]

Regarding motivation levels, the Australian respondent from the national urban water utilities association suggested:

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[39] This point is also an economic issue.

> "*if you can make some simple statements to show people how by doing this you can improve an environment so that people are supportive of the outcomes then people will see that there is a tangible benefit in doing it*" [p1, Urban water utilities (national association), Australia]

The Australian academic/researcher demonstrates how user preferences are indeed not static, by suggesting he and others who are in the habit of using urine diverting toilets may in fact find non-urine-diverting toilets strange. Understanding and influencing user behaviour and preferences may be useful for more effective uptake as well as practising good ethics by engaging the community in decisions that effect them.

Box 12: User preferences:

"I'm totally sold on it – I feel upset when I don't use one. A bit like the kids in those Ecovillages we interviewed…they wouldn't use the toilets at school because they weren't urine diverting toilets" [p8, Academic/researcher, Australia]

7.5 Opportunities for Australia

Identifying opportunities and how they might be harnessed is equally as important as identifying barriers and what would need to change to overcome such barriers. Respondents identified opportunities ranging from tapping into community willingness, to synergies with other waste streams.

7.5.1 Regulatory frameworks and institutional arrangements

While there were certainly numerous regulatory and institutional barriers, respondents also offered several specific opportunities. Such as the upcoming national and international guidelines, such as the risk-based ANZECC guidelines for wastewater treatment and reuse and WHO guidelines for reuse of human excreta. Both guidelines are risk-based rather than prescriptive, that is they require demonstration of barriers in place (to protect the environment and public health) and performance of barriers, rather than specifying a list of acceptable technologies. Urine diversion and reuse systems could therefore be feasible under these national guidelines if they can demonstrate appropriate barriers:

> "*The beauty of the new guidelines that we're pushing through across the country is…that it's a risk based approach. So if you can demonstrate that you've got enough barriers and the performance of those barriers, then you can do what you like*" [p5, Academic/researcher, Australia]

> "*Sydney has suddenly discovered its gotta get its' head around recycling. Its going to start moving that way, either immediately or the next generation of the crisis, which might be 10-15years down the road*" [p1, State Government staff (agriculture sector), Australia]

Several respondents also mentioned opportunities to integrate urine diversion and reuse systems into existing or future policy tools such as BASIX, which requires all new residential developments to meet a 40% reduction on household water use. The web-based tool allows developers to test what water savings they would achieve with different technical options.

> "*you could possibly make it mandatory down the track, but that would take a little while for people to get used to. The first thing I'd recommend is that you put it in our DCP so that people get used to it*" [p14, Municipal staff, Australia]

> "*a requirement in new developments or get it on to the score sheet, like a BASIX score sheet….I think that's almost a de-facto way of making it mandatory, and I think then it will compete with other solutions, and if it's a cost-effective way of doing it and people are willing to accept that, then it will be chosen*" [p7, Urban water utilities (national association), Australia]

The Australian municipal staff member suggested opportunities for new actors and system arrangements:

> "*If you do something to the P in the urine then it might make it a better product for the farmers to use, and might put in a step that makes it more logistically feasible than farmers interacting with thousands of people in the city, trying to come and collect their urine. So a single industry that collects urine turns it into fertiliser then on sells it, might be a more practical way to go*" [p10, Municipal staff, Australia]

The opportunities mentioned here focus more on ensuring there are no barriers to the introduction of urine diversion and reuse (such as prohibitive regulation), rather than proactively seeking opportune situations in which to implement urine diversion and reuse. However perhaps ensuring there are no regulatory or institutional barriers is more important than seeking opportunities to introduce urine diversion and reuse.

7.5.2 Community attitudes and perceptions

Respondents were asked about the perceived importance of nutrient and recycling in society today, compared to other water issues like water scarcity. Many were still confident community interest in nutrient and recycling issues was still prevalent in Australia:

> "*I wouldn't say the awareness or the interest has reduced I'd say if anything it has increased…a lot of education programs, and lost of committees, P committees, and there's a little Beaver or Platypus which was the mascot for some of those*" [p2, State Government (infrastructure, planning, natural resources), Australia]

> "*certainly while more people are focusing on the drought and certainly while there is a drought all of this is much easier, to get some attention to it. I mean water is in the paper every day. Who cared about a dam before*" [p7, State Government (infrastructure, planning, natural resources), Australia]

> *"you only have to listen to the talk back radio...people are ringing in saying we would drink recycled water… I think people want to save water. I think they'd want to save nutrients if they knew there was a problem"* [p4, Catchment management Authority, Australia]

The Australian respondent from the national urban water utilities association further suggested Australian culture should in some ways be conditioned or primed to reuse of excreta:

> "*If you can sell that message to a 7 year old child as well as a 70 year old person, everyone can then understand this cycle, and of course many people who have travelled widely in Asia understand that the Asians have been doing this for years. So I think Australians understand that human waste (biosolids and urine) can be used to grow things provided it's managed properly*" [p6, Urban water utilities (national association), Australia]

The importance of this issue in society – both at the community and political level – could effect how significant urine diversion and reuse is perceived and prioritised. Most respondents were confident that water, recycling and nutrients were all generally topical in Australia and thus provided a background awareness that could prove positive useful for the introduction or acceptance of urine diversion and reuse concept.

7.5.3 Technical, logistical and urban planning opportunities

Again, while respondents had offered a host of technical barriers, they were also forthcoming with possible opportunities. These included technical issues at the toilet interface, new developments and reuse options in existing areas. Several respondents suggested opportunities of collecting urine via waterless urinals – either in the domestic situation or public places:

"*In Australia, to get the technology accepted, you might have to collect urine from a waterless urinal in a household situation for men, as opposed to totally changing the way they use the toilet.*" [p4, Toilet manufacturer, Australia]

"*places where there is great synergies…where we have urinals. You already have diversion. The next step is to move towards waterless urinals. Then you've got that captured*" [p1, Academic/researcher, Australia]

However the Australian academic/researcher also suggested men could still stand with some current toilet models:

"*I actually find the toilet more convenient than a standard toilet. All that stuff about guys having to sit down to use a urine diverting toilet is rubbish…You just stand side on…aiming is no problem and splashing is no problem. Where as if you try and aim straight down of course it doesn't work, so you stand to the side*" [p8, Academic/researcher, Australia]

The Australian respondent from the national urban water utilities association suggested that technically odour and amenity are probably the key issues and offered possibilities for controlling them:

"*the main issue is that there's no odour or affect on amenity….. back into the air space…. back into the bathroom of the toilet from whence it came. And you could use a reflux valve where it goes into the holding tank*" [p3, Urban water utilities (national association), Australia]

In the context of urban planning, several respondents did not hesitate to recommend starting with new developments for cost-effectiveness and feasibility:

"*there's a whole pile of decent sized housing units springing up round in the middle parts of Sydney…and if you start thinking about…those sort of areas…then you've probably got a) the volume, b) got the storage area c) you've got a simplified delivery system*" [p2, State Government staff (agriculture sector), Australia

"*at least initially the focus on where…the economics are going to be very much in your favour, and look at the redevelopment of Sydney, look at all the new apartments*" [p5, Urban water utilities (national association), Australia].

"*you'd want to do it in a new development area… The advantages are, that near the new release areas you're going to have still a lot of farmland on the floodplain and within this big area they've reserved for open space and the environment, between the two big release areas, so they seem to be the opportunities… All those are big developments that could take some innovation to try and solve the problem of nutrient demand and water demand*" [Catchment management Authority, Australia]

The Australian municipal staff member also suggested areas within Sydney Water's Priority Sewage Program[40] (for currently unsewered areas in NSW under SWCs area of responsibility) could be an opportune scheme to trial urine diversion systems:

"*They come in and their engineers say how can we address this problem – its unsewered, its polluting the environment, what can we do? The whole urine diversion thing can happen at that stage easily because you're dealing with whole communities*" [p8, Municipal staff, Australia]

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[40] See for more information on Sydney Water's Priority Sewage Program: http://www.sydneywater.com.au/ProjectsandTendering/MajorProjects/PrioritySewerageProgram/

Some respondents also thought about opportunities at the reuse end of the system, in addition to collection. They suggested the main use of the collected urine could be on green spaces around Sydney:

> "*Every time Australia Stadium they have a big event all the guys drinking too much urinate so much release so much ammonia that it actually upsets the biological treatment plants there…So they would prefer to get rid of it in some other way. So what better way than simply to store it and use it for all those green fields around the park. So that to me is a very simple application, very little transport, just a bit of storage needed*" [p2, Academic/researcher, Australia]

> "*We've got a lot of golf courses around Sydney, that could handle a fair bit of urine, and local communities could support that"* [p4, Academic/researcher, Australia]

> "*in established areas the main use would be for irrigating parks and playing fields for councils*" [p3, State Government (infrastructure, planning, natural resources), Australia]

The suggestions of harnessing waterless urinals and new developments for collection opportunities were supported by 2-3 respondents, as was the idea of reuse of urine on local green fields. This latter suggestion however, is more in line with options for disposal to divert nutrients from reaching waterways, rather than the objective of returning nutrients to arable land.

7.5.4 System arrangements

This study did not directly intend to explore the detail of possible system arrangements in Australia, however many respondents offered valuable ideas of how a system might be configured in and around Sydney. There are numerous ways a urine diversion and reuse system could be configured. Ranging from individual collection systems and reuse onsite, to collection via truck pumpout, to a distribution network to 'end of street' or some local treatment system. Respondents felt the system arrangements needn't be limited to those in Sweden. Rather, they suggested several other possibilities.

In terms of collection, one respondent contemplated:

> "*I believe that a similar system to a rainwater tank could be adopted to store household urine.. It may be possible to install the tank above the ground in an area around the house or under the house if practical*" [p6, Toilet manufacturer, Australia]

Several respondents raised the possibility of a distributed pipe network on neighbourhood scale (eg. pipes to end of street where collection tank can more easily access), to transport the urine to a more accessible central point, rather than per household collection via trucks. Most were sceptical about trucks pumping individual household's urine tanks in urban areas.

> "*A fitting could be provided in the street for truck connection and collection. In a subdivision it may be possible to have storage tanks for groups of households operated by the council. Then that way, the householder doesn't worry about collection issues near the house*" [p6, Toilet manufacturer, Australia]

> *"they might do it through a pipe system as opposed to individual tanks and pump out. I'm a bit against pump out. We've got enough trucks and noise on the streets… We for some reason put up with garbage trucks stinking and making a hell of a noise over the mornings. We just take it for granted that's the only way to do it. Well its not really"* [p10, Academic/researcher, Australia]

> "*there's no reason why you couldn't in theory put a smaller bore pipe in existing sewers to take urine to a more centralised place for processing*. [p1, Academic/researcher, Australia]

> *"I'm wondering if there is any potential for your urine diversion scheme to be a regional reticulated scheme, rather than a per household system"* [p2, Municipal staff, Australia]

> *"the brownfield by suburb is possible…maybe you start off with the tankers and you evolve into when you've got enough households you whack down the old sewer as specially made for urine"* [p9, Academic/researcher, Australia]

If a distribution network is to be considered in more detail, there also still a trade-off to be addressed between gravity and pressure systems. Whilst gravity systems don't require the same pumping and energy costs, they may require deeper trenches for pipes. Pressure systems require increased cost due to pumping; however enable shallower pipes and the use of small diameter watertight pipes as the Australian academic/researcher explores.

> "*You'd end up having to have access points in through the sewers to get to the urinal pipe. That's why I quite like the idea of having a pressure or vacuum urine pipe to reduce potential – blocking occurs because of sedimentation and lack of velocity flow, but if you had a vacuum sewer you could maintain pulsing and surging to unblock it, so its much less likely to block… But that then starts costing more in terms of having electronics*" [p10, Academic/researcher, Australia]

While piping urine (whether gravity or pressure) to a neighbourhood level collection point in high density urban areas may provide cost and convenience savings in terms of transportation costs and access to each household, some experts caution against increasing piping due to increase maintenance requirements in addition to increasing potential for inflow from cracked pipes (Jönsson, pers comm).

Most respondents were however more amenable to thinking about community scale systems over onsite systems for a dense urban area like greater Sydney.

7.5.5 Synergies with other waste streams

A few respondents also proposed that urine could be managed in the context of other household organic waste streams. The Australian academic/researcher stressed several times that urine diversion should be considered in context of other household waste streams (depending on objectives of diverting the urine). It might be more cost-effective to transport organic solid waste, faces, urine and greywater together to arable land:

> "*I think we need to look at the best/most appropriate water service provision for a particular community, maybe urine diversion or maybe blackwater/urine/food back to agriculture, might be a better way of linking nutrients back to where they've come from…but it would certainly be one of the options I would look at*" [p3, Academic/researcher, Australia]

> "*if you're going to set up such a system…there's no reason they couldn't have both urine and greywater*" [p3, State Government (infrastructure, planning, natural resources), Australia]

> "*why divert it at all. It depends I guess where your organic residues are going to go. If you have a vacuum flush toilet with 1/2L per flush, then keeping faecal, food and urine together (pasteurise it by thermophilic type composting as they do in Norway) and drill it in to the ground for a soil and fertiliser, you'd probably get better cost-effectiveness. So in regions like Western Sydney, where you are close to agricultural activities, you could certainly use it in those areas without having to divert it in the first place…which captures rather than 50% you'd capture close to 90% of P <u>and</u> N <u>and</u> K*" [p1, Academic/researcher, Australia]

Finally the Australian academic/researcher visioned a scenario of integrated wastewater pressure sewers that could be another option for recirculating nutrient back to agriculture:

"*If we go to another paradigm for example, that we're working with pressure sewers, and every household has a vacuum flush type toilet system, it pokes into a pressure sewer which is only a small pipe, so its not a big sewer that leaks everywhere, so we don't have the environmental cost every time. It goes to a smaller decentralised plant where it gets processed and then reuse in that community or nearby in agriculture*" [p4, Academic/researcher, Australia]

Of those respondents suggesting urine could be considered in the same framework as other parts of the household waste stream, some were presenting views based on speculation/contemplation where as others were reporting views based in part on prior research and/or experience.

7.6 Analysis: comparison to the literature

Unlike the Swedish context, there is little or no available Australian literature to compare with stakeholder responses. Hence, it was not appropriate to provide in-depth analysis in this section. Rather, three known knowledge sets are identified and compared and contrasted with stakeholder responses. The Australian literature that is available, includes:

- a feasibility study of dry urine diverting toilets in a multi-residential dwelling in a high-density urban area of Melbourne (GHD, 2002);
- an academic paper on institutional change and sanitation systems (not specifically related to urine diverting systems, however still relevant) (Livingston et al, 2004); and
- anecdotal information from an informal trial of applying urine diverting systems to existing waterless toilets in an environmental education park in Melbourne (pers. Comm. Keith 22nd October, 2003).

Findings from the first source suggested urine-diverting dry toilets are both economically feasible in an urban apartment building and is likely to be acceptable to owners. The greatest cost was associated with transport of the urine offsite. The second source suggested while urine diversion and reuse could potentially be a cost effective sanitation system however might be rejected due to its peripheral nature to the water industry, and lack of any obvious organisational home. The third source found that diverting urine from public composting toilets with very high throughput was beneficial in terms of reducing odour and improving the composting process. The trial did find however that users, particularly school children did not fully understand how to use the system and thus there was a high level of cross-contamination of faeces in the urine bowl.

While these findings do not contradict issues raised by respondents during the interviews, most findings were not addressed, despite one respondent being an author on the second literature source. The significant cost of transporting urine was certainly alluded to by several stakeholders.

8 Assessing the costs and benefits

This section identifies and discusses the costs and benefits of urine diversion and reuse. A more detailed quantitative analysis was not considered worthwhile or meaningful due to a lack of data availability, reliability and expected data sensitivity in such a cost benefit analysis. Rather, a qualitative discussion of costs and benefits is perhaps more meaningful and is thus provided below. The far right columns in table 2 indicate whether each cost or benefit has an economic, environmental or social component. Some examples of cost-benefit calculations are provided to demonstrate their potential order of magnitude.

Table 2 discusses potential benefits of urine separation and reuse. In most cases, the size of the potential benefit will vary depending on region, logistics, whether the benefit can be quantified in monetary terms or other, the importance or perceived importance of the issue, short-term or longer-term vision.

Table 2: Potential benefits of urine diversion and reuse and an indication of whether these are economic, environmental, and/or social benefits.

Benefits	Discussion	Economic	Environmental	Social[41]
Reduce mining	Mining any virgin material is typically energy and resource intensive operation due to earthmoving operations, transportation, waste management and the conversion efficiency. Therefore reducing demand on mined phosphate rock by capturing phosphorus in urine is beneficial. Further, phosphorus is an essential non-renewable resource which is likely to run out in the coming centuries. Some sources suggest known economic reserves are likely to run out in the next 50-100 years (Cordell, 2005a). Section 2.2 discusses the issue of phosphorus as an essential, non-renewable and irreplaceable resource further.	(✓)	✓	✓

[41] Benefits to public health are categorised as 'social' for the purpose of this table.

Benefits	Discussion	Economic	Environmental	Social[41]
Reduce need for purchasing mineral fertilizer	If urine is used as a source of phosphorus, this will reduce the need to purchase chemical fertilizers. Maurer et al (2003) found recovery and reuse of nutrients from source-separated urine was more energy efficient than production from virgin sources. This benefit may be currently small in monetary terms (due to the low cost of fertilizers in Australia, Sweden and other developed countries). However it is significant in other parts of the world, where the price of fertilizer is much higher. For example, in West Africa, where the high cost of fertilizer coupled with phosphorus deficient soils means the economic value of urine as a replacement for mineral fertilizer is significant, hence creating a market for urine as a cheap fertilizer (Elizabeth Kvarnstrom, pers comm. 28/8/05). As the price of phosphorus rises in the future due to increased extraction and refinement costs, urine may become cost-competitive in developed countries.	✓		✓
Reduce water demand	Urine diverting toilets are designed to use less water than most flush toilets[42] (WRS Uppsala, 2001). If used correctly, they can significantly reduce toilet water demand. The paragraphs following table 3 discuss findings from 2 studies in Sweden of the water conservation potential of urine diverting toilets. On a macro scale, measures that reduce water demand can have significant economic benefits by delaying the need for captial worls like building new water supplies. The cost-effectiveness of deferral of large-scale supply systems with high construction costs has been demonstrated in numerous resource use efficiency projects (White, 2001; Fane et al, 2004; Louw D & Kassier, 2002).	✓	✓	
Reduce water pollution	Urine is the largest single contributor of nutrients to household wastewater (see Section 2.4). Discharges of nutrient-rich sewage effluent (in additon to agricultural runoff) is a key contributor eutrophication and toxic algal blooms of receiving water bodies (Naturvardsverket, 2002). Therefore by diverting urine away from the wastewater stream, nutrient loads on receiving water bodies can potentially be significantly reduced. Reducing nutrient pollution not only benefits river health, yet also reduces potential detrimental affects on drinking water supplies, the fishing industry and the tourism and recreation industry (see section 2.1).	✓	✓	✓
Reduce constraints on wastewater systems	Diverting urine from the mixed wastewater stream can reduce contraints on wastewater treatment system by two ways: 1. reducing wastewater generation (due to lower flush volumes or urine diverting toilets) and therefore reducing frequency and/or severity of overflows or need to increase capacity of infrastructure; 2. Reducing need for expensive end of pipe nutrient removal at the wastewater treatment plant, such as biological nutrient removal (BNR). (Tangsubkul et al, 2005). Maurer et al (2003) suggest source separating urine is more efficient from an energy perspective than recovery from wastewater. However the energy input required for urine collection infrastructure in individual houses should be closely considered.	✓	✓	

[42] In Australia, the most water efficient toilets currently on the market are the 4L/3L and 6L/3L dual flush toilet. Urine diverting toilets are designed to use no or very little water after urination (see section WRS Uppsala, 2001 for explicit details of flush volumes).

Benefits	Discussion	Economic	Environmental	Social[41]
Contribute to global food security	By closing the loop on phosphorus: an essential, non-renewable, irreplaceable ingredient for food production (Esrey et al, 2001). This is a longer-term global benefit, however possibly the most serious benefit of diverting and reusing urine in the long term.		✓	✓
Improve function of dry composting toilets	Diverting urine from faeces helps the composting process by removing excess moisture from the compost material. Further, the volume and weight will be reduced thus filling the collection system slower (Schönning & Stenström, 2004).	✓		
Reduce odour in dry composting toilets	Diverting urine from faeces also helps reduce potential odour, as most odour in composting toilets comes from the reaction between urea in urine with faecal matter (Schönning & Stenström, 2004; Drangert, 1998). Diverting urine is particularly beneficial in this respect in toilets with high usage.			✓
Facilitating appropriate treatment of micropollutants	Micro-pollutants in household wastewater such as endocrine disruptors and pharmaceutical residues are predominantly found in urine. These micro-pollutants currently pass through wastewater treatment systems largely untreated and discharged to receiving water bodies. Therefore by diverting urine from other wastewater streams, they can be more easily managed. Further, preliminary research suggests applying micro-pollutant containing urine to land/soil rather than discharging to water improves their breakdown and treatment (NOVAQUATIS, 2003; Jönsson, 2005; Martina Hammer, pers comm).		✓	✓
Facilitating reuse at household level	A benefit of onsite sanitation treatment is that they allow the option of onsite reuse the wastewater fractions. If urine is diverted it can be used directly onsite, if the land space and soil capacity permit.		✓	
Contributing to livelihood security	Urine (and other wastewater fractions) are constant reliable sources of plant nutrients (and irrigation water). Therefore their safe reuse can reduce households and communities dependence on external sources. The greatest livelihood benefit is likely to be in poorer areas where the price impact of artificial fertilizers and clean water is more apparent (Esrey, et al, 2001; World Bank, 2005).			✓

The benefits noted from the literature and stakeholder views can be assessed in absolute terms, or with particular reference to conventional wastewater management. For example, reusing urine to grow crops will reduce the demand on mineral fertilizer, where as other benefits, such as prevention of nutrient emissions to water bodies are more appropriately discussed in comparison to existing wastewater treatment and management.

Similarly, the benefit of reducing nutrient emissions to water bodies could be compared to other options

There are some potential costs associated with urine-separating toilets that should be addressed. These are described in Table 3. Other drawbacks of urine diversion are identified follow table 3.

Table 3: Potential costs of urine diversion and reuse and an indication of whether these are economic, environmental, and/or social costs.

Costs	Discussion	Economic	Environmental	Social[43]
Transport costs	Significant transport costs may be associated with collection of stored urine if not reused at household level. This is possibly the largest monetary cost of urine diversion and reuse. In Sweden, urine is typically transported via truck either directly to agriculture or to an intermediate storage tank prior to use. According to a Swedish study, urine can be transported up to 220km by truck from source to farmland whilst remaining less energy intensive than conventional treatment processes (Johansson et al, 2000). Similarly, it can be trucked 100km while remaining less energy intensive than producing and transporting fertilizers from mined phosphate rock (Johansson, et al, 2000). Other transport options could consider piping urine from households to a more neighbourhood or central collection point. This may be more appropriate in terms of access in high-density urban areas. Costs for different transport options, including capital and operating, environmental and social costs should be considered for each situation. Environmental costs of transport are most obviously energy related, while social costs might include the intrusion of more service trucks in residential neighbourhoods (and possible related noise and odour).	✓	✓	✓
Retrofitting costs	If existing dwellings are to be retrofitted with urine diversion systems significant capital costs could be involved. Replacing toilets, installing tanks and laying sub-surface pipes can be an expensive process. Therefore it may be more beneficial to consider installing urine diversion system in new dwellings.	✓	✓	✓
Maintenance	Both scheduled and repair maintenance will be required. For example, if pipe blockages occur due to build up of urea crystals in pipes if not managed appropriately. Some preventative maintenance of the toilets is typically required by householders. Whilst this may not be a direct cost to the system, increased user involvement (in terms of time and inconvenience) should be included in analysis of costs and benefits of urine diversion.	✓		✓
Additional infrastructure	Diverting and reusing urine results in at least two sets of physical infrastructure for urine, other wastewater. Careful planning should ensure the benefits of urine diversion are not outweighed by the costs of separate infrastructure.	✓	✓	
Possible reduce performance of sewerage system	It is possible that urine diversion, along with other sustainable water and sanitation solutions that generate less wastewater could result in perverse outcomes such as reducing flow in gravity sewers to below minimum required.	✓		
Institutional and regulatory change	Urine diversion and reuse involves cooperation of typically separate service providers, including sanitation, water, health, agriculture and food. This means roles and responsibilities will need to be clearly defined. Regulation and standards may need to be amended.			✓

[43] Institutional change is categorised as a 'social' cost for the purpose of this table.

Costs	Discussion	Economic	Environmental	Social[43]
Social change	In typically poo-phobic societies such as many Western cities (Drangert, 1998), a concerted effort to engage the community required for acceptance of using urine separating toilets and consuming food fertilised by urine;			✓
Investment in training and education	Any new sanitation system including urine diversion and reuse systems, will require timely investment training, education and communication for and between: users, operators, plumbers, regulators, agriculture industry, food industry.	✓		✓

Other possible drawbacks or limitations of urine diversion and reuse that should be considered even though they are not strictly costs, include:

- **Risk of cross-contamination** to urine collection from faeces and other body fluids (eg from. children, diarrhoea, menstrual blood, urine-infection);
- **Microbial and chemical risks** if persistent pathogens or micro-pollutants exist in urine at time of reuse. Pathogenic risks have been dealt with in several key reports, namely (Schönning and Stenström, 2004); and
- **Changes to male toilet behaviour** if men are required to sit down to urinate.

A simple quantification of costs, nutrient reduction and water conservation is provided below. The examples were chosen due to their significance to the Hawkesbury-Nepean catchment and data availability. The purpose is to indicate the potential scale of benefits or costs of urine diversion in the Hawkesbury Nepean Catchment.

Reducing nutrient load on receiving water bodies is likely to be one of the greatest short-term benefits of urine diversion and reuse to Australia (Tangsubkul et al, 2005). For a catchment like the Hawkesbury-Nepean which suffers from frequent algal blooms, a scenario of some meaningful reduction in nutrients could potentially be achieved through the installation of urine diverting toilets in areas whose municipal effluent is discharged into the Hawkesbury Nepean rivers and estuaries. For example, to reduce the phosphorus load by 64 tonnes/year might require the installation of around 170 500 household urine diverting toilets in the projected 300 000 new residential dwellings in the Hawkesbury-Nepean Catchment (NLWRA (2002)[44]. Or, from a different angle, if all 4.2 million Sydney residents installed urine-diverting toilets in their homes, around 901 Tonnes/year of phosphorus could potentially be diverted from entering receiving water bodies. Further, this equivalent amount of nutrients is then available as a fertilizer for arable land. Some Swedish studies indicate nutrient value in urine as a fertilizer can have around 70-100% fertilizer effect as mineral fertilizers (Jönsson 2001, Steinfeld, 2004).

This mass could be compared to that currently removed from the Sewage Treatment Plantss through biological nutrient removal or other processes. In one of the Hawkesbury-Nepean's municipalities, Hornsby Shire, an environmental levy on ratepayers provides $2 million/year to fund algal management, including the removal of nutrients from key hot spots in the Hawkesbury-Nepean catchment. This cost could be compared to the cost of installing enough urine diverting toilets to remove the same amount of nutrients. Of course, there

[44] Based on assumptions provided in Appendix D.

would be other costs than just toilet installation costs that should be considered, as identified in table 3.

According to the Department of Environment and Conservation (formally NSW EPA), a substantial portion of the nutrient load on inland rivers is now also known to originate from non-point sources such as runoff from rural and urban lands, rather than point sources like sewage treatment plants and industrial processes (NSW EPA, 1995). Although non-point sources are much more complex to reduce (HELCOM, 2000), both point and non-point sources need to be addressed to improve health of NSW waterways like the Hawkesbury-Nepean. Urine diversion and reuse only addresses point sources.

Installation and use of urine diverting toilets can also result in substantial water savings, however the actual savings can be highly dependent on user motivation levels (Jönsson (2001). In a Swedish study, Jönsson found actual savings were 80% of theoretical (calculated) savings in households that were both educated appropriately in how to use the systems and also motivated in why the systems were being used. In households that were not motivated and/or educated in how to use the systems effectively, only 12% of theoretical savings were achieved (Håkan Jönsson, pers comm. 31/8/05).

For a city like Sydney, if only 20% of households had dual-flush urine diverting toilets, this could in theory save 5.3 GL[45] of water a year[46]. Given the current challenge of securing Sydney's water supply, this could be a substantial benefit. These savings compare to the 10 GL projected savings in Sydney since 6/3L dual flush toilets[47] were mandated in Australia in 1992/3. However urine-diverting toilets would have the added benefit of nutrient capture in addition to water conservation.

A more detailed and robust investigation of costs and benefits of urine diversion would allow a more solid comparison of urine diversion and reuse with other water and nutrient management solutions for a given situation. This suggestion is crystallized in recommendation 3 in section 10.2.

[45] one GL = 1000 000 000 L
[46] Based on assumptions provided in Appendix E.
[47] from 1991 until 2005 (Turner et al, 2005; ISF, 1998).

VOLUME III:
CONCLUSIONS & RECOMMENDATIONS

How do we get from where we are now, to where we want to go?

Volume 3 synthesizes and summarises findings from the various analyses undertaken in this study, and provides recommendations targeted to the Australian context.

The following conclusions and recommendations were drawn from several sources: international literature review, Swedish stakeholder analysis, Australian stakeholder analysis, other personal communications not officially part of the stakeholder interviews and an assessment of costs and benefits.

9 Conclusions

The conclusions are divided into the following sections:

1. Sub-analysis conclusions
    a. Stakeholder interviews and analysis
    b. Literature review
    c. Quantitative analysis
    d. Swedish versus Australian context
2. Key overall findings of this study

The first four sections reflect on specific components of this study, while the fifth section provides conclusions from the study in its entirety.

9.1 Sub-analysis conclusions

This section provides reflective discussion on individual components of the analysis.

9.1.1 Discussion: stakeholder interviews and analysis

The analysis of Swedish stakeholder responses in comparison to formal and informal literature found that there was little conflicting information between stakeholder responses and the literature. However this analysis still validated the use of stakeholder interviews as an appropriate data collection technique because new information emerged from the stakeholder responses that were not captured in the literature, possibly due to the 'informal' nature of stakeholder interviews. For example, the discussion on key drivers for urine diversion and reuse yielded, among other responses, that a 'change agent' in a position of power was a key element to success. Several respondents suggested this informal institutional aspect was quite key to their success with implementing urine diversion systems, however it was not mentioned in the literature.

The interview questions in Sweden and Australia had slightly different foci, primarily because the Swedish interviews were evaluating an existing system, whereas the Australian interviews were envisioning the potential of such a system. However, there was some overlap. Some questions were the same, and some responses fell under the same themes, thus enabling some comparison between the Swedish and Australian interviews. The primary intention of the Swedish interviews was to draw lessons for guiding Australia on issues to consider when introducing urine diversion and reuse systems. Both sets of interviews involved a discussion on who is and who should be responsible for managing and financing urine diversion systems. With the advantage of hindsight, most Swedish respondents suggested that: householders should be responsible to some degree; municipalities as initiators and coordinators were essential; and that the national government should play a stronger leadership role. A few Australian respondents initially suggested it should be up to consumer preferences to select and install the toilets, while most also suggested the government should play a role in at least subsidising urine separation systems.

The potential benefits of urine diversion and reuse suggested by Australian respondents were almost identical to those discussed by respondents in Sweden where urine diversion and reuse systems have been installed. However it is likely that the Australian stakeholders' knowledge of these systems either came through Scandinavian sources directly or the introduction letter sent to potential stakeholder interviewees (see Appendix A for letter).

The purpose of the Swedish interviews was to document the Swedish experience of urine diversion and reuse to-date so that Australians could learn from this experience. Discussion of barriers to urine diversion and reuse were sometimes followed by suggestions for overcoming them, while other barriers appeared to have no obvious solution. For example, numerous technical barriers were raised, though stakeholders were fairly confident they could be (or are being) overcome when the need arose. On the contrary, the identified barrier of a changed political climate, currently moving away from the dominant environmental agenda, was noted as a barrier, with little recommendation offered for how this could be overcome.

The purpose of the Australian interviews was to document views on urine diversion and reuse from a cross-section of relevant stakeholders in Australia. As a whole, the Australian stakeholders interviewed in this study were surprisingly amenable to considering a demonstration trial of urine diversion and reuse in Sydney or surrounding areas, even when most had not heard of urine diversion and reuse prior to this study. Convincing stakeholders to participate in a trial was not an intention of the Australian interviews, however, it can be viewed as a sign of enthusiasm towards the possibilities of implementing urine diversion and reuse systems in the Sydney region.

Another observation from the Australian interviews was the tendency of stakeholders to believe that the introduction of urine diverting systems into Australia wouldn't be too hard and that uptake could be simply left to consumer preferences. Given that 'natural'[48] uptake rates of other source-separating or ecological toilet systems like composting toilets are extremely low when presented as percentage of the overall population, it was assumed prior to this study that the 'natural' uptake rates of urine diverting toilets in Australia would be too insignificant to impact positively on the environment (such as significantly reducing nutrient loads to waterways or conserving water). Therefore stakeholders were probed further to ask whether they though this alone would result in significant change, and if not, what would it take to see a meaningful impact on the environment? These latter discussions raised a whole range of barriers and potential opportunities.

9.1.2 Literature review

The international literature review was dominated by Swedish literature followed by German and Swiss, largely because most documentation on this topic emerges from Sweden, especially knowledge which is more relevant to a developed country like Australia. Australian literature largely referred to new sanitation arrangements (with a particular focus on decentralised systems). For the most part, the literature concurred with stakeholder views, however some key differences were noted:

- Most Swedish literature documented technical and health aspects of urine diversion, including guidelines on the collection and reuse of urine. In recent years there have also been several key reports on social aspects, including attitudes and behaviour.
- Overall there appears to be a gap in the Swedish literature on institutional barriers and opportunities[49] of urine diverting and reuse schemes and how large scale introduction of such schemes could be rolled out. The majority of the literature tends to focus on demonstration projects.
- Another noticeable gap in the literature was economics and the cost-effectiveness of such schemes. There were individual cost comparisons, however no comprehensive economic analysis was found in the literature that considered the spectrum of costs and benefits to society (ie. environmental and social in addition to economic).

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[48] That is, without interventions or incentives – economic, regulatory or communicative.

[49] excluding Johansson and Kvarnstrom (2005) which does provide an in-depth review of sanitation regulatory frameworks in Sweden. This report was released during the course of this study.

9.1.3 Assessment of costs and benefits

The qualitative assessment in Section 8 reveals a range of costs and benefits that spans a disparate group of environmental, economic and/or social issues. This is partly because both the concept and the application of urine diversion and reuse cover numerous disciplines, discourses and organisations. For example, environmental benefits range from reducing mining of a non-renewable resource – a very global, long-term benefit with no obvious or discrete organisational home – to reducing water pollution (by limiting toxic algal blooms), which will have obvious and immediate economic benefits to organisational groups such as the fishing, tourism and recreational industries. While costs also covered environmental, economic and social issues, they were less diverse in the sense that they could be attributed more readily to an organisational group or groups, were short- or medium-term in nature and were on more of a local or regional scale rather than global. These costs included the cost of transporting the urine (whether by truck or pipe), through to investment in training and education for users, plumbers, agricultural industry etc.

The size of each cost or benefit is likely to be very dependent on the specific situation or context. For example, transport costs will depend heavily on factors such as population density, distance to reuse end point and mode of transport (for example, truck, gravity pipe network, pressure network). Similarly, benefits such as reducing water pollution (toxic algal blooms), will depend on the proportion of nutrient pollution that originates from household wastewater, compared to, for example, agricultural runoff or industrial wastewater.

Simple nutrient and water balances were provided by way of example to indicate the potential order of magnitude of the benefits of urine diversion. They suggest significant potential water savings and nutrient capture is possible in a region like Sydney or the new development areas around Sydney. As discussed in section 8, a more detailed analysis was not considered useful due to lack of data, reliability and robust methodology.

9.1.4 Swedish versus Australian Context

To assess what Australia can learn from the Swedish experience with urine diversion and reuse, it is important to consider the findings against a contextual backdrop. This section highlights several key differences between Sweden and Australia, which may influence aspects of urine diverting systems in each country. This information has been drawn from the literature, stakeholder interviews and personal communications.

Political climate

The major demonstration trials of urine diversion systems in Sweden occurred against a political backdrop of environmental awareness in the mid-1990s. Urine diverting toilets became an icon of this era (Johansson et al, 2000). Sweden's future political climate, such as the governance by EU directives[50], is likely to further influence its policies and management of the water, sanitation and agriculture sectors. For example, the EU Water Directive Framework will require Sweden to improve the performance of its onsite systems. This is likely to stimulate the implementation of more urine diversion systems as a cost-effective measure to meet the new performance requirements (Johansson & Kvarnström, 2005).

Australia does not have a dominant environmentally focused political climate, nor is it currently governed by a super-national regulation.

Management at different government levels

Most water, sanitation and urban planning in Sweden occurs at the municipal level, with some direction from the national level. For example, Swedish municipalities are legally responsible for sanitation services, urban development and spatial planning (Johansson & Kvarnström, 2005). In Australia's urban centres, this planning occurs mostly at the State level (DIPNR[51],

[50] Sweden became and EU member in 1995.
[51] Department of Infrastructure, Planning and Natural Resources.

DEC[52], DEUS[53]) with limited direction from the national or municipal levels[54]. With regards to public health issues, these are managed by municipal authorities in Sweden, where as in Australia, the State health departments, such as NSWHealth are typically responsible for managing public health.

History of urine-separation

A rather apparent contextual difference between the two countries is Sweden's history of use and exposure to dry urine-diverting toilets dating back to the 1800's in Stockholm. Summer houses in rural Sweden commonly adopted dry urine-diverting toilets from the mid-1950s (Drangert, 2005). Although the key drivers behind those toilets differ from those of contemporary Sweden, the important point is that Swedish culture has been pre-exposed to the technology and concept of urine diversion. The Australian culture has certainly not been pre-exposed to urine diversion.

Natural resources: A quality or quantity issue?

A key constraint on the current water and sanitation systems in Sweden is related to water quality, such as insufficient removal and hence excess nutrient and BOD[55] loads on receiving water bodies (Johannson, pers comm. 27/8/05). In Australia, while water quality and excess nutrient loads are a significant problem for some inland waterways, the pertinent issue is perhaps quantity, due to scarce water availability (Hawkesbury–Nepean River Management Forum, 2004).

Demographics and urbanisation

Sweden has a relatively small proportion of the population living in large urban settlements compared to Australia, where more than 80% of the population live in large urban settlements[56] (NLWRA, 2002). Population numbers and densities of major cities in Sweden are therefore lower than Australia. This means that Swedish urban and regional settlements tend to have a greater total area around their peripheries and hence greater logistical opportunities to reuse urine in adjacent farmland. This is not to say that recycling of urban nutrients back to nearby agriculture is not feasible in and around Australian urban areas, such as Greater Sydney, however the different characteristics of Sydney's urban settlements should be taken into account when learning from the Swedish urine diversion and reuse arrangements.

Citizen awareness

In general, Swedish citizens have perhaps a greater awareness of environmental issues and a greater sense of responsibility for the environment and natural resources than Australians. This may be attributed to formal Swedish policy and Sweden's comprehensive approach to environmental challenges and sustainable development (OECD, 2001). It may or may not also be influenced by the predominantly agrarian culture that persisted in Sweden until the 1950s (as indicated in the previous section). Hjelmqvist, an Australian-Swede working on water and sanitation provision in Sweden's Norrköping municipality, speculated that Swedes in general tend to be more connected than Australians do with their land and the appropriate management practices for managing the landscape. White Australians not only have a significantly shorter history with the Australian landscape[57], they have also typically used inappropriate British or European land management practices passed down from generation to generation, rather than knowledge of appropriate management of the Australian landscape

[52] Department of Environment and Conservation
[53] Department of Energy, Utilities and Sustainability
[54] This is the case for centralised water and sanitation.
[55] Biochemical Oxygen Demand
[56] Approximately 30% of the Swedish population live in settlements with a population greater than 100 000, where as approximately 70% of Australians live in settlements with populations greater than 100 000. Based on calculations from ABS, 2002 and SCB, 2000).
[57] Australia was colonised by European settlers in 1788 (Commonwealth of Australia, 2005). Prior to that time, only native Australians, Aboriginal people, populated the continent.

which many indigenous Aboriginal people still hold (J. Hjelmqvist, pers comm., 2/9/05; Wentworth Group, 2002).

Climatic differences

Sweden and Australia's very different climates, including average temperature and humidity ranges (climate-zone.com, 2004), could influence the functionality of urine diversion and reuse systems in each country. For example, odour emitted during storage and application is typically easy to manage in Sweden (Jönsson, pers comm.), however Sydney's higher average humidity may increase odour, particularly during the application of urine to land.

Other differences

The differences mentioned above between the Australian and Swedish political, climatic and socio-cultural contexts are not intended as an exhaustive list, rather, they highlight the differences that have became apparent during the course of this research. Other differences emerging from the stakeholder interviews that could possibly impact on urine diversion and reuse in the two countries may include:

- The difference in level of householder responsibility in management of their own water and sanitation systems. This may reflect the level of trust issued by the health departments in respective countries (see Section 7.2 on roles and responsibilities and 7.3 on barriers).
- The willingness of males to sit while urinating. While there are mixed views on the level of willingness of Swedish males to do so, some Australian respondents suggest Australian males in general would almost certainly not be willing to sit while urinating (see section 7.3 on barriers).

9.2 Key overall findings from this study

The intention of this section (and indeed this study) is to advise Australian stakeholders of the possibilities of urine diversion and reuse, however the following findings are also applicable to the Swedish context (that is, they are applicable to urine diversion in general). The findings have been summarised and integrated from the lessons learnt from the Swedish experience via interviews and literature, in addition to insights from the Australian stakeholder interviews.

Overall findings are categorised under the following headings:

- Lessons learnt
- Barriers
- Opportunities
- Research gaps

9.2.1 Lessons learnt

Roles and responsibilities

There are numerous roles required for implementing and coordinating a urine diversion and reuse system. The diagram in figure 15 draws together the key roles required for a successful urine diversion and reuse system. Some roles are required throughout the entire system, such as managing environmental and public health risks, while other roles are specific to one part of the system, such as users of urine diverting toilets. These are general roles, and it is possible that additional roles will need to be identified for a specific local context.

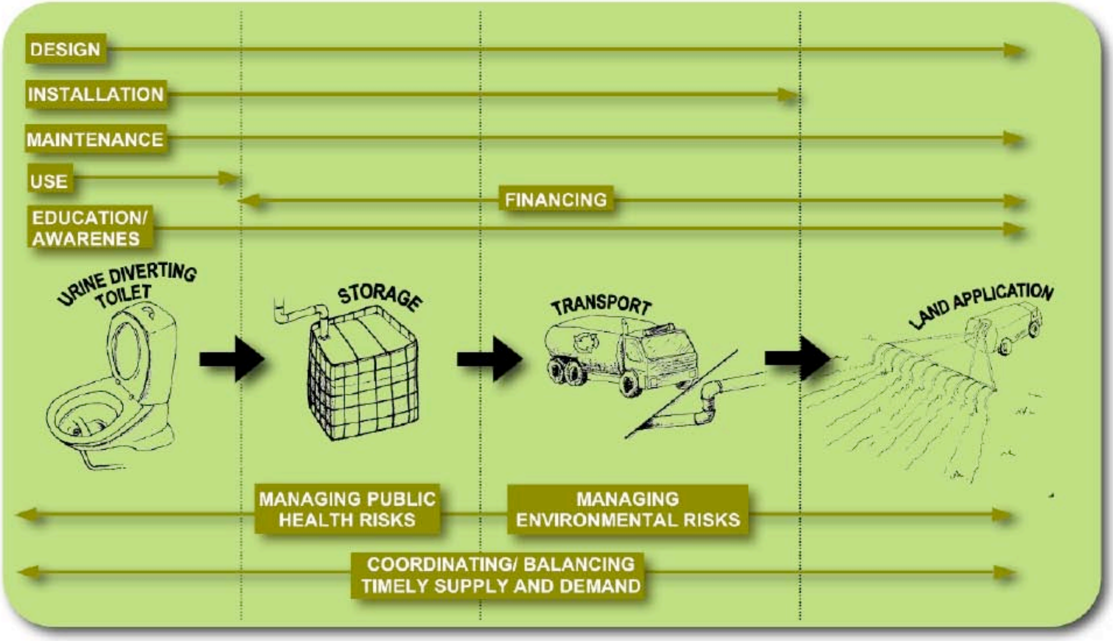


Figure 15: Roles required in a urine diversion and reuse system. These could be the responsibility of a number of stakeholders *[Note: the sketches of technical components drawn by the author are based on real examples of system technology in Sweden].*

The responsibility for each of these roles could be divided up in a number of ways. For example, which stakeholder is responsible for the collection and transport of urine to its final destination? The municipality, the water service provider, the farmer, or a third-party contractor? A distinction also needs to be made between the physical and the financial responsibilities of stakeholders or organisations for each role above. In one situation, the municipality could both finance and collect the urine, and in another example, householders could finance the farmers who physically collect the urine. Designation of responsibilities will likely depend on the local context, including present institutional structures, barriers and opportunities. It is therefore more appropriate to allocate such roles to individual organisations or organisational groups on a case-by-case basis through a participatory process. The diagram in figure 15 thus only identifies roles, not how these roles should be divided among stakeholders.

Technical system arrangements

The physical elements of a urine diversion and reuse system can be configured in a number of ways. In Sweden these arrangements have been fairly consistent, for example, in most cases houses have individual urine tanks that are pumped out to trucks for transportation, rather than piped to a more central location. However, just as with the non-physical elements of the process, such as roles and responsibilities, the preferred physical configuration is likely to be highly dependent on context. For example, contextual factors influencing the preferred system could include (and are interrelated):

- existing water, sanitation and nutrient management infrastructure;
- capital and operating costs;
- urban layout, housing density and logistics; and
- community preferences and awareness;

The above factors could influence decision-making on the optimal system for a particular region in Australia. For example, a form of decentralised piped network may be more cost-effective in a high-density urban area and more appropriate in terms of accessibility. Or the use of waterless urinals to collect urine might be considered appropriate based on community preferences, local regulations, and/or planning for their introduction for water conservation purposes.

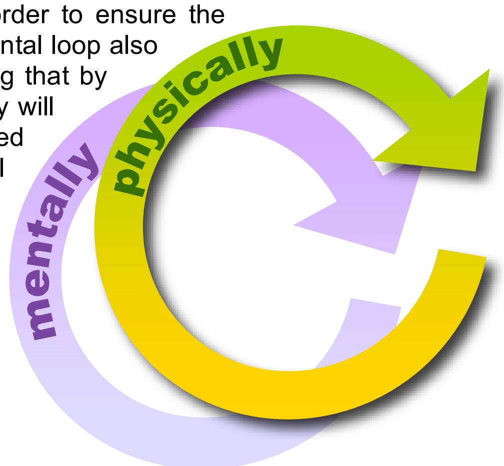
High correlation between user motivation and success of system

Another lesson learnt from the Swedish experience is that the success of a urine diversion and reuse system is highly sensitive to the motivation levels of the system's users. That is, if users are educated on *how* the system works, and more importantly on *why* the system is used, then there is a greater likelihood that users will willingly participate in a urine diversion and reuse system. This in turn means that the percentage of urine collected can be maximised and water consumption minimised.

This notion that the success of a new environmental socio-technical system is correlated to the motivation levels of its users, is echoed by some Australia studies on the sensitivity of kerbside recycling effectiveness and the motivation of householders. Their motivation was linked to the perception that their efforts were resulting in environmental outcomes. That is, their waste products were actually recycled and not disposed of to landfill along with general waste. This signifies a significant potential willingness of Australians to participate in household source separation of their waste streams if they are able to see the environmental benefit, and, receive feedback on the results of their efforts. This correlation is further supported by the plethora of research on household water use behaviour, linking water conservation to awareness of both general water scarcity issues and the direct impact of a householder's water use behaviour. Householder feedback mechanisms are being explored in the water demand sector, such as the use of smart meters to provide real-time feedback on household water consumption. This is not dissimilar to one Swedish respondent's[58] idea of creating a communication feedback loop in urine diversion and reuse systems. He suggested that in situations where the farmer collects the urine direct from the householder, the farmer could provide feedback to the householder about their previous urine contribution. This could involve showing them a basket of potatoes grown using their urine as a fertiliser, or an indication of productivity from urine-fertilized crops on the next household bill.

Another related social issue is the longevity of the 'education chain' beyond the initial owner of a urine-diverting toilet. For example, if a property developer sells apartments fitted with "eco" features like urine-diverting toilets to individual owners, over time the 1st generation owners will sell the dwelling to 2nd generation owners and so on. Therefore effective communication on *how* and *why* the system is used needs to be passed on from one owner to the next.

Thus, there is a need to 'close the loop' both physically and mentally to minimise losses in recirculating nutrients back to arable land. That is, in order to ensure the phosphorus or nitrogen cycle is physically closed, the mental loop also needs to be closed, such as householders understanding that by urinating in the front part of their urine-diverting toilet they will be maximising the amount of nutrients that can be captured and reused on arable land to grow new crops. The mental loop also needs to be closed between actors, for example, the actor responsible for the storage and transport of urine needs to understand that by ensuring the system is air tight, he/she will minimise loss of Nitrogen to the atmosphere (in the form of ammonia gas) and thus maximise the amount of nutrients reaching arable land from that collected at the toilet.



Technical improvements

Most stakeholders in Sweden indicated that some technical issues were still a problem, in that the urine diversion toilets and tanks currently on the market require technical refinements. For example, ensuring urine pipes are less likely to clog and/or cause odour,

[58] Respondent to stakeholder interviews in this thesis.

and maximising urine capture when men stand to urinate. These technical issues were not viewed as a significant challenge, rather, they were highlighted as issues to improve if urine-diverting systems were to be invested in or developed further. These technical lessons are relevant both for Sweden and Australia.

Dominant political climate

A majority of respondents from Sweden indicated a key driver of the development of urine diverting systems was the strong environmental flavour of the mid 1990s political climate. One respondent described urine-diverting toilets as a symbol, or icon, of that era. While this favourable political climate was a positive undercurrent at the time, the climate has now shifted to one dominated more by economics, which respondents viewed as unfavourable towards the proliferation of urine diversion and reuse this decade. Some felt that this was a current and possible future barrier to scaling up the development of urine diversion systems beyond what has been trialled and installed in Sweden to date.

While the central theme of Australian politics is certainly not flavoured by a deep environmental commitment, there are pockets of environmental concern among politicians that could be harnessed.

9.2.2 Barriers

Fragmentation of benefits

The benefits of urine diversion and reuse are distributed at several interception points along the entire system (as indicated in Table 2 in section 8). These benefits are therefore spread out among a number of different stakeholders or organisations who are responsible for each part of the system. This means, for a region such as Australia, where urine diversion and reuse is not currently practiced and rarely heard of, convincing one stakeholder or organisational group alone that the benefits outweigh the costs for their area of concern may not be sufficient to persuade that group to advocate urine diversion and reuse. For example, demonstrating to a water and sanitation service provider that urine diversion and reuse will reduce the nutrient load on the wastewater treatment plant and hence eliminate the need for expensive alternatives like biological nutrient removal at the end-of-pipe treatment plant, may not alone be enough to persuade them to take financial and institutional responsibility for the entire urine diversion and reuse system. Similarly, convincing the institution responsible for environmental pollution that they should invest in urine diversion and reuse because it will reduce nutrient loads on the water and hence can reduce algal bloom outbreaks and severity, may be a challenge.

Perhaps it is only when all the sum of all these individual benefits are accounted for that the overall advantage of urine diversion and reuse to the whole of society can be realised. Further, some benefits don’t even have an obvious beneficiary. For example, reducing society’s demand on a non-renewable resource is a longer-term benefit to society as a whole, thereby presenting a greater political challenge to convince any of society’s individual institutions to wholly support the concept. This may be particularly challenging in the Australian context given the political climate has never been flavoured by a dominant environmental theme in its recent history.

A ‘homeless’ paradigm

Due in part to the fragmentation of benefits described above, the concept and application of urine diversion and reuse does not have an obvious organisational home in the Australian context. The literature and some respondents (particularly Livingston et al, 2005 and the Swedish sanitation researcher and consultant) suggest that new ideas and paradigms require an organisational home to be effective. Livingston et al (2005) further suggest that urine diversion and other nutrient management and reuse concepts conflict with current institutional arrangements of water management in Australia. The fact that it is peripheral to the water industry and hence not valued relative to other more central water-related concepts is a more likely reason for its rejection or resistance by the water industry, rather than simply economic or technical reasons. This compares to the situation in Sweden, where regulatory and institutional structures are being modified in favour of such nutrient management and reuse paradigms.

Lack of regulatory targets

There are currently no set regulatory targets (national, state or regional) in Australia pertaining to the reduction of nutrients discharged to water bodies, or recycling of nutrients[59]. Whilst there are discharge requirements for individual 'polluters', there are none with any regulatory backing on a catchment or other regional scale to ensure the uptake of nutrient recycling systems such as urine diversion. This means there is little direct regulatory incentive to explore nutrient recycling systems in NSW.

9.2.3 Opportunities

Global and national guidelines and targets

Guidelines and standards published by reputable organisations can be seen as 'legitimizing' the concept or system to which they refer. According to some respondents and other personal communications, the forthcoming World Health Organisation *Guidelines for the safe use of wastewater, excreta and greywater* (WHO, *forthcoming*), may do just that: endorse the concept and practice of urine diversion and reuse systems. Such an endorsement may smooth the way for convincing governments and politicians of the validity and seriousness of this system. In 2004 the international Ecological Sanitation Research network *EcoSanRes*, produced guidelines on both the handling and reuse of urine and faeces in 2004 (Schönning and Stenström, 2004; Jönsson et al, 2004). At the national level, Sweden is due to produce national guidelines pertaining to source separating systems, including urine diverting and reuse systems.

While Australia has no comparable guideline or policy specifically referring to source separated systems, it is due to release new wastewater quality and reuse guidelines. These guidelines are risk based, that is, they are performance based and hence will not exclude opportunities for source separation systems like urine diversion and reuse, as long as they can meet the performance standards specified.

One policy measure that goes a step further than guidelines is perhaps targets. Establishing meaningful targets can pave the way for exploring and investing in the most effective means of reaching those targets. Some respondents felt that urine diversion and reuse would be one of the most effective means of recirculating nutrients back to agriculture. It was therefore not surprising that they saw the greatest opportunity for an increase in the use and development of urine-diversion and reuse systems would be Sweden's pending national targets – recycling a minimum of 60% of the phosphorus in sewage back to land (of which minimum of 30% should be to agricultural land). If these goals are accepted by parliament, it is anticipated it will have a significant positive effect on the uptake of urine-diverting systems.

Improvement on current wastewater system

Another opportunity for urine diversion is evident when it is compared to existing wastewater systems. Most respondents, as well as the literature, suggested that source separating urine was an improvement on existing wastewater systems, citing various reasons. If nutrient removal from wastewater is considered important for preventing water pollution and/or returning nutrients to agriculture, then urine separation can be more cost-effective.

[59] However there is a licence that sets a limit for 3 sewage treatment plants in combination on South Creek in the Hawkesbury-Nepean catchment.

Furthermore, source-separating urine from the wastewater stream means reducing or eliminating the associated volume of flushwater that typically accompanies urine via a flushing toilet. This latter benefit could be substantial for wastewater treatment systems nearing or at capacity. Reduced wastewater flows can defer capital expenditure on new or upgraded systems and/or reduce the incidence or severity of polluting overflows.

9.2.4 Research gaps

Pharmaceutical residues: a benefit or a limitation?

A relatively recent issue causing growing concern internationally, is the nature and risks associated with pharmaceutical residues and endocrine disruptors found in human urine. This was the largest health-related concern raised by respondents for the future of urine diversion and reuse and all wastewater systems. The literature also echoed this concern. However the conclusion is that it is essentially an unresolved issue, both in terms of the scale of the risk and, whether it is viewed as a significant challenge for urine diversion and reuse, or an opportunity when compared to conventional treatment and disposal or wastewater. Those perceiving the presence of such micropollutants as a significant challenge for urine diversion felt it could severely limit the reuse possibilities of urine if such substances were found to bioaccumulate in the soil or crops upon which they were applied. Those perceiving the presence of the micropollutants as an opportunity for urine diversion and reuse, suggested that separating the micro-pollutant-containing urine from the main wastewater stream was a positive form of isolation and containment. Further, some in this latter group suggested that applying urine to soil rather than discharging to water via effluent from sewage treatment plants, provided an extra barrier to the receiving environment and public health in risk management terms because of the extended residence time in the soil and the more effective soil environment encouraging breakdown of the micropollutants. Whichever way this issue was viewed, most people agreed that a substantial amount of new knowledge was urgently required to determine the nature and risks of these micropollutants in urine.

Economic analysis of urine diversion and reuse

The respondents that did refer to the economics of urine diversion and reuse, were unable to point towards any comprehensive analysis that addressed the complete, or even a near complete spectrum of costs and benefits of diverting and reusing urine. While they often referred to individual benefits, such as the distance urine can be transported via truck whilst remaining more cost-effective than conventional sanitation systems, there are few, if any, existing studies on the life-cycle costs and benefits of urine-diversion, either as part of a sustainable water and sanitation system or as a stand-alone system. Those economic analyses that do exist, do not address externalities such as environmental, health and amenity benefits, which are likely to be very significant, yet difficult to quantify in monetary terms, hence their exclusion from most analyses. However, a conservative economic analysis that only considers financial costs and benefits may conclude urine diversion and reuse is not beneficial, that is, the costs outweigh the benefits. More specifically, such a narrow economic analysis may conclude the use of urine-diverting systems pose an additional expense to an entire water and sanitation system, or that it is more costly compared to a conventional system. However this is a distorted view because the important benefits of urine diversion and reuse, namely returning nutrients back to agriculture and reducing risk of water pollution from toxic algal blooms, are excluded from the analysis, hence rendering the analysis meaningless from a urine diversion and reuse perspective.

Demonstrations in Australia

Most respondents suggested a demonstration trial would be essential before urine diversion and reuse was taken seriously in Australia. As discussed earlier, the benefits and costs, responsibilities for specific roles and physical system arrangements are likely to be context dependent. Although urine diversion is a proven technical system, a demonstration project of its application in Australia is an important step in establishing if and how it can work in the Australian context. Despite individual examples of urine diverting toilets in Australia, there are currently no large-scale examples of the complete urine diversion and reuse system including how management and financing roles could be structured.

Community preferences and awareness

Any new socio-technical system will need to be accepted and understood by the community before it can run effectively. Urine diversion and reuse is likely to be a concept little known to the Australian community. There are no Australian studies to date targeting perceptions of the Australian community towards urine, urine diversion or urine reuse on crops.

10 Recommendations

Some of the key findings were reported in section 9 were relevant to the Australian, Swedish and international contexts. The recommendations in this section refer specifically to the Australian context to address the research questions of this thesis.

While the greatest benefit of urine diversion in the longer term is perhaps its ability to return plant nutrients back from where they came, this may be a premature argument in Australia, considering Australia's current political climate. If the history of how Australia has politically responded to previous crises of over-exploitation of our natural resources is anything to go by, then making the case for urine diversion on the grounds of its resource conservation potential is not likely to hold its own. The importance of political will in driving change towards more sustainable water and sanitation solutions (including urine diversion) has been stressed by respondents from both Sweden and Australia and is supported by the literature.

In this regard, perhaps a more appropriate key benefit of urine diversion and reuse to 'sell' politically is its potential to prevent the nutrient pollution of receiving water bodies, in a more cost-effective way than stripping nutrients at end of pipe from existing centralised systems. However the message of closing the loop on phosphorus should not be downplayed as it is of utmost importance in avoiding a looming phosphorus crisis in the future.

Specific recommendations for considering urine diversion and reuse in future planning processes for Sydney's services are provided below. These should be integrated within various aspects, including: sustainable provision of water and sanitation services; catchment management (including river health); urban planning; natural resource management and food and agriculture.

10.1 Policy and decision-making recommendations

Four specific recommendations for Australian policy and decision-making processes are highlighted.

1. **Designated guardian**. The collection of pertinent issues addressed by urine diversion and reuse do not reside in any one institutional or organisational home, therefore, an existing or new actor may need to champion urine diversion and reuse. If the main tangible benefits to Australia would be related to water quality and natural resource management, it could be coordinated by the existing Natural Resources Commission and implemented at the local level through Catchment Management Authorities (CMAs). Other actors would need to be involved and commit to explicit roles defined and negotiated.
2. **Look for opportunities**. As with all new sustainable socio-technical systems and perhaps more so with those like urine diversion and reuse that lack an organisational home, it makes sense to look for opportunities to trial the system as they arise in areas where there are clear drivers. For example, in areas of Sydney were algal blooms from residential sewage effluent is a significant contemporary problem, or in a region where there is political will towards such an environmental approach. This could be within a Municipality, or championed by an individual MP[60]. Another obvious opportunity is synergies with waterless urinals in Australia. Waterless urinals have been trialled across the country and may be seriously considered as a water conservation measure for water-scarce urban Australia. Such wide-scale implementation of waterless urinals would provide a perfect opportunity for the collection of urine without the risk of cross-contamination from faeces.
3. **Introducing a new option in sustainable water and nutrient management**. There are a number of discourses on sustainable water and sanitation management in Australia today (as suggested in section 4) and even more options claiming to be the solution to Australia's water or nutrient problems. It is unlikely that one single option

[60] Member of Parliament of Australia.

will ever be the silver bullet[61], and thus it is essential to use appropriate decision-making frameworks that help determine the best option or suit of options for a given situation. This study does not advocate that urine diversion and reuse is one such silver bullet, however it does strongly suggest the concept be introduced to the water, sanitation and agricultural community and further research undertaken so that in the future it can be placed on the shelf for consideration along side other possible options for sustainable water and nutrient management.

4. Tips for an integrated decision-making process:

The following are principles to assist those involved in the decision-making process. They are generally applicable regardless of the main drivers and benefits of urine diversion and reuse are in a particular political or regional context.

- ✓ **Clear targets and objectives**. As highlighted throughout this study, urine-diversion can have wide-ranging benefits, from reducing eutrophication, to minimising consumption of non-renewable or scarce resources (phosphorus) and water. If urine diversion is being considered, it should be clarified which objective, or set of objectives, are being addressed in a given context, so that the potential contribution that urine diversion could make towards that goal (compared to other options) can be readily assessed. Targets can also be used to support policy making by strengthening the commitment to the identified objectives. In order to reach a meaningful scenario like recirculating a significant percentage of urban phosphorus and nitrogen to agriculture, it may be necessary to consider national, state or regional (eg. catchment-based) targets for recycling nutrients. This could be based on the Swedish model where one proposed National Environmental Objective sub-target is that 60% of phosphorus should be recycled from wastewater back to land.
- ✓ **Backcasting.** Once clear objectives and future targets for managing nutrients have been identified, decision-makers can work backwards from a meaningful future target towards the present, to determine the actions required now and the feasibility of those actions. Without backcasting or use of some other futures method, it would be difficult to know whether urine diversion and reuse should be seriously invested in and by how much. Simply putting urine-diverting toilets on the market in Australia may be relatively straightforward, according to Australian respondents in this study, however that action alone may be tokenistic if the intention is to ensure sufficient implementation of urine diversion and reuse systems to reach a meaningful target of recirculating nutrients or reducing eutrophiciation for example. Backcasting may reveal a different policy strategy is required for introducing urine diversion and reuse in order to achieve significant recirculation of nutrients or reduction in eutrophiciation, such as economic, regulatory, and/or communicative instruments to aid uptake.
- ✓ **Cost-effectiveness.** Given the limits of public budgets, it is desirable to select the most cost-effective means of reaching a given policy target. To determine the potential of urine diversion and reuse to meeting a given policy target, its cost and benefits need to be assessed. A cost-benefit analysis of urine diversion alone may not be appropriate, given the unquantifiable nature of some of its benefits, such as the recirculation of nutrients back to agriculture. In this context, a more appropriate analysis would be comparing urine diversion to other options that address the same target. Comparing the unit cost per option (eg. $/kg) of reducing nutrient loads to a receiving water body is a useful economic method to assist the decision-making process. Such an analysis is described further as a recommendation for future research in section 10.2.
- ✓ **Integrated approach.** Whether the goal of urine diversion and reuse is reducing eutrophication or facilitating source-separation for wastewater reuse, it is important to consider urine diversion in the broader context of the goal. For example, if the goal is to reduce nutrient loads on receiving water bodies (and possibly also reduce demand on non-renewable phosphorus reserves), it is necessary to consider all key sources of nutrient flows. It is likely that diffuse sources of nutrients such as agricultural and urban runoff are also substantial contributors to the overall nutrient load and should

[61] A magic or simple solution to a complex problem.

therefore also be considered for better management in working towards an overall goal.

10.2 Recommendations for further research

Five key recommendations are outlined below for further research to progress knowledge of the potential for urine diversion and reuse in Australia. Recommendation 1, 2 and 5 refer specifically to urine diversion and reuse, where as 3 and 4 take an integrated approach to urine diversion and reuse in the context of water, sanitation and nutrient management.

1. **A demonstration trial** of urine diverting toilets in a new residential development in or around Sydney to test the socio-technical system in the Australian (or NSW) setting. The new growth area of Western Sydney, adjacent to agricultural/horticultural land could be used to trial the system, enabling a trial of the sustainable reuse of urine for crop production. Urine could also be collected from waterless urinals in non-residential premises. This trial could assess technical aspects, regulatory barriers, economic aspects, user perceptions, and education and communication requirements. A demonstration would ideally trial the entire system and include land application of the collected urine on nearby agricultural land. Such a trial should involve several key stakeholders. This group could include a toilet manufacturer, property developer, federal, state and/or local government, researchers and/or consultants, water service provider, catchment management authority, politicians and expert advisors such as the Swedish stakeholders interviewed in this study. The final list of involved parties would depend in part on the location, political interest of each stakeholder and scope of the trial.

2. **Social research on user preferences and perceptions** should be undertaken simultaneous to the demonstration trial. This research should aim to understand users' perceptions of urine, their willingness and preferences for using a urine-diverting toilet and their views on consuming food or other agricultural crops fertilized with urine. Equally as important, this community consultation should also aim to communicate *why* urine diversion and reuse systems are used and *how* they can be used and configured. Effective and appropriate methods for engaging the community are described in section 4.10 and detailed further in Carson and Gelber (2001). During the demonstration trial, innovative communication methods to **motivate** users to participate effectively in urine diversion and reuse should be explored, such as the smart-feedback on bills suggested in section 9.2.1.

3. **Cost-effectiveness analysis** of urine diversion and reuse compared to other options for nutrient and sanitation planning and management. The analysis should be based on the principles of integrated resource planning (IRP) to enable comparison of resource conservation options to supply-side options and ensure the inclusion of key environmental benefits in the analysis. A broader analysis could also integrate economic costs and benefits with social and environmental costs, benefits and preferences and health risks. Such frameworks could be based on the MISTRA Urban Water manual (see MISTRA, 2000 and Malmqvist, *forthcoming*). Another approach could be using the Least Cost Planning (LCP) framework that has been applied extensively to water and energy management (see section 4.7 for reference to Least Cost Planning principles and applications). Applied to nutrient management, LCP can provide a methodology that compares alternatives for conserving, recycling or supplying nutrients, on an equivalent basis and incorporating a sustainability perspective. Once key nutrient fluxes are identified within a system, (eg. catchment or national), LCP would then be used to identify the most cost-effective means for managing nutrients within the limits of that system. For example, developing sustainable options for managing phosphorus flows between urban and rural areas, in a key catchment in Australia, through material accounting and least cost planning. Externalities around these options could be identified (and quantified where appropriate) including social, economic and environmental costs and benefits.

4. Review of **Extended Producer Responsibility** for managing micro-pollutants in household wastewater. A rapidly emerging challenge for sanitation systems is the 60,000 micro-pollutants being discharged untreated from sewage treatment plants across the globe. There is sufficient current or planned research exploring the nature and

characterisation of the most harmful micro-pollutants in urine[62], however there is no research on how such harmful micro-pollutants might be managed in the longer term. Some respondents and preliminary studies suggested urine diversion to land might be a better option than current discharge of effluent to water. While this may be an opportunity for the short to medium term, even urine diversion is not a truly 'at source' solution for managing micro-pollutants, as some of these, like pharmaceutical residues and endocrine disruptors originate from the chemical and pharmaceutical industries. This study could review and analyse the latest knowledge on key micro-contaminants in household sewage (like pharmaceuticals) and also the current regulatory and institutional frameworks in which they are managed. A strategic framework for managing such pollutants, based on the principles of extended producer responsibility (EPR), source separation and the use of material accounting tools could then be developed. Such a framework would address the pending responsibility of the chemical and pharmaceutical industries to better control the products they manufacture and sell. Similar policy frameworks already exist within the EU and internationally for managing solid waste, based on the principles of EPR (White, 2001). The study would be solution-focused, use case study contaminants, identify problems and also technical and regulatory solutions including the relative costs and benefits of such solutions. It would consider the potential role of the chemical and pharmaceutical industries in particular, to manage critical contaminants including loads, pathways, roles and responsibilities, barriers and opportunities.

5. Link in with existing international **networks** on urine diversion and reuse research and projects. There is already a substantial amount of knowledge generated by networks such as EcoSanRes (www.ecosanres.org) as indicated through the literature documented in this thesis. Australian stakeholders could either strengthen existing connections with international and national networks (including International Water Association's EcoSan Special Interest Group (www.ecosan.org) and the Australian Water Association's Integrated, Decentralised Water Systems (IDWS) Special Interest Group), or forge new links with the EcoSanRes network. Some of the above future research recommended could benefit if it was undertaken in conjunction with such networks to combine expertise.

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[62] See Institute of Wastewater Management and Water Protection, at TUHH, Germany: http://www.tuhh.de/aww/english/index.html; NOVAQUATIS at the Swiss Federal Institute for Environmental Science and Technology (EAWAG): http://www.novaquatis.eawag.ch/english/NOVA5_e.html, and the Swedish University of Agricultural Sciences (SLU): http://www.bt.slu.se/lt_old/lt-uppsala.htm

11 List of contacts

The following is a list of some key Swedish contacts and organisations in the field of urine diversion, to encourage further dialogue, knowledge sharing and collaboration. They range from researchers through to manufacturers.

Organisation	Description
EcoSanRes (hosted by Stockholm Environment Institute) www.ecosanres.org	International network on ecological sanitation: outreach (eg. networks), capacity building and pilot projects.
Municipalities: Norrköpings Kommun http://www.norrkoping.se/miljo-natur/ Tanums Kommun http://www.tanum.se/vanstermenykommun/miljo/toaletterochavlopp/urineseparation.4.8fc7a7104a93e5f2e8000595.html and http://www.tanum.se/vanstermenykommun/miljo/toaletterochavlopp/wateran dsanitationpolicy.4.8fc7a7104a93e5f2e8000636.html	Examples of Swedish municipalities who have mandated recycling nutrients through urine-diversion/reuse or equivalent.
Swedish University of Agricultural Sciences (SLU) http://www.mikrob.slu.se Contact: Håkan Jönsson hakan.jonsson@lt.slu.se	
VERNA Ekologi http://www.swedenviro.se/verna/index_en.html Contact: Mats Johansson mats@verna.se or Elizabeth Kvarnstrom Elisabeth@verna.se	Research consultancy on sustainable water and sanitation service provision (including urine diversion and reuse). Operating both in Sweden and internationally.
Stockholm Water Company (Stockholm Vatten AB) http://www.stockholmvatten.se/indexEng.htm	Sweden's largest urban water service provider who has been involved in large scale sustainable water and sanitation demonstration projects that included urine diversion and reuse.
Manufacturers: Gustavsberg www.gustavsberg.se Dubbletten http://www.dubbletten.nu/english-presentation/WCdubbletteneng.htm Wost Mans www.wost-man-ecology.se Separett http://www.separett.com/default.asp?id=1109 Aquatron www.aquatron.se	Some Swedish manufacturers of urine-diverting toilets or systems – both dry and flush toilet systems.

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EcoSanRes Ecological Sanitation Research network www.ecosanres.org

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Personal Communications

Assoc. Prof. Jan-Olof Drangert, Linköping University, Sweden, pers comm. 07/04/05.

Jane Hjelmqvist, Norrköpings Kommun, Norrköping, Sweden, pers comm. 02/09/05

Martina Hammer, PhD candidate, Institute of Wastewater Management and Water Protection 1-02, Hamburg University of Technology, Germany, pers comm. 11/10/05

Dr. Hakan Jönsson, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden, pers comm. 30/08/05

Mats Johansson, VERNA Ekologi AB, Technical Tour, World Water Week 2005, August 2005, Stockholm. pers. Comm. 27/8/05

Prof. Stuart White, Director, Institute for Sustainable Futures, University of Technology, Sydney, Australia, pers comm. 17/04/04.

Appendix A: Introduction letter to stakeholders

The following sample letters were sent to potential stakeholders requesting their participation in the research on urine diversion and reuse via a semi-structured interview. Letters to Swedish stakeholders were sent both in English and Swedish, while letters to Australian stakeholders were sent only in English.

2006-05-03

Bäste ……[Swedish stakeholder]…..,

Ang: Utvärdering av svenska erfarenheter avseende urinseparering

I fråga om införande av och forskning kring urinseparerande system är Sverige internationellt sett mycket framstående, men kartläggning och utvärdering av erfarenheter kring planering, förvaltning och ekonomi har hittills skett i begränsad omfattning.

Då du är en nyckelaktör inom området, inbjuder vi dig att delta i en utvärdering av svenska erfarenheter av urinseparerande system. Denna utvärdering kommer dels att utgöra underlag för ett Master-examensarbete vid Tema Vatten, Linköpings universitet, och vara del av en studie som stöds av The Institute for Sustainable Futures, University of Technology, Sydney (UTS) i Australien.

Syftet med studien är att dokumentera och analysera de lärdomar som ett urval av nyckelaktörer som arbetar med urinseparerande toaletter inhämtat. Resultatet av studien kommer att vara av betydelse för framtida utveckling, planering och förvaltning av urinseparerande system i Sverige och internationellt. Ytterligare ett syfte är att förstå vilka möjligheter och hinder det finns för införande av urinseparering i Australien, baserat på vad som framkommit i utvärderingen av de svenska erfarenheterna. På liknande sätt kommer även nyckelaktörer i Australien inbjudas att delta.

Din medverkan kommer att innebära deltagande i en intervju som tar ca 45-60 minuter och äger rum på din arbetsplats. Intervjun kommer att behandla dina erfarenheter kring forskning av urinseparerande toaletter, och relatera till nyttor och kostnader, möjligheter och hinder, utmaningar, roller och ansvarsfördelning. Informationen kommer att hanteras strikt konfidentiellt och i enlighet med gängse forskningsetiska principer (HSFR). Du behöver inte förbereda något material inför eller efter intervjun, men finns det underlag tillgängligt så mottas det tacksamt.

Genom ditt deltagande i denna studie kommer du att bidra till utvecklingen av urinseparering som ett verktyg för en mer uthållig avloppshantering i Sverige, Australien och internationellt.

Intervjun (och utvärderingen som sådan) kommer att utföras av Dana Cordell. Dana är från Australien och intervjun kommer att genomföras på engelska. Om du vill att en kollega är med under intervjun som språkligt stöd kan du diskutera detta med Dana. Hon är anträffbar på telefon 0734-438118 och email dana.cordell@uts.edu.au.

Dana kommer att ringa upp dig i nästa vecka med en förfrågan om ditt intresse att delta och för att avtala tid för intervjun. Då finns också möjlighet att ställa ytterligare frågor kring studien.

Vi ser fram emot ditt deltagande!

Med vänlig hälsning,

Jan-Olof Drangert, FD

Dana Cordell
Masters student, Linköping University, and
Research Consultant,
Institute for Sustainable Futures,
University of Technology, Sydney, (UTS) Australia

2006-05-03

Dear …[Swedish stakeholder]……,

Re: Evaluating the Swedish experience with urine separation

Sweden is one of the world leaders in research and implementation of urine-separating systems, however there has been little evaluation of the experience with regards to management and cost-effectiveness.

I would therefore like to invite you to participate in an assessment of the Swedish experience of urine separation due to your key position in this field. This assessment is being undertaken as part of a Masters Thesis at The Department of Water and Environmental Studies at Linköping University and is supported by the Institute for Sustainable Futures at the University of Technology, Sydney (UTS) in Australia.

The purpose of this research is to document and analyse the 'lessons learnt' from a selection of key Swedish stakeholders working in the field of urine-separating toilets. It is anticipated that the outcomes of this research will be beneficial to the future development and management of urine-separating systems in Sweden and internationally. A further purpose is to understand opportunities and barriers for the application of urine-separation in Australia, based on an assessment of the Swedish experience. Similar interviews will also be conducted with key Australian stakeholders.

Your participation would involve an interview/discussion of approximately 45-60 minutes duration at your workplace, covering your experience in researching urine-separating toilets. Such discussion questions relate to benefits and costs, opportunities and barriers, challenges, roles and responsibilities. The information you provide will be strictly confidential. The study will conform to the Research Ethics guidelines provided by the Swedish Research Council. There is no need to prepare any material prior to or following the interview, however if you do have any material available it would certainly be appreciated.

By participating in this study you will be contributing to the advancement of urine-separation as a means for sustainable sanitation in Sweden, Australia and internationally.

The interview will be carried out in english by Ms Dana Cordell, an Australian researcher. If you would like to arrange a colleague to be present to assist in any translation, please let Dana know. Her contact details are 0734-438118 or email dana.cordell@uts.edu.au.

You will receive a phone call from Dana in the next week to see if you are willing to participate and to arrange a time for the interview. You will also have an opportunity to clarify any queries you may have regarding this research.

We look forward to your involvement in this new research!

Yours Sincerely,

Jan-Olof Drangert, and Dana Cordell
Masters student, Linköping University, and
Research Consultant,
Institute for Sustainable Futures,
University of Technology, Sydney, (UTS) Australia

5th July, 2005

Dear ……[Australian Stakeholder]….,

Re: innovative opportunities for nutrient and water management through urine-separation

Australia is currently engaging with innovative strategies to manage its stressed water resources and excess nutrient loads on inland waters. The use of urine-separating toilets is one innovative option to both reduce water consumption and capture nutrients. Urine separating toilets are a proven technology and have been installed in numerous households, communities and non-residential premises across Scandinavia. Despite their success in managing nutrients in Sweden and other Scandinavian countries, there have been little or no studies on their potential role in Australia at a regional scale for reducing nutrient loads on waterways, reducing water demand and increasing nutrient reuse.

I would therefore like to invite you to participate in a study of the issues and opportunities for urine separation in Australia due to your key position in this field. This assessment is being undertaken as part of a Masters Thesis at The Department of Water and Environmental Studies at Linköping University in Sweden and is supported by the Institute for Sustainable Futures at the University of Technology, Sydney (UTS).

The purpose of this research is to document and analyse the 'barriers and opportunities' for urine-separation in Australia from a selection of key Australian stakeholders who influence or are influenced by water and/or nutrient management strategies. Interviews with key Swedish stakeholders are currently underway to explore the 'lessons learnt' from the Swedish experience and how they may be relevant to the Australian context. It is anticipated that the outcomes of this research will be beneficial to the development of cost-effective sustainable water and nutrient management strategies in Australia and internationally.

Your participation would involve an interview/discussion of approximately 45-60 minutes duration at your workplace, covering your experience in water and/or nutrient management and exploring the potential role of urine-separating toilets. Such discussion questions relate to opportunities and barriers, challenges, benefits and costs, roles and responsibilities. The information you provide will be strictly confidential. The study will conform to the Research Ethics guidelines provided by the Swedish Research Council. There is no need to prepare any material prior to or following the interview, however if you do have any material available it would certainly be appreciated.

The interview will be carried out by Ms Dana Cordell. You will receive a phone call from Dana in the next week to see if you are willing to participate and to arrange a time for the interview. You will also have an opportunity to clarify any queries you may have regarding this research. She can be contacted by email dana.cordell@uts.edu.au phone (02) 9514 4978.

We look forward to your involvement in this new research!

Yours Sincerely,

Jan-Olof Drangert

Dana Cordell
Masters student, Linköping University, and
Research Consultant,
Institute for Sustainable Futures,
University of Technology, Sydney, (UTS) Australia

Appendix B: Stakeholder interview questions

The semi-structured stakeholder interviews were based on the following questions. However they were not necessarily asked in the given order.

B-1 Swedish stakeholder interview questions:

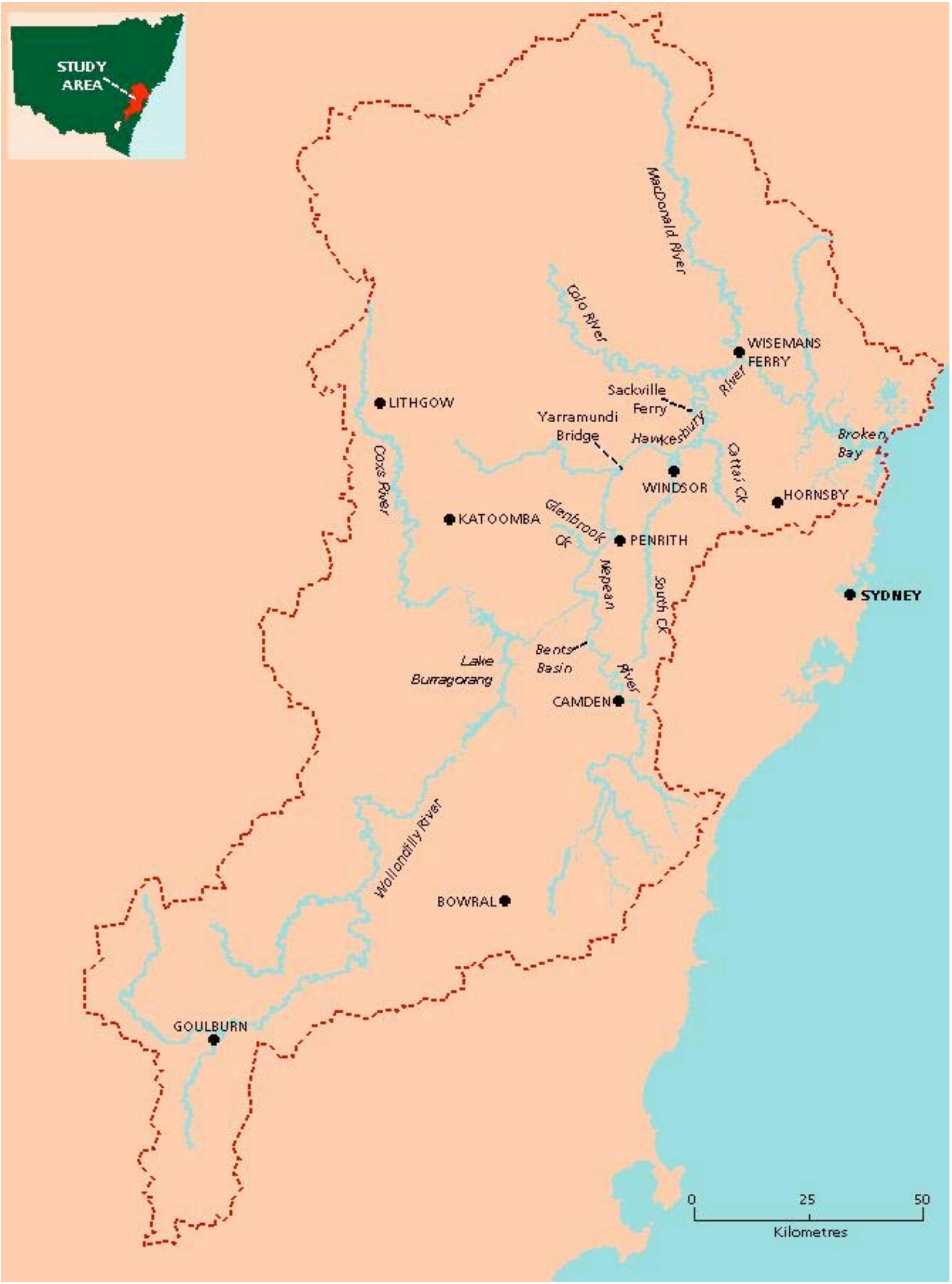
Category	Question
1.Stakeholder category and profile	• Name? • Organisation? • Role? • What role have you played to date in relation to urine separation in Sweden? • What is the 'scope' (including geographical coverage, single or community scale, range of technology)?
2. UST technology (if relevant)	• System details: including type, model, scale, age, expected lifetime, features? • Costs: including capital and operating, parts, labour, energy. • Resource use: energy, chemicals, material parts • Maintenance and management requirements (including both routine and as-needed) • Reliability: How reliable/flexible is the system? How often does it fail? (what would usually be the cause of failure?). • Responsibility (with whom? Owner? Operator? Both?)
3. Drivers and Benefits	• Main drivers for implementing USTs? • Did you explore other alternatives to reaching this goal? (how did you decide on urine-sep toilets?) • Other benefits of USTs? • What situations do you think UST are most appropriate for? (eg. Residential or non-residential, single- or mulit-dwelling, urban or rural, new or existing dwellings; environmentally aware or water scarce or rocky areas) • When do you think UST are **not** appropriate? • Any quantifiable actual benefits? (eg. Nutrient savings, water savings)
4. Costs, Limitations and barriers	• What do you see as the main costs associated with USTs? • Do you have any quantifiable actual costs? (eg. capital and operating, including labour). • What are the main limitations/drawbacks of UST to date? (in your experience or others) • Do you think these limitations or barriers can be overcome? If so, how?
5. Roles and responsibilities	• Who is (are) the responsible institutions or stakeholders for the management, maintenance and liability of USTs? • Do you agree with this? If not, what would you change and why?
6. Lessons Learnt	• If you could do things differently next time, what would you change? • What have been the most successful elements of your experience with UST? Why? • What has been the greatest challenge? Why? • What key issues would you recommend/highlight to others with less experience with USTs? (such as if UST were to be introduced into Australia)

7. Knowledge gaps	• What do you see as the key knowledge gaps in this field that require further research of information?
8. Further information (informal snowballing)	• Do you have any data, publications or other information which may be useful for this study? Are there any issues with sharing or quoting this information? • Is there anyone else you think I should talk to regarding this issue? Or other literature you know of? • Do you know of any trials or use of US in Australia?
9. Additional thoughts	• Is there anything else you would like to mention regarding your experience with USTs?
10. Future contact & confidentiality issues	• As mentioned, your name and organisation will not be revealed in the report, however your organisational category (eg. Municipality, manufacturer may be). • Do you mind if I contact you again if need to clarify any of the issues we have discussed?

B-2 Australian stakeholder interview questions:

Category	Question
1.Stakeholder category and profile	*Name?* *Organisation?* *Role?* *Have you had an experience with USTs?*
2. Current level of understanding of USTs	*What is your understanding of urine-separating toilets? When and where did you first hear about them?* (describe UST if unfamiliar or unsure)
Benefits and opportunities	5. *Main drivers for implementing USTs?* 6. *Other benefits of USTs?* 7. *What situations do you think UST are most appropriate for? (eg. Residential or non-residential, single- or mulit-dwelling, urban or rural, new or existing dwellings; environmentally aware or water scarce or rocky areas)* 8. *When do you think UST are **not** appropriate?* 9. *Any quantifiable actual benefits? (eg. Nutrient savings, water savings)*
Costs, Limitations and barriers	*Can you foresee limitations of introducing such a system in Australia might be? (potential probe – financial costs, social acceptability, health issues, liability etc)* *How do you think these barriers or limitations could be overcome?*
Roles and responsibilities	*Assuming USTs are found to be cost effective for reducing nutrients into receiving waterways and reducing toilet water demand, who (or which groups) do you think should be responsible for:* 1. *managing urine-separating toilets? Including ensuring appropriate education, training, maintenance, liability? (potential probe – state/local/fed gov, water utilities, CMAs, householder? Health dept? etc.)* 2. *investing in urine-separating toilets? (potential probe – state/local/fed gov, water utilities, CMAs, householder?)*
NSW priority issues re nutrients, water.	*How important do you think the issue nutrient removal/management is in NSW catchments at the moment?* *a) in terms of water pollution and* *b) in terms of recycling nutrients back to agriculture?* *Has this changed or do you think this is likely to change?*
Changes required	*What would need to happen/change in order for USTs to be introduced into NSW? (generally, or specific to your field/organisation).*
Other options to reduce P loads.	*If reducing nutrient loads (and thus potential toxic algal blooms) into H-N waterways is a key potential benefit of urine-separating toilets, what other options to reduce nutrient loads could also be addressed? (potential probe – improved STP nutrient removal, improved agricultural practices and fertilizer use, reduced P detergent use, improved land-use practices etc).*
Further information (informal snowballing)	*Finally, do you have any data, publications or any information which may be useful for assessing the costs and benefits of USTs in Australia, or more specifically the HN catchment? (probe – eg. Nutrient flows, clean-up costs, existing research on USTs, demographics in HN catchment, domestic water use in HN catchment etc).*
Additional thoughts	*Is there anything else you would like to mention regarding your views on USTs?*
Future contact & confidentiality issues	*As mentioned, your name and organisation will not be revealed in the report, however your organisational category (eg. Municipality, manufacturer may be).* *Do you mind if I contact you again if need to clarify any of the issues we have discussed?*

Appendix C: Hawkesbury-Nepean catchment



Source: NSW EPA (1995) http://www.epa.nsw.gov.au/soe/95/image.php?image=hawk_npn

The Hawkesbury-Nepean catchment was selected as it is one of Australia's most significant catchments. Its' 2.2 million hectares provides water to almost all the 4.2 million people of the Sydney, Blue Mountains and Illawara regions (HNCMA, 2004).

Agricultural and other economic activities within the Catchment contribute to 70% of goods and services produced in the state (HNRMF, 2004). In addition to drinking water, the Catchment also supplies Sydney with most of its fresh food and generates over $1 billion each year in agriculture. (HNCMA, 2004). Further, the tourism and recreation industry has an important socio-economic function within the Catchment and relies on a healthy river and surroundings. Similarly, the fisheries industry is heavily reliant on the health of river (DUAP, 2000; Cordell, 2005b).

Appendix D: Assumptions for nutrient reduction calculations

Table D-1: Assumptions of nutrients in urine and urine diverting toilet use behaviour.

Parameter	Assumption	Source
Urine generated per person per day	150ml/person/day	(Steinfeld 2004; Drangert, 1998)
Maximum phosphorus generated in urine per person per day	1.2g of P	(Vinnerås, 2001)
Assumed proportion of toilet usage at home versus away from home in the Sydney and Hawkesbury-Nepean area	70%	Assumption
Assumed efficiency of nutrients captured at source	70%	Assumption based on Jönsson (2001)
Expected new inhabitants in Hawkesbury-Nepean catchment by 2020	300 000	HNCF (2004)
Population of Sydney	4.2 million	ABS (2005)
Occupancy ratio (ie. average number of persons per household) in Sydney and Hawkesbury Nepean area	1.76	ISF, 1998; Turner et al 2005.
Assumed number of toilet per home	1	assumption

Projected annual phosphorus captured by urine diverting toilets per person:

= 70% x 70% x 1.2g x 365 days

= 214.6 g/ year

For 300 000 new inhabitants (or 170 500 new houses)

= 214.6 x 300 000

= 64.4 Tonnes/year phosphorus captured

(corresponding number of toilets = 300 000/1.76 = 170 500)

For 4.2 million residents of Sydney

= 214.6 x 4 200 000

= 901 Tonnes/year phosphorus captured

(corresponding number of toilets = 4 200 000/1.76 = 2.4 million)

Appendix E: Assumptions for water conservation calculations

Table C-4: Sydney water use assumptions

Parameter	Assumption	Source
Population of Sydney	4.2 million	ABS (2005)
Average toilet flush based on mix of 50% 6/3L dual flush toilets, 10% 9/4.5L toilets, 5% 11/6L toilets and 35% 11L full flush toilets	6L/flush	ISF, 1998
Household flushes per person per day	3.8	Roberts (2005)

Table C-5: urine diverting toilet assumptions

Parameter	Assumption	Source
Use per flush	0.2L urine flush 4L full flush	Based on range from Swedish models: 0-2L single flush 2-6L full flush
Ratio of full flush to half flush	1:3	Assumption (studies in Australia found this figure can vary significantly with dual flush toilets based on behaviour and the flush volumes, Cordell et al, 2003).
Household flushes per person per day	3.8	Roberts (2005)

Annual per capita toilet water demand in Sydney households

= 6L/flush x 3.8 flushes x 365 days

= 8322 L/year

Predicted annual per capita urine diverting toilet water demand

= [(3/4 x 0.2L) + (1/4 x 4L)]L/flush x 3.8 flushes x 365 days

= 1595 L/year

Therefore if 20% of Sydney residents used urine diverting toilets, water savings would be

= [8322 L/year - [20% x 1595 L/year + 80% x 8322 L/year]] x 4.2 million

= 5.6 GL/year water savings