Damien GIURCO[1] (Damien.Giurco@uts.edu.au), James PATTERSON[1], Albena BOSSILKOV[2], Alex KAZAGLIS[1]
[1]Institute for Sustainable Futures, University of Technology Sydney (Australia)
[2]Centre for Excellence in Cleaner Production, Curtin University of Technology (Australia)

ASSESSING INDUSTRIAL WATER REUSE SYNERGIES: A PORT MELBOURNE SCOPING STUDY

Urban water scarcity from drought and an increasing population are driving a range of water saving options to be explored in Melbourne (Australia). This paper assesses the cost-effectiveness of five water treatment and industrial reuse options in the Port Melbourne industrial area. In consultation with industrial stakeholders and the local water utility, the scoping study design began by identifying potential water sources and sinks in the area. Treatment technologies for each option – using a combination of membrane bioreactors (MBR) and in some cases reverse osmosis (RO) technologies – were developed. In evaluating the potential for future implementation, the cost effectiveness ($/kiloLitre) was assessed relative to supply and demand-side options available in Melbourne. Industrial water recycling at the proposed scale (250–350 kL/day) was found to be more expensive than efficiency options (water reduction at source) and also large-scale desalination. The paper describes drivers (increasing water and trade waste prices, saving water, corporate social responsibility) and barriers (capital and operating cost) to implementation identified by the companies and these are discussed in comparison with water reuse synergies which were successfully implemented in the Kwinana industrial area (Western Australia). Future implementation of industrial ecology opportunities requires strong stakeholder involvement processes as described in this work. Furthermore, the energy costs of the proposed water recycling technologies in Port Melbourne were significant and suggest further potential through co-generation to improve water and energy efficiency simultaneously.
Keywords: water; recycling, industrial ecology; regional synergies

INTRODUCTION

Urban water scarcity from continuing drought and an increasing population are driving a range of water saving options to be explored and implemented in Melbourne (Australia). These options include encouraging the use of efficient toilets, showerheads and washing machines and rain tanks in homes, assisting industry to save water through efficiency and recycling initiatives and the construction of a desalination plant in addition to the existing rain-fed water supply system. In the Melbourne area, annual water consumption is approximately 470 GL divided between the following uses: 60% in residential homes, 30% in industry and commercial uses, 10% in non-revenue water (Our Water Our Future, 2006), meaning that water saving initiatives are directed toward both residential consumers and industry.

One strategy to reduce the industrial demand on the centralised supply system, would be to recycle water between companies within a heavy industrial area such as Port Melbourne. A scoping study of the technologies, costs, barriers and opportunities for water reuse synergies forms the focus of this paper. Water reuse synergies have been identified and successfully implemented at other industrial areas in Australia, most notably in Kwinana, WA and similarities and differences are discussed in this paper.

The aims of this paper are to:

1. Describe the industrial water reuse synergies identified in the Port Melbourne area and the process by which they were developed
2. Outline the role of a cost-effectiveness framework in prioritising scoping study options
3. Discuss the barriers and drivers for implementation of industrial water reuse synergies in Port Melbourne, and contrast them with the barriers and drivers in Kwinina, Western Australia.
4. Recommend generalised areas for further research to overcome barriers and promote the appropriate development of regional synergies

APPROACH

Background to case study

This project is based in the Port Melbourne area, an industrial zone located close to the centre of Melbourne, with historically much heavy industry and more recently increasing commercial and light industrial developments alongside established manufacturing and production sites.

The companies located at the Fisherman's Bend site in Port Melbourne that participated in this study, along with the types of processes performed by each company are:

- Kraft (food production)
- Boral (plasterboard production)
- Holden (metal component milling and manufacture)
- Boeing (metal component manufacture, soon to be carbon fibre manufacture)
- Symex (commercial fats and proteins production)
- Herald and Weekly Times (newspaper printing)
- Crema Group (precast concrete manufacture)
- Independent Cement (cement production and precast manufacture)

Overview of approach

The Port Melbourne scoping study described here was the final phase of a broader project lead by researchers at the Institute for Sustainable Futures, University of Technology Sydney and undertaken for the Smart Water Fund. The Smart Water Fund was established by the Victorian Government and (government owned) Melbourne water retailers to encourage and support innovative development of water and biosolids recycling and water saving projects within the community. Preliminary stages of the broader project included a literature review of approaches to regional synergy identification (Kazaglis et al., 2007), presentation to stakeholders from government and industry to identify potential case study sites, and development of a systematic approach for prioritising potential case study sites across Melbourne. This approach sought to combine generic industry locations from the Australian Bureau of Statistics with generic input-output characteristics for industry types based on LCA software to identify sources and sinks for water and other materials. The approach did not work as the generic data available was too coarse to identify specific areas of opportunity and company level data was not readily available.

Rather, the selection of the Port Melbourne case study was made in consultation with the water utility who had been approached by companies in the area seeking to explore regional synergy opportunities. This in the end was most favourable as opportunities initiated by industry themselves have been found to be more successful than those initiated by governments or regional authorities (Heeres et al., 2004).

The details of the approach taken in this case study is shown in Figure 1. The scope of the investigation relates to identify water recycling opportunities between companies, rather than within companies or other on-site efficiency options (as these investigations are occurring through other programs lead by the utility).

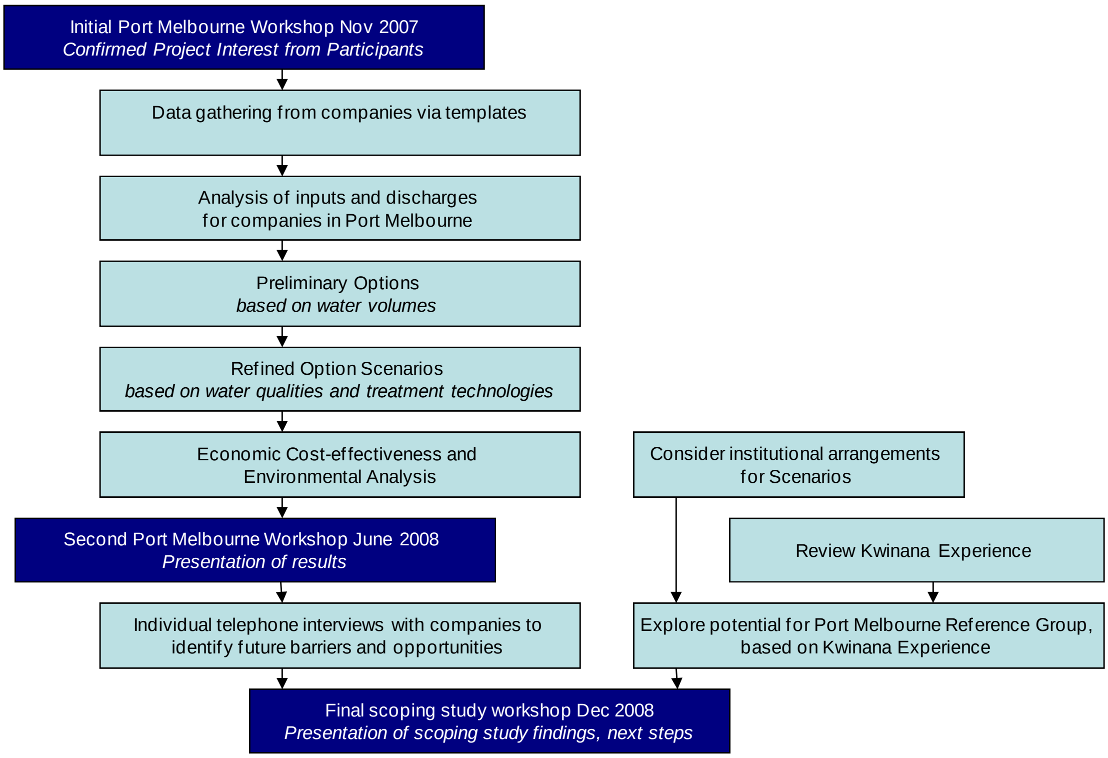


Figure 1: Overview of approach

Data gathering

Data on the water inflows, outflows and quality of discharges and required inputs was gathered from each of the participating companies using the following template shown in Figure 2.

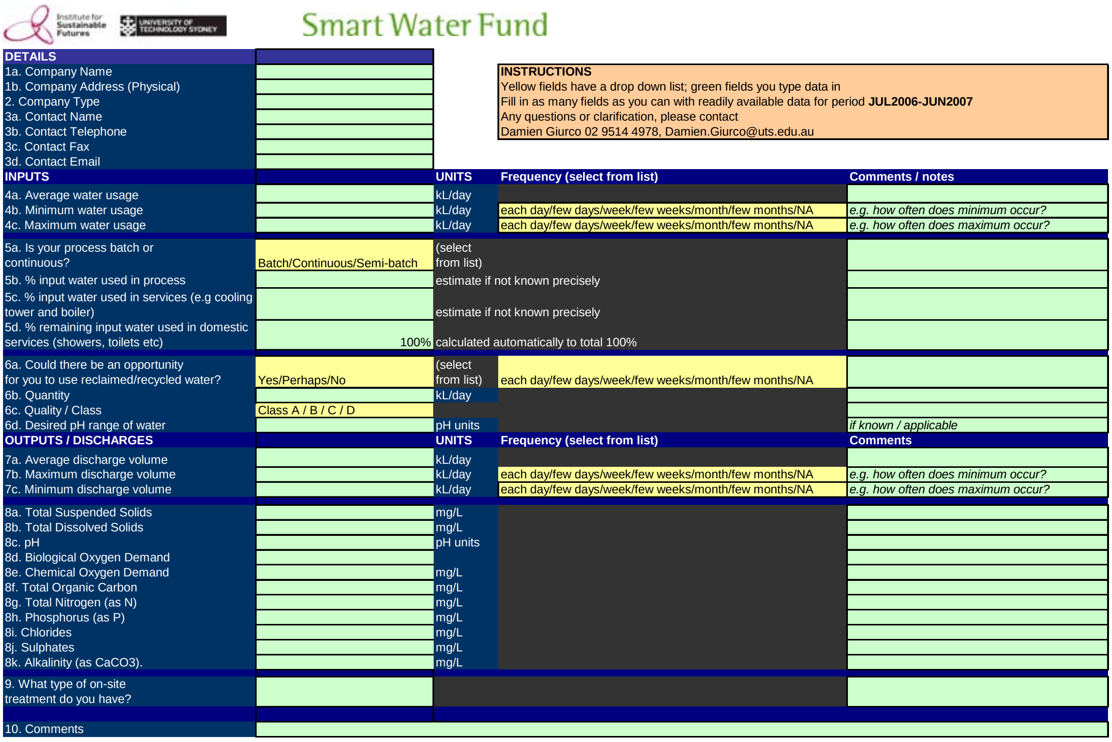


Figure 2: Template for gathering data from companies

The collected enabled a graphical mapping of potential water sources and sinks across the study area, based initially only on volumes. Inputs ranged from 5kL/day to 700kL/day and discharges ranged from 2kL/day to 400kL/day. Two broad classes of generalised options were then explored, the first having a centralised treatment facility involving all major companies and the second involving two individual companies, one acting as the source and the other as a sink.

Using the water quality data (initially to match discharge and required input pH) in addition to quantity data, detailed options were then developed, including required technologies and costs and are discussed further in the results section. The economics of each option, including capital and operating costs together with cost effectiveness analysis were performed.

Water reuse synergies identified in this paper are evaluated using a cost-effectiveness framework ($/kilolitre). Cost-effectiveness is the cornerstone of Integrated Resources Planning which has been advocated in the water and energy industries for comparing supply augmentation and demand reduction measures on an equal footing (Turner et al., 2008, White and Fane, 2002). Its use in this paper is twofold. Firstly, it is to rank the cost-effectiveness of the options developed on an equivalent basis. Secondly, it is used to compare the water reuse synergy options relative to other options such as efficiency and desalination which the utility could consider implementing in order to meet recycling and demand reduction targets whilst ensuring supply-demand balance in the longer term.

Initial environmental analysis was limited to energy intensity.

These draft options were presented to participating companies at a second workshop. Feedback at the workshop on barriers and drivers was followed up with individual discussions with companies and the experiences were compared with those of Kwinina, WA who have had experience in implementing regional water synergies. An important aspect of the Kwinana model was the central role played by the Kwinana Industries Council and consequently a similar industry-based reference group was proposed for formation amongst the Port Melbourne Companies following the conclusion of the scoping study to assist with further development of options and implementation.

The next section presents results of the options and technologies identified, their cost effectiveness as well as an introduction to barriers and opportunities.

RESULTS AND DISCUSSION

Technology options

Results for five water reuse options developed are presented in Figure 3. The major companies that were assumed to be sources of wastewater or sinks for reclaimed water are given in the figures for indicative purposes, and *other possible companies that could function in these roles are also given in separate boxes in italics in the figures*.

The benefits realised through development of these options are reduced potable water consumption from the mains supply, reduced discharge to sewer

Note that in calculating the quantities of water produced by each scenario the following assumptions were made:

- 9% loss in water volume due to sludge generation from the MBR treatment process
- 20% loss in water volume within the retentate / reject stream from an R/O process used to polish either part or all of the Class A water in some scenarios

The depiction in Figure 3 for MBR encompasses a treatment train of:

- Upstream anaerobic sludge blanket (UASB) pre-treatment stage,
- Aerobic activated sludge process to reduce BOD,
- Anoxic stage to reduce nutrient concentrations,
- Membrane bioreactor (MBR) +ultrafiltration stage to produce Class A reclaimed water, and
- UV disinfection stage to produce Class A water

The parameters for Class A water are shown below (EPA Victoria 2003). Class A water may be may be utilised for urban (non-potable) use with uncontrolled public access; agricultural use e.g. human food crops consumed raw or industrial use in open systems with worker exposure potential
Indicative objectives:

- <10 E.coli org/100 mL
- Turbidity <2 NTU
- <10 / 5 mg/L BOD/SS
- pH 6-9
- 1 mg/L residual chlorine(or equivalent disinfection)

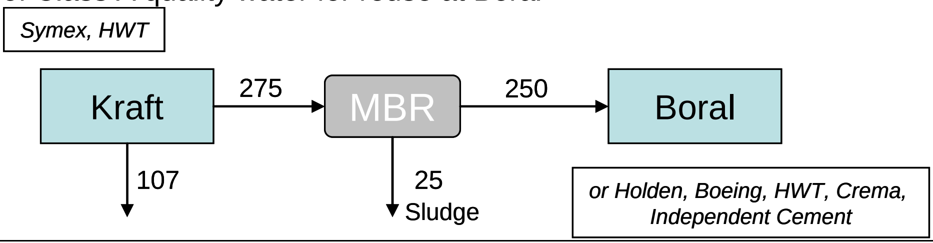
Tertiary and pathogen reduction with sufficient log reductions to achieve:

- <10 E.coli per 100 mL;
- <1 helminth per L
- <1 protozoa per 50 L
- <1 virus per 50 L.

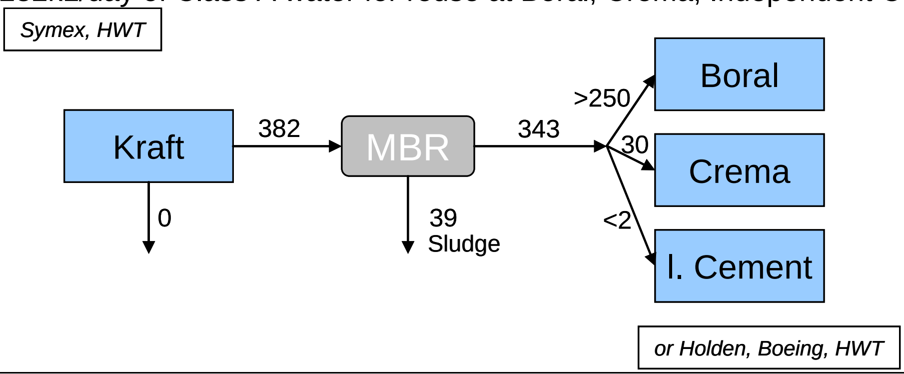
Where depicted in Figure 3, RO refers to the addition of a Reverse Osmosis treatment train to produce a higher than class A quality water (notably, it reduces the salt load).

Figure 3: Options for water reuse synergies in Port Melbourne

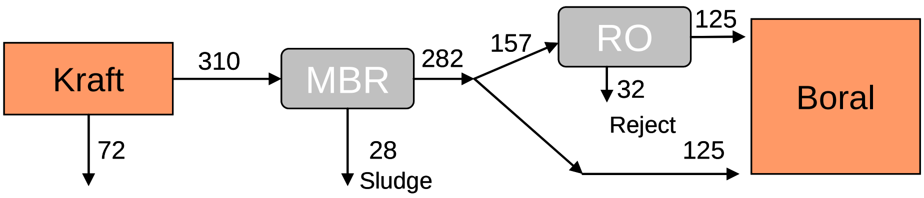
Option 1: Recover 275kL/day of wastewater from Kraft using MBR to produce 250kL of Class A quality water for reuse at Boral



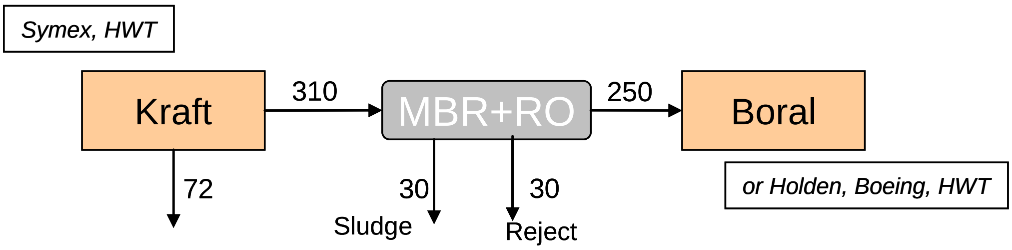
Option 2: Recover 382kL/day of wastewater from Kraft using MBR to produce around 282kL/day of Class A water for reuse at Boral, Crema, Independent Cement



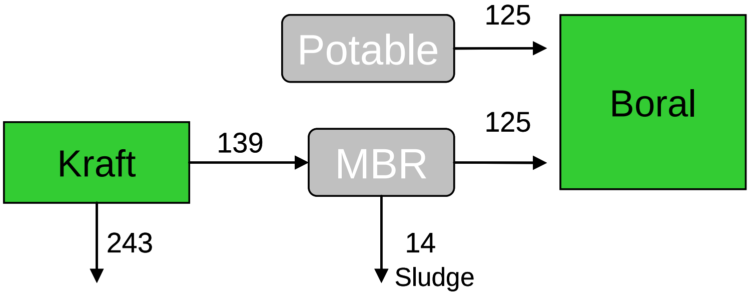
Option 3: Recover 310kL/day of wastewater from Kraft using MBR and R/O on 50% of the MBR Class A product stream, to produce 250kL/day of lower-salt water for reuse at Boral



Option 4: Recover 343kL/day of wastewater from Kraft using MBR and R/O polishing of the entire Class A stream to produce 250kL/day of very high quality water for reuse at Boral



Option 5: Recover 175 kL/day of wastewater from Kraft using MBR and 50% potable water dilution to generate 250 kL/day of low salt water for use at Boral



Assumptions, capital and operating costs, cost-effectiveness, energy intensity
The assumptions made in the economic analysis are given below:

Cost elements included:
- Treatment plant capital costs (including plant construction, equipment, and balance tanks)
- Operating costs (including energy costs, trade waste costs)

Cost elements excluded:
- Costs of land acquisition were excluded and could be significant
- Pipeline costs; deemed not significant

Treatment plant construction and operation:
- The major structural elements of the plant are designed and constructed for a minimum of a 20 year life span (economic modelling done for 10 year time frame)
- Membranes on the MBR will require replacement at 3-5 years while R/O membranes if installed may require replacement at 1-2 years
- Other operating equipment such as pumps, blowers, diffuser membranes, valves will need regular maintenance and have life spans of around 5 years
- Plant construction could be completed within a 12 month time frame
- Plant operates for 300 days/year

Water input charges and energy tariffs:
- Current water tariff assumed to be A$1.00/kL, and water and trade waste tariffs increasing at 14.8% p.a. from 2009-2013 (confirmed) and assumed 5% p.a. increase into future beyond 2013
- Water prices charged for reclaimed water are assumed to be 85% of potable water prices to provide an incentive for companies to purchase the recycled water[FOOTNOTE TEXT] The marginal cost of supply under a water recycling option at the site is probably not currently competitive with potable water supply charges. However water prices in Melbourne are increasing by 14.8% p.a. over the next 5 years and by 2013 when retail water tariffs are forecast to be $1.70/kL this type of option will become more financially viable. However to ensure that there is a financial incentive for companies to purchase recycled water over the life of the project, the recycled water prices should be similar or less than potable water tariffs. [END FOOTNOTE]
- Energy tariff assumed to be 10c/kWh and forecast as fixed into future, this is likely to be an underestimate as energy prices would be expected to rise under a Carbon Pollution Reduction Scheme.

Economic analysis:
- 7% discount rate
- Forecast horizon for plant operation was 10 years (beginning 2009)
- Straight line depreciation (10% p.a.) of assets over forecast horizon
- Note: two Australian dollars is approximately equivalent to one Euro (2AUD=1EUR)

Table 1: Capital and operating costs, cost effectiveness and energy intensity

Option	Approx. capital cost (AUD)	Approx. operating cost (AUD/yr)	Cost effectiveness (AUD/kL)	Energy intensity (kWh/kL)
1	$2 500 000	$420 000	$9/kL	15.4
2	$2 700 000	$550 000	$8/kL	15.0
3	$2 700 000	$570 000	$14/kL	19.2
4	$2 800 000	$730 000	$18/kL	28.1
5	$2 700 000	$490 000	$27/kL	15.4

Table 1 shows similar capital costs for all options, but increased operating costs for options 3 and 4 involving reverse osmosis. The cost effectiveness is also higher for options 3 and 4 involving reverse osmosis than for 1 and 2 which use MBR only. Option 5 has the highest cost per kL water as it also includes the purchase of potable water for diluting the final salt content of the recycled water.

In comparison with a range of water demand and supply options, water recycling options can be (and in this case are) expensive, particularly due to the limited size of the recycling facility. Were the facility to be larger, greater economies of scale could be realised, thereby reducing the unit cost. For example, efficiency options for saving water can vary between $0.20/kL to $1.00/kL, and desalination can vary between $2/kL to $5/kL. The usefulness of using a cost effectiveness frameworks is to raise the question of whether the utility would pay for this activity as a water saving measure when it can save or supply water more cheaply with other options. The options developed are not self sufficient from a cost perspective as outlined later and hence would not be implemented by companies in the absence of financial assistance. There are also regulatory barriers to the companies themselves acting as third party water suppliers/recyclers.

The MBR options (options 1, 2 and 5) generate a unit energy demand of approximately 15 kWh/kL of wastewater treated, and option 4 which is 100% RO approximately doubles this energy demand to 28 kWh/kL. The current average energy intensity of water supply, distribution, pumping and treatment across Victoria is approximately 0.87 kWh/kL, and therefore this water recycling option will be highly energy intensive relative to catchment-based supplies and also compared to unit energy intensities reported for recent desalination projects across Australia. This could result in an increased energy demand of up to 1,100-2,300 MWh/a for a 250 kL/day plant, or 1,500-3,000 MWh/a for a 340 kL/day plant. Depending on the greenhouse intensity of electricity used to power the treatment facility , this could produce greenhouse gas emissions of between 1,500-3,000 t/a or a 250 kL/day plant, or 2,000-4,000 t/a for a 340 kL/day plant.

With the impending implementation of an Australian Carbon Pollution Reduction Scheme (CPRS) it is likely that energy prices will increase due to a carbon cost component being passed onto consumers through increased energy tariffs and this could reduce the financial viability of a water recycling scheme.

In order to mitigate the significant additional energy and greenhouse costs of this type of scheme, various energy options should be investigated and concurrently implemented. These could range from energy recycling among the group of companies at the site including recycling of waste heat, utility sharing of cogeneration capacity and boilers which are currently underutilised at various companies, installation of solar power to supply or augment energy for the treatment plant, or purchase of Green Power to supply the energy for the scheme. Overall, it will be essential to consider the energy implications of future options in addition to potable water savings.

Cumulative cash flow after ten years is given in Table 2. None of the options are cash flow positive after ten years time unless some form of financial support is offered to the companies for implementation. The form of support outlined in the table is ‘0% interest on loan’ and an AUD 2 000 000 capital grant.

Table 2:Cumulative cash flow after 10 years (negative figures bracketed)

	Cumulative Cash Flow after 10 years ($million)	
Option	**All capital costs loaned at 0% interest**	**$2m capital grant & 10% interest on remaining loaned funds**
1: 250kL/day output MBR, one-to-one (Kraft-to-Boral) or many-to-many	$450 000	$1 400 000
2: 282 kL/day output MBR, one-to-many or many-to-many	($210 000)	$1 100 000
3: 250 kL/day Kraft to Boral 50% MBR and 50% RO higher quality water than MBR only	($1 100 000)	$300 000
4: 250 kL/day Kraft to Boral 100% RO, one-to-one (Kraft-to-Boral)	($3 800 000)	($5 400 000)
5: 250 kL/day (50% MBR recovered, 50% potable), one-to-one (Kraft-to-Boral)	($1 100 000)	($2 600 000)

Obtaining financial support for the project is a barrier, though not insurmountable – the capital sums are modest and government and utilities are spending significant amounts on water saving initiatives as the system storages for the rain fed system in Melbourne sit below 30% (desalination is committed but yet to be built). The larger question of whether financial support is warranted remains (relative to other activities which could be pursued to save water). The answer is – it depends – to a large part on the other (including non-financial) barriers and opportunities which such a project contains. These barriers and opportunities in the Port Melbourne context are now discussed.

Barriers and opportunities for water reuse synergies in Melbourne

The challenges of rising water prices and trade waste prices act to make water recycling opportunities more cost-competitive with the price of water from the mains, however as Australia moves to implement a Carbon Pollution Reduction Scheme, then the augmented energy requirements of a recycling scheme will impose an additional cost. A summary of drivers for water reuse synergies in Melbourne and their implications for this study are given in Table 3.

Table 3: Summary of context

Item	Description	Implications for study
Central Region Sustainable Water Strategy and Water supply-demand strategy for Melbourne 2006 - 2055	The Victorian Government has set short-term water conservation targets for the Central Region: - 25% reduction (from 1990s level) in overall and residential per capita drinking water use by 2015; 30% by 2020 - at least 1% annual reduction in current water consumption in the non-residential sector	Contributions to reducing potable water consumption and consumption in the non-residential sector will assist in meeting targets. The current recycled water target for Melbourne is 20% by 2010.
Water price increases	Due to water scarcity and also commitment to desalination as a response, water prices are rising significantly over next 5 yrs	Securing a local water supply through recycling becomes more cost-competitive
Trade waste review	Being conducted by Department of Sustainability and Environment and may lead to new charges for trade waste, particularly relating to metals	Potential of increased trade waste charges provides further incentive for recycling between industries
Carbon Pollution Reduction Scheme	Carbon intensity of options will have a future cost	Favours water efficiency options over recycling which is more energy intensive Promotes use of cleaner energy sources including cogeneration
Proximity to city	Land use in Port Melbourne is changing with less heavy industry and more commercial / light industry	Consider current and future configuration of land uses in study
Melbourne Water Sewage Strategy 2060	Role of centralised and decentralised infrastructure for Melbourne being re-examined	Consider localised water treatment facility in Port Melbourne within wider network

The last point envisages a greater role for localised water treatment plants, given that these will need new governance models and institutional arrangements, implementing such a project as the options discussed could provide a pilot case to resolving such issues. Individual companies have their own views and stakeholder interviews were undertaken to assess their individual barriers and opportunities. These are explored further in the next section and contrasted with those presented by companies in the Kwinana Industrial Area where there is a history of successful implementation of water, utility and material synergies.

Barriers and Opportunities – comparison between Port Melbourne and Kwinana Industrial Area (KIA)

Valuable lessons can be learned from regional synergy experiences in Kwinana. The diverse range of identified barriers and opportunities at KIA is contributed to the long lasting cooperation between companies, facilitated by the Kwinana Industries Council (KIC) which addresses a broad range of issues common to the industries in the area. KIA is recognised as best practice example in implementation of regional synergies, characterised with its maturity, number of resource exchanges and the diverse blend of key processing and manufacturing industries (van Beers et al., 2007).

Table 4 below presents the major barriers and opportunities for both industrial areas. Although not all drivers, barriers, and trigger events listed in the table can be discussed in detail some specific examples from Kwinana are provided below to illustrate each of the main categories. The listed barriers and opportunities for KIA refer to the whole range of regional synergies (by-product and utility) and these are defined as a result of the in depth study carried out at Curtin University of Technology, WA, since 2004 (van Beers et al., 2007). On the other hand the limited number of identified barriers and opportunities for Port Melbourne became apparent from the scoping study discussed and are limited only to potential water synergies. As can be seen from the table, whilst some barriers and opportunities are similar (corporate social responsibility within companies), there are differing region-specific issues.

Table 4 Barriers and Opportunities for Regional Synergies

Kwinana Industrial Area		Port Melbourne	
Barriers	**Opportunities**	**Barriers**	**Opportunities**
Economics			
• Relatively low price for utility resources discourages recycling • Relatively low costs for waste disposal	• Increased revenue • Secure availability and access to vital process resources	• Higher unit cost ($/kL) for recycled water than efficiency or desalination due to limited size of recycling plant	• Water price security – lock in price for recycled supply to insulate against further rises in mains water charges
Information availability			
• Confidentiality and commercial issues	• Strong industry organisation • Local and regional studies have been undertaken	• Uncertainty around quality tolerances for input water required	• Sharing information may identify further synergies (not water)
Corporate social responsibility and business strategy			
• Core business focus • Community engagement and perception	• Corporate sustainability focus • Community engagement and perception	• Cultural challenges within a company	• Corporate sustainability focus
Region specific issues			
• Distance between companies inhibits synergies	• Major new project developments provide opportunities for new synergies	• Changing industry presence in area (less heavy industry) • Some companies located 1.5km from main cluster of companies • Limited land availability	• Water scarcity encouraging a range of water saving options to be explored • Expansion development
Regulation			
• Existing environmental regulations	• New pollutant targeted regulations (e.g. carbon tax and mandatory energy audits)	• Third parties (other than government utility) cannot sell recycled water to companies in Victoria	• Trade waste review could raise costs for discharge and encourage recycling
Technical issues			
• Availability of (reliable) recovery technologies	• Major brownfield development within company	• Water quality requirements for receiving companies • Perceived water quality and health and safety risks of recycled water	• Opportunity to link with cogeneration on site • Water reuse synergies versus on-site efficiency?

Economics

<u>Operational costs and revenue as synergy opportunity:</u> Whilst the Port Melbourne water reuse synergy would only be viable with financial subsidy, in Kwinana, successful synergy projects must make good business sense, through a combination of lower input costs, lower operational costs and/or increased revenues. One of the recently identified synergies in Kwinana features a mineral processing plant that produces an effluent stream containing a small fraction of hydrocarbons. The plant's water treatment is not designed to treat hydrocarbons so this effluent is currently disposed as waste at very high costs. The BP refinery wastewater treatment plant is especially designed to target hydrocarbons. The oily wastewater could be trucked to the oil refinery. The two companies are working on the operational arrangements (e.g. contracts) at present.

<u>Resource scarcity as an economic opportunity:</u> A number of utility synergies have come to fruition because of concerns for continued access to a vital resource for running the business. The development of the Kwinana Water Reclamation Plant (KWRP) was triggered to accommodate the establishment of HIsmelt which was unable to secure another source of large volume process water. In contrast in Port Melbourne, the concern was not over access to the water resource, but rather to water price security, meaning that by linking with the water reuse synergy, a fixed price may be negotiated thus avoiding planned future price rises in the mains supply.

Information availability

Local and regional studies as synergy opportunity: While some synergies were happening it took an external study to review and document regional resource flows and synergy opportunities to trigger broader industry interest and commitment for industrial symbiosis. In Kwinana, the regional economic impact study was coordinated by the Kwinana Industries Council and financially supported by the Commonwealth and state government. It revealed the exponential growth in the industry integration in the area over the 1990s, and suggested many more exchanges would in principle be possible. Similarly this scoping study undertaken in Port Melbourne has identified further potential for co-generation in the area and implementation of a water reuse initiative could be used as a vehicle for closer collaboration amongst companies to realised synergies with energy and other materials. The barrier to this occurring is that if the water utility (or government) subsidises the initial synergy, it is unlikely to directly reap benefits of future energy or material exchange synergies.

Corporate social responsibility and business strategy

Community engagement and corporate sustainability as synergy opportunity: Kwinana is increasingly subject to urban encroachment and resulting higher community expectations, with regard to environmental and safety performance, and overall amenity. Kwinana is located on the shore of the Cockburn Sound, a sensitive marine environment and recreational area for local residents. The opportunity to transfer the discharge of treated process wastewater from the coastal area into the deep ocean outlet as part of the KWRP project was therefore an important consideration for local companies. In Port Melbourne, high-rise urban development is occurring at Docklands located adjacent to Port Melbourne and overlooks the company sites. In keeping with the desire to be good corporate citizens, several Port Melbourne companies are interested in pursuing a 'green icon' project for the region and this could act as a trigger for strengthening relationships with the local communities and amongst neighbouring companies. However, if recycled water were to be such a project, it would need to be linked with a clean energy source due to the increased energy intensity of the process compared with mains water.

Core business focus as synergy barrier: The emphasis of site personnel is to devote their efforts to core business activities resulting in potential missed synergy opportunities unless there is an overwhelming commercial benefit. This is recognised by various site personnel who see one of the main aims of the regional synergies research is to identify and progress synergy opportunities, which are unrelated to core business. In Port Melbourne this is less a concern as the utility would be the owner and operator of the plant.

Region-specific issues

Major capital projects as synergy opportunity: This can include new operations or significant capacity expansion projects in existing operations. In Kwinana, two new industrial facilities have been built and commissioned in 2004 (Kwinana Water Reclamation Plant and HIsmelt direct reduction iron making plant). The HISmelt plant will be able to source a number of inputs locally in the Kwinana area, such as lime, lime kiln dust and treated wastewater and provide outputs with potential for reuse in the KIA, such as slag and gypsum. HIsmelt triggered the undertaking of the Kwinana Water Reclamation Plant (KWRP) as the groundwater allocation for the area had already been licensed to the existing industries and there was limited availability of catchment (scheme) water in Perth Metro. In Port Melbourne there are no major heavy industrial customers coming to the region, rather there are more light industrial and commercial companies moving to the area.

Distance between companies as synergy barrier: For the recovery and reuse of process energy and water the distance between involved operations does make it more complicated than just transferring a by-product across a boundary fence to a neighbouring operation. In Port Melbourne, this may favour a direct exchange between neighbouring companies rather than a centralised treatment plant which would need to cross many major roads.

Regulation

Environmental regulations as synergy barrier: Kwinana companies are experiencing obstacles in obtaining governmental approvals for use of alternative fuels and materials (although not water). Although some by-product synergies appear techno-economical feasible and have a positive sustainability impact (e.g. alternative fuels in cement kilns, and use of bauxite residue for soil conditioning), their practical implementation have been halted by uncertainties in the legislative framework, in particular with regard to the final responsibility for approved reuse options, and community concern. Additionally, if a by-product is classified as a controlled waste (for example fly ash), strict transportation procedures and requirements apply. In Melbourne (and hence Port Melbourne) there is currently not provision for private operators to sell water (nor recycled water). This presents a barrier to an industry owned and operated plant, however, it is not the core business of the companies involved and their interest in establishing a plant as a revenue generating centre is limited – the business proposition is not favourable enough. Hence the most likely scenario would be for the government owned utility (South East Water) to own and operate the plant. The situation for private players entering as water retailers in Melbourne may change in future, however the Port Melbourne case study is unlikely to motivate such a change in legislation. By way of comparison, the state of New South Wales has recently enacted the *Water Industry Competition Act (2006)* allowing third parties to become licensed water retailers and local councils in Sydney to sell water. The success of this legislation as it becomes tested would provide useful input to any Melbourne-based proposals seeking to adopt a similar approach.

Technical issues

Technical obsolesce of existing process equipment as synergy opportunity: The Kwinana Cogeneration Plant is located on land of the BP oil refinery, and produces all process steam for the refinery, and generates electricity for BP as well as the grid. The cogeneration plant is fired with excess refinery gas from the oil refinery supplemented with natural gas. The cogeneration plant built in 1996, substituted both BP steam boilers that were in need of replacement at the time. This synergy is estimated to have saved the refinery in approximately 15 million AUD in capital expenditure while ensuring a cost competitive reliable source of steam and electricity for their refinery. In addition BP provides process water to the cogeneration plant and accepts their wastewater stream. Similar co-generation opportunities were identified in Port Melbourne, but not in detail.

Role of regional synergies versus on-site efficiency: A key consideration for water reuse synergy projects is how recycling waste water for use at an adjacent site affects the pursuit of future water efficiency opportunities on site (which are very cost effective). Once a recycled water plant had started operation, reductions in water discharges to feed the plant (and increases in pollutant loads) would affect the viability of the recycled plant. Whilst an important consideration for water reuse synergies in Port Melbourne, this is less of a concern for other material exchanges in Kwiniana where by-products from some processes currently have no other uses and any reuse opportunity is beneficial.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

This paper has provided an overview of the Port Melbourne scoping study of water reuse opportunities. The technologies and costs associated with five water treatment options show that all are technically viable using proven technologies, however further pilot testing of input water quality would be required for receiving plants. All options require a financial subsidy to be viable and there is the potential to secure such assistance from the government and utilities. The use of a cost effectiveness framework to evaluate options shows that the $/kL increases with smaller plant size and also with the use of Reverse Osmosis technology (in addition to MBR technology). The pilot trials of whether the output quality from MBR options is sufficient for use directly as a process input would shape the final choice. The cost effectiveness metric also allows a broader comparison with other options open to the utility to realise water savings and shows reuse at Port Melbourne to be more costly than water efficiency and large scale desalination. In addition to describing options, the authors have emphasised the process by which the options are developed as successful implementation examples from Kwinana have shown the central role of establishing trust amongst participating stakeholders and for this reason the participating companies in Port Melbourne agreed to meet independently following the facilitated scoping study project as an Industry Reference Group.

The range of barriers and opportunities identified and compared between Kwinana and Port Melbourne will be of interest to others seeking to implement reuse synergies and underlines the need to asses local context as several barriers differ markedly.

Future work should focus on the energy implications of water reuse synergies and explore co-generation and tri-generation. Further research is required within the industrial ecology community to ascertain when and at what scale reuse synergies should be pursued and when and at what scale efficiency should be prioritised, and how this varies for water, energy and other materials.

Given the benefits of contrasting Kwinina and Port Melbourne experiences, further efforts could usefully be undertaken to establish a network of regional industry councils (e.g. Gladstone Area Industry Network, Kwinana Industries Council, Geelong Manufacturing Council) for sharing lessons and implementation strategies.

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