City of Melbourne

10 May 2010

Southbank Sustainable Utilities Study

Meeting Eco-City Targets in the Southbank Structure Plan

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Prepared for

City of Melbourne

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Executive Summary

The City of Melbourne (CoM) developed a Structure Plan for the Southbank precinct to illustrate a proposed structure and layout for future development of the precinct. The plan indicates how CoM proposes to promote development by providing a framework to guide the consideration of development proposals. To ensure the plan's objectives are achieved while minimising environmental and social impacts, AECOM was commissioned to establish a sustainable utilities strategy to support resource use reduction and generation.

The sustainable utilities strategy provides an approach to infrastructure design at the precinct level to reduce resources consumed within Southbank. The strategy feeds into and shapes the Structure Plan, to deliver and build on existing environmental polices established by CoM.

Proposed development of the Southbank Structure Plan

Southbank is in an ideal position to deliver the goals of Future Melbourne and a new urban paradigm that will establish the city as a world leader in sustainable living. Southbank currently has a poor public realm with a lack of activity and vibrancy, unsustainable buildings and a lack of human scale and civic quality to the built form. The following strategies address these issues and provide an alternate future for Southbank. The key strategic recommendations from the Southbank Structure Plan are to:

- provide three new activity nodes that can provide focal points of new commercial, retail and community infrastructure development
- position Southbank as the natural extension of the City, creating an intensified area of mixed use activity and establishing the Yarra River as part of the city's centre, not its edge
- establish new built form controls that deliver human scaled built form, activated streets and improve the quality of the public realm
- stitch together the northern and southern areas of Southbank by decking above the circular exit ramp onto Power Street (over the void) with new development to create a connected and continuous mixed use area
- deliver key public realm initiatives of the Southbank Structure Plan and establish two new large parks within the area
- establish City Road, Southbank Boulevard, Power Street and Coventry Street as key pedestrianised east-west routes, and Clarendon Street, Queensbridge Street, Kings Way and Sturt Street as key pedestrianised north-south routes
- deliver buildings that have a high environmental performance
- establish mechanisms for the delivery of sustainable servicing initiatives, including distributed energy generation and water reuse.

Opportunity

Southbank has several characteristics which makes it suitable for the generation of natural resources. Some, like the wind, sun, Yarra River and an aquifer, are naturally occurring. Others, such as car parks, roads, stormwater drains, landfill waste and wastewater, are the result of human activity. Each of these, if harnessed in the most viable method, will minimise the ecological impact of servicing the needs of the residents and employees within the Southbank precinct. The different sources that can be harnessed and the resources they can generate include:

- utilising the sun and wind to generate renewable electricity
- using the Yarra River as a means of generating potable water and as a heat sink
- storing water during the wetter seasons of winter and spring in the underground aquifer, which can then be extracted and used during the drier seasons
- planning for car parks to become energy hubs in the future (cars are only actively utilised for eight percent of their life; electric vehicles can be recharged by the grid and provide power back into the grid when idle and at times of peak electricity demand)
- providing fit for purpose water use through recycling waste water to reduce potable water consumption
- using the main Melbourne sewer drain as a heat sink
- recovering solid waste on site for recovery and reuse within the precinct
- composting biodegradable waste and applying it to land as a soil conditioner, while burning any biogas generated via a CHP system to provide heat and electricity
- providing recycled water within and outside the precinct by installing a dual pipe system to supply surrounding parklands and new developments.

Sustainable Utilities Strategy

The Sustainable Utilities Strategy for Southbank locates systems and technologies which are suitable for a technology to operate so resources for the precinct can be generated. As the capacity of some systems cannot provide continuous supply and will struggle to deal with fluctuations in demand, the approach involves a combination of micro and centralised resource generation. The selection of a sustainable utilities strategy is based on the specific benefits and constraints of each system, and the site based opportunities to reduce and generate resources. The elements of the sustainable utilities strategy include:

- establishing three Central Services Hubs (CSH) to provide the essential infrastructure required to capture, treat, generate and deliver resources throughout the precinct These could include:
  - the generation of heat, coolth and electricity from a tri-generation plant that uses gas as the fuel source
  - the distribution of hot, cold and recycled water pipes
  - the treatment of sewage to and reticulation of Class A water (recycled water)
  - the collection and treatment of stormwater for reticulation as hot water (potable water)
  - feeding generated electricity into the grid
  - heat rejection via the Melbourne Main sewer
- constructing a combined services tunnel under existing road corridors to enable the installation of a network of service pipes and conduits to distribute the resources generated by the CSH, involving separate recycled, hot and cold water pipes
- installing micro-wind turbines and photovoltaics on existing infrastructure and new buildings to generate renewable electricity
- storing storm water in a network of underground distributed units that can send water on demand, using an intelligent network, to the CSH for treatment and reticulation throughout the precinct via the services tunnel for hot water supply
- converting car parks into electricity generators

- recovering of solid waste to provide heat, electricity and fertilizer
- increasing green space by expanding parklands, landscaping and roof top gardens will reduce the urban heat island affect, improve visual amenity and wellbeing, increase biodiversity and improve the quality of storm water run-off.

A schematic diagram showing the proposed location of these initiatives across the precinct is presented in Figure 1.

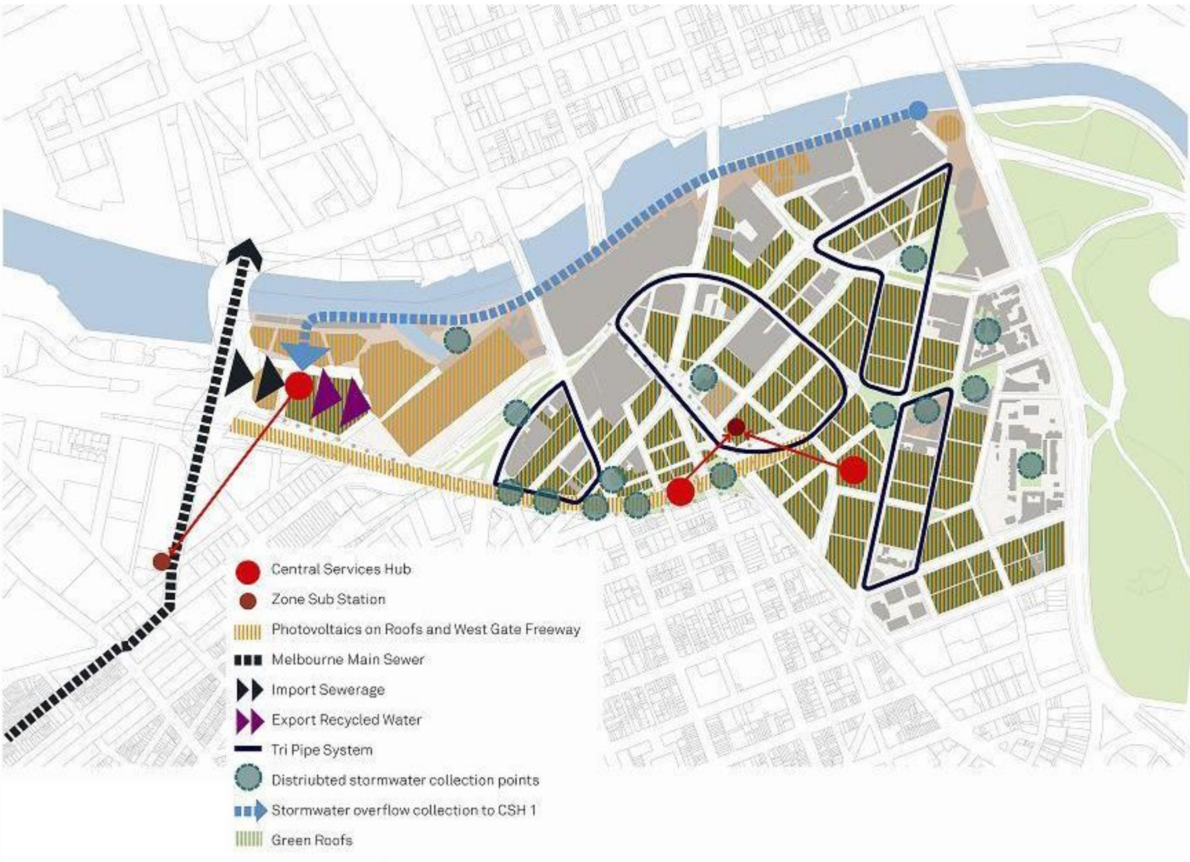

Figure 1 Schematic diagram of the proposed integrated sustainable utilities strategy for the Southbank precinct

Source: AECOM, 2010

A systems diagram of the sustainable utilities strategy presents the inputs and outputs of the system, depicting how resources are drawn into the precinct at the central hub, in open space and within the built form. Within these three modes, resources are generated to create treated water (potable and non-potable), thermal energy (chilled and hot water), electricity, green space and fertiliser. A systems flow diagram of the sustainable utilities strategy is presented in Figure 2.

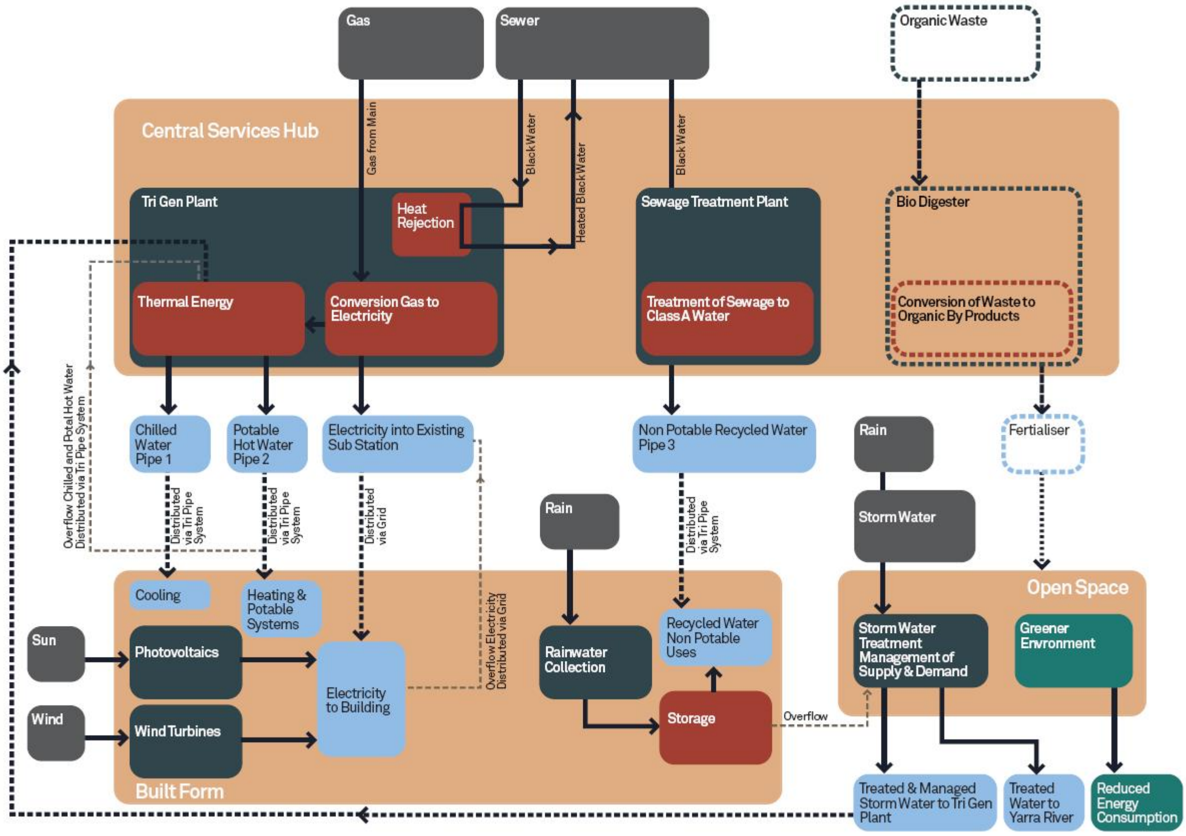

Figure 2 **Systems of the proposed integrated sustainable utilities strategy for the Southbank precinct**

Source: AECOM, 2010

Recommendations

At present, the regulatory barriers governing the supply and distribution of utility services do not support the implementation of the proposed sustainable utilities strategy. To realise the concept, CoM needs to take on a stewardship role to drive the realisation of the sustainable utilities strategy. It is recommended that CoM integrate the strategy into the next stage of development, by undertaking a feasibility study in collaboration with the relevant utility companies.

Implementation of the sustainable utilities strategy will support meeting all Future Melbourne eco-city goals. To bring about a sustainable vision for Southbank it is recommended that CoM:

- adopts the sustainable utilities strategy as part of the Southbank Structure Plan
- undertakes a feasibility study to further develop the strategy
- takes the lead role in further developing and driving this strategy forward
- establishes an Implementation Review Committee comprising representatives of Council, Department of Planning and Community Development, utility companies and other relevant key stakeholders as determined by CoM.

1.0 Introduction

1.1 Background

Cities consume significant quantities of resources and have a major impact on the environment, well beyond what can be managed within their borders (Melbourne Principals for Sustainable Cities, 2002). Such trends are unsustainable and need to be reversed so cities are capable of providing and managing the resources they consume. Achieving sustainable outcomes in cities will provide a significant step towards a sustainable future. This study supports the Structure Plan for Southbank by exploring potential strategies to address the sustainable servicing of new and existing developments within the precinct. This study also assists in the implementation of a number of the CoM sustainability policies in the Structure Plan for Southbank, these include:

- *Zero Net Emissions*
- *1,200 Buildings Program*
- *Climate Change Adaptation Study*
- *Total Watermark*
- *Future Melbourne Eco-city.*

For Southbank to be a vibrant, attractive and self-sustaining major arts, retail, residential and business precinct, which is better able to service the needs of the community, the future development of Southbank needs to be resource efficient and adapted to climate change.

The sustainability vision for CoM is captured in Future Melbourne Eco-city, which seeks to create a city that prospers within the Earth's ecological limit. Measurable targets have been established to guide and direct the achievement of the five objectives of this policy.

The Structure Plan for Southbank will set out the structure and layout of future development in the precinct. To incorporate this study as part of Southbank's Structure Plan, CoM commissioned AECOM to establish a framework for achieving a sustainable service infrastructure in Southbank focusing on the supply, consumption and capacity of resources

1.2 Future Melbourne and Eco-city

Future Melbourne is the community's vision for the management, development and direction for the city to 2020 and beyond (CoM, 2008a). It replaces the existing strategy contained within City Plan 2010, and builds on Council's vision for Melbourne as a 'thriving and sustainable city'. The success measures of achieving this vision are outlined under six headline goals, one of which, making Melbourne an Eco-city, forms the guiding philosophy and sets the target for this study, the Southbank Sustainable Utilities Study.

Future Melbourne Eco-city seeks to reduce the municipality's ecological footprint and adapt to a changing climate to ensure a:

- healthy environment
- high quality of life
- growing economy.

The key Future Melbourne Eco-City targets and objectives are outlined in Table 1.

Table 1 The key Future Melbourne Eco-city objectives and targets the sustainable utilities strategy seeks to meet

Eco-city Goals	Targets and Objectives
01. Zero net emissions city	
Emissions reduction per resident	35% on 2005/06 levels by 2020
Emissions reduction per employee in the commercial sector	59% on 2005/06 levels by 2020
Existing office buildings retrofit (1,200 buildings)	70% of existing (2008) commercial office buildings by 2020
City of Melbourne purchase of renewable energy	50% by 2010
Increase of people who use public transport, cycle or walk to work in the central city	90% by 2020
02. The city as a catchment	
Potable water consumption per employee	50% reduction based on 1999/00 levels by 2020
Potable water consumption per resident	40% reduction based on 1999/00 levels by 2020
Potable water consumption by Council	90% reduction based on 1999/00 levels by 2020
'Absolute' water saving	25% reduction based on 1999/00 levels by 2020
Alternate water sources for Council's water needs	Source 30% by 2020
Alternate water sources for non-Council land managers' water needs	Source 9% by 2020
Total suspended solids in stormwater system	20% reduction based on 2000 levels by 2020
Litter reduction on Council and non-Council land	30% reduction based on 2000 levels by 2020
Phosphorus reduction	20% reduction in total phosphorus based on 2005 levels by 2020
Nitrogen reduction	35% reduction in total nitrogen based on 2005 levels by 2020
Waste water reduction	30% based on 1999/00 levels by 2020
03. Resource efficient	
Reduce household waste in the city	5% reduction by 2012 (as approved for the Waste Implementation Plan 2009-2012)
Reduce commercial waste in the municipality	Targets to be developed
Recycling and waste collection more economic	Targets to be developed
04. Adapted for climate change	
Manage climate change risk to and adaptation of municipality	Innovative and productive climate adaptation solutions tailored specifically to the municipality and which make a measurable contributions to greenhouse gas mitigation
05. Living and working in a dense urban centre	
Proportion of people who live and work in the municipality	65% by 2020
Total amount of green space in the municipality	Equitable distribution and investment in trees
Number of city users (including residents) per hectare of parkland	1500 per hectare
Proportion of fresh food consumed locally but grown within 50km of the municipality.	30% increase by 2020

Source: City of Melbourne, 2009

1.3 Scope and objectives of the study

The sustainable utilities study identifies opportunities that will contribute towards delivering the objectives of the Future Melbourne Eco-City goals. This analysis is focused on the electricity, gas, water supply, stormwater and sewer 'service mains' that form the backbone of the utility services network. The study examined the interaction of the utility infrastructure, the systems they connect into, and technologies used to reduce resource consumption within Southbank.

While behaviour change and efficient building design are critical elements in realising Southbank as a sustainable precinct, they are considered outside the scope of this work. Promoting behavioural change among individuals involves promoting the benefits of change, encouraging people to change, establishing new community norms, removing barriers to the desired change, and making it convenient for people to maintain the new desired behaviours. These considerations need to be incorporated into the design and planning phases of the Southbank precinct so the desired sustainable behaviours become a natural consequence of development.

While the majority of streets have smaller reticulation mains that service each individual property, that level of detail is beyond the needs of this investigation. The study investigated available technologies that are less polluting, use resources in a sustainable manner and will recycle more waste or products than current utility supply systems.

The objectives of this study were to:

- support and inform development of the Southbank Structure Plan in relation to the provision of sustainable utilities
- develop a strategy to influence and guide the development of the Southbank Structure Plan that embraces the strategy of Future Melbourne's Eco-City targets
- explore innovative options restricted by perceived institutional challenges
- look beyond the boundaries of Southbank for opportunities involving neighbouring precincts.

1.4 Structure of the report

This sustainable utilities study is structured as follows:

- Section 2 – Sustainable utilities strategy
- Section 3 – Assessment of sustainable utilities strategy against Eco-city
- Section 4 – Methodology
- Section 5 – Constraints and opportunities at Southbank
- Section 6 – Design options
- Section 7 – Implementation strategy
- Section 8 – Recommendations.

2.0 Sustainable Utilities Strategy

The Sustainable Utilities Strategy provides an approach to infrastructure design at the precinct level to assist in reducing resources consumed within Southbank. The strategy feeds into and shapes the Southbank Structure Plan, to deliver and build on a number of existing environmental polices established by CoM. Refer to section 1.1 for an overview of these policies.

The systems diagram of the sustainable utilities strategy presents the inputs and outputs of the system, depicting how resources are drawn into the precinct at the central hub, in open space and within the built form (see Figure 3). Within these three modes, resources are generated to create treated water (potable and non-potable), thermal energy (chilled and hot water), electricity, green space and fertiliser.

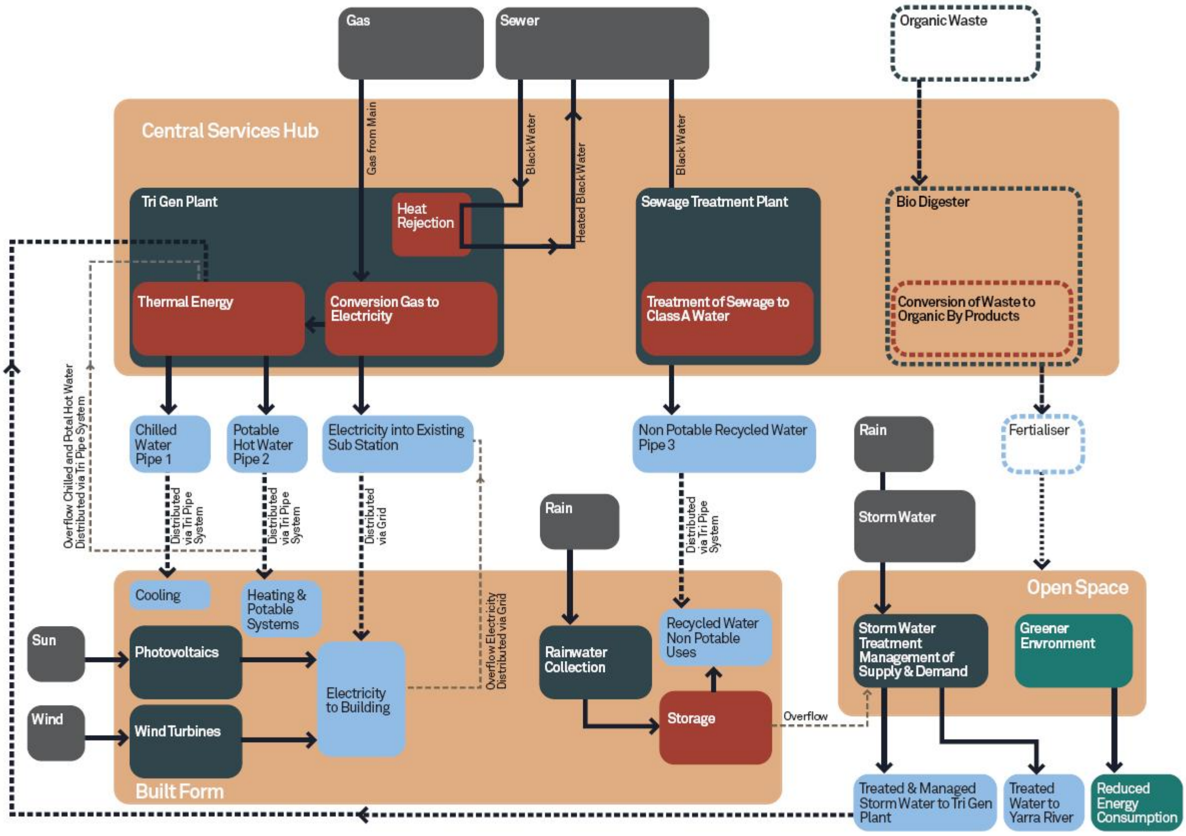

Figure 3 **Systems diagram of the proposed integrated sustainable utilities strategy for the Southbank precinct**

Source: AECOM, 2010

Three Central Services Hubs (CSH) are proposed to be located within the precinct to allow the generation and harvesting of energy and water resources. The location of these hubs is based on a land use requirement of approximately 800 square metres (sqm) each, access to ventilation, ability to reduce noise and sound vibrations, vehicle access and proximity to buildings that will use generated resources. CSH will contain water treatment and tri-generation plants that will produce electricity, hot water, chilled water and recycled water and the primary fuel source will be gas. These services will require reticulation throughout the precinct. Cooling towers in the tri generation process consume a significant volume of water which will be supplied with recycled water.

The following functions are proposed to occur within the CSH:

- sewerage will be treated to Class A standard, and will be reticulated as recycled water and as chilled water to reduce the quantity of potable water and energy consumed
- storm water will be collected, and after a series of treatments to potable water quality, will be heated and reticulated as potable hot water
- electricity will be generated via a tri-generation plant from high pressure natural gas and fed back into the grid
- heat from the returned chilled water pipe will be rejected via the most efficient system, a sewer heat exchanger, tri-generation plant or chillers. Where additional heat is required this waste heat will also be captured for reuse via the tri-generation plant.

The network of service pipes entering and exiting each CSH are proposed to be distributed underground via new service tunnels could be constructed under the energy demand of Southbank's streets. A vacuum sewerage and recycling system could be installed within the tunnel; however this technology requires further investigation.

Within the built form, energy is proposed to be generated from roof mounted micro wind turbines and solar photovoltaics (PV). Roof top gardens and the greening of open space across the precinct would reduce the urban heat island effect and the energy required to cool during summer. Where possible, rainwater tanks on the roof top of buildings could capture rainwater and store this for use on the roof top gardens. The overflow from these tanks could run into the storm water network where it would be captured, undergo minor treatment (filtration) and be stored in a series of underground distributed storage units. Using an intelligent network, this stored resource could be sent on demand to the CSH where it undergoes further treatment before being distributed throughout the precinct as hot water.

Organic waste generated within the precinct can be collected and composted to generate a fertilizer for use on the CoM's gardens. The methane generated by this process could be captured and converted into energy.

A schematic drawing of the proposed integrated sustainable utilities strategy in presented in Figure 4.

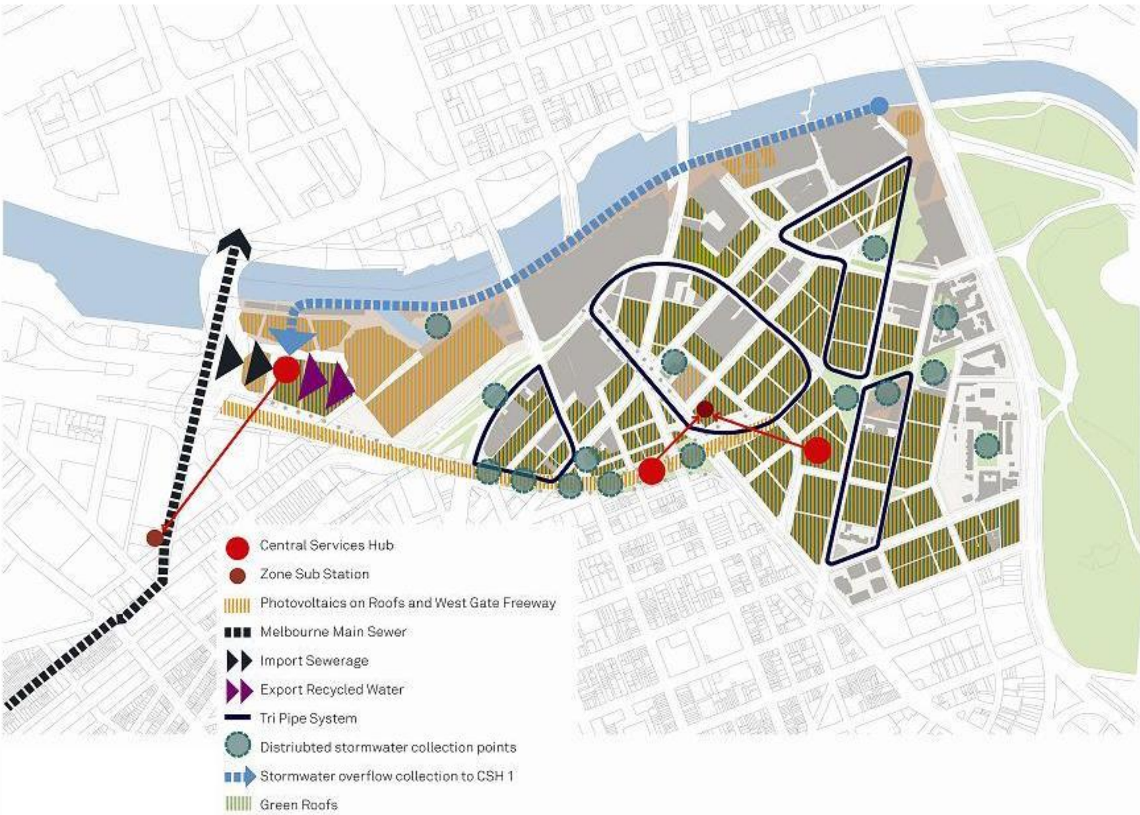

Figure 4 Schematic diagram of the proposed integrated sustainable utilities strategy for the Southbank precinct, (source: AECOM, 2010)

What follows is a discussion of the selection and benefits of each infrastructure initiative that together form the sustainable utilities strategy. An assessment of the strategy against the Eco-city targets is also provided. The discussion is presented in four sections, grouped into the following:

1) Integrated infrastructure services
2) Energy initiatives
3) Integrated water supply services
4) Resource recovery
5) Open space

2.1 Integrated infrastructure services

2.1.1 Central Services Hub

The floor area of each CSH will need to be between 8,000 and 12,000 square metres. The possible location of each CSH needs to provide access to pressurised gas, the sewer and the electricity grid, the ability to exhaust combustion emissions and access to open air to provide ventilation to the cooling towers. Due to the nature of the soils at Southbank it is proposed that the CSH is above ground. There is an opportunity to design the structure in a manner that visually communicates the principles of sustainability and engages with the community.

The use of CSHs will:

- reduce a multiple point source of pollutants from refrigerants, cooling towers and smoke stacks
- defers the need to increase the capacity of power plants
- reduce transmission losses
- have greater efficiency than a building by building approach due to lower energy losses with a central plant
- have greater efficiency in implementing centralised wastewater treatment and recycling than a building by building approach
- improve the management of the wastewater treatment process by removing the need to install treatment plants at the building level.

2.1.2 Services tunnel

A combined services tunnel is proposed to house the multiple new service pipes and conduits that would be installed in developing the precinct to provide the distribution network required to operate the CSH. The service tunnel would require an initial investment that will provide long term gain, and would be located under the road network at an approximate depth of three metres. The tunnel would need to be approximately two metres in diameter. The water strategy alone would potentially involve five separate water pipes: potable water, potable (hot) water, non-potable (chilled) water, non-potable (recycled) water, and sewer. These pipelines could be located in this services tunnel, along with other utilities such as electricity, gas, telephone and broadband.

The benefits of a services tunnel include:

- central quality control at the precinct scale and ease of access to service the asset
- less disruption from road closures when retrofits, maintenance or technology upgrades are required
- simplification of the services allowing for the improved cross- connection of services
- increasing the ability to monitor and repair water leakages
- the ability to become an income generating asset.

2.1.3 Vacuum sewers

Vacuum sewers are well suited to replace ageing sewers within high density precincts as they could be constructed at grade and located within the services tunnel. Combining these with new water tight sewers will significantly reduce inflow and infiltration allowing for smaller diameter pipes. While vacuum systems are not capable of transporting sewage over very long distances, the waste could be pumped from the precinct into the Melbourne main sewer located along Montague Street. The benefits of a vacuum sewer for the Southbank precinct are that:

- it can be constructed (at grade) and located within the services tunnel
- it will significantly reduce inflow and infiltration if combined with new water tight sewers, allowing for smaller diameter pipes
- usually only a single vacuum pump station is required rather than the multiple stations required for gravity and low pressure networks (this releases land for other purposed and reduces energy and operational costs)
- trenching can be at shallow depths, close to the surface
- no odours occur along the closed vacuum sewers
- stormwater infiltrates gravity feed systems, with vacuum systems no infiltration occurs (this creates less load to manage at the treatment stations)
- sewers may be laid in the same trench with other services (including potable water or storm water), as well as in water protection areas.

2.2 Energy initiatives

Approximately 92 percent of Victoria's grid electricity is generated by burning fossil fuels, with coal forming approximately 70 percent of the fuel mix. This 'high-carbon' form of energy generation, combined with the minimal use of natural gas, results in 99 percent of Southbank's non-transport related greenhouse gas emissions being the result of grid electricity use. As such, 'de-carbonising' electricity generation represents the greatest single opportunity for greenhouse gas reduction in Southbank.

Realising these opportunities will require a shift from supply-side solutions involving large, centralised systems to smaller decentralised systems. The lower greenhouse gas intensity of electricity supplied from gas fired co-generation plants, combined with maximising onsite renewable energy generation, may provide electricity at a scale that meets demand whilst reducing net greenhouse gas emissions.

2.2.1 Tri-generation

Cogeneration or Combined Heat and Power (CHP), is the generation of both electricity and heat at or near the point of use. A tri-generation system is the addition of an absorption chiller to provide cooling. Absorption chillers provide a way of using thermal energy to deliver cooling and air-conditioning as an alternative to conventional electrically driven refrigeration. By using the heat stream from a co-generation system as the thermal energy source, absorption cooling offers the potential to expand the range of co-generation's applications. The use of co-generation is considered viable at Southbank as the precinct requires significant heat and electricity, in the ratio of approximately two units of heat (unit) to one unit of electricity (unit). The system should be optimised to ensure the design meets heat demands, as the cost to transport heat is greater than the cost to transport electricity. A schematic diagram of input puts and outputs from the tri-generation process is presented in Figure 5.

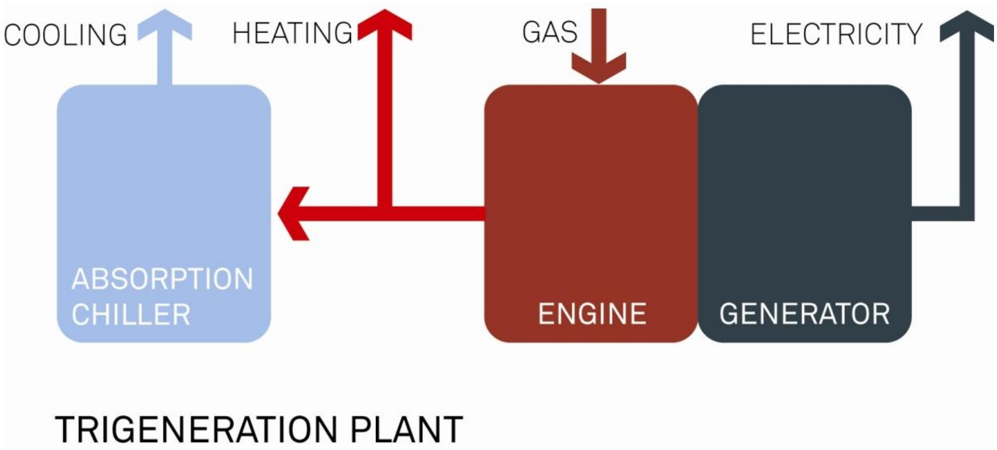

Figure 5: Schematic diagram of input puts and outputs from the tri-generation plant

There can be many forms of fuel suitable for a tri-generation system, including municipal solid waste, biomass, biogas, natural gas and coal. While biomass and biogas are often the preferred fuel sources from a sustainability perspective, guaranteeing a secure supply of these fuels is difficult at present. As markets for biomass and biogas fuels are immature and emerging, it is currently not possible to provide a reliable quantity of feedstock to generate enough energy to meet the demand of the precinct. The most common form of fuel utilised in tri-generation systems is natural gas as there is a reliable supply and it has lower greenhouse gas intensity than grid powered electricity.

Benefits

The key site-specific benefits of tri-generation include:

- improved competitiveness through reduced the operating cost base (that is, lower electricity and thermal operating costs)
- improved energy supply reliability, security and flexibility
- substantial improvements in the cleanliness, efficiency and security of meeting energy needs
- increased utilisation of energy assets compared to standby generation
- the use of an established technology, with continued incremental efficiency improvements (that is, through reciprocating engines and turbines)
- efficiency of energy generation is increased by 30-40 percent by avoiding transmission losses and capturing waste heat (SEAV, 2004)
- an opportunity to support moves towards decentralised forms of electricity generation, with generation systems designed to meet the needs of Southbank
- the provision of electricity from a less greenhouse gas intensive generation source.

Power distribution via embedded generation connected to the grid has the benefit of:

- no requirement to provide reverse feeder capacity charges
- no transmission losses
- delaying the need to augment infrastructure and a potential share of savings could be apportioned.

Barriers

There are several economic, regulatory and technical barriers to the implementation of tri-generation systems:

- a major economic barrier to cogeneration is the extent the benefits of avoided transmission losses can be captured, which is primarily a question of regulation barriers.
- capturing the reduced greenhouse gas emission from energy generated by a gas fuelled tri-generation plant
- regulatory barriers are both diverse and complex, with the Australian Energy Regulator (AER) currently developing guidelines to encourage and guide distributed generation.
- as embedded generators are direct competitors of the Distribution Network Service Providers (DNSP), incentives are not in place for DNSPs to upgrade the network for distributed generation connections
- a connection agreement is required to supply electricity to the grid (this agreement sets out the connection costs and the standards of service that the connecting party will receive; the AER is currently developing a framework to oversee these connection agreements)
- there is a disparity between the connection costs embedded generators are charged in comparison to transmission-connected generators, as new transmission-connected generators are not required to pay for downstream transmission augmentation.

Siting requirements

In selecting an appropriate area within Southbank to locate the tri-generator the following factors need to be considered:

- access to services, including electrical, heating and fuel supplies
- noise emissions
- exhaust emissions
- ventilation and air quality requirements
- delivery, access and positioning of the system
- maintenance requirements
- land area relative to system size

Three areas have been identified as suitable locations for the CSHs: South Wharf, under the freeway between Moray and Clarke Street, and within the circular exit ramp onto Power Street. All potential locations are low grade land, located along the perimeter of the Westgate Freeway which is heavily impacted by traffic noise, vehicle emissions and vibrations.

A summary of the consumption values and energy output of a tri-generation system that will meet the energy demand of Southbank is provided in Table 2.

Table 2 Consumption values, energy output of a tri-generation system that will meet the energy demand of Southbank

Variable	Quantity
Peak generator output	90,000 kWe
Number of gen sets	20 - 25 units
Capacity of gen sets	2 – 4 MWe
Total water consumption	1,000 to 1,200 kL pa.
Peak water consumption	150 l/s
Peak gas consumption	20,000 to 22,000 m^3/hr
Peak heat rejection	250,000 to 300,000 kWt
Minimum parcel footprint	8,000 to 12,000 m^2
Reduced greenhouse gas emissions (compared to consumption of grid power electricity)	30%

2.2.2 Heat rejection

A large heat rejection capacity (approximately 250 to 300 MWt) to support the future projected capacity in Southbank is required. Traditionally heat rejection is undertaken by cooling towers located on the roof of buildings. While they are efficient from an energy perspective, they are heavy water users, consuming approximately 1,000 to 1,200 KL per year. This section discusses alternative methods of rejecting heat from Southbank.

Yarra River

While the Yarra River appears an ideal solution in which heat could be rejected to reduce water and energy demand, potential river health impacts present a barrier. For river health quality a temperature differential of water taken from and released back into the river can be no more than 2°C. In contrast, the temperature differential required to efficiently reject heat is up to 15°C. As the temperature differential allowable for utilising the Yarra River in rejecting waste heat is so small, larger quantities of water would be required, increasing water pumping energy demand which would negate any energy gains. With this option there would still be a significant reduction in potable water demand. However, the EPA restricts water extraction from river systems, which may prevent this option from being realised.

Sewer Mining

The Melbourne main sewer operates at a temperature which is ideal for recovering and rejecting heat energy, and using it for this purpose would contribute to reducing the energy demand and greenhouse gas emissions. The costs and benefits associated with the installation of such a system would need to be investigated in greater detail to determine the energy savings, energy offset (that is, gas or electric based), benefits of heat rejection and generation, system size and the arrangements required by Melbourne Water.

The potential benefits are of using the sewer in this manner include:

- efficient use of a renewable and sustainable form of energy
- use of a local decentralised heat source.

If compact, efficient and cost-effective heat exchangers are utilised for the system, and are installed above ground, establishment and maintenance costs will be minimised. Additionally, the system should be designed for minimal interference with the existing sewers (for example, only providing two access points).

The temperature range of the sewer (between 10°C and 20°C depending upon the season) permits the economical operation of heat pumps and heat rejection. There is a slight risk that increasing the temperature of the sewage by dumping heat in the sewer, may turn it septic before it reaches the Western Treatment Plant. Additionally, increasing the heat in the sewer may increase corrosion. Additional research is required to determine the risk of these impacts occurring.

Sewage flow rates need to be carefully considered when sites for the installation of sewer heat transfer systems are selected. The Melbourne Main sewer that runs from north to south on the western edge of the precinct is considered a suitable site. However, further study is required to confirm local sewage flows, site costs, energy benefits, system size and integration with the CSH.

2.2.3 Photovoltaics

Photovoltaics (PV) are a reliable technology requiring minimal maintenance that provides a source of renewable electricity. However, without government subsidies the technology is expensive per unit of electricity produced, with paybacks of more than 50 years. Additionally, PV systems produce an intermittent, variable supply of electricity according to the available solar energy and must be installed in an area with limited overshadowing.

The choice of a proper location for PV systems is partly determined by ensuring that the modules are exposed to direct sunlight without shadowing from at least early morning to late afternoon. To maximise the power generating capacity of PW systems, they must be installed with a tilt angle calculated to expose the panels to as much direct sunlight as possible. Additionally, as shading will reduce the electricity output of PV systems, there needs to be consideration of any shading from surrounding buildings. Implementing height restrictions to allow adequate solar access on building roof tops can minimise the impact of overshadowing.

Proposed suitable locations for the installation of PV systems within Southbank include:

- the roof area of new developments assumes a 50 percent coverage
- a new noise barrier along the Westgate Freeway, assuming 1,300 metre length.

A noise barrier can be built as a feature of the freeway, with the modules fixed on the main barrier. An installed example of such a feature is the PV noise wall installed along the Tullamarine Freeway at the Calder Interchange, adjacent to Essendon Airport (see Figure 6). Further investigation is required to verify the:

- optimum electricity output of PVs to account for the effects of overshadowing
- height of the barrier, loading implications and structural fixings for the noise barrier.

Figure 6: PV noise wall on the Tullamarine Freeway at the Calder Interchange, adjacent to Essendon Airport, Melbourne. Source (TCI, 2009)

The energy output of PV systems is determined by solar access, the size of the array and the PV technology chosen. Initial calculations for this study indicate a PV generating capacity of approximately 87 MWh for Southbank (see Table 3), assuming:

- an average daily electricity output of 130 watts (W) per square meter of installed PV
- 50 percent of the roof area of new buildings will be covered in PV systems
- a noise wall with an integrated PV system 1,300 metres in length is developed along the Westgate Freeway.

Table 3 Annual renewable electricity generated from PVs within Southbank

Location	Area of coverage	Electricity Output (kWh per year)
Roof area of new developments	200,000 m^2	48,600
Westgate Freeway noise barrier	1,300 m^2	38,400
	Total	**87,000**

2.2.4 Micro Wind Turbines

The ideal position to install micro wind turbines (MWT) in Southbank is in open spaces unobstructed by structures and trees, while being open to the prevailing southerly winds. In installing MWT, consideration needs to be given to the weight and power output of the turbines, wind turbulence, obstructions, vibration, noise and wind speed. The structural integrity of the intended mounting structure needs carefully considered due to the particular structural loads imposed by wind turbines. The bottom of the sweep of the moving rotor blades should be at least 6 m above any obstacle that is within 76 m of the mounting tower (Energy Matters, 2009) limiting the number of suitable sites.

The available wind resource is the most important factor in calculating the economic viability of a wind turbine, which is very difficult to predict in an urban area. For MWT to be effective Energy Matters (2009) recommends correct siting and a wind speed of at least 4.5 meters per second (m/s) average or more, with the best results being achieved with average wind speeds of 5.4 m/s. The Alternative Technology Association (ATA) undertook a study for the Victorian Government into the effectiveness of MWT in urban environments which involved testing the wind speed at 10 locations across Melbourne. Results from this study for the Melbourne CBD showed an average wind speed of 3.94 m/s.

The testing of the wind resource potential at individual sites within Southbank was beyond the scope of this investigation. Given the structural complexity of the precinct's built form, and the confounding effect of turbulence on wind resource potential, the use of anemometers would be advised to check the feasibility of an MWT installation at any potential site that CoM could support. In general, MWT have performed poorly overseas and payback periods are likely to be long (ATA, 2009).

The number of grid connected MWT across the state is at present very small and, as a result, councils are yet to produce any planning guidelines governing their installation. At this stage they are assessed by council on a case by case basis. In the City of Port Phillip, as part of their commitment to environmental and social sustainability, no planning permit application fee for small scale wind turbines is required (City of Port Philip, 2009). Most recently MWT were installed on the rood on the new ANZ building in the Docklands, with the approvals for their installation forming part of the planning and building approvals. The cost per kWh generated and the amount of power produced from this installation is not currently publicly available.

2.2.5 Vehicle-to-Grid power

The use of vehicle-to-grid (V2G) systems will be enabled by the emergence of electric drive vehicles (EDV), which is likely to occur over the next 20 years. EDVs reduce greenhouse gas emissions and ambient air pollution if the electricity which they consume produces less emissions than the cars which they replace (that is, cars with internal combustion engines). Therefore, EDV's emissions reduction potential will be determined by broader moves towards less greenhouse gas intensive electricity generation. Another benefit of EDVs is likely to be a reduction in Australia's exposure to crude oil prices and oil import dependency.

EDV power plants can be battery-electric, a fuel cell or a plug-in petrol (or diesel) electric hybrid (Kempton and Tomić 2005). Plug-in hybrid electric vehicles, or those with battery-electric power plants, can charge when electricity demand is low, improving the efficiency of the electricity grid by reducing troughs in demand. All three EDV types can discharge electricity back into the grid during peaks in demand, reducing the need for back-up generators. Utilising EDVs in this manner may accelerate a transition towards these vehicles by improving their commercial viability.

Vehicle to grid (V2G) systems can provide the link for two critically important systems: the electricity network and the petroleum-based transport system by replacing petroleum as a fuel source with electricity. The potential benefits of V2G systems include:

- reducing the operational costs of electric vehicles, making them even more attractive to consumers
- generating revenue for owners of electric vehicles
- reducing demand charges for electrical consumers
- increasing the stability and reliability of the electricity grid
- lowering electrical system costs
- spreading infrastructure investment costs
- acting as inexpensive storage for intermittent renewable electricity
- reducing greenhouse gas emissions.

The electricity grid and light vehicle fleet are complementary systems for managing energy and power. The power grid has essentially no storage (other than its small pumped storage capacity), so generation and transmission/distribution must be continuously managed to match a fluctuating customer load. This is generally accomplished primarily by turning large generators on and off, or increasing or decreasing their power output, some on a minute-by-minute basis. By contrast, the light vehicle fleet must have the ability to store energy and to have large and frequent power fluctuations, due to their mobile nature.

In Southbank, a V2G system could be implemented by aggregating a number of systems into "parking-lot power plants" for vehicular distributed generation. Potential applications include commercial fleet vehicles, car-rental companies and parking lots. An example of a parking-lot power plant using idle airport-rental vehicles to provide electricity services is shown in Figure 7.

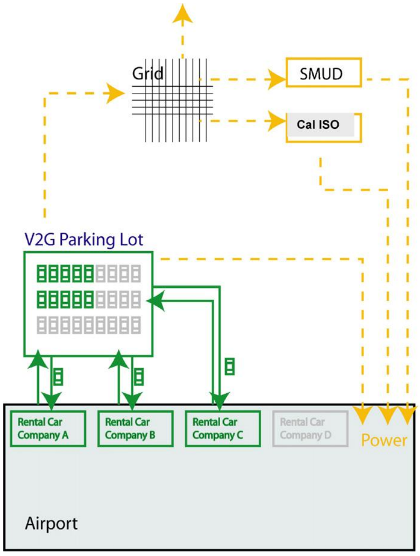

Figure 7: Vehicle-to-Grid – Parking Lot Power Plant Model (Williams and Kurani 2007)

One factor which suggests such benefits may exist relates to the fact that private vehicles are parked on average 95 percent of their lifetime. Each parked vehicle contains underutilised energy and fuel (or battery) storage capacity, and may actually create negative value due to parking costs. Accordingly, generating V2G power from parked vehicles could better utilise an expensive investment, thereby enabling vehicles to provide both mobility and energy services. V2G may thus provide a means to utilise the spare power capacity available in each parked vehicle and reduce the need to maintain the excess conventional electricity generation capacity which is currently required (Kempton and Tomić 2005; Sovacool and Hirsh 2009). With over 700,000 m^2 or approximately 10 percent of Southbank's proposed gross floor area (GFA) dedicated to car parking, Southbank provides the degree of scalability which might be required for the potential commercialisation of this technology when it is mature enough for installation.

However further investigation needs to be undertaken to determine the merits of an electric vehicle-to-grid (V2G) approach to determine consistency with the CoM emissions reduction strategy. For example, in order for broad scale to be justified on the grounds of reducing greenhouse emissions, electricity supplied to V2G would potentially need to be sourced from renewable power and be additional to any renewable power contributing to Australia's legislated renewable energy target. To do otherwise would result in increased demand for electricity without offsetting demand for electricity elsewhere. For example, using baseload grid power electricity which is predominantly generated from the combustion of emissions intensive brown coal will not lead to the objective of reducing greenhouse gas emissions. Alternatively batteries could be recharged from electricity sourced from GreenPower or the CSH.

2.2.6 Fuel cells

CSIRO has been undertaking research on a range of fuel cell technologies for a number of years, from which Ceramic Fuel Cells Ltd (CFCL) emerged (DRET 2008). CFCL are currently developing a fuel cell based electricity generator which is suitable for households, called the BlueGEN. This dishwasher sized unit converts natural gas to electricity and heat via ceramic fuel cells, without any combustion or noise (CFCL 2009). Each unit is expected to cost $8,000 (when in mass-production) with an eight-year simple payback, based on annual savings of $1,000 (assuming some benefit from the resale of electricity back into the grid). This is a technology that could emerge commercially over the next 10 years.

Similar 'stationary' fuel cells suitable for residential use are currently entering niche commercial markets, in Europe (mostly Germany), Japan and the USA. The development of this technology is largely the result of long term and substantial research and demonstration (R&D) investment and government support (DRET 2008). The United States Department of Energy is working closely with its national laboratories, universities, and industry partners to overcome critical technical barriers to fuel cell commercialisation. Current R&D focuses on the development of reliable, low-cost, high-performance fuel cell system components for transportation and buildings applications (USDE 2008).

The benefits of fuel cells are that they:

- allow electricity to be generated and consumed at the point of use
- are very efficient at converting fuel to electrical energy, even at partial loads
- are low emissions (depending on the fuel source)
- emit little noise
- are modular in nature, so the size of a generating station can be built up gradually as needed without losing economies of scale
- allow a variety of fuels to be used, with some reforming
- generate waste heat which can be used to run steam turbines or other heat consuming processes (high temperature fuel cells only)
- are able to produce sufficient electricity for remote areas where the normal electricity grid may not be available (AIE, undated)
- are ideal for primary household supply and as back-up for peak or emergency use or for remote areas (Nolan, 2010).

This technology could be best applied as a retrofit solution for the existing residential market. However, this application is clearly limited by the development of the technology and access to natural gas. In high rise residential dwellings natural gas is not always supplied to dwellings. The technology, if fully developed and proven over the next five to 10 years could be a solution for reducing the greenhouse gas intensity of electricity supply. Fuel cells are not as energy and cost efficient per kWh as centralised co-generation plants, as the barriers to retrofitting the service pipes to existing buildings are likely to be prohibitive. However, the installation of fuel cells during planned refurbishments or for new buildings is likely to be more commercially attractive.

2.3 Integrated water supply services

The key challenge for Southbank is to grow without increasing its potable water consumption (that is, demand reduction), to diversify water its supply sources, to harvest water wherever possible, and to ensure that the infrastructure to enable these three goals is developed.

A schematic of the preferred strategy for Southbank that represents these interrelated components is presented in Figure 8.

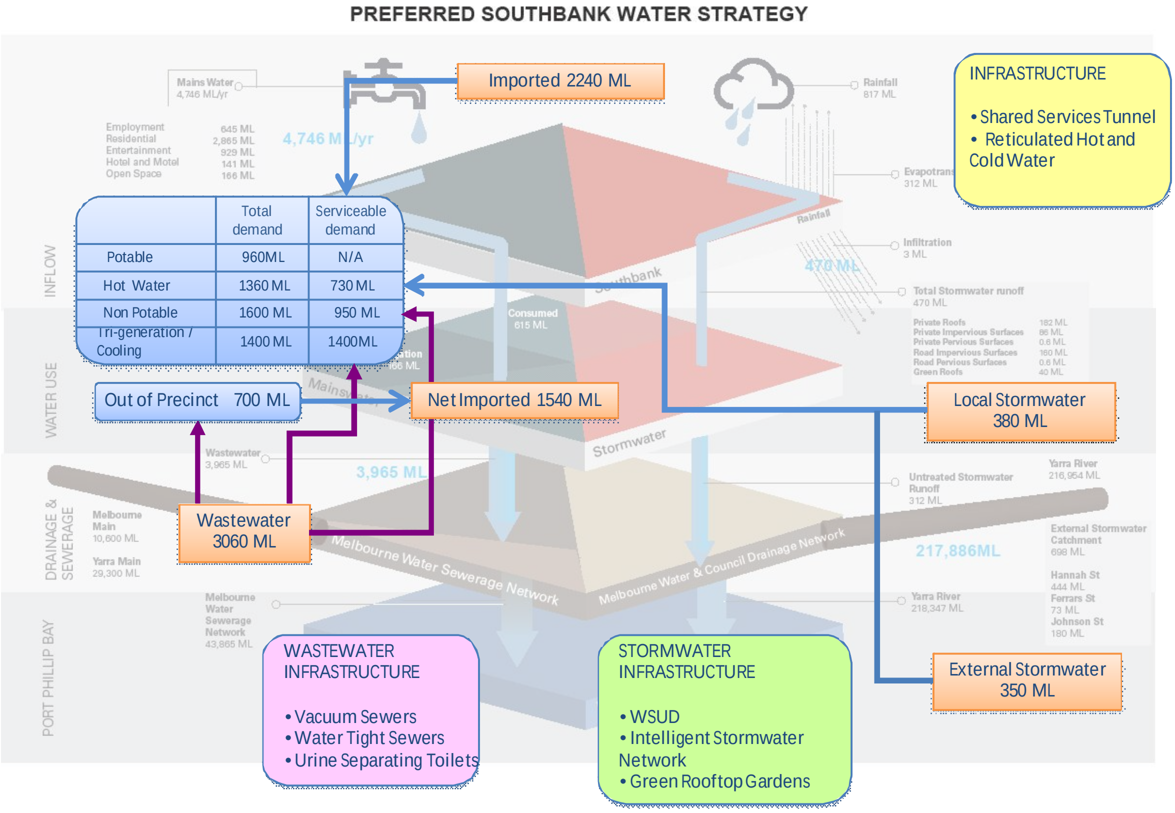

Figure 8: Southbank integrated water strategy

Source: AECOM, 2010

2.3.1 Water supply services

With climate change expected to reduce future rainfall and hence Melbourne's water supply (DSE, 2008), reduced water storage coupled with future population growth will likely lead to greater water scarcity. In an uncertain climate, having a range of water supply options will create more certainty as if one option fails there will be alternatives (Brown, 2009).

There are a number of potential sources of water that can assist in reducing potable water usage in the Southbank precinct. These alternative water sources can be utilised for a number of purposes where potable water is not required (subject to appropriate treatment) including cooling towers, toilet flushing, laundry and the irrigation of open space and gardens. Through initiatives such as recycling, water conservation, Water Sensitive Urban Design (WSUD) and stormwater harvesting, new and better ways of managing water resources within the Southbank precinct can be implemented.

Sustainable water supply options include stormwater capture from manmade impervious surfaces, and water recycling. A key consideration is the level of projected water demand for Southbank's future growth scenario and the potential level of supply from the available options. Seasons are also a critical factor, as peak demand (the hotter months of the year) and supply periods are not synchronised.

The water balance for Southbank is presented in Table 4 and graphically in Appendix A, which shows the water sinks or demand and the potential water sources. The breakdown of the future water demand and supply sources in Southbank is provided in Table 5.

Table 4 Southbank water balance

Water Balance	Quantity of water (ML / year)
Sinks	
Mains water demand	5,320
Evapotranspiration	310
Infiltration	3
Sources	
Wastewater	3,965
Rainfall	820
Stormwater runoff	380
External stormwater catchment - Melbourne Main drain	10,600
External stormwater catchment - Yarra Main drain	29,300
Melbourne Water sewerage network	43,000
Yarra River	218,000

Table 5 Breakdown of the future water demand and supply sources in Southbank, units in ML/ yr

Demand		Supply	
Source	**Quantity**	**Quantity**	**Source**
Potable			
Other potable	960	960	Mains supply
Hot water	1,360	730	Stormwater runoff (630 ML from mains supply)
Non-potable			
Cooling towers	1,400	1,400	Recycled water from sewer (750 ML from mains supply)
Toilet flushing, laundry and open space	1,600	950	
Total			
Total Water Demand	5,320	5,320	Total Water Supply
Outside of precinct			
Irrigation of open space outside of precinct	700		Recycled water from sewer

From the figures in these two tables, based on the total projected water demand and the principle of 'fit for purpose' water supply, approximately 60 percent of the precinct's water can theoretically be supplied with non-potable water.

The average annual rainfall within Southbank is 820 mega-litres per year (ML/yr) of which approximately 60 percent is discharged as surface run-off, with around 140 ML/yr running off residential and commercial building roofs. This run-off provides an abundance of water with the potential to be harvested and used for garden irrigation, toilet flushing, hot water and laundry.

2.3.2 Distributed stormwater catchment and storage

By rethinking and reinvesting in the design of stormwater infrastructure to capture and store, rather than dispose of, rainwater, and reusing wastewater, potable water consumption can be significantly reduced. Doing so will also improve the quality of stormwater run-off into the Yarra River and reduce the energy used to pump water and sewage to the Western Treatment Plant. Through these initiatives up to 80% of the local stormwater run-off, and up to 50 percent of the external runoff from the main drain, could be harvested.

Collection and storage

Stormwater within the precinct could be stored at Albert Park Lake or within a distributed, intelligent storage network. With each of these options, the existing stormwater infrastructure could still be utilised to collect and distribute stormwater. Extraction of water from these systems could potentially be from Melbourne Water main drains along Hanna and Ferrars Street.

Southbank's alluvial soils and the underground water table limits the depth of any potential underground storage units.

Assuming approximate values for:

- the ground level 2 metres above average height datum (AHD)
- the water table 1.5 metres below AHD
- an additional 1- 2 metres below the groundwater table due to buoyancy effects as a function of engineering works (weight required to counteract the buoyancy effects of the groundwater table within reasonable construction measures).

Based on these assumptions, water storage units could be built 3-5 metres below ground level. While these values are indicative only, they provide some sense of scale. Further investigation is recommended to determine the feasibility and design of the strategy before implementing this initiative. The implementation of an intelligent storage network would combine with a decrease in impervious area and attenuation through WSUD and roof top gardens to reduce localised flooding issues. Distributed underground storage tanks would be located under the open spaces, and be operated via an intelligent storage network to mange peak storm events and water demand.

Onsite tanks could be installed as header tanks for firefighting pumps with the added benefit of buffering peak demands within the reticulation system. These tanks would most likely be connected to the supply source for firefighting (proposed to be recycled water in this instance) but could also be connected to both potable and non potable supplies.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is a means of storing water, but may also provide further water treatment depending on the geo-chemical processes within the aquifer. The principle involves collecting stormwater and recycled water and treating and pumping them via one or more wells into an aquifer. Extraction for reuse could be via the same well. ASR provides an opportunity to store winter storm and recycled water, which could then be extracted to meet peak demand in summer. In this scenario, water would be stored close to the community or the site of use, reducing distribution losses through leakage and pumping related energy use. Such an approach could also be cheaper than the construction of new dams and reservoirs, and evaporation losses are avoided.

Additional investigation is recommended to determine the suitability of the aquifer underneath Southbank for an ASR system, to determine the:

- storage capacity and water quality of the existing aquifer
- rate of injection able to be achieved and the access conditions required to bore into the aquifer
- water balance to verify the quantity of water that can be stored and supplied based on seasonal flows (that is, not an annual analysis)
- land required to build a detention storage and/or treatment plant.

Treatment

The following levels of stormwater treatment are recommended to be provided in the Southbank precinct:

- removal of sediments, nutrients and other contaminants through water sensitive urban design
- source pre-treatment at the distributed underground network of storage units
- tertiary treatment and disinfection at the Central Service Hub (CSH).

Use

It is recommended stormwater collected through the distributed underground network of storage units is supplied to the tri-generation plant before being reticulated through the precinct to supplement the supply of hot water. Additionally, all elements arising from the water sensitive urban design, including rooftop gardens, should draw from the distributed storage systems.

- **Up to 80 percent local stormwater runoff harvested**
- **Up to 50 percent external stormwater runoff from main drain harvested**
- **Mains potable water demand reduced by 12 percent**
- **Energy consumption increased**
- **Piping and treatment infrastructure required**

2.3.3 Wastewater

A sewer mining plant could be constructed in the vicinity of South Wharf to extract wastewater from Melbourne Water's nearby Main Sewer which runs along Montage Street. The extracted effluent would need to be treated to Class A standard via an on-site treatment plant, disposing of the residual waste back into the sewer. Recycled water could then be reticulated to users through a dual pipe network; to supply toilets, open space, laundries, fire fighting assets, cooling towers and tri-generation plant for use in heat exchangers. While this approach has the potential to reduce potable water demand by up to 55 percent, the energy required to treat and pump the water would be significant. This approach provides the opportunity for Southbank to become a net provider of recycled water outside of the precinct to Albert Park, Government House, Alexandra Gardens and Fawkner Park. The potential annual supply from sewer mining is approximately 2,600 ML of wastewater.

- **Potable water demand reduced by 55 percent**
- **Energy consumption increased**
- **Piping and treatment infrastructure required**
- **Potential to become a greywater resource provider**

2.3.4 Yarra River

The Southbank precinct could achieve a net reduction in imported potable water use through implementing the proposed demand management strategies and utilising the Yarra River as an alternative water supply source. The energy consumption for treating the Yarra River's brackish water to a standard appropriate for use as potable water would be less than the supply of water from seawater desalination. However, this opportunity presents significant environmental, social and technical barriers.

Even if the extraction of water from the Yarra River could be negotiated with Melbourne Water, various other impacts would require investigation to determine if a net environmental benefit could be realised, including:

- environmental impacts from the water intakes
- release of warm brine into the river
- level of greenhouse gas emissions from the energy intensive treatment process.

Impacts could possibly be minimised by extracting less brackish water further upstream and releasing brine into the river's salt wedge.

Further studies to determine the social acceptance of such a project are also recommended. If the CoM's environmental objective is for the municipality to become a provider of potable water, this option should be investigated further.

- **Opportunity to become a net potable water provider**
- **Significant energy consumption required**
- **Piping and treatment infrastructure required**

2.4 Resource recovery

The CoM has developed a Waste Management Strategy and a Waste Implementation Plan, which include targets for improved performance within municipal solid waste, dumped rubbish, public place recycling and waste management from council buildings. A key factor in meeting the objective of the strategy to improve diversion rates of materials from landfill will be the establishment of Alternative Waste Technologies (AWTs) or Advanced Resource Recovery Technologies (ARRTs). It is envisaged these facilities will have the capacity to take the residual waste stream (currently going to landfill) and, through a process of sorting and treatment, enable the recovery of materials for recycling and the production of other useful by-products. The AWT and ARRT facilities generally have some level of residual material that would need to be disposed of to landfill.

The Dynon Road waste transfer station, which is located in Kensington, owned by CoM and operated by CityWide, may not be available on a long-term basis. As a result, CoM may need to consider the establishment of a new site which could potentially include an AWT or ARRT facility.

2.4.1 Advanced Resource Recovery Facilities

An AWT or ARRT facility for CoM might be:

- primarily instigated by CoM and located within the its municipal boundary
- instigated In conjunction with other councils and located within the CoM municipal boundary
- instigated in conjunction with other councils and located outside the CoM municipal boundary
- influenced by or arise from the Victorian Government's Victorian Advanced Resource Recovery Initiative (VARRI).

Regardless of the location and ownership of the facility, the CoM envisages taking residual material which is currently sent to landfill to this new facility from household collections. There is an expectation that the successful facility will not require source separation by householders of organics from the residual landfill stream, rather, the current two-bin system of commingled recycling and residual material would be retained. This would avoid the need to implement a three bin system (that is, recycling, organics and residual), which would require substantial effort to implement and maintain, due to the need for bin infrastructure, education and additional collections.

While CoM only have direct responsibility for residential material (commercial and industrial waste generators are responsible for the disposal of their own waste), they would encourage commercial and industrial waste generators to make use of the facility.

CoM supports the inclusion of the option to investigate a possible AWT or ARRT site within the Southbank Sustainable Infrastructure Plan. However, they are not at the stage of being able to decide on a particular technology or confirm that an ARRT would be established within the municipality. One possible location proposed by this strategy would be the South Wharf corner of Montague Street and the West Gate Freeway, as this site provides heavy vehicle access, is in an industrial area and is less likely to be affected by the noise, emissions and odours associated with this type of facility.

- **Opportunity to be guided by pending state, regional and council strategies currently in development**

2.4.2 Building waste collection systems

CoM's Waste Services advises that for apartment buildings:

- of total waste produced, recycling rates are no more than 30 percent for towers with a recycling bin as well as a garbage chute on every floor (that is, 70 percent of waste produced goes to landfill)
- recycling rates are generally 10-15 percent for towers with a garbage chute on every floor and a central recycling area, for example, in a car park or bin room located on the ground floor.

Waste collection systems will not increase recycling rates when considered in isolation, as there needs to be behaviour changes within the community. The recycling rates listed above indicate a clear relationship between providing appropriate waste recovery facilities and the rate of recycling. Given the projected population increase within the precinct, and the current lack of focus on including infrastructure for residents to divert their recyclable materials as easily as they can dispose of landfill waste, there is an opportunity to ensure all new buildings allow for appropriate waste recovery facilities. The draft *Best Practice Guide for Waste Management in Multi-Unit Developments* (Sustainability Victoria, 2009) provides some ideas on collection infrastructure within apartments. Once these guidelines are finalised they should provide a good reference for new developments.

CoM has provided input into the review of the Planning Scheme that is currently underway, requested inclusions in the planning regulations to allow developers to find a 'best fit' for their situation, rather than prescribing what must be undertaken. The proposal is for the planning scheme to stipulate that:

- all refurbishments and new buildings should provide practical waste and recycling services for their tenants
- the distance a tenant has to travel to recycle should be the same as the distance required to deposit landfill waste.

- **Opportunity for planning scheme to influence building waste collection systems**

2.4.3 Urine separation

Urine separation would best be implemented initially as pilot study which could be rolled out for wider implementation pending successful results. This would move the precinct towards "closing the loop", and positions the system operator to take advantage of the anticipated increase in fertilizer costs. Urine separation reduces water use and nutrient discharges to sewage treatment systems and the receiving environment, and increase the potential for closing the nutrient loop as the stored urine can be used as a fertiliser.

Urine is the fraction of urban waste containing the largest amounts of nutrients, contributing approximately 70 percent of the nitrogen and 50 percent of the phosphorus and potassium of all household waste and wastewater fractions. The levels of heavy metals are expected to be very low in the urine, making it a very clean fertiliser. Urine separation has the potential benefits of:

- reducing the discharge of nitrogen and phosphorus the environment by decreasing the nutrient load of the sewage system
- efficiently replacing mineral fertilisers,
- reducing water consumed in flushing away the urine
- decreasing the energy required to pump wastewater by decreasing its volume
- reducing the volume of chemicals required to remove phosphorus from wastewater

- **Opportunity to be guided by pending state, regional and council policies currently in development**

2.5 Green and open space

Open space is generally divided into the public or private realm, and then into active or passive spaces. *Future Melbourne* sets a goal of increasing the amount of green open space (that is, space with substantial vegetation), noting the need for spaces to provide 'ecosystem services'. This goal can be achieved through the increased provision of public gardens, private roof gardens, green walls and the use of Water Sensitive Urban Design (WSUD).

Using open spaces to provide ecosystems services will help to regulate the climate, filter water and provide recreational and spiritual benefits. Designing Southbank's urban landscape to trap and filter water will green open spaces, creating cooler and moister environments which has the potential to limit the impacts of drought and the urban heat island effect. The implementation of WSUD measures in open spaces needs to be balanced against the community cohesion, health and well-being benefits of open space. WSUD will improve the quality of storm water through the filtration of pollutants. The addition of green roofs will reduce the 'heat island' effect and provide ecological benefits to the precinct.

- **A proportion of the open space should provide ecosystem services**

2.5.1 Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) within Southbank could be used to replace between 2-3 percent of the impervious surface area of the precinct with porous and permeable pavements. As the precinct develops it is proposed that WSUD is delivered by taking land from roads and redesigning active recreation areas. The benefit would largely to reduce the impact of stormwater entering the Yarra River by reducing its pollutant loadings. Allocating an indicative cost is difficult due to the site specific nature of the capital and operating costs. Project specific cost examples are provided in the Technology Toolbox (refer to Appendix B).

2.5.2 Roof gardens

Green roof gardens can reduce the Urban Heat Island Effect, preserve and enhance biodiversity and improve air quality, the city aesthetically and stormwater quality. Roof gardens can also help to regulate internal building temperatures by acting as thermal insulation; studies have shown that indoor temperatures in buildings with green roof gardens can be between 3°C and 4°C lower than outside temperatures of 25-30 °C (Wong et al., 2003; Getter et al. 2006). Green roof gardens can also improve the electricity production of PV panels because the evapotranspiration of vegetation has a similar effect to evaporative air conditioning (Appl et al. 2004).

In the design of a roof garden, consideration needs to be given to the micro-environment at roof level, particularly wind speed and available sunlight and the structural impacts the additional loads a roof garden may generate. Green roofs can be sited around building plant and equipment. Research into the suitability of Australian native plants for use on green roofs is currently being undertaken by the University of Melbourne (UoM, 2008).

Other benefits of green roofs are qualitative and benefit the wider community, not necessarily the building developers, such as those identified in Appendix B. As such, governance controls by the CoM may be required to maximise the uptake of this approach in support of the *Future Melbourne Eco-city* targets. For example Toronto's local authority has created by-laws mandating green roofs (Wordpress 2009a). An example of what a green roof could look like in Southbank is shown in Figure 9, which shows the ACROS Fukuoka building in Japan. It is proposed that 50 percent of the roof area of new developments in the Southbank precinct is dedicated to green roofs.

Figure 9: ACROS Fukuoka building in Japan (Source: WordPress 2009b)

- **Net increase in green space 315,800 m^2 (85 percent)**
  - **green roofs 305,800 m^2 (50% of new building developments)**
  - **addition of a Central Park covering 10,000 m^2**
- **Reduced urban heat island affect**
- **Increased water demand of approximately 111 ML / yr**
- **Improved stormwater quality**

3.0 Assessment of the strategy against Eco-City targets

The eco-city targets for the Southbank Structure Plan can be met for all areas with the exception of the greenhouse emissions from the commercial sector. The Sustainable Utilities Strategy as outlined in section 2.0, involves the implementation of:

- onsite energy generation through a tri-generation plant, PV systems and micro wind turbines
- stormwater capture and reuse for hot water
- greening open spaces
- heat rejection to the sewer
- recycling wastewater into non-potable water
- integrated infrastructure services (service tunnel and three Central Services Hubs).

In addition there is an opportunity for the precinct to become a net provider of recycled water. With the potential to install a dual pipe could along Kings Way to supply recycled water to surrounding parklands and new developments.

The greenhouse gas savings for the commercial buildings will predominately be realised through the development of new building stock; the Structure Plan establishes a vision whereby 35 percent of the commercial buildings which will eventually be in the Southbank precinct are yet to be built. It is assumed that the existing commercial building stock achieves a 38 percent improvement in energy efficiency (as per the *1,200 Buildings Program*), and that 35 percent of the energy supplied to these buildings is low carbon (that is, from renewable energy sources, GreenPower and/or connecting into the CHS).

Renewable energy generated from PVs installed on 50 percent of new building roof tops has the potential to generate up to one per cent of the precinct's electricity demand.

The low wind speed and turbulence created from Southbank's complex built environment is not ideal for generating electricity from micro wind turbines (MWT). The speed, reliability and turbulence of wind determine the viability of MWT as energy generators. In built up urban environments structures, buildings and vegetation create significant surface roughness, causing turbulence in the air flow reducing the quality and speed of wind. Some wind ridges have been identified as potential locations for installing MWT; electricity output from turbines located at these sites is estimated to be less than 0.1 percent of total energy demand.

In calculating the performance of the Southbank Sustainable Utility Strategy, the assumed rates of resource efficiency are based on the savings that will result from CoM initiatives promoting Ecological Sustainable Design (ESD) in new and existing developments and from encouraging behaviour change. These have been taken into consideration when calculating the contribution of sustainable servicing initiatives. The following assumptions have been made about the performance of current and future buildings within Southbank:

- a 10 percent improvement in the energy efficiency of the existing residential building stock over time
- all new residential buildings will be built to a 6 Star Green Star level of building fabric performance, PV systems will be installed on 50 percent of their roof area and they will be connected to a CSH
- all existing commercial buildings currently have an energy performance rating of 2.5 Star NABERS rating and will over time reduce energy consumption by 38 perent (as per the CoM strategy in the 1,200 buildings program)
- all new commercial buildings will be built to and perform at a 5 Star NABERS rating (whole building), PV systems will be installed on 50% of their roof area and they will be connected to a CSH
- water consumption will be reduced to 110 l/p/day per resident (European best practice)
- water consumption will be reduced to 91 l/p/day per employee (current Eco-city target).

The rate of resource consumption within Southbank per employee and resident is presented in Table 6 for the: current rate of consumption (referred to as business as usual (BAU)), the eco-city targets (referred to as City of Melb policy (Eco-city)) and the assessment of the Sustainable Utilities Strategy 9referred to as the design).

Table 6 Rate of resources consumed in Southbank compared to the eco-city targets and strategy to reduce consumption

Resource	Source	Use	BAU	CoM policy (Eco-city)	Design	Sustainable utility strategy
Potable Water	Mains water supply from dams and reservoirs	Toilets, showers, kitchens, cooling towers, laundries, landscape	179 l/p/d per resident 95 l/p/d per employee (based on 2005/06)	178 l/p/d per resident 91 l/p/d per employee ↓25% from 1999/00 (1,500 ML)	25 l/p/d per resident 55 l/p/d per employee ↓23% from 1999/00 levels (1,540 ML net usage)	To reduce potable water demand through fit for purpose recycled wastewater and stormwater to hot water
Wastewater	Waste product from the consumption of water - generated by commercial, residential and industry operations	Not currently used as a source	100% discharged to Western WWTP	↓30% discharged to Western WWTP from 1999/00 levels (1,190 ML)	Min 2,781 ML/yr wastewater re-use required 3,060 ML/yr wastewater harvested from the Melbourne Mains Sewer	Recycle to fit for purpose use to supply new buildings with recycled water
Stormwater	Rainfall runoff	Not currently used as a source	470 ML	Achieve various stormwater quality improvement targets through treatments such as WSUD elements	WSUD implemented 80% precinct stormwater harvested	Stormwater to hot water
Alternative water use	Possible sources include stormwater, wastewater, Yarra River and groundwater	Not currently used as a source	0% alternative water sources within Southbank	Council to source 30% Non-Council to source 9% Note: Total CoM target 3,280 ML/yr	3,060 ML/yr wastewater 730 ML/yr stormwater	Includes sourcing out of precinct wastewater and stormwater
Energy / Greenhouse Gas Emissions	Waste product from the consumption of electricity and gas - generated by commercial, residential and industry operations	Lighting, power, heating, cooling, ventilation, hot water, appliances	7.8 t CO_2-e / yr per resident 9.9 t CO_2-e / yr per employee	5.1 t CO_2-e /yr per resident 4.1 t CO_2-e / yr per employee	↓50% 2.6 t CO_2-e / yr per resident 4.1 t CO_2-e / yr per employee	Decarbonise energy supply through renewables and tri-generation

Resource	Source	Use	BAU	CoM policy (Eco-city)	Design	Sustainable utility strategy
Solid Waste	Waste product from the consumption of goods – generated by commercial, residential and industry operations	Small proportion of recycling by residents	23% of municipal solid waste recycled	No quantifiable targets established as yet – aspiration to reduce and recover waste	CoM are currently investigating relocating waste transfer station (WTS)	Increase waste recovery and recycling Implement ARRT into CoM's waste management implementation plan 2009 – 2010 and influence design of WTS
Open Space	Public areas	Minimal use as a source	56,500 m^2	No quantifiable targets established as yet – aspiration to increase green open spaces	Net increase: ↑80% or ↑315,800 m^2	Increase the green space

Source: CoM and AECOM, 2009

4.0 Methodology

4.1 Scope

The scope of this study was to determine the contribution of a sustainable infrastructure servicing study towards achieving the Eco-city goals for the Southbank precinct. The boundary of the assessment was defined to explore:

- options outside of the building envelope
- beyond just efficient design and behaviour change
- the interaction of the service infrastructure and the urban form and the systems they connect into
- the technologies that could be applied to reduce resource consumption within Southbank.

4.2 Project team

This study was undertaken in collaboration with the utility companies and in parallel with the Southbank integrated water review study commissioned by South East Water. Conducted by AECOM, the integrated water review study was established to aid the development of water management options. Through this project a water balance model was developed for the precinct and a series of strategies were identified and assessed against the same criteria as used in this study. These options assisted in informing the selection of alternative water supply sources outlined in the sustainable servicing infrastructure scenario.

The Southbank Sustainable Infrastructure Plan was developed through a background investigation followed by the development of a sustainable infrastructure servicing scenario.

Utility service related investigations were completed in collaboration with MulitNet, CitiPower, Melbourne Water and South East Water as relevant.

4.3 Staging

4.3.1 Stage one – assessment of existing utilities system

Stage One formed the background to the investigation, identifying the current level of resource consumption, mapping the existing utility infrastructure and identifying appropriate technologies that could be applied within the precinct's boundary. The following actions were completed:

- An inception meeting was held with CoM to confirm high level objectives for the study.
- The utility companies were engaged by CoM and AECOM. They collaborated throughout the project by providing information that assisted in mapping the location of infrastructure, identifying capacity constraints in their networks and providing resource consumption data.
- The Southbank precinct was then analysed to determine opportunities and constraints as they related to the site characteristics, land use, asset conditions and key existing infrastructure.
- AECOM then researched and consulted with the utility companies and Sustainability Victoria to identify a range of sustainable infrastructure options within and external to the precinct. These options were referred to as the 'Technology Toolbox', which summarises the key benefits, siting requirements, indicative costs, advantages and challenges of each initiative.
- A background report, referred to as Stage One Report, was developed that outlined the infrastructure technologies that could be deployed and the process for selection, as outlined in Table 11 (refer to Section 6.0).

4.3.2 Stage two – design options

Stage two involved selecting and locating technologies which would reduce greenhouse gas emissions, resource consumption and adapt the precinct to inevitable climate change. Broadly, this involved selection with respect to the water, waste and greenhouse gas emission reduction hierarchy, the selection criteria and the performance measurement indicators are outlined in Section 6.0. The following actions were completed:

- To meet the needs of the future growth scenario (refer to Section 5.4) and the assumed efficiency rates of consumption (refer to Table 3), the yearly consumption rates for the precinct were calculated.
- A water balance model was developed for the precinct. The water balance was completed for existing and future growth scenarios with demand management targets for the precinct.
- The assessment criterion was used to complete a “traffic light” triple bottom line assessment to screen the suitable technologies, which informed a series of strategies that combine the various acceptable options under a number of themes.
- A workshop of the wider AECOM project team was held to review the sustainable infrastructure options, demand management targets, project goals and potential draft strategies.
- The capacities of various technologies were scoped for their level of contribution towards realising the eco-city targets. The spatial requirement needed to house the technology was identified, so that locations for the preferred initiatives could be identified based on land use, footprint, proximity to co-located services and serviceability.
- Three strategies were then developed and evaluated against their performance in meeting the eco-city targets, with a preferred strategy agreed.
- A refinement of the preferred scenario against the type, scale and location of technologies was then completed, requiring a final assessment of their contribution towards Future Melbourne eco-city targets.

5.0 Constraints and Opportunities at Southbank

5.1 Current Utilities demand

Southbank is well serviced from a centralised supply of gas, water and electricity and its disposal infrastructure for wastewater through a localised distribution network. A description of Southbank's current land use, population, resource consumption and utility infrastructure and any identified constraints and opportunities follows.

5.1.1 Land use and population

Approximately 39,000 people are employed in the Southbank precinct (City of Melbourne 2008b). The number of people living in Southbank has recently grown to 10,500, largely due to the addition of new high rise apartment buildings such as Eureka tower and Freshwater Place. This trend is set to continue with the construction of the Triptych apartment building which is currently being built in Kavanagh Street. Approximately 12 percent of the CoM's residents reside within Southbank.

Commercial operations including hotels, conference centres, car parking, retail and office buildings comprise more than 50 percent of the floor space (Gross Floor Area (GFA)) utilised in Southbank. Of the remaining GFA, residential accommodation occupies approximately 20 percent and entertainment/ recreation and open space contribute between 10-15 percent each.

5.1.2 Resources consumed

The current level of resource consumption within the Southbank precinct, based on data provided by the utilities outlined in Methodology above, is provided in Table 7.

Table 7 Resources generated by and consumed within the Southbank precinct

Utility Service	Resource generated or consumed per year	Asset Manager
Grid power electricity	499,004 MWh	CitiPower
Mains gas supply	136.1 TJ	MultiNet (Jemena)
Greenhouse gas emissions from gas and electricity	615,781 t CO_2-e	
Mains Water	1,800 ML	South East Water
Stormwater	500 ML	City of Melbourne and Melbourne Water
Sewer	1,500 ML	South East Water
Municipal Solid Waste (MSW) - landfill	3,022 t	City of Melbourne
Municipal Solid Waste (MSW) – combined recycling	858 t	City of Melbourne

*Note: all values are for the 2008 calendar year except for energy and greenhouse gas emissions which are for FY 2007/08

5.2 Comparison of existing demand with Eco-city targets

When comparing the current resource consumption rates to the eco-city targets, the potable water consumption rate has almost reached the target. This is a direct result of the water saving initiatives that CoM has implemented. Additional work needs to be done to achieve the waste and stormwater eco-city targets. Current rates of energy consumption require a significant reduction to reduce employee and resident greenhouse gas emissions by 60 percent and 35 percent respectively. The challenge of reducing resource consumption is highlighted in Section 3.0 which outlines the resources used within the precinct, the source of the resource supply, how it is consumed and the rates of consumption against the eco-city targets.

5.3 Existing infrastructure systems

The existing infrastructure within the Southbank precinct includes electricity and gas, mains water supply, stormwater drainage and sewerage. In general terms, the following discussion explores the capacity of these utilities and the impact of future development. The study finds that the interconnection of these services to surrounding suburbs will alter their capacity.

5.3.1 Electricity

The Victorian electricity network is divided into the generation, transmission and distribution sectors. CitiPower is the responsible authority for maintaining and operating the electricity distribution and subtransmission network within Southbank. These systems transfer power from the high voltage transmission network (operated by another company) to the major load centres via terminal stations and zone substations. The distribution system then accepts power from the zone stations and distributes it to the final consumers.

The electricity infrastructure within Southbank supplies an area which extends beyond the Southbank precinct. As such, the capacity of the Southbank electricity network is not limited to the demands of the Southbank area. CitiPower design the electricity network to an N-1 standard. This means an allowance is made in the system for planned or unplanned removal from service of any line, such as the transformer or circuit breaker at the time of 50th percentile maximum demand loading.

The Southbank Precinct is supplied by three 66kV/11kV zone substations (ZSS):

- South Melbourne (SO) on the corner of Miles and Dodds streets in Southbank
- Montague (MG) on the corner of Munro and Johnson streets in South Melbourne
- Southbank (SM or SB) on the corner of Kavanagh and Balston streets in Southbank.

The Albert Park (AP), West Gate (WG), Docklands (DLF), Flinders-Ramsden (FR) and Mcillwraith Place (MP) zone substations and Richmond Terminal Station (RTS) also supply electricity into the Southbank Precinct.

The three main zone substations are supplied via 66kV ring sub transmission lines from the Fishermans Bend Terminal Station. The SM ZSS is currently decommissioned and is to be replaced at the same location by a new zone substation (SB) in 2011. When commissioned, the SB ZSS will be on the same sub transmission ring as the SO ZSS. The MG ZSS shares its sub transmission ring with the AP ZSS. A 22kV sub transmission line also runs through the Southbank area to the Tavistock Place (TP) ZSS in the CBD. The indicative location of the zone substations is visually represented in Figure 10.

Based on calculations undertaken by AECOM from data provided by CitiPower, the SO ZSS currently exceeds its N-1 capacity by 2.2 percent and the MG ZSS is loaded to 94 percent of its N-1 capacity. The Southbank area only comprises a small proportion of the total supply area for the MG ZSS, so the six percent N-1 spare capacity is not limited to increases in load in the Southbank area. Of the zone substations that supply minimal power into the Southbank precinct, the AP and WG ZSS are running at 113 percent and 50 percent of their N-1 capacities respectively. The availability of supply from the other remaining ZSSs is dictated more by the capacity of their distribution feeder lines rather than the capacity of the ZSS itself.

In the short term there is limited spare capacity in the zone substations which supply the Southbank precinct. Spare capacity in the area will be increased in 2011 with the commissioning of the new SB ZSS and the subsequent redistribution of the zone substation loadings. The installation of new zone substations and distribution substations is difficult due to the limited space available in the area. New developments may need to consider the location of a distribution substation within the site or building.

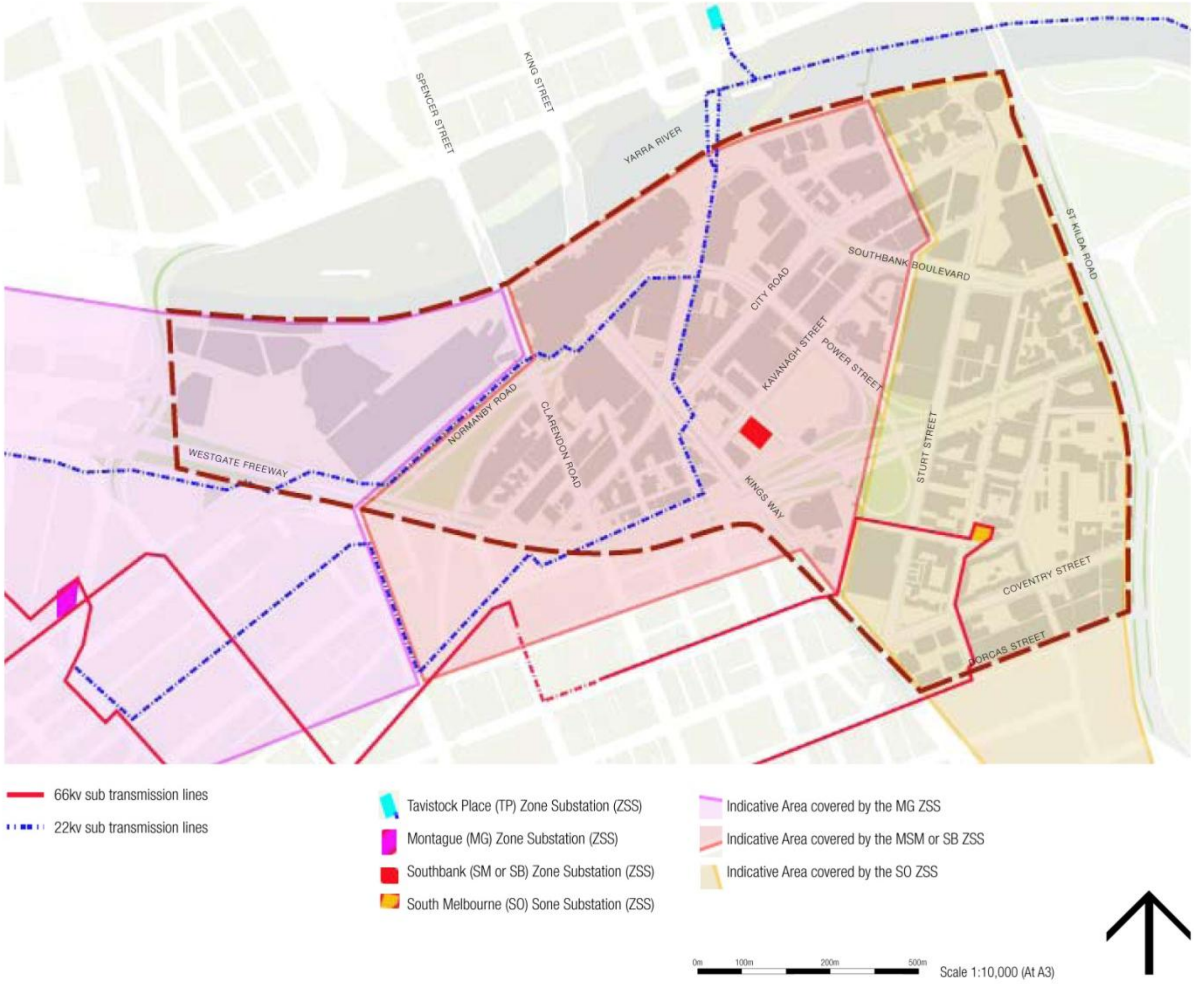

Figure 10: Map of the electricity zone substations which supply the Southbank precinct.

From the zone substations, power is reticulated through the Southbank precinct via a combination of overhead and underground 11kV distribution feeders. These distribution feeders connect to numerous 11kV/415V distribution substations which then supply power to consumers. Some larger consumers take their power at the higher 11kV voltage. Figure 11 shows the indicative locations of the distribution feeders through the Southbank precinct.

A significant proportion of the Southbank area is supplied by overloaded distribution feeders. Each new load in the area will need to be addressed on an individual basis. It is unknown at this stage how the feeder loadings will change with the commissioning of the SB ZSS. The nature and time of any network modifications required will not be known until CitiPower has completed their assessment (planned for 2010).

The power system will require significant modifications in the future as new developments are completed and upgrades are required to substations and transmission and feeder lines.

Figure 11: Map of the electricity distribution feeders supplying the Southbank precinct.

5.3.2 Gas

MultiNet Gas has an extensive gas pipe network which covers Southbank, including transmission and high pressure distribution pipes, as shown in Figure 12. The transmission pressure pipes run north south through the precinct and also service municipalities on both sides of Southbank. The transmission pressure pipe network is the backbone of the gas network that delivers gas to downstream reticulated pipe networks. The high pressure pipes are fed from the transmission pipes and are distributed throughout Southbank to provide coverage. The extensive gas reticulation pipe network that provides gas supply to all properties and feeds from the distribution pipes is not shown in Figure 12.

The area is generally regarded as a high cost construction zone due to the high costs of reinstatement and traffic management and other asset congestion in the ground. While this requires significant planning in undertaking works to provide additional capacity within the Southbank precinct, it is not constrained by a practical or technical ‘cap’. In the foreseeable future the low pressure reticulated gas network is not planned to be upgraded by replacement to high pressure unless load applications warrant such an upgrade. Augmentations of upstream facilities and additional main laying would accommodate any reasonably conceivable amount of additional natural gas load required, including multiple centralised co-generation plants. It should be noted that the:

- low pressure reticulated gas network has no unutilised capacity
- high pressure reticulated gas network has minimal unutilised capacity in most areas.

Figure 12: Map of the gas distribution pipe network for Southbank

5.3.3 Water Mains

The main source of water supply for the Southbank precinct is the 600mm diameter pipeline that traverses the area and originates from the north, across the Yarra River, to link with a 900/750/600mm diameter pipeline located in Punt Road to the south. The 600mm diameter pipeline, which has an estimated overall capacity of 85 ML/d, currently supplies part of the CBD, Southbank, South Melbourne and Port Melbourne. South East Water has an extensive water main network, comprising several kilometres of pipes of varying diameters that service Southbank. A map showing the extent of coverage in Southbank is provided in Figure 13.

The capacity constraint that could be caused by extensive growth within Southbank and the surrounding areas has the potential to be partly solved by methods beyond the current conventional water supply means. Alternative water supplies and a reduction in demand on water would free up capacity in the network.

Figure 13: A map of the water supply infrastructure supplying the Southbank precinct.

5.3.4 Stormwater

The stormwater network is an interconnected system affected by the capacity of the surrounding drainage network. Stormwater in the Southbank precinct is captured in the drainage system and discharged into the Yarra River where it eventually flows into Port Philip Bay. Melbourne Water is responsible for managing the larger stormwater drains in Southbank, which is part of an extensive network covering the Port Phillip and Westernport catchment, made up of over 1,200 kilometres of stormwater drains. As such the water quality and flow are also partly controlled by the City of Port Phillip. The CoM is responsible for maintaining Southbank's stormwater drains, road networks and street and property drainage that feed into the larger stormwater drains and into the Yarra River. A map of the stormwater network is provided in Figure 14.

Figure 14: A map of the stormwater network in Southbank

The wider catchment of the Melbourne drainage network is highly developed (mostly covered by roof and paved surfaces and with minimal parkland). Any increase in development is expected to have minimal impact on the percentage of rainfall runoff. The stormwater pipe network is commonly sized for smaller 'minor storm' rainfall events. 'Major storm' rainfall events will normally exceed the capacity of the pipe network and flow overland. As such, the predicted higher frequency and intensity of extreme weather events as a result of climate change will most likely increase the risk of flooding in Southbank. This is likely to be exacerbated by other climate change impacts, such as sea level rise which could combine with more intense rainfall events to increase water levels in the Yarra River potentially blocking drainage pipe outflows.

The land subject to inundation from a climate change induced sea level rise of 1.1m by 2100 has been modelled by the CoM, as shown in Figure 15. This map depicts flooding to South Wharf and along Kings Way. Modelling undertaken on the affect of climate change on flooding within Southbank to date has only considered sea level rise; storm surge, changes in extreme rainfall, draining network infrastructure and tidal impacts have not been considered. It is anticipated the inclusion of these variables will exacerbate the level of flooding. Incorporating inundation protection, enhanced flood management and 'adapted to climate' design strategies should considerably increase the resilience of future development to respond to sea level rise and flooding impacts.

Figure 15: Map of the flooding inundation from a 1.1m sea level rise by 2100 due to climate change. Source: City of Melbourne, (2009)

5.3.5 Sewer

South East Water (SE Water) manage and maintain an extensive sewerage network servicing the Southbank precinct, including a pump station within the Crown Casino complex and three main branch sewers receiving flows from an extensive reticulation network. Located just outside the precinct boundary to the south east and west are two main sewer networks (the Melbourne and South Yarra main sewers) which are operated by Melbourne Water and receive flows from SE Water's branch sewers. Some private dwellings in Southbank may operate small scale black or grey water treatment systems, with the exact number and types of these systems unknown.

Melbourne Water is replacing a section of the existing Melbourne Main Sewer. The new main sewer will travel approximately 2.3km from the Docklands precinct and cross the Yarra River upstream of the Charles Grimes Bridge into Port Melbourne. During the project, approximately 2.5km of new local branch and reticulation sewers will be constructed to reconnect the existing local sewers into the new Melbourne Main Sewer. Six vertical access shaft sites will be located along the route of the new sewer, with one of the shaft sites located within Southbank at South Wharf. The project is due for completion by 2012.

The map of the sewer network provided in Figure 16 shows these branch sewers and sewer mains. Property connections are serviced by an extensive reticulation main network along the majority of streets which is not shown on the map for clarity reasons.

Improvements in water use efficiency have resulted in decreased dry weather flows, while shorter more intense storms resulting from climate change are expected to increase wet weather flows in the upstream reaches of sewer catchments. These combined impacts should be considered when assessing the long term viability of sewer mining opportunities. Based on the projected growth as outlined within the Southbank Structure Plan, the expected increase in sewer flows will require SE Water's branch sewers to be significantly upsized along with extensive upgrades to the reticulation system feeding the branch sewers. Furthermore, as the effects of climate change become more pronounced, the sewer system may have to be upgraded to allow for sea level rise and storm surge inundation of the sewer vents.

Figure 16: A map of the sewer network servicing the Southbank precinct.

5.4 Future growth in Southbank: structure plan scenario

Southbank is in an ideal position to deliver the goals of *Future Melbourne* through a new urban paradigm that will establish the city as a world leader in sustainable living. Southbank currently typified has a poor public realm with a lack of activity and vibrancy, unsustainable buildings and a lack of human scale and civic quality to the built form. The following strategies address these issues and provide an alternate future for Southbank. The key strategic recommendations from the *Southbank Structure Plan* are outlined below:

- Develop three new activity nodes that can provide focal points for new commercial, retail and community infrastructure development.
- Position Southbank as the natural extension of the City by creating an intensified area of mixed use activity and establishing the Yarra River as part of the city's centre, not its edge.
- Establish new built form controls that will deliver a human scaled built form, activated streets and improve the quality of the public realm.
- Stitch together the northern and southern 'halves' of Southbank by decking above the circular exit ramp onto Power Street (over the void) with new development to create a connected and continuous mixed use area.
- Deliver the key public realm initiatives of the *Southbank Structure Plan* and establish two new large parks within the area.
- Establish City Road, Southbank Boulevard, Power Street and Coventry Street as key pedestrianised east-west routes, and Clarendon Street, Queensbridge Street, Kings Way and Sturt Street as key pedestrianised north-south routes.
- Deliver buildings that have a high environmental performance.
- Establish mechanisms for the delivery of sustainable servicing initiatives including distributed energy generation and water re use.

A preliminary investigation of the service infrastructure required to meet the needs of the additional growth forecast by the Structure Plan shows that all utilities have some spare capacity in the interim, but that additional supply will be required in the longer term (within five to 15 years depending on the actual growth rate in the area). While local augmentation could permit short to medium term development within the Precinct, indications are that additional capacity will be required to service long term forecast growth of this magnitude.

Table 8 presents a summary of the key population, dwelling and employee growth figures for Southbank, as presented in the Structure Plan.

Table 8 Current and forecast population, dwelling and employee numbers within the Southbank precinct.

Factor	Existing*	Proposed in the Structure Plan
Total residential population (people)	10,500	81,300
Total number of dwellings	5,250	54,600*
Total employment population (people)	38,000	47,800

*Note: The residential population density assumes 500 people per ha, 340 dwellings per ha and 1.3 people per dwelling.

The Southbank Structure Plan proposes servicing the needs of the precinct to:

- address the significant number of overloaded distribution networks on a collective basis, rather than the current approach which is on an individual basis
- retain land for the future development of additional service infrastructure within Southbank
- reduce network augmentation.

There are several unique resource characteristics that define Southbank, some of which are naturally occurring, including the wind, sun, the Yarra River and an aquifer, whilst others have been developed by people, including car parks and waste. Each of these, if harnessed correctly, presents an opportunity to reduce the ecological impacts of servicing the needs of residents and employees within the Southbank precinct, as outlined below:

- The sun and wind can be harnessed to generate renewable electricity.
- The Yarra River provides the option of generating potable water onsite and acting as a heat sink.
- The aquifer can provide a means for storing and recovering water during the wetter seasons of winter and spring, for extraction during the dryer season of summer.
- Cars are generally used for 8% of their life, at other times they remain idle. With the movement towards electrified vehicles, car parks could become energy hubs of the future. Cars can not only be recharged by the grid, they can also provide power back into the grid in times of peak electricity demand.
- The large quantity of water and solid waste generated is an opportunity for recovery and reuse within the precinct. Waste water could be recycled to provide 'fit for use' water and the organic component of solid waste could be recovered for reuse as a fertiliser, with methane captured for energy generation.

6.0 Design options

The initiatives identified in Stage One of this study were summarised into a Technology Toolbox, as a suite of possible initiatives that could be implemented in the Southbank precinct. Refer to Appendix B for this toolbox which discusses each initiative in more detail than presented in this section.

The following discussion is a summary of the assessment of these options to determine their suitability for use within the Southbank precinct to assist in meeting the eco-city targets. While the assessment has been guided by the option's ability to satisfy the water, waste and greenhouse gas emission reduction hierarchies, each initiative has been assessed against established criteria to determine their suitability.

A summary of the benefits and disadvantages of the options is provided below, followed by a summary of the assessment of each initiative's potential performance against the selection criteria identified above.

6.1 Discussion of initiatives

6.1.1 Energy initiatives

A Central Services Hub (CSH) would have the benefit of significantly reducing resource consumption whilst enhancing properties as less plant space would be required in each building (that is, connected buildings would not require chillers, boilers or cooling towers). This would allow roof space to be utilised for other means, such as health clubs and green roof gardens whilst generating more rent for the building owner and lowering operating costs.

A district system compared to a building based system creates the ability to supply a range of buildings with different energy demand profiles from one location, improving economies of scale and efficiency of operation by 'smoothing demand'. The larger plant required for such a system also makes carbon reduction technologies more commercially viable through economies of scale, while the further consolidation of plant allows a reduction in the electrical and water infrastructure. Such systems also typically provide an improved reliability of service and lower operating and maintenance costs. Other benefits and issues are discussed below:

- District chilled water provided from a central services hub (CSH) and generated by a tri-generation plant with an absorption chiller is a more reliable form of providing coolth than solar cooling. Whilst building based chillers are reliable, they often run on greenhouse gas intensive grid electricity.
- Co-generation is a more efficient form of energy generation than fuel cells. However, fuels cells have the benefit of being able to be retrofitted into existing dwellings (co-generation plants are only able to be when unusually large plant rooms are available).
- There are no high pressure reduction stations within the Southbank precinct to which pressure reduction valves can be applied.
- PV systems and micro wind turbines are potential sources of renewable energy generation.
- Solar hot water is more suited as a technology in a low density residential supply scenario. Given the high density residential and commercial proposed by the Structure Plan, there will not be sufficient roof space for solar hot water to be a feasible option.
- The large cooling demand of the precinct will require some form of heat rejection.
- The potential underground storage space in Southbank is limited by the alluvial soils, prohibiting the ability to store thermal energy.

6.1.2 Water initiatives

The proposed water initiatives will push conventional boundaries by supplying recycled wastewater for laundry uses and harvesting stormwater to supply hot water from the CSHs. Hot water from CSHs would also supply a proportion of the demand for laundry, showers, dishwashers and taps. The recycled water network could be extended beyond the boundaries of the Southbank precinct to supply large open spaces and new developments.

Potable water demand management could achieve best practice targets while the availability of excess recycled water would promote the establishment of additional green spaces throughout the precinct and on its boundaries. As public acceptance and understanding of recycled water and other alternative supply sources continues to grow, it is now possible to substitute a greater proportion of end uses traditionally supplied by potable water.

Stormwater harvesting would have the additional benefit of meeting stormwater quality discharge targets, while localised flood mitigation would be achieved through a combination of harvesting, green roof gardens and a decrease in the impervious area throughout the precinct. It is expected that enough potable water demand substitution could be provided through these strategies to avoid large network upgrades. As such, balance tanks are not included, although detention tanks for wastewater will still be required.

Key Features:
• Best practice demand management and increased green space. • Localised wastewater recycling plant. • Dual pipe reticulation of recycled water for advanced non potable uses (laundry and cooling). • Rainwater and stormwater reuse for hot water. • Out of precinct supply of recycled wastewater. • Irrigation of green roof gardens.

A range of further water related issues and opportunities are discussed below:

- Recycled water can be reticulated to buildings through a dual pipe network. Supply opportunities outside of the precinct should be sought including Albert Park, Alexandra Gardens and Fawkner Park. Recycled water could supply toilets, open space irrigation, laundry, fire fighting, cooling and tri–generation systems. Providing recycled water to tri-generation plant would allow recycled water to be reticulated throughout the precinct as chilled water. It could also be used to supply the large process water demand of tri-generation.
- Recycled stormwater could be collected both locally and from external Melbourne Water main drains passing through the precinct. This stormwater could be treated, supplied to the tri-generation plant and reticulated throughout the precinct as a hot water supply.
- A variety of storage options should be explored, including local aquifer storage and recovery, storage at Albert Park Lake, or distributed storage as part of an intelligent storage network.
- An opportunity exists to make Southbank a net potable water provider. Potential local brackish water supplies include the Yarra River and a localized confined groundwater aquifer. Both of these opportunities have significant environmental, social and technical issues to be overcome. However, the extraction of water from the Yarra River in particular appears to have significant potential.
- Vacuum sewers could replace ageing sewers within high density precincts. These sewers could be constructed at grade allowing for installation within a shared services tunnel. Combining this technology with new water-tight sewers would significantly reduce inflow and infiltration, allowing for smaller diameter pipes.
- Urine separation would reduce water demand and enable the recovery of nitrogen and phosphorus.
- Onsite tanks could be installed as header tanks for fire fighting pumps, with the added benefit of buffering peak demands within the reticulation system. These tanks would most likely be connected to the supply source which supplies the fire fighting system (proposed to be recycled water in this instance) but could also be connected to both potable and non-potable supplies.

6.1.3 Solid waste resource recovery initiatives

Provided below are several points discussing opportunities and issues relating to solid waste recovery:

- Waste composting and anaerobic digestion is beneficial for recovering organics for use as a fertiliser and for generating renewable electricity at a rate of approximately 1MW per 10,000 tonnes of municipal solid waste digested (DECC 2009).
- Waste incineration does not capture any benefits from recycling or reusing waste, and does not encourage minimising waste generation. As such, it does not adhere to the waste management hierarchy.
- The cost to retrofit an extensive solid waste distribution pipe network within Southbank, and the energy required to operate a vacuum waste collection system, would be significantly greater than the benefit.

6.1.4 Infrastructure initiatives

To support the recovery and reuse of sustainable resources, through the implementation of energy, waste and water initiatives, infrastructure needs to be created, as discussed below:

- Central Services Hubs (CSH) are proposed to house wastewater treatment and tri-generation plant.
- A combined services tunnel could house the multiple new service pipes and conduits that would need to be installed during the development of the precinct.
- Header tanks could assist the storage and pressurisation of recycled water.
- Vacuum sewers are well suited to replace ageing sewers within high density precincts and they could be constructed at grade and located within the services tunnel.

6.1.5 Open space and green space initiatives

Open spaces contribute to a wide range of sustainable development objectives, including water management, a reduced urban heat island effect, acting as carbon sinks, providing noise and thermal insulation, improving outdoor amenity, and improving stormwater quality by filtering pollutants before entering the Yarra River. Benefits will be maximises if the space is designed to support these objectives in combination rather than isolation.

Furthermore, open space enhances the biodiversity value of urban environments, and enhances community health, wellbeing and social cohesion. For example, an iconic waterfall feature falling from the top of a building in a highly visible location would create an extraordinary space with cooling benefits to recreational users, its envelope of green space as well as to the urban form.

6.2 Assessment of the initiatives

The criteria used for the assessment of initiatives are presented in Table 9. Initiatives were classified according to whether it met the selection criteria either mostly, in part or failed.

Table 9 Selection criteria for Southbank precinct sustainable Initiatives

Criteria	Performance measurement indicator
Cost	Capital, operating, avoided costs, marketability
Environment	Adherence to the water, waste and energy hierarchy Resource recovered, generated and contribution towards eco-city goals, increase in urban biodiversity
Social	Precinct amenity, social acceptability, physical and mental health
Performance	Reliability, operational and maintenance requirements
Installation and integration	Site specific constraints, opportunities and land use requirements, regulation constraints, ability to interconnect with existing networks (new and existing infrastructure and buildings)
Legacy issues	Ownership and governance of the technology and interface with relevant authorities. Adaptability to climate change, consumer habits development trends and growth
Synergy	How well the technology can be used in conjunction with other technologies to maximise benefits within the region.

Each initiative was assessed against each of the criteria and is given a rating for each. The ratings, presented in Table 10 correspond to a +1, 0, -1 scoring system, the sum of which gives the overall rating in terms of whether the criteria mostly, partly or fails to satisfy the criteria. The assessment is presented in Table 11.

Table 10 Legend for the rating classification of each criteria

+1	mostly satisfies all criteria
0	partly satisfies the criteria
-1	fails to satisfy most criteria

Table 11 Assessment of sustainable servicing initiatives

Infrastructure Servicing Initiatives (from the Technology Toolbox)	Cost	Environment	Social	Performance	Installation	Legacy Issues	Synergy	Summary
Energy initiatives								
Central chilled water / district cooling	0	+1	+1	+1	0	0	+1	+1
Co-generation / Tri-generation	0	+1	0	+1	+1	0	+1	+1
Fuel Cells	-1	+1	0	-1	0	+1	0	0
Heat Rejection	0	+1	0	0	0	0	0	+1
Micro and mini wind turbines	+1	+1	+1	0	+1	+1	+1	+1
Pressure Reduction Turbines	+1	+1	+1	+1	-1	-1	0	+1
Solar Photovoltaic	+1	+1	+1	+1	+1	+1	+1	+1
Solar thermal hot water	+1	+1	+1	-1	-1	+1	+1	+1
Thermal energy storage	-1	+1	0	-1	-1	0	0	-1
Solar cooling	0	0	0	-1	0	0	+1	0
Electric Vehicles to Grid (V2G)	0	+1	0	-1	0	0	0	0
Water initiatives								
Sewer Mining	0	+1	+1	+1	+1	0	0	+1
Stormwater Harvesting	+1	+1	+1	+1	+1	0	+1	+1
Aquifer Storage & Recovery	0	+1	+1	0	-1	0	+1	+1
Yarra River to supply potable water	-1	-1	+1	+1	-1	0	0	-1
Sewer mining to supply potable water	-1	-1	-1	+1	0	0	-1	-1
Sewer mining to supply recycled water	0	+1	+1	+1	0	0	-1	+1
Stormwater and rainwater to supply recycled water	+1	+1	+1	+1	+1	+1	+1	+1
Stormwater and rainwater to potable water	+1	+1	0	+1	+1	0	+1	+1
Solid waste resource recovery initiatives								
Waste composting and anaerobic digestion - bio-digester	0	+1	0	+1	0	0	+1	+1
Waste incineration via a biomass boiler	0	0	0	0	0	0	0	0
Urine separation	-1	+1	-1	0	-1	0	-1	-1
Vacuum waste collection system	-1	-1	+1	-1	-1	-1	-1	-1
Infrastructure initiatives								
Central Services Hub	-1	+1	+1	+1	-1	0	0	+1
Services tunnel	-1	+1	+1	+1	-1	+1	0	+1
Vacuum sewers	-1	0	+1	+1	-1	0	0	0
Header tanks	-1	0	+1	+1	-1	0	0	0
Distributed underground water storage tanks	-1	+1	+1	+1	-1	0	+1	+1
Open Space initiatives								
Water Sensitive Urban Design (WSUD)	0	+1	+1	+1	0	+1	+1	+1
Green Roofs	+1	+1	+1	+1	0	+1	+1	+1
Private Outdoor Spaces	+1	+1	+1	+1	0	+1	+1	+1
Green Walls	0	+1	+1	0	0	-1	+1	+1

The assessment of the initiatives against the selection criteria shows that all technologies have impediments to delivery. In analysing the assessment a few interesting trends emerge; the biggest inhibitors are the cost, installation and legacy issues; while unsurprisingly the technologies generally performed well against the social and environmental criteria. The standout performers are proven technologies commonly installed in existing urban environments, including:

- Photovoltaics (PVs)
- Stormwater reuse
- WSUD, and
- Green roof gardens.

Thermal energy storage, generating potable water from the Yarra River or sewer mining, waste incineration and a vacuum waste collection system, all performed poorly, which is also unsurprising. The ground conditions render thermal storage on the scale required unfeasible, there are river health impact issues to consider with extracting water from the Yarra River and social barriers still exist to drinking recycled wastewater. Additionally, the waste hierarchy does not promote waste incineration and CoM are considering broader waste management strategies. An extensive network of infrastructure is required for vacuum waste collection and the benefits do not warrant the investment to install such an intensive system in an established urban environment. The infrastructure initiatives all have cost and installation impediments.

7.0 Implementation strategy

The aim of this study is to present a sustainable utility strategy that will reduce resource consumption within the Southbank precinct. The strategy presented is based on the development of Southbank over the next 30 years. At present there a number of constraints that will need to be addressed to enable the delivery of the proposed strategy. An implementation strategy will provide the framework to navigate these barriers and a process to develop deliver the strategy in practice.

Several issues require detailed consideration due to their potential impact on technical and commercial constraints. Broadly these have been categorised into four areas:

- Regulation barriers to obtain the required approvals for the supply and distribution of utility services.
- Commercial arrangements associated with financing, contracts and business models for project delivery, construction, ownership and operation.
- Stakeholders will be affected at different stages as the strategy develops, from the users, operators, authorities, council and community, they will need to be informed, engaged and become part of the process.
- Development of the strategy to determine the optimum sizes and exact location of each infrastructure type will need to incorporate commercial and regulatory considerations.

In developing the strategy, these issues need to be managed to ensure due consideration is given to the influence they have in shaping the technical and commercial aspects. The strategy needs to be underpinned by technical and commercial studies to establish the optimum size and exact location of each proposed infrastructure type. For the strategy to be a success there needs to be a strong governance structure with the capability to balance various aspects that will at times compete against and influence each other. These elements will play out when managing the process, engaging with stakeholders, seeking to change regulations, establishing innovative financing arrangements and designing the detail around the technical considerations.

To ensure that these issues are addressed and overcome, the CoM needs to take on stewardship role to guide and drive the delivery of the sustainable infrastructure servicing strategy. Following is a discussion of regulatory, commercial, design and stakeholder issues, and an outline of a plan to guide the development of the strategy.

7.1 Issues for consideration

There are several issues that will require careful consideration and management to determine and minimise their impact on influencing the development of the strategy. These have been grouped to facilitate their management and co-ordination into regulation, commercial, design and stakeholders, as outlined in Figure 17. A discussion of each of these follows.

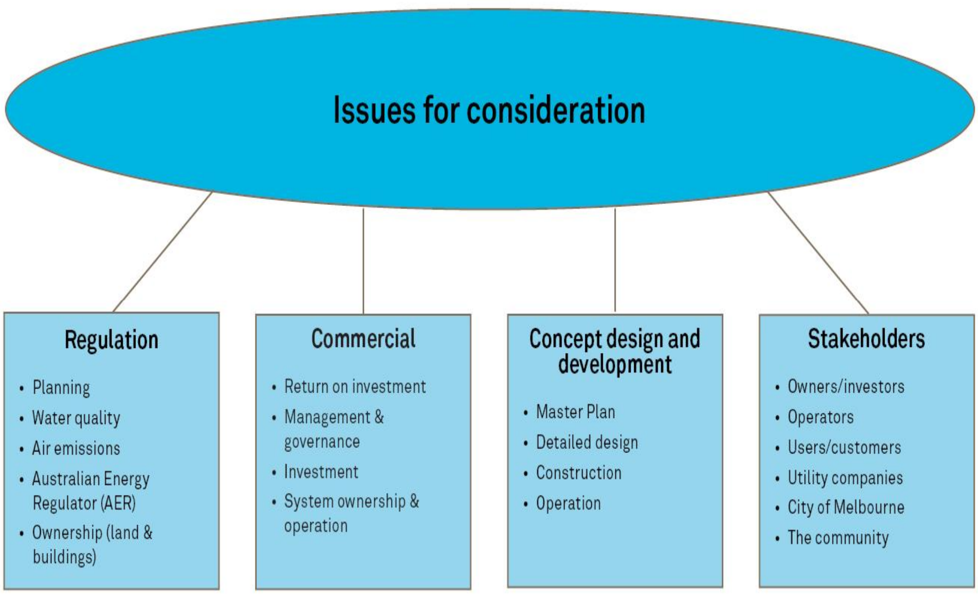

Figure 17: Issues for consideration by City of Melbourne in developing the sustainable utilities strategy

7.1.1 Regulation

Current regulations do not support the implementation of the sustainable utilities strategy, with changes required to the *CoM Planning Act (2010), Energy Regulations (2010), Water Quality Requirements and the Building Control Act* (2010). An outline of some of the required changes is provided below. However, the detail of these provisions will need to be developed further for consultation and decision making by CoM.

The CoM are advised to collaborate with the Australian Energy Regulator, electricity distribution companies and relevant government agencies such as Infrastructure Australia's Major Cities Unit to overcome barriers to implementing distributed energy generation. This might be through:

- changing the National Electricity Rules to require distributed energy options to be implemented wherever they are cheaper than network augmentation
- streamlining the complex and costly licensing requirements and procedures required for distributed generators to produce and supply electricity to the grid
- establishing financial incentives to support distributed energy options
- establishing annual targets for distributed energy and publicly report on progress.

The planning scheme also needs to be aligned with the requirements of the sustainable utilities strategy. Planning controls are designed or selected to deliver the particular strategic and development outcomes envisioned for an area, with clarity, consistency and ease of use. Changing the planning scheme itself requires Ministerial approval. Simplistically, this requires that the changes to the planning scheme are well resolved, supported by information which justifies the need for change and support the delivery of state planning policies and initiatives.

The tools available within the Melbourne Planning Scheme to implement the sustainable utilities strategy include state and local policy, land zonings, overlays and provisions dealing with services. A more detailed discussion of progressing amendments to the planning scheme for implementing the sustainable utilities infrastructure plan is presented in the CoM's Southbank Structure Plan (AECOM, 2010). The potential changes to the planning scheme are outlined below:

- Investigate the option of mandating that all new buildings within Southbank are to source heating, cooling and recycled water from a CSH, to ensure that the plant is utilised to optimum capacity. This would remove the ability to choose a service provider. In terms of the electricity supply regulations, all consumers must be able to choose an electricity retailer. While it is unknown if the same regulations would apply, mandating the cost of the service to be lower than market cost will most likely be required.
- A council wide policy could be adopted to promote renewable energy similar to the 'Merton Rule' in the UK, which is a prescriptive planning policy that requires new developments to generate at least 10 percent of their energy needs from on-site renewable energy equipment. Also, many councils, such as the Oxford City Council, have, since Merton introduced 10 percent, moved to 20 percent. The exact policy text below has been extracted from the Borough of Merton (2010):

  > "The council will encourage the energy efficient design of buildings and their layout and orientation on site. All new non residential developments above a threshold of 1,000sqm will be expected to incorporate renewable energy production equipment to provide at least 10 percent of predicted energy requirements.
  >
  > The use of sustainable building materials and the re-use of materials will also be encouraged, as will the use of recycled aggregates in the construction of buildings. This will be subject to the impact on the amenity of the local environment, taking into account the existing character of the area."

- A new planning scheme should be investigated which stipulates waste service infrastructure such that all refurbishments and new buildings provide practical waste and recycling services for their tenants, and the distance a tenant has to travel to recycle is the same as the distance required to deposit landfill waste.
- Central Service Hubs could raise issues of amenity, noise and odours for neighbouring land uses. These sites are yet to be selected. However, mitigation of these impacts could influence site selection, or the detailed design of the CSH. Further investigation into the nature of the operation of any CSH, the potential locations and the resultant amenity impacts is required before the land use framework can be resolved.

- A consolidated and agreed planning framework could provide the basis for the resolution of the current situation where two planning authorities (the City of Port Phillip and CoM) control different parts of Southbank.
- The vision for Southbank may take some time to deliver. In this regard, one alternative is to undertake planning scheme amendments for the whole area to ensure that all new development accords with this vision. Another alternative approach would be to stage the implementation of these initiatives and to roll them out over time. The downside of this approach is that land uses may be established that are contrary to, and might impede the, subsequent delivery of the Southbank Structure Plan.

The future Southbank anticipates that development will link into a Central Services Hub (CSH) that will provide raw product inputs into that facility and will use its outputs. The CSH approach will require the input of raw products (such as natural gas and wastewater) and a minimum demand of the outputs (heat, coolth and power) to be viable. This will require each development to provide the infrastructure that can use this system. Clause 56 of the planning scheme includes provisions for new residential subdivisions to use this infrastructure. However, this principle will need to be extended to the Southbank precinct.

Whilst the planning scheme is one vehicle for this provision, another alternative is to look at other legislation outside of planning where compliance is more likely to be mandatory (eg. the *Building Control Act 1993*, a new local law, the *Subdivision Act 1988*). Indeed, such is the nature of issues being considered for the Southbank precinct, the notion of "excising" Southbank from more conventional regulations and its establishment as a pilot for a different legislative process (not dissimilar to the principles behind the recently introduced *Major Transport Project Facilitation Act 2009*) should be investigated.

7.1.2 Design

The design needs to be developed in a staged process, so that at each stage greater detail can be added. Financial, commercial, technical and regulatory issues will also require consideration at each of these stages to guide and influence the process. Decisions on the design of the system need to be resolved by the CoM.

Some of the issues that require resolution over what the system may seek to incorporate are outlined below:

- CoM's current waste strategy is currently under review, will its stance regarding the generation of energy from waste unresolved. This needs to be resolved as this will influence the establishment of any waste to energy systems.
- It is unclear if a Master Plan for decentralised energy would be designed to address peak or total yearly electricity demand.
- It is unclear if there will be the potential for the electricity network to become independent of the local distribution grid to enable island generation operation (that is, a private wire network).
- It is unclear if recycled water will be exported from the precinct to supply other areas, such as parklands and new developments.
- The role and responsibilities of the CoM in developing the design are not yet determined.
- It is unclear if elements of the design will be undertaken separately.
- It is unclear what elements will become mandatory in new and existing developments without removing the flexibility for developers to innovate. It also hasn't been determined if this could involve establishing benchmarks regarding:
  - rainwater collection
  - a proportion of a building's energy supplied by on site renewable energy systems
  - green roof gardens
  - resource efficient building design, including potentially using rating tool targets
  - mandating that all new building connections utilise the reticulated recycled, hot and cold water from a CSH.

CoM may wish to explore the option of issuing the strategy as separate staged packages of work for further development. However there will need to be an allowance that enables these strategies to feed into each other as they are interdependent on one another. This could be broken down into the following packages:

- combined cooling, heat and power (tri-generation)
- renewable energy
- waste to energy plants (dependant outcome of pending state, regional and council strategies)
- water treatment and supply
- increased green spaces.

7.1.3 Commercial

CoM needs to determine what assistance they will provide to facilitate this strategy, potentially including regulations, planning controls or financial contributions. These decisions should be governed by a transparent business model that will guide the management and implementation of the strategy through the development of its Master Plan, detailed design, construction and its eventual operation.

As there is a considerable amount of uncertainty inherent in this process, risks will need to be prioritised to ensure the strategy is developed into a design that can be implemented.

An understanding on the interdependency of the different elements of the strategy will be required to manage the process. Key features will need to be identified as required outcomes at each stage of the strategy delivery process. This will require a project delivery model to be developed for managing the process and key strategies.

Other commercial considerations may include:

- financial arrangements
- ownership models
- contractual arrangements
- project delivery methods (BOOT, D&C, novation, alliancing and project management)
- an electric retailer's licence as legislation requires a retail licence to sell electricity (no licence is required for selling hot or cold water)
- a generator licence is required for a generator greater than 2MVA
- an EPA emissions licence is required for a generator greater than 20MVA
- works approval is required for generators greater than 5MVA.

7.1.4 Stakeholders

The careful management of stakeholders and their input into developing the design, commercial arrangements, staging implementation, rollout and operation will be required. Stakeholder engagement will be critical to the project's success by:

- assisting to build a deeper understanding of the project's impact
- helping to articulate the objectives behind the strategy
- facilitating the regulatory approvals process
- gaining a broader level of participation, awareness and acceptance of the strategy
- proactively improving relationships.

The CoM will need to determine to what extent they will undertake stakeholder engagement. In doing so, the role of stakeholders should be identified (for example, will they be advisory or participatory?). The rationale for engaging stakeholders should guide the style of engagement. Clarity about when engagement with the various stakeholder groups will occur also requires consideration.

The stakeholder engagement process could include the following objectives:

- Establishing a committee to facilitate stakeholder engagement.
- Seeking endorsement from the public, councillors, authorities, utility companies and within CoM, not only for the principles of the strategy presented here, but a commitment to its delivery.
- Engaging with stakeholders to facilitate a shift in thinking to treat the provision of resources within the precinct like other urban and community services.
- Encouraging an appreciation of the various technical, commercial, regulatory and consultative challenges in implementing decentralised energy and water supply systems.
- Communicating the need to stage the implementation over a long period of time.

7.2 Implementation plan

7.2.1 Project governance

Project governance is required to help ensure the successful delivery of the sustainable utilities strategy. A set of processes and policies guiding the manner in which the projected will be implemented and managed and a process for the management and resolution of issues that will arise during the project needs to be established. Once a framework for managing the project is created, a robust business case that underpins the strategy should be established. This should also identify stakeholders and define communication methods.

One option would be the establishment of an Implementation Review Committee comprising representatives of the CoM, DPCD and other key stakeholders whose mandate would be to monitor and improve the delivery of the Structure Plan. This Committee could also orchestrate more formal reviews of the Structure Plan and its implementation.

It is proposed that:

- CoM should seek to amend the current planning regulations and influence the energy regulations to encourage and support the implementation of the sustainable utility strategy
- CoM should seek to endorse the next stage of developing the strategy into a Master Plan so that a business case can be developed as outlined in section 2.0 of this report
- CoM commits to a stewardship role to guide the implementation of the strategy and to engage with critical stakeholders within the council, state government, the community and the utility companies. A governance structure should be established for stakeholder involvement in overseeing and reviewing the implementation of the Structure Plan.
- the Structure Plan and the planning framework is be used to implement the sustainable utilities strategy, and that this should be reviewed on a semi-regular basis to measure the effectiveness of the initiatives and improve delivery where required.

7.2.2 Developing the strategy into a Master Plan concept

To confirm that the sustainable utilities strategy is viable, it needs to be developed to a stage that will enable further analysis to demonstrate its commercial feasibility. This would involve the development of the strategy to a design standard from which preliminary cost estimates to be can be formed, referred to as the 'Master Plan'. Work on developing the strategy is recommended to commence after:

- CoM has confirmed its role as stewards of the strategy
- the initial phase of community consultation and stakeholder engagement is complete
- a governance structure is established to guide the process.

Costs at the Master Plan stage are generally accurate to plus or minus 30%, which is increased to plus or minus 10 percent at the detailed design stage. A proportion of the work involved in developing the strategy to a Master Plan standard has been undertaken as part of this study. As such, it is not proposed that this work is fully revisited, rather that further development and consolidation is undertaken. The outcomes of the process that have in part been undertaken at the conceptual framework, but will require further investigation include:

- identifying the barriers to implementation and developing a plan for navigating these
- providing the required background information to inform the next stage of developing the proposed strategy to detailed design and business case
- outlining a process to guide and inform ongoing stakeholder consultation.

Developing the preferred strategy to a Master Plan will involve:

- developing a description of the operational philosophy of the system
- identifying and confirming existing conditions (including any existing assets)
- confirming reductions in greenhouse gas emissions, water, energy and waste
- calculating the local air quality impacts from the operation of a tri-generation plant
- developing the strategy to a Master Plan design for all assets in the sustainable utilities strategy. Potential innovations in scale, configuration, treatment, operational philosophy, ownership and commercial arrangements and synergies between infrastructure systems will need to be considered. Additionally, any operational constraints or considerations, including operations during times of no inflow/generation and/or no demand will need to be detailed
- determining the likely location, size and configuration of collection and distribution networks, generation, treatment and storage facilities. The optimal plant size should be determined based energy (heat to power ratio) and water demand profile projections for the precinct, while considering the phasing of the plant size to match precinct development
- developing a staging plan to service the initial stages of development. As the loading of the plants will be incremental, they will most likely need to be installed in a modular fashion aligned with the build out of the development will be over an extended period
- identifying key strategic, regulatory, technical and commercial risks and proposing mitigation measures
- identifying any significant institutional or approvals requirements which may have a material impact on the technical or commercial feasibility of the recommended strategy. Any regulatory and commercial barriers will also need to be fully understood to progress the strategy
- developing capital and operating cost estimates and a preliminary commercial delivery framework
- developing the business management model for the implementation of the strategy from Master Plan to detailed design, construction and operation.

7.2.3 Business case development and investment and ownership models

Following the development of the Master Plan, a business case should be undertaken to confirm the investment value proposition for the CSHs and other sustainable infrastructure options. This would involve an analysis of the total project cost on an NPV basis, with an appropriate sensitivity analysis. The impact on utility pricing and developer costs should also be determined.

Consideration should also be given to potential growth opportunities, incentives, barriers and risks to investment, government support, technology partners and funding models. The staging of investment will be critical to success.

A key challenge will be overcoming the legalities of an ownership model and the regulation barriers governing the implementation and operation of sustainable energy and water distribution infrastructure. Issues of ownership of private assets on public land will also need consideration. The size of the plant will require the operator to hold a licence to generate. It is likely that implementing a CSH will take the form of a BOOT contract funded by the operator. The contractor would then be granted exclusive rights for the construction, financing and operation of the necessary works.

7.2.4 Detailed design, construction and operation

Following the approval of the business case further functional design will need to be undertaken by an appropriately qualified multi-disciplinary team. Detailed design, construction and operation of the system will be dependent on the selected delivery mechanism.

While the CSH will need to be substantially constructed at the commencement of this project, a staged installation of plant and equipment is the most likely technical and financial scenario. This could be through a modularisation of the CSH, where units are added to match demand. Revenue for the CSH operator will be dependent on the growth of the system, with the full revenue potential only being achieved at full development. New business relationships must be developed with the utility industry, so that new business models and partnerships can emerge to deliver the infrastructure servicing strategy.

Construction and operation of any new infrastructure would involve the following steps:

- Develop a staging program for the implementation of the initiatives.
- Allocate a capital works budget, prepare a final design option, obtain formal approvals from relevant authorities and prepare and implement construction documents.
- Commence the implementation of the staging program.
- Monitor operations to optimise asset management and environmental performance.

8.0 Recommendations

This study outlines an infrastructure servicing strategy that could be implemented within the Southbank precinct. This strategy supports the delivery of the City of Melbourne's (CoM) *Future Melbourne Eco-city targets* and creates a sustainable vision for the precinct. To progress the strategy, it is recommended that CoM:

- adopts the sustainable utilities strategy as part of the Structure Plan (as outlined in section 2.0)
- adopts the Implementation Strategy (as outlined in section 7.0)
- commits to a stewardship role in leading the development and implementation of this strategy
- progresses the strategy into the next stage of development in collaboration with the utility companies (as outlined in section 7.0
- establishes an Implementation Review Committee comprising representatives of CoM, DPCD and other key stakeholders (as outlined in section 7.0).

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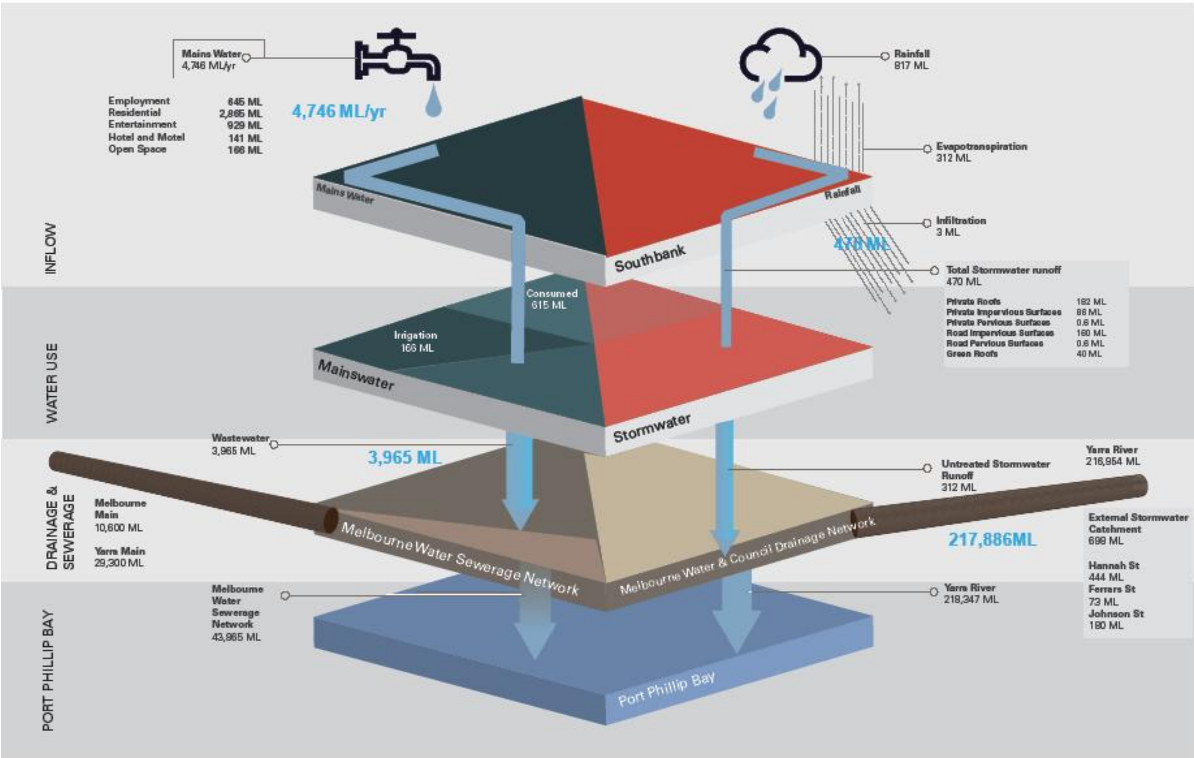
Appendix A

Water Balance

Appendix A Water Balance

PREFERRED SOUTHBANK WATER STRATEGY



Appendix B

Technical Toolbox

Appendix B Technical Toolbox

Energy initiatives

Element	Description
Name	**Central chilled water**
Description	Centralised chilled water plant, also known as district cooling, involves generation of chilled water for building and process cooling in a central location to serve multiple buildings/facilities. Electric driven chillers by their nature have efficiencies that vary depending on load. The larger the chilled water load, the higher the efficiency of the chilled water generation. The main advantages of centralised plant include: • Total installed mechanical and electrical chilled water plant can be reduced when compared to de-centralised plant (as a result of load diversity). • Maintenance of plant can be simplified. • Electrical infrastructure can be simplified. • Increased efficiency results in reduced running costs and carbon emissions. • Feasibility of other environmental technologies such as solar cooling and tri-generation is increased. Plant diversity exists as peak chilled water consumption for each building in a precinct often occurs at a different time of the day/year. The result is that less chilled water plant is required when installed centrally than when installed within each building being served.
Energy output	Centralised chilled water plant output is only limited by the distance chilled water can be reticulated from a central location. This can in some instances be over a kilometre where large distances exist between locations of chilled water demand. The feasibility of reticulating chilled water large distances depends on the load requirements and load profile throughout the year. Commonly centralised chilled water plant installations are in excess of 5MWr.
Siting requirements	Centralised chilled water plant is best located central to the area or precinct being served to minimise the distance to reticulate chilled water. Centralised chilled water plant are often sited in a Central Services Hub (CSH) that would be positioned close to electrical or natural gas feeds to the precinct.
Barriers to take up	A majority of the barriers associated with the implementation of centralised chilled water plant are related to setting up centralised plant within an existing area/precinct. In an existing precinct the following issues need to be addressed; • A suitable location for central plant needs to be found. • Chilled water reticulation needs to be coordinated with existing services within the area. • Existing buildings need to be reconfigured to accept chilled water from street level. • Existing buildings need to be reconfigured to operate with common chilled water flow and return temperatures. No legislation currently exists to regulate private central plant on-selling chilled water to buildings within an area/precinct. As no utility providers currently exist for on-selling chilled water, plant operation costs would need to include the administrative costs associated with billing and regulating the on-selling of chilled water to private operators within the area/precinct.
Indicative cost	Costs vary depending on capacity and site specifics. Plant area costs are upward of $3000/m2 with additional costs for plant and chilled water infrastructure.
Trend in take up	Central chilled water plant is becoming an increasingly popular method for reducing energy consumption and carbon emissions. Central chilled water plant is very common within the middle east.
Known applications	• Dandenong CSH. • RMIT City Campus. • Grid X – Sydney. • National University of Singapore (NUS). • Royal Melbourne Hospital. • James Cook University – Townsville.

Element	Description
Name	**Cogeneration & Tri-generation**
Description	Cogeneration (also combined heat and power – CHP) is the process of producing electricity by combusting fuel and utilising the waste thermal energy of the combustion process for heating purposes. Waste thermal energy can also be used to produce chilled water with the addition of an absorption chiller. When power generation is combined with the production of heating hot water and chilled water the generation scheme is termed Trigeneration. Cogeneration and trigeneration systems have the benefit of increasing the utilisation of energy released through the combustion process to increase overall energy efficiency. Fuels that can be used for co/trigeneration include; • Natural gas. • Biomass. • Diesel / Bio-diesel. • Oil / Coal. • Any combustible material. Natural gas reciprocating engines are commonly used in commercial developments due to the availability and low carbon content of natural gas, and the high electrical efficiency of reciprocating engines. As there are multiple products of a co/trigeneration plant, plant is generally setup to run under electrical or thermal lead. For instance, in electrical lead, the generator is setup to modulate electrical output on electrical demand. Heat or thermal energy in this instance becomes the waste product to be used or rejected via cooling towers. As natural gas generators significantly reduce in electrical efficiency at part load, generators are selected for the electrical and thermal building/precinct demands to ensure part load operation is minimised. Load modelling of the building/precinct is recommended to ensure generator selection is optimised for the electrical and thermal demands of the precinct.
Energy output	Reciprocating engines are widely used in applications that range from 50kWe to 4500kWe whereas gas turbines are used for larger scale applications that range from 500kWe to 200MWe. Gas turbines have a greater heat output per unit of electricity generated than reciprocating engines that make them better suited to industrial processes. They also have a low part load efficiency and take longer to modulate output than reciprocating engines.
Siting requirements	Cogeneration and trigeneration systems both require extensive infrastructure connections such that location can be critical to the feasibility of the plant. Co/trigeneration plants serving a large area or precinct are generally setup within a Central Services Hub (CSH). Design considerations include; • Generators have a large noise and vibration output and plant needs to be located accordingly. • Location of plant preferably minimises alterations to existing infrastructure; hence plant is located near to existing electrical infrastructure, natural gas infrastructure and close to the buildings being served.
Barriers to take up	The following design factors often effect the feasibility of co/trigeneration plant; • Co/trigeneration plant has a large spatial requirement that can complicate finding a suitable location for plant, specifically in an already developed area. • Large upfront infrastructure and running costs often decrease economic feasibility. • Large base-load utility demand is often required to optimise plant utilisation. Other legislative barriers exist with setting up a co/trigeneration plant. Local government is increasingly becoming active in this area to reduce red tape. Electricity providers are often reluctant to connect generation plant to their existing electrical infrastructure and even more reluctant to purchase electricity from small private generators. The Melbourne CBD in particular has an antiquated electrical infrastructure that is not designed to deal with fault currents that can be imposed by onsite electrical generation plant. Electricity providers require detailed fault level analysis to be carried out on the local network and reserve the right to refuse connection of supply. Co/trigeneration

	plant can operate in island mode, without grid connection, however this requires complicated switching arrangements and increased plant costs. No legislation currently exists to regulate decentralised co/trigeneration plant on-selling electricity, heating and cooling. For large co/trigeneration plants serving multiple buildings, the model used for on-selling plant output is critical to co/trigeneration feasibility.
Indicative cost	Costs vary significantly depending on infrastructure connection costs and site specifics. Costs are upward of $5m for a 1MWe trigeneration plant.
Trend in take up	Interest in co/trigeneration has recently increased significantly as a means to reduce carbon emissions. As the overall efficiency of the electrical plant is increased with utilisation of waste heat output, and the use of low carbon intensive natural gas, co/trigeneration can be significantly less carbon intensive than the use of grid electricity. Reductions in carbon emissions can increase to as high as 70% with well utilised plant and minimal grid electricity consumption. Fuel cells can also be used in a co/trigeneration plant although at present, electrical efficiencies and plant costs are resulting in a preference for reciprocating plant.
Known applications	• ANZ Docklands. • Dandenong CSH. • Blackmore's – Sydney. • Royal Children's Hospital.
Links to further information and key references	Cogen Europe. Viewed 10 Oct, 2009. <http://www.cogeneurope.eu/> Combined Heat and Power Association. Viewed 10 Oct, 2009. <http://www.chpa.co.uk/>

Element	Description
Name	**Fuel Cells**
Description	A fuel cell is an electrochemical device that produces an electrical current through a chemical reaction carried out within the cell. The cell contains an electrolyte and oxidant that act as a catalyst to separate the components within the fuel, in doing do releasing energy. This energy release is similar to the process of combustion as oxygen is commonly required as a catalyst; however energy is released in the form of electricity. The waste products of the fuel cell process are commonly water and/or carbon dioxide. Fuel cells have been developed to use a range of fuels such as; • Alcohol (methanol or ethanol). • Hydrogen. • Petroleum & petroleum derivatives. • Natural gas. • Diesel. • Methane. A majority of the commercial fuel cells operate using a Solid Oxide Fuel Cell (SOFC) design. These can be setup to run with a majority of fuels at efficiencies theoretically as high as 70%[1]. Commercial fuel cells presently have efficiencies up to 50%[2]. Solid oxide fuel cells also generate heat, with fuel cell systems operating between 500 and 950degC. As such, collection of waste heat is also feasible, similar to the process carried out with co/trigeneration. Due to their low noise output, fuel cells are popular for use in developed areas where combustion engines would create unwanted noise or vibration. A majority of fuel cells currently marketed have the drawback of limited longevity. Fuel cells may operate between 3 and 5 years before the internal plates need to be cleaned or replaced. This along with the relatively high cost of fuel cells has limited their commercial success to date. Ongoing research into fuel cell technology is constantly improving fuel cell efficiency, longevity and reducing cost.
Energy output	Fuel cells scale well with small demonstration units having the ability to power mobile phones while larger industrial units produce up to 2.8MWe.
Siting requirements	Fuel cells require positioning in a similar fashion to combustion engines with infrastructure connections to the electrical grid and fuel source (commonly natural gas).
Barriers to take up	Although research is ongoing, fuel cells currently have a high cost and limited longevity that make them less economically viable than traditional combustion process for electricity generation. Fuel cells however have a number of advantages over combustion engines such as scalability, low noise/vibration and high part load efficiencies that make them advantageous in certain situations.
Indicative cost	Fuel cells vary in cost with small 2kWe demonstration units starting at $50k[3].
Trend in take up	Fuel cells are becoming more popular as research increases their economic viability. Currently there is work underway to setup a number of demonstration scale projects in Melbourne, with one in Dandenong by VicUrban. Large scale fuel cell installations are more common in the US where fuel cells have been used to generate power from land fill gas or coal mine methane; http://www.epa.gov/coalbed/docs/fuel_cells.pdf

[1] Fuel CellsMarkets Pty Ltd, Bucks, United Kingdom, viewed 12 October, 2009,<http://www.fuelcellmarkets.com>
[2] Fuel Cell Energy, Danbury, California, viewed 12 October 2009, <http://www.fuelcellenergy.com>
[3] Ceramic Fuel Cells Limited, Victoria, viewed 12 October, 2009, <http://www.cfcl.com.au/>

Element	Description
Known applications	Some stationary fuel cells suitable for residential use are entering niche commercial markets, in Europe (mostly Germany), Japan and the USA and is largely the result of long term and substantial research and demonstration (R&D) investment and government support[4]. The United States Department of Energy is working closely with its national laboratories, universities, and industry partners to overcome critical technical barriers to fuel cell commercialisation. Current R&D focuses on the development of reliable, low-cost, high-performance fuel cell system components for transportation and buildings applications[5]. Commercial effort in fuel cell technology is relatively small in Australia and is concentrated mainly on the Solid Oxide Fuel Cell technology.
Links to further information and key references	Fuel CellsMarkets Pty Ltd, Bucks, United Kingdom, viewed 12 October, 2009,<http://www.fuelcellmarkets.com> Fuel Cell Energy, Danbury, California, viewed 12 October 2009, <http://www.fuelcellenergy.com> Ceramic Fuel Cells Limited, Victoria, viewed 12 October, 2009, <http://www.cfcl.com.au/>

[4] http://www.ret.gov.au/energy/clean_energy_technologies/energy_technology_framework_and_roadmaps/hydrogen_technology_roadmap/DokLents/HYDROGEN%20ROADMAP.pdf

[5] http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/

Element	Description
Name	**Heat Rejection**
Description	Heat rejection as the name suggests involves the rejection of heat from a mechanical or electrical process to the surrounding environment. Heat rejection is required for the following technologies: • Central chilled water plant. • Co/Trigeneration plant. • Fuel cells. • Solar cooling. Heat can be rejected in the following ways: • Open type air cooled cooling towers. • Closed type adiabatic coolers. • Open or closed ground loops. • Open or closed loop river or waterway heat rejection. • Sewer heat rejection. Due to their large heat rejection capacity, the most common form of heat rejection involves open type cooling towers that reject heat through the evaporation of water. This water is generally potable water however recycled water is becoming more common as a means to reduce potable water consumption. Open type cooling towers require ongoing maintenance and water treatment to mitigate any risk of infection. Open type cooling towers operate at temperatures that potentially promote the growth of legionella. Bromine is a common biocide used in the prevention of legionella infection.
Energy output	Heat rejection capacities common to each technology; • > 20kW - Open type air cooled cooling towers. • < 2MW - Closed type adiabatic coolers. • < 2MW - Open or closed ground loops. • EPA limited - Open or closed loop river or waterway heat rejection. • < 20kW - Sewer heat rejection.
Siting requirements	• Cooling towers and adiabatic coolers reject heat to the air and require positioning in an open air environment. • Ground loops require suitable geology or aquifer to reject heat. • Sewer heat rejection requires a suitably sized sewer main.
Barriers to take up	Each heat rejection type has its own advantages and disadvantages. Design item to note include: • Use of recycled water within open type cooling towers has strict infection control requirements. • The DHS currently recommends adiabatic coolers due to their reduced legionella risk over open type cooling towers. • Operating temperatures for each heat rejection type must be taken into account during the design as the choice of heat rejection may have a significant effect in overall plant operational efficiency. • Water authority and/or EPA approval is required for ground and water source heat rejection. • Adiabatic coolers have a large spatial requirement and noise output that often precludes their use.
Indicative cost	Costs vary depending on heat rejection type, capacity and site specifics.
Trend in take up	A majority of commercial buildings require heat rejection in some form to reject heat from solar, occupant and equipment heat loads. Open type cooling towers are common in the commercial environment. Interest is increasing in alternative heat rejection technologies such as adiabatic coolers and river/water way heat rejection to reduce potable water consumption.

Element	Description
Known applications	• Sydney's 'Workplace6' utilises water from the adjacent harbor to provide heat rejection. http://www.building.co.uk/story.asp?storycode=3123791 • Muller 3C adiabatic coolers have been used successfully on a range of jobs including; Kingston Aged Care Redevelopment Stg2, Sunshine Hospital and Royal Melbourne Hospital.

Element	Description
Name	**Micro and Mini Wind turbines**
Description	Wind energy is captured by wind turbines to generate electricity. While large wind power plants are typically built in rural areas, small wind power plants (10kW single phase or 30kW three phase[6]) are suitable for the private and commercial domain. The height of these wind turbines are between 6.5m and 25m and the rotor diameter is between 3.5m and 9m. The output depends on the wind speeds of the location. A small scale wind power plant operates effectively with an average wind speed of 4 m/s. There are two main types of wind turbine: Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). Currently about 10 different brands and 30 different models of domestic wind turbines are available in Australia. These range from output of below 1kW up to 20kW. Deployment of micro wind turbines technology in Australia is at a very early stage. Some home owners in rural areas already have domestic wind turbines which tend to be in unobstructed surroundings and are generally not grid connected, whereas urban grid-connected turbines are relatively rare.
Energy output	Although there is an emerging market for domestic roof-mounted turbines, very little research has been published on the potential energy output. The power output is affected by the wind resource and the wind turbine. Anticipating the power output of a wind turbine is a complex process requiring a synthesis of data produced from a wind resource assessment and turbine specific wind speed power data (power curve). Turbine power curves are curves fitted to empirical data that relate wind speeds to turbine power output. However, turbines behave significantly different from test conditions to the real world affecting the accuracy of an output estimate. Depending on the average annual wind speeds the annual output of a 2.5 kW wind turbine (Proven 2.5) would be 2,500 kWh at lighter wind sites with a typical average wind speed of 4.5 m/s and 5,000 kWh at higher wind speed sites with a typical average wind speed of 6.5 m/s. Wind resource is the most important factor in calculating the economic viability of a wind turbine, however it is very difficult to predict in an urban area. For MWT to be effective Energy Matters (2009) recommends correct siting and a wind speed of at least 4.5 m/s average or more, with the best results being achieved at averages of 5.4 m/s. Proper siting is a critical factor in the performance and longevity of MWT.
Siting requirements	The ideal position for a wind power generator is a flat open space with good wind from at least one direction (known as the prevailing wind direction), a coastline, or a smooth hill top with an open area in the prevailing wind. The wind speeds up significantly near the top of the hill and the air flow should be reasonably smooth and free from excessive turbulence. Excessive turbulence or "bad wind" causes fatigue damage and shortens a generator's working life. Mounting a wind turbine on structures presents a range of issues which require careful consideration. MWTs have significant weight comparable to the weight of solar panels. Unlike solar panels the turbine will introduce forces about the mounting structure. Vibrations from the turbine are transferred to the structure creating noise and structural instability. The structural integrity of the intended mounting structure needs careful consideration due to the turbine's load. Current standards in place to address the mounting of turbines on structures include AS1170 - minimum design loads on structures. There is potential for wind turbine structures to develop in a similar manner to PVs (ATA, 2007). When solar PV cells were first introduced to the market many consumers built home-made frames to mount them on roofs. Now PV mounting structures must be approved and as a result they are generally purchased off-the-shelf. Energy Matters (2009) recommends that the height of the bottom of the rotor blades is at

[6] Utility Regulators Forum (URF), Draft National Code of Practice for EG" (February 2006), (http://www.mce.gov.au/assets/dokLents/mceinternet/DraftCoPEGforWeb20060221154032.pdf),

Element	Description
	least 6 m above any obstacle that is within 76 m of the tower, 7.6 m to the hub. In built up urban environments, this will limit the number of suitable sites. Wind speed will generally increase with tower height. However, increasing the height of the tower will increase installation cost and may be limited by planning regulations.
Planning requirements	The Victoria Planning Provisions do not currently include guidelines to assist decision making on MWT. Planning requirements specifically targeting small scale wind turbines in urban Melbourne are still some way off. Planning considerations may include construction, noise, shadow flicker, height and size, they are likely to require, but do not at present, more complex regulations than solar PVs (ATA, 2007). Noise is a critical issue for small turbines especially in the urban context, as they will always be positioned close to homes. The number of grid connected MWT across the state is at present very small and, as a result, councils are yet to produce any planning guidelines governing their installation. At this stage, turbines are treated on a case by case basis, resulting in little consistency. As part of the City of Port Phillip's commitment toward environmental and social sustainability, the planning permit application fee for small scale wind turbines is not required. (City of Port Philip, 2009)
Barriers to take up	• Power generation - limited by turbine size, type, the location and quality of the wind speed. • A lack of urban locations possessing both suitable wind speeds and minimal interference from surrounding buildings and vegetation • Legislative barriers - including the lack of targets and incentives, the low value of energy exported to the grid and difficulties in obtaining planning permission • Technology development and affordability - high cost of micro-wind turbines, coupled with the lack of rebates and incentives to pursue the technology on a domestic or small-scale • Complexities with planning and connection approvals – noise, especially HAWTs, and amenity issues coupled with grid connection challenges • Structural and compliance issues presented by installing a turbine on building, including vibration caused by rotation of the turbine • Low consumer awareness in obtaining information and advice for installers and end users. The main issue facing grid connected wind turbines in Australia is a lack of available, approved inverters designed specifically for wind turbines. To connect with the electricity grid, all micro-wind turbines require inverters. There are significant compliance requirements for the design and installation of inverters that need to be met. Most inverters available in Australia have been designed for PVs. The only wind-specific inverter available is the SMA Windyboy and this is still in the process of being approved for use in Australia.
Indicative cost	In general, the economic performance of MWT has poor payback periods. A general rule of thumb, the fully installed and connected package is equal to the cost of the turbine plus $10k. As a guideline on the fully installed costs, some local retailers (Energy Matters, 2009) provide package deals for full installation and grid connection of selected wind turbines. They are priced at: • Soma 1kW including Latronics PV Edge inverter and 20m tower - $16,400. • Whisper 1kW including Latronics PV Edge inverter and 20m tower - $14,600. • Westwind 3kW including Fronius IG30 inverter and 24m tower - $32,000.
Known applications	Some known micro wind turbine installations in Victoria include: • CERES Community Park, Brunswick - 15kW wind turbine • Gippsland TAFE - Monash Freeway and Warrigal Road intersection • Hume City Council - Hush Trial

Element	Description
	• City of Melbourne - recent planning application submitted for the installing an array of wind turbines on the rooftop of a building. In Elephant and Castle (London) a research project has been undertaken on a pilot wind turbine installation to assess the viability of deploying small scale roof top turbines across the Elephant and Castle core development area with a view to generating a significant proportion of the Mayor's 10% renewable energy requirement. Phase 1 involved a 6 kW HAWT; Phase 2 (currently underway) involves a 6 kW VAWT.
Other considerations to implementation	Where the micro wind turbines are designed to operate to provide electricity back to the grid, electricity connections need to be arranged with the distribution network provider. Depending on the size of the wind array, timing and the cost of connection will alter significantly.
Links to further information and key references	Alternative Technology Association, Domestic Wind Turbines, Melbourne, viewed 12 October, 2009, <http://www.ata.org.au/projects-and-advocacy/domestic-wind-turbines> Utility Regulators Forum (URF), Draft National Code of Practice for EG" (February 2006), http://www.mce.gov.au/assets/dokLents/mceinternet/DraftCoPEGforWeb20060221154032.pdf

Element	Description
Name	**Pressure reduction turbine**
Description	Water or natural gas utilities are commonly distributed at very high pressure to maintain flows along main distribution branches. These pressures are often significantly greater than final distribution pressures. These pressures are regulated down to final distribution pressure at regulation stations, commonly through the use of throttling valves. It is possible to replace these throttling valves with an energy recovery device, such as a turbine, to utilise this energy that would otherwise be wasted. In the case of natural gas, this energy can be used to heat high pressure natural gas before pressure is reduced. This reduction in pressure drops the temperature of the gas. As such natural gas often requires heating prior to a reduction in pressure to ensure the gas will not freeze. Although the energy generated by a pressure reduction turbine would commonly be wasted, in most instances this technology would not be deemed renewable as the medium has been increased in pressure by water or natural gas distribution stations, commonly operating off grid electricity. An exception to this would be a gravity fed water main where pressure reduction turbines would act in a similar way to a hydro-electric station.
Energy output	The energy output of a pressure reduction turbine is limited to the pressure drop and volumetric flow of the medium. For most installations this will represent a small proportion of energy used in distributing the utility.
Siting requirements	Pressure reduction turbines have limited spatial requirements however need to be sited within existing or proposed gas or water pressure reduction stations, or large commercial facility with high pressure utility connections . Existing pressure reduction stations may not immediately have space to house pressure reduction turbines. Pressure reduction turbines may be incorporated within a Central Services Hub (CSH) that uses a large quantity of natural gas or water. These facilities may require high pressure utility connections due to peak flow requirements.
Barriers to take up	Issues with implementation include; • Locating a suitable site for pressure reduction turbines. • Electrical infrastructure required to on-sell electricity generated requires local electrical authority approval.
Indicative cost	Costs are dependent on the type of service utilising the pressure reduction turbine, the size of flow and the magnitude of the pressure drop.
Trend in take up	Pressure reduction turbines are an established technology in industry. Interest is increasing in large commercial developments that require high pressure gas or water connections as a means to offset overall energy consumption or supplement electrical output.
Known applications	Although the technology is commonly utilised within the industrial sector, there are no known applications of this technology within the commercial sector.
Links to further information and key references	FuelCell Energy, Inc, Danbury, California, viewed 12 October 2009, <http://www.fuelcellenergy.com/files/FCE%20DFC-ERG%20090507.pdf>

Element	Description
Name	**Solar Photovoltaic**
Description	Solar photovoltaic (PV) cells generate electricity when exposed to sunlight. PV cells are arranged in solar panels and usually connected to the grid through an inverter, which converts the direct current output into 240 alternate current (AC) suitable for household appliances and feeding into the grid. The majority of PV cells are made from silicon, with 4 different types available: • Monocrystalline. • Polycrystalline (also known as multicrystalline). • Ribbon silicon. • Amorphous silicon (abbreviated as "aSi," also known as thin film silicon). Other non-silicon thin-film technologies are becoming more available, using materials such as cadmium telluride (CdTe) and copper indium diselenide (CIS). PV systems may be either grid-connected or store energy in batteries: • **Grid connected PV systems** are not capable of storing surplus energy for night use. Grid connection is viable when the energy demand profile correlates well with daylight. For office buildings occupied during the day and vacant at night, this is usually the case. When a grid-connected system is generating more energy than you need, your electrical metre turns backwards. Domestic applications, which generally peak in demand after normal working hours, will use grid connection to generate income from the sale of unused PV generated electricity. Many large arrays are intended solely for use as power plants, enhancing or supplanting the need for conventional power plants. • **Off-Grid PV systems** gather energy from solar modules and direct into energy storage devices for use when needed. Many off-grid PV systems are used to energize remote homes, facilities, and devices. Note an area is required for the batteries storing the energy generated from the PV system. • **Building-Integrated Photovoltaics (BIPV)** can be used as an attractive building material. In some cases, they can replace conventional building materials, for example, roofing tiles can be replaced by solar cell laminates.
Energy output	Based on an average annual peak sun hours[7] for Melbourne of 4.6 per day across the year, a 1 kWp PV unit is capable of producing 1,260 kWh per year. The PV efficiency can vary depending on the type of PV model used and decreases with increasing temperature. One method of reducing roof temperature and improving the electricity production of PV panels is through their integration with a green roof. The roof cools the PV panels through evapo-transpiration, maintaining a higher electricity production than would be the case without the vegetative layer (Appl et al. 2004).
Siting requirements	PV cells can be installed on rooftops (1 – 2 kWp) or in solar arrays or integrated into the building (Building integrated photovoltaics BIPV). The average daily power output for a 1 kW solar panel installed in Melbourne is approximately 3.38 kWh (for a 2 kW solar panel this output is doubled). Shading of the PV modules impacts significantly on the system performance therefore should be considered when siting installations. For example, consider the shading of a roof top from adjacent buildings.
Barriers to take up	While the environmental benefits of PVs are a driver for some customers, the popularity and prevalence of solar PV is primarily a function of its cost relative to grid electricity. This can be tied to an interaction between the following factors: • Existence, size and eligibility criteria for rebates on capital outlay • Presence and financial incentives of feed in tariffs • The cost of grid electricity • Cost of solar PV technology

[7] Peak sun hour are the equivalent number of hours per day when solar irradiance averages 1 kW/m^2. For example, four peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance for four hours been 1 kW/m^2.

Element	Description
	There are several government polices currently in place to reduce the cost of solar PVs in Australia and drive their uptake.
Indicative cost	A capital cost for solar PV is $11,000 per kWh for the multicrystalline (BIPV is again more expensive per kWh)
Trend in take up	Given the economics of solar PV, growth in Australia and the world has been a direct result of policy intervention. In Australia, the increase in grid connected PVs over the past decade can be largely attributed to a significant reduction in the purchase price due to the federal government's rebate program *Solar Homes and Communities Plan (SHCP)* and the increased efficiencies achieved through the rollout of bulk installations. These initiatives reduced the cost of a typical 1.3 kW[8], residential grid connected PV system, from $12,000 to around $4,000. The government assistance for purchasing PV systems has undergone a number of changes over recent years, which have impacted the rate of uptake of PV. Non-export PV sales in Australia have grown by approximately 15% per year over the last five years, in comparison the world growth rate has exceeded 40% per year since 2000 (BCSE, 2006). However, solar power still represented only 0.1% of global electricity generation in 2007 (Ferrier, 2008). The average annual growth of the worldwide PV market up to 2008 is projected to be 27%, then rising to 34% between 2010 and 2020 (Aubrey, 2004). Although experiencing significant growth, a shortage in polysilicon over the last few years has limited the growth of crystalline PV technologies. This is due to a doubling in the production capacity of crystalline PV technologies in the last 3 years to meet demand. Over half of the electronic grade silicon produced in 2007 was used in the production of crystalline PVs. Between 2008 and 2010 it is projected that more than €4.1 billion will be invested in upscaling silicon production capacities to end the shortage in supply by late 2009 or early 2010. (EPIA, 2008) The temporary shortage in crystalline PVs production provided the opportunity for the thin film PV technology to meet the demand shortfall. While thin film represented less than 5% of the total production capacity in 2005, at around 90 MW, it is expected to grow to more than 20% in 2010, or around 4 GW, and 5% in 2013 with about 9 GW. Among the thin-film technologies, the non-silicon based technologies hold significant growth potential. As it is based on non-silicon material, it is not sensitive to fluctuations in the polysilicon market. New companies are establishing non-silicon production lines, increasing the availability of thin film PVs (G.J, 2009).
Known applications	• **Tullamarine-Calder Interchange**, adjacent to Essendon Airport freeway noise-wall (sound barrier) constructed of a 500m length of vertically-inclined PV panels, totalling 24kW of peak power output. • 50 Lonsdale St, Melbourne – 4kWp rooftop PV • **40 Albert Road,** Solar Pergola • Bridgewater Solar Energy Research Centre, near Bendigo; a 2.6MW trial site is using heliotrope (sun-tracking) fields of solar panels. • **Ballarat University** - 8.4kWp Building Integrated PV
Links to further information and key references	• Roland Appl / Wolfgang Ansel (2004), Future Oriented and Sustainable Green Roofs in Germany, Proceedings from Green roof tops for sustainable communities conference, Portland, 2004 • www.goingsolar.com.au • www.bp.com/solar

[8] Department of Environment, Water Heritage and the Arts (2009), Solar Homes and Communities Plan, Program Statistics, Watts Installed by Month, available from http://www.environment.gov.au/settlements/renewable/pv/pubs/wattsbymonth-feb09.xls

Element	Description
Name	**Solar thermal hot water**
Description	Solar hot water systems use the sun's energy to heat water through a solar collector. In a direct heating system, water is heated as it circulates through a solar collector and stored in an insulated storage tank for later use. A hot water booster is often required to increase the temperature of stored water on days when solar energy may be insufficient to meet all hot water requirements. Boosters may be run on off-peak electricity, gas (natural or LPG) or solid fuel. There are two main types of solar collectors[9]: Flat Plate Collectors • typically consist of a blackened metal absorber plate within a glazed and insulated metal box (flat-plate collector). Pipes attached to the absorber plate carry the liquid that is heated by the sun. This can be direct heating of water for use within the building or heating of a heat transfer medium circulated within a closed loop. • Advantage: Most popular system in Australia. Reliable and relatively inexpensive. • Disadvantage: as fluid temperature increases, so does radiation loss. Absorber plates coated with selective surfaces suffer less from this problem. Evacuated Tube Collectors • Are typically made up of 10-15 glass tubes with each tube consisting of an outer tube to provide protection from the elements and an inner tube coated with high absorption, low reflection material through which water passes and absorbs heat energy • Advantage: Very efficient, producing high temperature water or steam. Because the collector surface is circular, the suns rays always fall on them at right angles to the surface, which minimises reflection • Disadvantage: fragile and higher cost. Even in cooler climates or during winter, solar collectors can be sized to serve a majority of a buildings domestic hot water use. Solar thermal systems can even be used in winter to generate hot water for heating.
Greenhouse gas savings	The greenhouse gas savings from an instantaneous gas hot water system compared to an instantaneous gas boosted solar hot water system are commonly greater than 60%[9].
Siting requirements	Collectors should be positioned on a north-facing roof (no more than 45° east or west of north) at an angle between 15° and 50° (standard roof pitch is usually sufficient). Other roof orientations may also be suitable, provided the unit is mounted on a frame to face north.
Barriers to take up	For large installations, sufficient roof space will often affect the feasibility of solar hot water. Solar hot water installations will collect on average 4.8kW of heat per square metre of solar collector during peak periods.
Indicative cost	\$600-750 / m^2 of collector, includes storage but not installation or booster heating[9].
Known applications	The application of solar hot water systems has become very common in the domestic environment. Use of solar hot water for commercial buildings is less common given the demand for hot water in commercial developments as compared to the free roof area available. There can also be issues with commercial systems overheating during weekend or holiday seasons when no load exists.
Links to further information and key references	Rheem Australia Pty Ltd, 2006, Rheem Hot Water Manual, Rydalmere New South Wales,) 12 October, 2009, <http://www.rheem.com.au/manuals.asp?view=commercial>

[9]Rheem Australia Pty Ltd, 2006, Rheem Hot Water Manual, Rydalmere New South Wales, 12 October, 2009, <http://www.rheem.com.au/manuals.asp?view=commercial>

Element	Description
Name	**Thermal Energy Storage**
Description	Thermal energy storage refers to a number of technologies that store energy in a thermal reservoir for later reuse. They can be employed to balance energy demand between day time and night time, and different seasons. The thermal reservoir may be maintained at a temperature above (hotter) or below (colder) than that of the ambient environment. Thermal energy storage technologies store heat, usually from active solar collectors, in an insulated repository for later use in space heating, domestic or process hot water, or to generate electricity. Most practical active solar heating systems have storage for a few hours to a day's worth of heat collected. There are also a small but growing number of seasonal thermal stores, used to store summer heat for use during winter. Seasonal thermal storage can be divided into three broad categories: • Low-temperature systems use the soil adjoining the building as a low-temperature seasonal heat store (reaching temperatures similar to average annual air temperature), drawing upon the stored heat for space heating. Such systems can also be seen as an extension to the building design (normally passive solar building design), as the design involves some simple but significant differences when compared to 'traditional' buildings. • Warm-temperature inter-seasonal heat stores also use soil to store heat, but employ active mechanisms of solar collection in summer to heat thermal banks in advance of the heating season. • High-temperature seasonal heat stores are essentially an extension of the building's HVAC and water heating systems. Water is normally the storage medium, stored in tanks at temperatures that can approach boiling point. Phase change materials (which are expensive but which require much smaller tanks) and high-tech soil heating systems (remote from the building) are occasionally used instead. For systems installed in individual buildings, additional space is required to accommodate the size of the storage tanks. In all cases, very effective above-ground insulation / superinsulation of the building structure is required to minimize heat-loss from the building, and hence the amount of heat that needs to be stored and used for space heating.
Energy output	By its nature, thermal energy storage has no net energy output and acts as a store only. The capacity of storage is only limited by the space available for storage.
Siting requirements	Thermal energy storage would generally be sited in close proximity to the source of heat or cooling. Large spatial requirements and weight often precludes situating thermal energy storage at roof level of a building.
Planning requirements	No specific planning requirements exist for the installation of a thermal energy store.
Barriers to take up	The successful use of thermal energy storage depends on the ability of storage to do one or more of the following; • Decrease net utility costs through offsetting electrical demand from peak to off-peak tariffs. • Increase the efficiency of plant through regulating thermal demands. • Increasing utilisation of energy through collection and reuse of waste heat. • Decrease in requirement for installed chiller or boiler plant. Consideration of the above items along with the cost of the storage tank and maintenance can determine the economic feasibility of thermal energy storage.

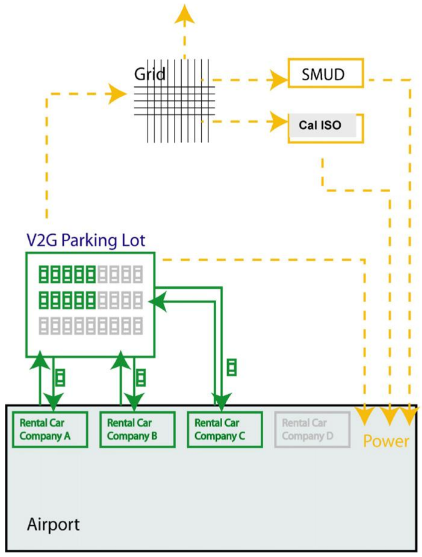
Indicative cost	Costs vary depending on the size of thermal storage and the medium being stored. Chilled water storage is often more expensive per kWh stored due to the small differential temperatures.
Known applications	James Cook University – Townsville; http://www.jcu.edu.au/office/centralservices/Energy/Energy%20&%20Water%20Bulletin%20No%2010.pdf
Links to further information	Australian Institute of Energy, viewed 12 Oct 2009. <http://aie.org.au/Content/NavigationMenu/Resources/SchoolProjects/FS16_ENERGY_STORAGE.pdf>

Element	Description
Name	**Solar Cooling**
Description	Solar cooling is a thermally driven cooling process which utilises heat collected from solar collectors to drive an absorption chiller. An absorption chiller uses heat to generate cooling through the absorption cycle. Correctly sized solar cooling systems have the advantage of being able to modulate cooling output with solar heat load within the building being served. Solar cooling systems require a large quantity of heat rejection as the system needs to reject the heat collected from the solar collectors to drive the absorption process, as well as reject the heat that is drawn from the building. There are a number of different solar collectors available to drive the absorption process. The most common of these being evacuated tube collectors or concentrating trough collectors. These can be connected in series or parallel to an absorption chiller. Connecting two concentrating trough collectors in series (twin stage), has the ability to generate temperatures within the circulation fluid up to 172degC[10]. At this temperature the absorption chiller can operate with a COP as high as 0.78 (generating 0.78kW of cooling for every 1kW of heat applied)[11].
Energy output	The thermal cooling output of a solar cooling installation depends on type of solar collector used and how these collectors are connected to an absorption chiller. Twin stage concentrating trough solar collectors are generally the most efficient producing up to 1kW peak cooling per m^2 collector area[10].
Siting requirements	Collectors should be positioned on a north-facing roof (no more than 45° east or west of north) at an angle between 15° and 50°. Other roof orientations may also be suitable, provided the unit is mounted on a frame to face north. Due to the high temperature fluid circulated within solar collectors, absorption chillers are ideally located in close proximity to the solar collectors.
Barriers to take up	Due to the large spatial requirement and the ability to generate cooling only when the sun is at its peak, solar cooling systems struggle to become economically viable in most commercial installations.
Indicative cost	Concentrating trough collectors cost around $975/$m^2$ collector, including controls and auxiliary equipment[10]. Cost will vary largely depending on the scale of the solar cooling system, an example from the sunshine solar cooling which showed that costs ranged from $785k to $1.1m for a 350kW absorption chiller system.
Known applications	Although all technology utilised within solar cooling systems are well developed, solar cooling installations are not common due to the large land area and high installation cost per kW output. Most installations to date are demonstration scale. Solar cooling systems have been applied successfully in warehouses where cooling requirements are limited and the building roof area is similar in scale to the area being cooled.
Links to further information	Broad absorption chillers - http://www.ecsaustralia.com/aircon.php

[10] "Estimating performance of a solar cooling installation in Melbourne", Kuba Szczepanik - *IIR 2008 HVAC energy efficiency best practice conference*.
[11] Broad absorption chillers - http://www.ecsaustralia.com/aircon.php

Element	Description
Name	**Electric Vehicles to Grid (V2G)**
Description and benefits	Electric-drive vehicle (EDV) technology is likely to play an important role in the future of motor vehicles in Australia. EDVs may reduce GHG emissions and ambient air pollution, while reducing energy consumption. Vehicle-to-grid (V2G) systems are a sub-set of EDVs and may represent a potential opportunity to bring forward and accelerate a transition towards EDVs by improving the commercial viability of new technologies. The V2G strategy involves using EDVs to supply generation services to the electricity grid while parked. The EDV can be a battery-electric vehicle, fuel cell or a plug-in hybrid electric vehicle (PHEV) (Kempton and Tomić 2005). Battery-electric vehicles can charge during low demand times and discharge electricity into the network when required. Some of the main potential benefits of V2G power include: • Reduce the operational costs of EDVs, thereby making them even more attractive to consumers. • Generate revenue for EDV owners from electricity generation. • Reduce demand charges for commercial electrical consumers. • Increase the stability and reliability of the grid. • Lower electrical system costs. • Act as inexpensive storage for intermittent renewable electricity.
Types	Three types of EDVs are relevant to the V2G power concept: battery-electric, fuel cell and PHEVs: • **Battery-electric** vehicles store energy electrochemically in the batteries; they plug in to charge their batteries and unplug to drive. Battery vehicles must have grid connections for charging, so the incremental costs and operational adjustments to add V2G are minimal. • **Fuel cell** vehicles store energy in molecular hydrogen that feeds into a fuel cell to produce electricity (with heat and water as by-products). Currently, distribution infrastructure, on-board storage of hydrogen, and conversion losses pose significant challenges to the practicality and cost-effectiveness of fuel cell vehicles. The cost of grid connection is outside the transport function and would thus be attributed to V2G costs. • **Plug-in hybrid electric** vehicles use an internal combustion engine whose shaft drives a generator. A small battery buffers the generator and absorbs regenerative braking. Current hybrids have much larger mechanical than electric drive power, small batteries and no electrical connection to the grid. Thus, they are impractical for V2G power. With the addition of an enlarged battery and an electric plug to recharge, plug-in hybrids become more relevant when considering V2G power. In relation to V2G, the plug-in hybrid requires a grid connection for its transport function and a large enough battery to provide V2G from the battery alone. Plug-in hybrids can provide V2G power either as a battery vehicle (not using the internal combustion engine when doing V2G) or as a motor-generator (using fuel while parked to generate V2G electricity). Plug-in hybrids are the “obvious” first link of a potential transition to V2G power (Kempton and Tomić, 2005).
Resources output and consumed and generated	Electricity consumed and released by the vehicles. The carbon intensity depends on the proportion of renewable energy in the initial charge for the vehicle.

Siting requirements	Land and space requirements for the establishment of V2G are minimal, requiring connectivity to the grid which can be installed in new and existing car parks and garages. On-board technology must be designed for V2G to control the discharge of electricity into the grid protecting reliability and value for the driver.
Barriers to take up	Technology (vehicle and grid infrastructure), costs, institutional and other challenges pose significant barriers to EDV entry into the market. The most often-cited barriers to commercialisation of advanced vehicle technologies are: • **Price:** the cost of the required battery technology is currently making them more expensive than a comparable internal combustion engine vehicle. The competitiveness of EDVs will also depend on how their operating costs compare with gasoline and diesel vehicles. There are currently significant cost advantages in electricity compared to gasoline and diesel, and this is expected to continue into the future. • **Performance:** power and energy per unit of volume remains an important technological hurdle, along with the fact that durability and safety remain unproven. • **Infrastructure:** EDVs would also require the support of new infrastructure, such as battery recharge points and changeover stations, or facilities for home charging.
Indicative cost	Home connection hardware between the vehicle and the home presents an additional cost of V2G technologies. Recent studies estimate that the cost of wiring, metering, communication to the grid manager, and safety systems can be about US $400 for a basic V2G system with a capacity of 6.6 kW and an additional US $1,000 to US $1,500 to upgrade to 10-15 kW (Turton and Moura, 2008). Thus far, prototype vehicles have a cost of about US $70,000 each, or a US $55,000 premium over an economy car (Karplus et al., 2009). The two main costs are the battery and the power electronics unit. High costs for both are due in part to low production volumes. The introductory pricing in Australia for EDV will be relatively high, expected somewhere in the range of AU $40,000-$70,000 (Bradley and Frank, 2009).
Known applications	**Individual Residential** The individual residential applications of V2G may be a high-cost launching point for the V2G market. While they involve individual households that have the freedom to make decisions about how to use their vehicles, they are likely to be the most difficult to implement and the longest-term of the V2G market. The individual market would involve: • The costs of high-power V2G infrastructure to be borne at the individual residential level. • Significant coordination between the grid, the ISOs, and every household selling V2G services. • A guarantee that vehicles are charged when drivers need them. **Aggregation** Spatial aggregation into “parking-lot power plants” might be more attractive initially as an option for vehicular distributed generation. The main benefits would include the ability to spread infrastructure costs, simplify coordination, limit bi-directional power flow centres and the need for time-sensitive price signals, aggregate capacity and energy supply into utility-friendly and distributed-generation hardware-friendly units, and aggregate V2G benefits. The main examples of potential applications include commercial fleet vehicles, car-rental companies and parking lots. A conceptual example of a parking-lot

	power plant using idle airport-rental vehicles to provide electricity services is shown below.  **Vehicle-to-Grid – Parking Lot Power Plant Model** **Source: Williams and Kurani, 2007**
Other considerations to implementation	Maintaining grid reliability, balancing the supply and demand, and supporting the transmission of electric power from seller to purchaser.
Links to further information and key references	**Kempton and Tomić 2005**

Water initiatives

Element	Description
Name	**Water Harvesting**
Description and benefits	Water harvesting, commonly referred to as rainwater harvesting and stormwater harvesting, involves the capture and treatment of rainfall runoff and can be collected at broadly three scales; regional, precinct and building. • Regional – Collection and treatment of stormwater flows originating externally and passing through the precinct via the underground drainage system. • Precinct – Collection of stormwater runoff from public spaces, particularly paved areas, for treatment, preferably via WSUD treatment. • Building – Collection of roof water runoff, requiring minimal treatment, stored on-site and plumbed back into the building for re-use, generally without entering Council drainage infrastructure. (Refer toolbox on roof water harvesting). Note: A 142-lot subdivision in Warrnambool utilises roof water runoff for indirect potable reuse on a precinct scale, and is discussed further in the 'known application' section of the toolbox on roof water harvesting These benefits align with aims of the State Planning Policy Framework, by: • Increasing greenery, which provides benefits to air quality by adsorption of pollutants (Cl 15.04) and noise abatement (Cl 15.05). • Providing an additional driver to create more open space (Cl 12.05). Furthermore, Councils *Future Melbourne* vision for an Eco-City contains goals that are supported by WSUD techniques: • Support for biodiversity. • Excellent air quality. • Generous open public space and landscaping.  *WSUD tree pits, Docklands, Melbourne.* The Climate Change Adaptation Strategy (Draft 2008) identified stormwater harvesting as the most significant tool for mitigating the effects of climate change in the City, such as flash flooding, reduced water supply and the UHIE. However, CoMs Total Watermark strategy highlights that on the hierarchy of alternative water sources, roof water harvesting supersedes stormwater harvesting due to the minimal treatment required. A separate toolbox covers roof water harvesting at the building scale. Overall benefits include:

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td></td><td>

- Reduction of potable water demand.
- Mitigation of climate change impacts.
- Improved urban ecology.
- Maintaining soil moisture within services zone.
- Reduction of pollutant loadings to receiving waters.

</td></tr>
<tr><td>Water Sensitive Urban Design (WSUD)</td><td>

At the regional and precinct scale, WSUD treatment systems such as bio-swales and wetlands are recommended for the harvesting of stormwater to Class A non-potable standard (refer ‘treatment’ below), with WSUD elements vital in the collection and treatment of stormwater runoff. This has multiple benefits of:

- Retaining water within the urban landscape mitigating the Urban Heat Island Effect (UHIE – discussed further in the Green Roofs Toolbox), and moisture loss in the soil (due to effects of climate change such as increased temperatures and decreased annual rainfall), placing increased stress on buried pipe infrastructure through ground movement.
- Assisting nature conservancy, creating a natural/urban interface and improving urban ecology.
- Replacing rigid stormwater infrastructure with natural elements.
- Enhanced aesthetics.
- Visible infrastructure, assisting maintenance.
- Reducing pollutant loadings to receiving waters, particularly the Yarra River.

Royal Park Wetlands, Melbourne

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<tr><td>Rainwater harvesting</td><td>

The temporal variability of rainfall means that many end-use demand patterns are difficult to service (with a high level of reliability) without provision for large storage volume. The harvest and reuse of rainwater however, presents opportunities to provide a significant non-potable (additional treatment required for potable) water source with minimal energy inputs.

- Typically runoff from small rainfall events is captured (<1 year ARI, which provides >95% of annual rainfall volume). An optimal tank size could be considered to capture around 80% of average annual rainfall by volume.
- Landscaping irrigation requirements display significant variance in response to climate and are approximately the seasonal inverse to annual rainfall patterns. Therefore to harvest rainwater to meet irrigation demands results in a larger storage requirement to achieve acceptable levels of reliability. Generally it is not economically feasible to attain reliabilities in excess of 85% and the harvested rainwater must therefore be

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Element	Description
	supplemented with alternative sources. • Building water demand is typically more constant (subject to land-use) and can readily be augmented with a reduced storage requirement. Based on the overall servicing concept of buildings, rainwater can be plumbed in to meet non-potable demands such as toilet flushing with buffer tanks providing intermediate storage. As with landscape demands, harvested rainwater will likely need to be supplemented with alternative sources.
Types	• WSUD elements (refer toolbox) • Roof water harvesting (refer toolbox)
Treatment	Harvested and treated stormwater will typically have a pollutant profile characterised by reduced nutrient concentrations and salinity when compared with treated wastewater. In line with the fit for purpose approach to re-use, treated stormwater is therefore more suited to land based applications (irrigation) where percolation and runoff may connect back to natural water bodies. In situations where water servicing strategies stipulate treated wastewater for internal non-potable uses (such as toilet flushing) treated stormwater can be elevated to be used for augmentation of hot water supplies. Storage of stormwater will potentially impact on treatment requirements with underground tanks requiring effective TSS removal and open water storages (ponds) requiring effective nutrient removal to reduce algal management issues. Additional treatment may be required where contact applications are intended such as irrigation of playing surfaces. Refer the WSUD toolbox for more detailed treatment methods.
Resources output and consumed and generated	There will be a resultant power demand to distribute harvested water via a 'third-pipe' system and/or throughout buildings. This demand will be the same as for the distribution of recycled wastewater.
Siting requirements	Stormwater harvesting schemes at the regional scale rely on the mining of underground stormwater drains, with treatment and storage located as close to these drains as possible. Booster pumps, underground storage and mechanical treatment devices require minimum 1m clearance service pipes and conduits. At the precinct scale, collection, treatment and storage of stormwater runoff via WSUD elements requires open space (refer WSUD toolbox), with the option of constructing green roofs for water treatment purposes (refer Green Roofs toolbox). Roof water harvesting requirements are discussed further in the roof water harvesting toolbox. Access to power will be required for associated booster pumps.
Barriers to take up	Economic cost-benefit perspective taking precedence over environmental and social outcomes. Capital cost (tank/pump design and construction) and opportunity cost (gross floor area and/or land take) implications on any cost-benefit analysis.
Indicative cost	Stormwater harvesting $0.10 to $1.50 per kilolitre. Indirect potable reuse $1.68 to $2.60 per kilolitre. (Marsden Jacob Associates 2007:xii). Anaylsis of eleven WSUD harvesting site in Sydney (DEC 2006:78) reveals a capital cost of stormwater harvesting of around $500,000 for a yield of 10 ML/yr. Larger projects were observed to have a reduced unit cost with around $1.2 million for 60 ML/yr. There was, however, large variability between unit cost of each site, highlighting the site specific nature of water harvesting project cost.
Known applications	*Regional Scale* Royal Park Wetland, Parkville, Victoria. • Extending over 170 hectares, Royal Park is the largest park in the City of Melbourne. • Trin Warren Tam-boore, the park's new urban wetland designed to treat stormwater runoff, creates a new habitat for wildlife, provides 135ML/yr recycled water for use in Royal Park and cleans stormwater before it reaches Port Phillip Bay.

Element	Description
	Dongtan City, Shanghai ,China. • Comprising 80,000 residents by 2020 and 500,000 residents when completed in 2040. • Located fifteen kilometres north of Shanghai on 630Ha of delicate wetlands at the mouth of the Yangtze River. • Water will be collected, treated and recycled within Dongtan and then used to irrigate surrounding farmland. • Dongtan will act as a template for food research and production. • Green roof, green areas and wetlands are proposed in close proximity. • Further information can be viewed at <http://www.resourcesmart.vic.gov.au/dokLents/SEZ_Case_Study_Dongtan.pdf>. *Precinct Scale* Victoria Park WSUD Strategy, Sydney, Australia. • Conversion of 25 hectares of industrial land to medium-density residential and commercial development. • Water-based ecological corridors within the streetscape and public domain zones of Victoria Park. • Reworked streetscapes, bio-retention swales in median. • All stormwater runoff from buildings, pedestrian paths and roads pass through the bio-retention system. • Landscaped wetland systems in public realm areas accept and treat this water for irrigation reuse. Docklands WSUD Strategy, Melbourne, Australia. • Melbourne Docklands is the largest urban renewal project in Australia. • Stormwater generated from hard surfaces is treated near its source, using a variety of forms and scales of landscape elements for filtering. • Treated stormwater from parts of the Melbourne Docklands precinct is directed to sub-surface storage facilities and used to irrigate four hectares of central parkland area. Inkerman Apartments, St Kilda • 236 unit medium density development. • Stormwater runoff collected and treated via wetlands. • Treatment via GPTs, small wetland and then combined with recycled greywater in a MBR before UV disinfection. • Harvested water reused for garden irrigation and building toilets. • Further information can be viewed at <http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp>. *Building Scale* Refer roof water harvesting toolbox.
Links to further information and key references	Department of Environment and Conservation, 2006. *Managing urban stormwater: harvesting and reuse.* NSW Government. Marsden Jacob and Associates 2007. *The cost effectiveness of rainwater tanks in urban Australia*, National Water Commission. Australian Government. Melbourne Water, Water Sensitive Urban Design: Case Studies, viewed 14 October 2009. <http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp>. Sustainability Victoria c2008. *Smart energy zones: Case study Dongtan, China*. Viewed on 7 October, 2009. <http://www.resourcesmart.vic.gov.au/dokLents/SEZ_Case_Study_Dongtan.pdf>.

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td>Name</td><td>Roof Water Harvesting (attachment to Water Harvesting)</td></tr>
<tr><td>Description and benefits</td><td>Capture of rainfall runoff from building roof areas and stored either within or adjacent to the building, commonly for non-potable building uses such as toilet flushing and irrigation of surrounding landscaping. Re-use of rainwater for potable uses is also feasible; however, additional treatment is required.

Benefits include:

• Reduction of potable water demand.
• Increased diversification and security of water supply.
• Comparatively clean water source, often requiring no treatment for non-potable re-use where roof areas are maintained.
• Can provide a “site-specific” solution, with minimal involvement of service authorities, depending on end-use.
• Low environmental impact.
• Social benefits through increased awareness of residents.

Rain garden, Victorian College of the Arts, Southbank.</td></tr>
<tr><td>Treatment</td><td>As rainwater collected from well-maintained rooftops is generally of a quality that is safe for non-potable uses, the need for treatment is unlikely. However, in some circumstances there may be a need to treat rainwater.

It is recommended that rainwater systems that serve multi-unit residential, commercial and community sites incorporate treatment to remove microbial hazards when rainwater uses have a moderate risk of ingestion (for example showering and hand basins). This is particularly important when elderly, very young or people with suppressed immune systems are likely to be using rainwater.

Treatment options for rainwater systems most commonly include:

• Filtration; and/or
• Disinfection (usually chlorine disinfection or ultraviolet light (UV) disinfection).
The type and level of treatment required depends on the hazards that require control. In most cases, treatment by disinfection should be sufficient if the contaminants of concern are microbial, and the rainwater has little suspended material and is of low turbidity (indicatively <1 nephelometric turbidity unit (NTU)).

Hot water services that heat and store water at 60°C (consistent with the requirements in AS/NZS 3500 National plumbing and drainage code) will provide treatment for most microbial contaminants in rainwater, and so the use of untreated rainwater in these systems should be acceptable in most scenarios.

However, it should be noted that food businesses (as defined under the Food Act 1984) must use potable water for all food preparation activities. The use of rainwater in hot water services that supply kitchens may therefore not be appropriate at these sites.</td></tr>
<tr><td>Types</td><td>Rainwater tanks are available in a range of materials including galvanised steel, fibreglass, polyethylene, concrete and a number of proprietary products. All can be suitable, providing the materials used will not contaminate the rainwater, and they comply with the relevant Australian Standards

Concrete tanks:

• Design of any size possible with in-situ construction of tank.
• Heavy – may impact on viability to store above ground level, however advantageous to counteract flotation where groundwater is high.

Polyethylene tanks:

• Proprietary sizes range from 0.6 kL to 50 kL</td></tr>
</table>

Element	Description
	Metal tanks: • Proprietary sizes range from small (~10 kL) to large (>2000 kL). Sizes available are dependent on a water balance analysis considering quantity of rainfall runoff and water demand to determine optimal tank size range, which is then subject to land/space availability.
Resources output and consumed and generated	• Water captured, as per above. • There is essentially no waste generation. • Power consumption to pump water through building, dependent on building height, flow rate and pumping distance required.
Siting requirements	Commonly storage tanks are located in building service areas, basements or structurally designed to form part of the building (at any level, however this may be costly and problematic). Tank size is dependent on a water balance analysis (described above), while many shapes are possible. Clearances are minimal with the pump station enclosed for safety and amenity purposes within a concrete sump well (must be accessible for maintenance) or a dedicated shed. The pump station would require supply of electricity. The quantity of roof water collected may be reduced by taller adjacent structures blocking rain falling at an angle for smaller rainfall events during windy conditions. A nearby clearance zone from the roof edge may be required (possibly at 1:1 slope). Similarly, consideration should be given to the water harvesting potential from the face of tall buildings, which could be collected and diverted into the downpipe system (with same treatment as roof water, outlined above). It is important to consider the roof surface that rainwater is being collected from; rainwater should not be harvested from roofs coated in bitumen products or lead-based paints, or roofs affected by emissions from industrial processes within the building. Roof access (to collection areas) should be minimised to maintenance only and structures available for perching of birds should be relocated.
Barriers to take up	Lack of planning controls to enforce roof water harvesting. Spatial and structural considerations: Limited space to install tanks, particularly at roof level due to plant and equipment. Limited maintenance access in space constrained areas. Building structure must be sufficient to support the weight of the tank in its chosen location. However, if roof structure cannot support the tank then the basement or other ground locations could be considered.
Indicative cost	$0.10 to $1.50 per kilolitre (Marsden Jacob Associates 2007:xii). Viability of roof water harvesting is impacted by the price of reticulated potable water, which, when viewed from an economic cost-benefit perspective, is in direct competition. The cost of rainwater is currently not competitive with the cost of reticulated water. Reduced supply from drinking water catchments and increasing demand due to climate change and population increase and large infrastructure projects such as desalination are expected to place upward pressure on potable water prices, increasing the economic viability of roof water harvesting over time.
Known applications	Federation Square, Melbourne • Harvesting of water for public toilet flushing. • Jointly funded by Federation Square Authority and the Australian Governments Community Water Grant. • 100 kL tank harvesting water from Alfred Deakin Building and Atrium roof. • Further information can be viewed at <http://www.federationsquare.com.au/index.cfm?pageID=131>. Warrnambool Demonstration Site • 142-lot subdivision within Russell's Creek growth corridor of Warrnambool.

Element	Description
	• Demonstration project carried out by Wannon Water, the local Water Authority. • Roof water runoff collection via dedicated pipes to existing Wannon Water raw water storage for treatment to Class A potable standard and substitution with existing town potable water supply. • Expected to supply 75% of total subdivision water demand when completed in 2010. • Further information can be viewed at <http://www.wannonwater.com.au/index.php?option=com_content&task=view&id=320&Itemid=345#Demonrtation%20Site%20-%20Warrnambool>. Victorian College of the Arts, Southbank, Melbourne. • Roof water and stormwater runoff from St Kilda Road is directed to a rain garden located prominently in front of the centre. • Utilised as an educational tool for the Yarra River Youth Conference, and passersby. • Further information can be viewed at <http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp>.
Other considerations to implementation	Roof-derived rainwater not able to provide sufficient water for toilet flushing in apartments and office towers due to insufficient roof area. AS1319 '*Safety signs for the occupational environment* 'sets labelling requirements for taps where recycled water is used. Where sensitive groups are involved, who may not obey signage (for example childcare centres), additional controls should be considered such as using taps with removable handles or locating taps 1.5 metres or more above the ground. Low-risk possibility of roof water runoff contamination leakage from HVAC refrigerant gases.
Associated Benefits/Other Considerations	Roof water harvesting reduces the potable water demand of the Southbank precinct and forms part of Councils 'Total Watermark – City as a Catchment' philosophy.
Links to further information and key references	AS1319 '*Safety signs for the occupational environment* ' City of Melbourne, *Total Watermark – City as a Catchment*, viewed 21 September, 2009. <http://www.melbourne.vic.gov.au/info.cfm?top=120&pg=1638>. Department of Human Services (2007). Rainwater Use in Urban Communities, viewed 10 October, 2009, <http://www.health.vic.gov.au/environment/water/tanks.htm>. Marsden Jacob Associates, 2007. *The cost effectiveness of urban rainwater tanks in Australia*. National Water Commission. Australian Government. Melbourne Water, Water Sensitive Urban Design: Case Studies, viewed 14 October 2009. <http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp>. Wannon Water, Roof water harvesting, viewed 14 October, 2009. <http://www.wannonwater.com.au/index.php?option=com_content&task=view&id=320&Itemid=345#Demonrtation%20Site%20-%20Warrnambool>.

Element	Description
Name	**Water Sensitive Urban Design (attachment to Water Harvesting)**
Description and benefits	Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates land and water planning and management into urban design. WSUD is based on the premise that urban development and redevelopment must address the sustainability of water *(Engineers Australia, 2006).*  *Kogarah Square, Sydney* WSUD objectives may be achieved through: • Design of localised water treatment and servicing strategies. • Capture and re-use rainwater and stormwater to reduce demands on traditional potable water sources. • Use of vegetation to filter water. • Design of water efficient landscaping and where possible encompass functional treatment elements and/or passive irrigation. • Protecting downstream aquatic (freshwater and marine) environments. • Designing to reflect natural hydrology and water balance of systems. Benefits include: • Reduction in pollutant loadings into downstream receiving waters. • Mimicry of natural catchment hydrology and water balance to reduce impacts on downstream habitat and stability (erosion). • Cost effective provision of vegetated public/private open spaces with subsequent interrelated benefits (shade, air quality, habitat etc).

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td>Types</td><td>Collection, treatment and storage of stormwater runoff from paved surfaces typically on a precinct scale. WSUD elements include:
Grassed Swales, typically requiring ~3m width to edge of pavements when servicing minor catchment areas.


Grassed Swale, Lynbrook Estate, Melbourne
Tree pits.
Bio-filter trench drains.
Permeable pavements.</td></tr>
<tr><td>Typical WSUD treatment techniques.</td><td><u>Gross Pollutant Traps</u>

Gross pollutant traps (GPT) are a primary treatment device which will typically be used as pre treatment for further downstream technologies. GPTs can vary significantly in design but will typically be designed to remove anthropogenic litter, coarse sediments and other large particles. GPTs may be located at the source of a drain network or positioned on line within the drainage system. GPT devices may be proprietary systems with well defined performance specifications or site specific systems designed in response to particular operating requirements. The choice of device should be based on the expected gross pollutant loads generated in the contributing catchment.

<u>Bioretention systems</u>

Bioretention systems operate by filtering stormwater runoff through densely planted surface vegetation and then percolating runoff through a prescribed filter media. During percolation, pollutants are retained through fine filtration, adsorption and some biological uptake. Systems are flexible in their design and can be applied at different scales, taking many different forms including street tree systems, bioretention swales, rain gardens and green roofs (refer Green Roofs toolbox).</td></tr>
</table>

Element	Description
	 *Bioretention System, Lynbrook Estate, Melbourne (Source Parliament of Victoria 2004)* Bioretention systems serve as a tertiary (last) stormwater treatment device in stormwater treatment trains. Bioretention systems target fine sediments, metals, particulates and dissolved nutrients. Particulates including organic matter are captured on the surface of these systems while dissolved pollutants are removed as the stormwater percolates into the filter media. Bioretention systems typically provide the highest level of stormwater treatment per unit of treatment area. Bioretention systems are typically sized at approximately 2% of the contributing impervious catchment area, the systems total footprint area increases depending on the batter design. Specific design of bioretentions systems is a function of inflow frequency/duration, influent pollutant profile and overall landscape objectives. Water conservation outcomes can be achieved through the passive irrigation of these landscape elements which can provide functional green spaces within development areas. Treated stormwater can be readily harvested from underground drains and conveyed to additional storage for re-use applications. Based on re-use applications, further treatment (UV disinfection) may be required where human contact is likely. Opportunities exist within the Southbank area to retrofit either linear or dispersed (tree pits) bioretention systems to treat stormwater runoff resultant from the existing road infrastructure. Areas of public/private open space can be designed to incorporate bioretention treatment within the landscaped realm with the objective of integrating the functional aspects with the amenity of vegetated landscapes. <u>Constructed wetlands</u> Constructed wetlands are densely vegetated water bodies that use enhanced sedimentation, fine filtration, adhesion and biological uptake and biogeochemical transformation processes to remove pollutants from stormwater. Wetlands generally consist of an inlet zone (sediment basin), a macrophyte zone (shallow densely vegetated section) and bypass. With appropriate pre-treatment and diversion configuration, small scale wetlands can be integrated into landscaped areas and designed to provide visual amenity. Constructed wetlands typically serve as a tertiary (last) stormwater treatment device in stormwater treatment trains. Constructed wetlands target fine sediments, metals, particulates and dissolved nutrients. Constructed wetlands are typically sized at approximately 3% of the contributing impervious catchment area, the systems total footprint area increases depending on the batter design. Specific design of constructed wetlands is a

Element	Description
	function of inundation frequency/duration, influent pollutant profile and overall landscape objectives. Wetlands can be constructed on many scales, from lot scale to larger precinct/regional systems. In highly developed areas such as Southbank, wetlands may have a hard edge and be part of a streetscape or forecourt. In a precinct/regional context (such as providing stormwater treatment in parkland east of St Kilda Road) wetlands may be more natural in appearance and have potential to provide greater wildlife habitat. <u>Permeable pavements</u> Permeable paving is an alternative to traditional impermeable pavement design and is available in a number of commercially available products. Modular block structure is overlaid on permeable sands or fine gravels to allow free draining. Porous paving provides some removal of sediments and bound pollutants but the main purpose is to reduce runoff volumes and delay runoff peaks by providing retention storage capacity. Porous paving is typically only designed for precipitation falling within its footprint and should not be used to treat stormwater from adjoining impervious catchments. Porous paving should be designed to function parallel to other treatment strategies such as bio-retention and wetlands. An allowance for a 50% reduction in infiltration capacity over 20 years should be made during design. Within developments typical of Southbank opportunities exist incorporate permeable paving in areas of car parking and pedestrian pathways.
Siting requirements	WSUD collection, storage and treatment elements require the provision of open space (an exception being possible treatment via green roofs, refer Green Roof toolbox). Treatment options such as bio-retention and wetland systems require between 2-3% of the impervious catchment area it serves.  *Roma Street Gardens, Brisbane*
Barriers to take up	Economic cost-benefit perspective taking precedence over environmental and social outcomes. Capital cost (WSUD treatment elements and pumping) and opportunity cost (land take from roads and active recreation areas) implications on any cost-benefit analysis.
Indicative cost	Refer Altona Green Park under 'known applications' for project example costs. Estimated costs based on total phosphorus removal (a major function of WSUD elements) in eleven site case studies in Sydney demonstrate a large fluctuation from $300 to $63,000/kg/year, with an average levelised cost of $9,000/kg/year (DEC 2006:77). This highlights the site specific nature for capital and operating costs.
Known applications	*Altona Park Green, Melbourne, Australia.* • Creation of two sporting ovals and recreational open space. • Stormwater is collected and treated via grassed swales and stored in a 400 kL

Element	Description
	underground tank. • Harvested water is used for the irrigation of two sports ovals. • Capital cost was WSUD harvesting system was $250,000 out of a total development cost of $6 million. • Significantly, developer contributions to the Laverton Drainage Scheme were waived, saving $200,000, due to the level of stormwater treatment and storage gained by the project. *Batman Drive WSUD, Melbourne, Australia.* • The system provides treatment for runoff from the road and associated shared pathway. The bioretention systems installed in the inner city area are an example of how urban elements, in this case pedestrian seating, can be integrated with stormwater treatments. *Little Bourke Street and Little Collins Street WSUD, Melbourne, Australia.* • Bioretention tree planters. • Integrated stormwater treatment infrastructure, which meets high-level aesthetic requirements and has the approval of local traders *Green Streets, Portland, Oregon, USA.* The Portland Bureau of Environmental Services has developed Sustainable Stormwater Management standards that actively promote the development of 'Green Streets', the inclusion of WSUD features into high density urban streetscapes on a street-by-street retro-fit, or precinct-wide concept. Green Streets integrate with Portland's transport management strategy in assisting the promotion of active transport measures, walking and cycling, by reducing the width of street crossings, making pedestrians and cyclists more visible and incorporating bike lanes into Green Street retrofit construction. Examples can be viewed at: – River East Centre Stormwater Management <http://www.portlandonline.com/shared/cfm/image.cfm?id=204063>. – SE12th and Clay Green Street <http://www.portlandonline.com/shared/cfm/image.cfm?id=203152>. – Stormwater Education Plaza <http://www.portlandonline.com/bes/index.cfm?c=47012&a=196277>.
Links to further information and key references	*(Engineers Australia, 2006)* City of Portland, *River East Centre Stormwater Management*, viewed on 29 September, 2009. <http://www.portlandonline.com/shared/cfm/image.cfm?id=204063>. City of Portland, *SE12th and Clay Green Street,* viewed on 29 September, 2009. <http://www.portlandonline.com/shared/cfm/image.cfm?id=203152>. City of Portland, *Stormwater Education Plaza,* viewed on 29 September, 2009. <http://www.portlandonline.com/bes/index.cfm?c=47012&a=196277>. Department of Environment and Conservation, 2006. *Managing urban stormwater: harvesting and reuse.* NSW Government.

Element	Description
Name	**Aquifer Storage and Recovery**
Description and benefits	Aquifer storage and recovery (ASR) involves the capture of water at ground level, ensuring treatment to acceptable health standards before injection into an underlying aquifer for storage, and subsequent recovery from the same aquifer for water supply purposes. Relative to new dams, ASR can be more readily utilised as it requires much less land and can be developed in inner city areas. The capital costs are also significantly lower, and the loss of biodiversity is greatly reduced.
Treatment	Due to saline groundwater conditions, Reverse Osmosis (RO) treatment will be required before use, similar to Yarra River extraction.
Types	Aquifer storage and recovery; aquifer storage, transfer and recovery; infiltration ponds; infiltration galleries; soil aquifer treatment; percolation tanks or recharge weirs; rainwater harvesting for aquifer storage' recharge releases (NWC 2009).
Resources output and consumed and generated	Power consumption for the treatment plant can be considered within the same ballpark as the RO plant for Yarra River extraction, assuming similar quantities of water supply.
Siting requirements	Siting requirements for the treatment plant can be considered within the same ballpark as the RO plant for Yarra River extraction. Balancing storage is required prior to injection into the aquifer.
Barriers to take up	Saline or brackish aquifers will reduce the water quality of injected water, which may be an issue where the water is intended for more sensitive uses.
Indicative cost	Capital costs of stormwater ASR projects in the range 75-2000 ML/yr ranged from $4,100 to $10,000 per ML/yr, with the most expensive outlay being $8.2M for a 2000ML/yr project (NWC 2009).
Known applications	Grange Golf Course, Adelaide, South Australia.
Other considerations to implementation	Total Watermark (CoM 2008:17) states that "groundwater is unlikely to be a significant resource across the municipality because of the shallow, saline water table across the Yarra Delta region", however that there is some potential for ASR in the lower reaches of the City of Melbourne.
Links to further information and key references	National Water Commission, 2009. *Managed aquifer recharge: An introduction.* Dillon, P., Pavelic, P., Page, D., Beringen, H. and Ward, J. Australian Government.

Element	Description
Name	**Yarra River Extraction**
Description and benefits	The Yarra River borders the northern edge of the Southbank Precinct and is within the estuarine zone, with stratification of fresh and salt water existing most of the time, allowing targeted extraction of fresh water. The quality of this water source necessitates use of Reverse Osmosis (RO) treatment technology. A consequence of RO is a concentrated brine waste outfall, which can be diluted with some of the river water extracted until it is of similar quality to that of the salt water strata in the River, thereby greatly minimising negative environmental.
Treatment	Reverse Osmosis (RO) provides a high level of treatment and can remove dissolved particles such as salinity, phosphorus and nitrogen. There are limitations on the level of log reductions achieved due to the inability to undertake challenge testing.
Resources output and consumed and generated	For extracted fresh river water, there could be: • Class A potable water OR Class A non-potable water produced. • diluted brine waste outflow. • power demand. **OR** For fresh river water extracted from the Yarra River, there will be a diluted brine waste outfall back to the river, a high power demand with generation of Class A potable or non-potable water end product.
Siting requirements	With reliance on the Yarra River for its water source, it is advantageous to site the RO treatment facility close to the river to minimise pumping required. The extraction point will also likely require a large sump pump, confined to minimise public disturbance, however this could be best placed away from highly trafficked areas such as Southgate. The RO treatment facility will require connection to mains power to ensure reliable and continuous supply. Ecological sustainability principles and targets outlined under the *Future Melbourne* Eco-City section may require production of renewable energy to directly power the facility and / or offset facility power demands. This requires associated infrastructure be built into the facility or elsewhere in the precinct.
Barriers to take up	• Environmental concerns with brine waste outfall.
Other considerations to implementation	• Agreements with Power Authority re electricity supply capacity and connection to grid. • EPBC approvals. • SEW approval.

Element	Description
Name	**Wastewater Recycling**
Description	Wastewater provides a reliable and continuous source of water that, with appropriate treatment, can be recycled for: • non-potable uses such as toilet flushing, washing and irrigation, or; • potable uses either directly (dedicated plumbing) or indirectly (potable substitution) – currently not applicable in Victoria under existing Government policy (refer 'Other Considerations' below). With population densification, increased loadings to the centralised wastewater system will inevitably occur, requiring large capital expenditure to upgrade ageing networks and treatment plants. This will also increase the nutrient loads that could potentially reach Port Phillip Bay. Increased decentralised wastewater recycling for dedicated use within precincts and buildings will reduce these negative economic and environmental impacts. Broadly, wastewater can be collected at three scales: • Regional (sewer mining): collection and treatment of wastewater flows originating external to the precinct and passing through via the SEW sewerage system. • Precinct: collection and treatment of wastewater flows originating within the precinct that have entered SEW sewerage infrastructure. • Building: collection, treatment and storage of building wastewater discharge on-site, and plumbed back into the building for re-use, without entering SEW sewerage infrastructure.  *Inkerman Apartments, St Kilda* Wastewater may also be defined as grey or black water. The Department of Human Services Environmental Sustainability Guidelines (2007) identifies greywater as "non sewage water which has previously been used at least once from mains or other supply sources". Blackwater includes sewage such as toilet flushing and commercial and industrial

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td></td><td>wastewater.</td></tr>
<tr><td>Benefits</td><td>Key benefits of wastewater systems

Reduction in potable water demand.
Reduction in sewage flows to centralised transfer and treatment facilities (and mitigation of future increased loading due to population densification).

A key benefit of recycling wastewater originating from buildings for reuse within buildings is that the supply distribution is closely linked to the demand distribution, thereby greatly reducing the storage requirement. The collection and treatment of wastewater for reuse back into the building provides an environmental benefit in reducing the demand for potable water.</td></tr>
<tr><td>Treatment systems and types</td><td>Advanced treatment is required to treat wastewater to achieve Class A standard. The fit for purpose end use may alter the quality requirements and therefore treatment required. For toilet flushing and unrestricted irrigation around the building there is a requirement for Class A and based on the following key parameters:

<10 E Coli per 100mL.
Log 7 reduction in viruses from wastewater.
Log 6 reduction in protozoa from wastewater.

Note: Log removal is the standard specified by Victorian Department of Human Services (DHS) and the National Water Quality Management Strategy (NWQMS).
<table>
<tr><th>Treatment system</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Membrane Bioreactor (MBR)</td><td>The MBR process involves a suspended growth activated sludge system that utilises microporous membranes for solid/liquid separation. This very compact arrangement produces high quality recycled water suitable for reuse applications. MBR may achieve up to 4 log removal of virus (depending on the membrane nominal pore size).</td><td>Applications at present are probably on a slightly larger scale than what would be considered for the building scale.

Higher operational and maintenance requirements.</td></tr>
<tr><td>Filtration including: Ultrafiltration (UF), Microfiltration (MF)</td><td>Well proven technology, can generally achieve 4 log reductions of both viruses and protozoa depending on supplier.</td><td>Higher operating expenditure due to the higher pressure flows for the membranes.

Chemicals required for membrane cleaning.</td></tr>
<tr><td>Disinfection including Chlorination, Ultraviolet (UV), Ozonation, Advanced Oxidation Process (AOP)</td><td>Chlorine is good at removing viruses (2-3 log reductions) whereas UV will target the protozoa (2-3 log reductions), so often there is a requirement for a combination of the two disinfection processes.

AOP is being increasingly used for advanced treatment of wastewater where considering indirect potable substitution as it can remove organics including pharmaceuticals.</td><td>Ozonation and AOP are less proven in Victoria and they are not pre-validated, which means approval process will be more onorous and costly.

AOP and Ozonation require storage of chemicals, as does chlorination.</td></tr>
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<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td></td><td><table><tr><td>Reverse Osmosis (RO)</td><td>RO provides a high level of treatment and can remove dissolved particles such as salinity, phosphorus and nitrogen. There are limitations on the level of log reductions achieved due to the inability to undertake challenge testing.</td><td>Extremely high in energy use.</td></tr></table></td></tr>
<tr><td>Resources output and consumed and generated</td><td>There are differing resource outputs and consumption for wastewater and greywater recycling systems.

Wastewater:

• A wastewater treatment plant uses approximately 55% more energy than a greywater plant.
• Wastewater can provide a greater capture of water and eliminate flow to the SEW sewerage system, thereby mitigating future infrastructure upgrades.
• Additional sludge waste is contained within wastewater; however this could also provide a nutrient resource.

Greywater

• Additional piping is required to collect and distribute greywater only.
• Greywater has a lower capture of water compared with wastewater.

Greater efficiencies (cost, energy use etc) can be achieved for either system outlined above when applied on a larger scale, for example at precinct scale compared with building. A consequence however is that additional piping is required to discharge wastewater to the treatment plant, and to distribute recycled water via a ‘third-pipe’ system.

A regional scale system relies on the continued inflow of wastewater from suburbs and Council zones upstream. Forecast increases in population and total water demand in Melbourne should ensure this resource continues, however Council planning controls and SEW strategic planning may result in increased decentralised recycling systems across Melbourne, impacting on this resource.</td></tr>
<tr><td>Siting requirements</td><td>To distribute recycled water at the regional and precinct scale, a ‘third-pipe’ infrastructure system is required, this is generally provide for under the roadway, to deliver non-potable water to customers.

Booster pumps, underground storage and mechanical treatment devices require minimum 1m clearance service pipes and conduits.

<u>Building level:</u>

It is likely that any treatment system would be located in the basement of the building. This will be dependent on the area available. Service area dependent on the size of the treatment facility.</td></tr>
</table>

Element	Description
	Most treatment plants will require some form of storage in addition to the treatment plant itself. System would also require potable back up to ensure water available when treatment plant may be offline or in the event that there isn't a suitable volume of wastewater.
Barriers to take up	• Cost of treatment system. • Approvals required enabling dual pipe installation, i.e. Class A validation. • Monitoring and operation of the system over time. • Community acceptance – research indicates that "acceptance of recycled water use decreases as its use becomes increasingly personal" (Hurlimann et al, 2007:111). This supports general acceptance of recycled water use for irrigation, industrial use and toilet flushing. However, public perception is increasingly changing and is considered at present to be in a state of flux, changing in response to education programs and improved understanding (Hurlimann, 2006:58).
Indicative cost	$0.06 to $6.00 per kilolitre (Marsden Jacob Associates 2007:xii). The range in price reflects the site specific nature of wastewater recycling schemes. The Inkerman Apartments (refer 'known applications' below) capital cost for their greywater recycling and stormwater harvesting system was just under $700,000, with on-going annual costs of $40-60 per residential unit (Melbourne Water).
Known applications	Regional Scale (Japan) • Urban integrated dual-pipe systems have been in use since 1968 due to severe water shortages. • Wastewater recycling was legislated as a requirement for large metropolitan buildings. • Tax incentives offered to developers to include recycling. • Reference: Hurlimann et al (2007:110). Precinct Scale (Grand Canyon Village) • Dual-pipe system set up in 1925 to meet rising tourist water demand. • Reference: Hurlimann et al (2007:110). Building Scale • City of Melbourne, Council House Two (CH2) building, Melbourne, Australia. - Recycling of wastewater generated within the building and mining of approximately 100 kL/day. - Treated to Class A non-potable standard for building cooling tower, toilet flushing, watering plants and nearby street cleaning and street trees. - More information can be viewed at <http://www.melbourne.vic.gov.au/info.cfm?top=171&pa=4112&pa2=4091&pg=4077>. - *Note: this building is still being commissioned* • Inkerman Apartments, St Kilda, Australia. - Grey water reuse. - 236 unit medium density development. - Treatment via MBR before UV disinfection. - Recycled water reused for garden irrigation and building toilets. - Maintenance of wastewater treatment plan completed by private firm over initial 12 months, with South East Water subsequently controlling maintenance under a six-year agreement. - It was reported that the approvals process was a significant obstacle due to the innovative nature of this system. - Further information can be viewed at <http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp>.

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td></td><td>

K2 Sustainable Housing Project, Australia.

Greywater Recycling System which has the capacity to treat up to 10,000 litres of greywater per day; reused for toilet flushing and irrigation of landscaped areas.
96 residential apartments in 4 buildings.
More information can be viewed at http://www.housing.vic.gov.au/buildings-projects/environmental-sustainability/k2.

Millennium Dome, London, UK.

Large in-building grey water recycling system servicing circa 6.5 million visitors in year 2000.
Instigated by Thames Water.
Meets the flushing demand of all toilets and urinals.
Water management system also includes rainwater and groundwater harvesting.

Kolding, Denmark

Inner-city block within regional town of Kolding.
145 apartments, five storey complex.
Wastewater recycling retro-fit.
Water recycling system based on a “glass pyramid”, located within a an enclosed courtyard.
Wastewater from the complex is treated by a small-scale primary and secondary waste treatment plant located underground. Discharge is pumped into the glass pyramid using photovoltaic cells and a battery.
Organic matter and nutrients are removed as water passes through a series of ponds on the ground floor containing algae, plankton animals, and finally a fish pond complete with aquatic plants.
Water is then pumped to the top of the pyramid and trickles down over 15,000 plants, which are cultivated and sold locally. The interior of the pyramid resembles an exotic greenhouse.
The water then passes out to a small wetland before it is allowed to run down a cascade to form a small creek through the common gardens and a children’s water playground. This water is mixed with harvested rainwater and stored underground.

Reference: Newman and Jennings (2008:113).
</td></tr>
<tr><td>Other considerations to implementation</td><td>
Wastewater recycling for potable reuse:

Current Victorian Government policy mandates no potable reuse (Victorian Government White Paper: Securing our Water Future Together).
Community acceptance of wastewater is changing (refer ‘Barriers to take up’), however generally the public does not approve of recycling for potable use. (The Toowoomba Water Referendum in 2006 saw 62% vote against recycling for potable use,
Further information can be viewed in the Australian Broadcasting Corporation article referenced below.
However, this option has the potential, in high-density activity centres such as Southbank, to provide 50-90% of household water supply through potable substitution (Hurlimann et al, 2007:112). On-going monitoring of community opinion is recommended as the necessary treatment technology currently exists.

Building scale treatment systems:

Quality of on-going operation and maintenance by private operators.
Shock loadings such as chemicals, nutrients, flow volume etc.

Other:

Approvals (planning, permits).

</td></tr>
</table>

Element	Description
	• Connection agreements (water and power). • Time / access. • Noise. • Visual for precinct scale (may need architecturally designed building). • Buffer distances (100m <1000m EP).
Links to further information and key references	Australian Broadcasting Corporation, 2006, viewed 7 October 2009, <http://www.abc.net.au/news/newsitems/200607/s1700516.htm>. Department of Human Services, c2009. State Government of Victoria, Australia, viewed on 7 October, 2009. <http://www.housing.vic.gov.au/buildings-projects/environmental-sustainability/k2>. Hurlimann, A., Hes, D., Othman, M., Grant, T., 2007. *Charting a new course for water – Is black water reuse sustainable?* Water Science and Technology – Water Supply Vol 7, Nos 5-6 pp 109-118 Hurlimann, A., 2006. *Melbourne office worker attitudes to recycled water.* Water: Journal of the Australian Water Association, November 2006. Jennings, I., & Newman, P., 2008. *Cities as sustainable ecosystems: principles and practices.* Washington, DC: Island Press. Marsden Jacob Associates, 2007. *The cost effectiveness of urban rainwater tanks in Australia*. National Water Commission. Australian Government. Melbourne City Council, 2008, viewed 14 October, 2009. <http://www.melbourne.vic.gov.au/info.cfm?top=171&pa=4112&pa2=4091&pg=4077>. Melbourne Water, Water Sensitive Urban Design: Case Studies, viewed 14 October 2009. <http://wsud.melbournewater.com.au/content/case_studies/case_studies.asp>.

Solid waste resource recovery initiatives

Element	Description
Name	**Biomass Boiler**
Description	Biomass boilers utilise renewable sources of combustible materials to generate heat for use in building heating. As the products of combustion are renewable, heat created by a biomass boiler can be considered carbon neutral. Biomass fuel can include; • Wood waste from industry. • Coppice – fast growing forestry off cuts. • Municipal solid waste. The mass burn combustion or incineration of municipal solid waste (MSW) is the most commonly used thermal process. The caloric value of MSW is around 10 GJ/tonne which can be partly recovered as heat or electricity. Waste wood or coppice is often pre-processed into a pellet form to assist in storage, transport and combustion efficiency. A number of small companies exist within Australia producing wood pellets for combustion[12]. The production of wood pellets for biomass is expected to increase with demand for renewable energy sources. A $25m wood pellet plant has been proposed near Mt Gambier, that will supply pellets to Australian and international markets. Biomass boilers generally have a lower operating efficiency than gas or oil fired boilers as the fuel used often burns unevenly or has a high moisture content. Efficiencies commonly range between 60 and 80% whereas conventional gas or oil fired boilers have efficiencies in excess of 80%. The efficiency of biomass can be increased through the use of fermentation to generate bio-ethanol. Fermentation processes utilise fuels similar to the bio-digestion process and include most starch based grains or sugars such as: • Corn. • Sorghum wheat. • Sugarcane. • Millet. • Cassava. The heat produced from a biomass boiler can also be used in the generation of renewable electricity.
Energy output	Biomass boilers have outputs common to traditional gas or oil fired boilers, ranging between 5kW (similar to an open fireplace) to 5MWt.
Siting requirements	Biomass boilers can be situated in a similar means to traditional gas or oil fired boilers however require additional space for biomass fuel storage. The space required for fuel storage depends on the fuel used. For example, a 1MWt pellet boiler would require around 80m^2 footprint with around an 80m^2 fuel storage area (depending on boiler usage and security of fuel supply).
Barriers to take up	Common difficulties in setting up a biomass boiler include: • Security of supply of fuel source – currently only a small number of companies manufacture and distribute commercial quantities of solid fuel, in log or pellet form. • Additional fuel storage and feed mechanisms required for solid fuel biomass boilers increase spatial requirements, initial infrastructure and maintenance costs. • A majority of commercial biomass boilers are manufactured in Europe, often complicating ongoing maintenance and warranty. • EPA requirements may exist due to the high particulate, SOx and NOx emissions from burning biomass.

[12] Pellet Heaters Australia; http://www.pelletheaters.com.au/

Element	Description
	• Some biomass fuels create excessive tar and ash which can increase boiler maintenance requirements.
Indicative cost	Costs are upward of $80k for a 1MWt ethanol fired boiler, not including fuel storage or installation. Solid fuel biomass boilers are more expensive as they require fuel feed mechanisms and ash removal.
Known applications	Biomass boilers are common in the industrial or agricultural industry where waste products from other processes can be utilised. Interest in biomass boilers within the commercial sector is increasing as a means to reduce carbon footprint.
Links to further information and key references	Steam Systems Pty. Ltd, Viewed 7 Oct 2009, <http://www.steamsystems.com.au/> Wood Energy Ltd, Viewed 7 Oct 2009. <http://www.woodenergyltd.co.uk/prod2/boilers.ashx> Froeling Wood Pellet Boilers. Viewed 8 Oct 2009. <http://www.froeling.com/en/>

Infrastructure initiatives

Element	Description
Name	**Central Services Hub (CSH)**
Description	A Central Services Hub (CSH) is a central installation setup to supply the surrounding buildings with their required services. Centralisation of services provision is designed to increase overall efficiency of the systems, reduce total installed plant and reduce waste. Plant within a CSH may include any of the following technologies: • Bio-digester. • Blackwater recycling (with or without Sewer mining). • Co/Tri-generation. • Fuel cells. • Solar cooling. • Thermal energy storage. • Electrical chillers &/or natural gas fired boilers. • Heat rejection plant. Depending on the plant to be installed within the CSH, services reticulated from a CSH may include the following: • Electricity. • Heating hot water &/or chilled water for building heating and cooling. • Heating hot water for domestic hot water requirements. • Medium temperature condenser water for heat rejection. • Recycled non-potable water. Services connections to a CSH may include: • Natural Gas. • Electricity. • Potable or Non-potable water. • Waste water (for Sewer mining). A CSH often increases the feasibility of the above technologies as plant operation can be optimised and total installed plant can be reduced. Total installed plant can be reduced for centrally installed plant as peak utility consumption for each building in a precinct often occurs at a different time of the day/year. This is known as plant diversity.
Siting requirements	A central services hub would generally be sited close to the buildings being served and in a position to minimise alteration to existing site services. Design considerations depend on the technologies utilised however commonly include; • Noise and vibration output of plant needs to be taken into account when locating plant. • EPA requirements for plant need to be taken into account if airborne emissions exist.
Barriers to take up	Locating a suitable site, specifically within an existing developed area often proves difficult. Some plant have acoustic and emission output that precludes them from positioning in locations that could affect the operation of existing buildings. No legislation currently exists to regulate the on-selling of locally distributed services. Local utility providers are often reluctant to purchase and on-sell utilities and ongoing administration costs exist for private utility networks. The model used for on-selling utilities from a CSH is often critical to the plant feasibility.
Indicative cost	Costs are upward of $3000/m^2$ for plant area only. Land and installed services cost are additional to this.
Trend in take up	Central Services Hubs are quickly becoming attractive as they increase the feasibility of implementing environmental technologies such as tri-generation and black water recycling.
Known applications	• RMIT City Campus • Dandenong CSH • Grid-X Sydney • Royal Melbourne Hospital

Element	Description
Name	**Services Tunnel**
Description and benefits	A tunnel constructed as a tunnel, for example beneath pavements or within connected buildings to conveniently install, maintain and operate services infrastructure replacing the need for different trenches. The benefits of a services tunnel: • allows for a central quality control at the precinct scale and ease of access to service the asset. • less disruption form road closures when retrofits, maintenance or technology upgrades are required. • simplifies the services and minimises the impact to other assets (such as roads). • allows for improving cross connection of services. • increase the ability to monitor and repair water leakages. • can be an income generating asset.
Resources output and consumed and generated	Typical construction materials consumed during the construction and fit-out of the tunnel to ensure services are securely installed. The volume of excavated soil will be greater than typical trenches and will be dependent on the dimensions and length of the tunnel.
Siting requirements	Where a services tunnel is to be retrofitted into a precinct, the site would need to be excavated to the required depth and width, and may require relocation or realignment of existing services infrastructure.
Barriers to take up	Where retrofitted, construction may require significant disruptions to traffic as excavation of roads would be required.
Indicative cost	Costs are dependent on dimensions and lengths of the tunnel, the soil to be excavated, and any relocation of existing services (i.e. gas mains).
Other considerations to implementation	Excavation and management of excavation of soils would require planning permission and consents from relevant authorities for the treatment and/or disposal of soils. Access and health and safety requirements (i.e. emergency exits). Engineering considerations for the connection of services into buildings.

Element	Description
Name	**Vacuum Sewers**
Description and benefits	Vacuum sewers use differential air pressure to move sewage through the sewerage network instead of using water and gravity flow. The system is connected to dwellings using gravity flow to the connection point to the vacuum system. This technology reduces water consumption and the vacuum system does not require design in consideration of gravity flow. The system is air- and water-tight and can be installed at shallow depths, therefore making it well suited to waterfront locations in lieu of conventional deep collection pipes installed below the watertable.
Types	To be cost effective, the system typically requires a minimum of 74-100 customers. Pipe sizes vary depending on number of houses served, for example 4in diameter for 80 houses, 10in diameter for 750 houses.
Resources output and consumed and generated	Electricity consumed to create differential air pressure relative to size of the system to be installed.
Siting requirements	Vacuum systems can be limited by topography, as it can be capable of lifting sewage 5-6m (15-20ft). A central collection system is required, and the use of the technology may be more appropriate than conventional systems in areas of unstable soils, flat terrains, high water tables, and existing urban developments.
Known applications	Municipal projects, private developer projects. Installed in locations worldwide. For example: http://www.airvac.com/ Large system installed at Tea Gardens development in New South Wales.
Other considerations to implementation	Human health considerations around the central collection system. Planning approvals for land use and services installation
Links to further information and key references	AirVac (2007). *Vacuum Sewers 101*. Availble at http://www.airvac.com/pdf/Vacuum%20Sewers%20101.pdf , viewed 4 Feb 2010.

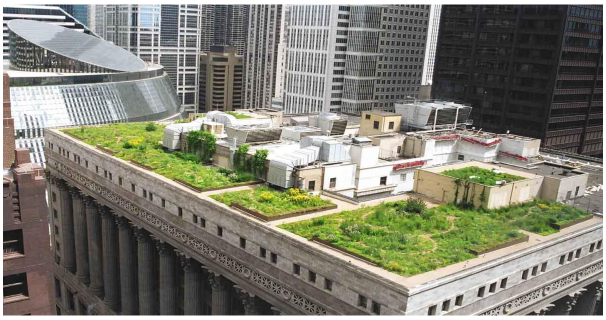
Element	Description
Name	**Header tanks**
Description and benefits	Header tanks are water tanks installed on the roofs of buildings to store water and increase the head and water pressure within the building. It also improves the efficiency of supplying water throughout the building. Water is pumped to the header tank from the mains where it is stored, and consumed within the building. When the water level declines to a threshold it is replenished.
Types	Header tanks to service the building replace the need for individual small scale and less efficient pumps to service the buildings on demand when water is required. Header tanks also act as an emergency supply of water for firefighting.
Resources output and consumed and generated	Electricity consumed within pumps, dependant on size, and efficiency of pump.
Siting requirements	The size of the tank for a given application will vary depending on the demand within the building and the available roof space.
Barriers to take up	Header tanks may be difficult to retrofit to existing buildings as space may be limited, and connection into the existing water infrastructure may require extensive modification. The technology is readily available for installation on new buildings.
Indicative cost	Dependant on tank size, height of building, type and size of pump, and connection costs into new and/or existing infrastructure.
Known applications	Apartment buildings for providing water to toilets (http://aquaco.co.uk/) Council House 2 (CH2), Melbourne
Other considerations to implementation	The weight of a full header tank may require strengthening of existing building roofs as it is unlikely that there is sufficient capacity within the design loading. Within an apartment building, agreements with tenants likely to be required regarding the utilities company responsible for providing the water as each tenant may lose their ability to choose alternate suppliers.

Element	Description
Name	**Distributed Underground Storage Tank**
Description and benefits	A series of tanks or storage basins to collect and store stormwater which would otherwise be discharged to the Yarra River. This water can then be used as recycled water as required to balance out peaks and troughs in supply and demand. These systems, if reuse is not intended, can also store the water and release it slowly to reduce to downstream flooding.
Types	Underground tanks, open storage basins.
Resources output and consumed and generated	Once constructed, energy consumed for pumping water as required.
Siting requirements	Site requirements will vary depending on storage volume requirements, available space, the type of storage required (tank or basin) and the quality of stormwater. Access is required for maintenance purposes.
Barriers to take up	Land availability in existing urban areas. Underground storage can be integrated within open space however retention basins can require a significant area (depending on volume requirements).
Indicative cost	Dependant on type on installation, land available, connectivity to new or existing infrastructure and whether it is incorporated within new development or retrofitted.
Other considerations to implementation	Land use planning requirements and connectivity into services infrastructure (agreements with any service owners). If underground, safe access requirements for maintenance.

Open space initiatives

Refer Water Harvesting and attachments under "Water Initiatives", above.

Element	Description
Name	**Green Roofs**
Description and benefits	Green roofs are intentionally vegetated roofs, i.e. the roof is designed either to allow vegetation to colonise naturally or to be deliberately seeded or planted as part of the roof construction. Green roofs typically comprise of plantings with a soil and/or crushed aggregate medium overlain on various synthetic layers eliminating the passage of moisture and roots. Two types of green roofs generally exist, extensive and intensive, which are described below. A modification of extensive green roofs may also be achieved as part of a water treatment process (either wastewater recycling or stormwater harvesting).  *ACROS building, Japan* Green roofs can contribute to a wide range of sustainable development objectives, including: • Water management e.g. water treatment and reduction of peak runoff to the stormwater drainage system. • Thermal insulation to regulates internal temperature; Wong et al. (2003) and Getter et al. (2006) have shown that under a green roof, indoor temperatures were found to be at least 3 to 4 °C lower than outside temperatures of 25 to 30 °C. • Improving the electricity production of PV panels; the green roof cools the PV panels through evapotranspiration, maintaining a higher electricity production than would be the case without the vegetative layer (Appl et al. 2004). • Reduction of Urban Heat Island Effect (UHIE). • Removal of pollution from the air. • Noise insulation - the growing medium blocks lower frequencies of sound and the plants block the higher frequencies. Tests show that 12 cm of growing medium alone can reduce sound by 40 db. Further details can be viewed at <http://www.crd.bc.ca/watersheds/lid/roofs.htm>. • Preserving biodiversity (they may improve biodiversity in retrofit cases). • Improved city aesthetic. • Open 'green' space and relaxation opportunities. • Net reduction of building carbon dioxide emissions through creation of a carbon sink. Green Roofs reduce the imperviousness of urban areas, resulting in decreased storm runoff entering the stormwater drainage system. This has been attributed as the primary benefit of green roofs (VanWoert et al, 2005:1036), particularly in Europe and parts of USA where stormwater is commonly discharged to combined sewers, causing sewer overflows that pollute rivers and streams. With separated stormwater and sewer systems in Australia, and a generally hotter climate,

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td></td><td>thermal benefits may provide a more significant driver, such as reduction of the UHIE, with modelling estimates in hot cities such as Riyadh showing an 11.3 degree Celsius drop in local area temperatures due to Green Roofs (O'Loan 2007).</td></tr>
<tr><td>Types</td><td>There are broadly two types of green roof, intensive and extensive.
Extensive Green Roofs:
• Thin profile (up to 300 mm depth) spread across the extents of available roof space.
• Require less maintenance than intensive green roofs.
• Structural loadings up to 150 kg/m^2 (O'Loan 2007) and 120 kg/m^2 for 100 mm depth (City of Sydney).
• Not usually designed to accommodate use by people.
• Often use local grasses, wild flowers and sedum plant species.
• Can comprise crushed aggregate (possibly reclaimed rubble from brownfield sites) on a waterproof base, creating habitat for birds, insects and spiders. Soil and seeds may be added to produce vegetation.
Extensive Green Roofs for water treatment:
• Involves pumping of water to building roof for treatment, with storage at roof level allowing gravity feed into building plumbing system.
• Wastewater recycling (reed bed treatment systems) and WSUD (bio-retention) for typical soil profiles required, however as a general rule >300 mm depth is required.
Intensive Green Roofs:
• Thick profile (300 mm – 1800 mm depth).
• Structural loadings up to 2000 kg/m^2 (O'Loan 2007) and 1000 kg/m^2 for 800 mm depth (City of Sydney).
• Designed for people, extending internal spaces outdoors, with plantings intensively placed at targeted locations.</td></tr>
<tr><td>Resources output and consumed and generated</td><td>Green roofs require the transportation of soil, aggregate and plant species.</td></tr>
<tr><td>Siting requirements</td><td>Green roofs can be sited around building plant and equipment and designed as needed for use by occupants by utilising extensive or intensive designs, with varying depths as described above.

Chicago City Hall
Wind, light, temperature, rainfall, access, construction type and maintenance are all key considerations in determining whether a green roof is appropriate for a site, and which type of green roof may be appropriate. Consideration needs to be given to the micro-environment at roof level, particularly wind speed (largely dependent on building height) and available sunlight (affected by shadowing of surrounding structures).</td></tr>
<tr><td>Barriers to take up</td><td>There has been limited uptake in Australia of green roofs, both commercial and residential. As such, knowledge of appropriate plantings in local conditions is minimal; however, University of</td></tr>
</table>

Element	Description
	Melbourne has recently commenced research into the suitability of Australian native plants for use on Green Roofs (UoM, 2008). Recent competitions such as 'Growing Up: The Blueprint to Green Roof Melbourne', an initiative of Committee for Melbourne (supported by Melbourne Water), seeks to increase their use. Further details can be viewed at <www.growingup.org.au>. Quantification of the economic benefits of Green Roofs may be limited to building energy efficiency, increased usable gross floor area (in case of intensive green roof designed for occupant use) and reduction of stormwater discharge to existing drains. However, many benefits of Green Roofs are qualitative and benefit the wider community, not necessarily the building developers, with outcomes such as reduction of UHIE, preservation (and enhancement) of biodiversity, improved city aesthetic and improved air quality. This suggests governance controls from Council are required to ensure adequate uptake of Green Roofs to help realise *Future Melbourne* eco-city targets. Discussion of Toronto by-laws mandating Green Roofs can be viewed at <http://greenroofs.wordpress.com/>.
Indicative cost	The cost of a Green Roof can vary significantly depending on the type of green roof i.e. extensive or intensive. A Green Roof may cost one third more than the cost of a conventional roof. However, when you take into consideration the benefits including energy savings and increased roof lifespan, the cost of a green roof may be as little as half of a conventional roof when considered over the lifespan of a green roof (Carpenter, 2008).

Known applications	City of Melbourne – Council House 2
	
	• Combination of vertical planters with climbers, semi-extensive roof with modular planting and roof garden (amenity space).
	• East-core roof has series of modules with trial plantings in a sand substrate, depth of 200-300 mm.
	• Vertical planting consists of planter boxes on balconies in a sand substrate.
	
	Semi Extensive Green Roof, CH2, Melbourne
	
	Ford Truck Assembly Plant
	
	• Dearborn, Michigan, USA.
	• 42,000 m^2 living roof.
	• 300mm depth with total saturated weight of 10 lbs/sq.feet.
	• The Green Roof is expected to:
	  o Decrease building energy use by 7%.
	  o Provide for 25% of the productive habitat of an undisturbed green site.
	  o Improve air quality above the roof by 40%, in terms of dust absorption and the decomposition of hydrocarbons.
	• Ford have established a bee apiary adjacent the site, with bees gathering nectar from

Element	Description
	Green Roof sedum blossoms. • Further information can be viewed at <http://www.greenroofs.org/index.php/grhccommittees/290?task=view>. ACROS, Intensive Green Roof, Japan • Fukuoka Prefectural International Hall completed in 1994, designed by Emilio Ambasz & Associates, Inc. • 100,000 square feet. • Accessible intensive green roof, stepped over 15 terraces with 2 degree roof pitch. Ekostaden Augustenborg Botanical Green Roof. • Malmo, Sweden. • 9,500 m^2 botanical green roof spread across several buildings joined by footbridges for pedestrian connectivity. • Further information can be viewed at <www.greenroof.se>. Chicago Town Hall • Chicago, USA. • Retrofit of >100 year-old building in 2001. • Flat roof with mix of soil depths between 100-450 mm. • Monitoring during the roofs first summer indicated a reduction in temperature on the roof surface of 70 degrees Celsius, and 15 degrees Celsius to the local area air temperature. • Visible from 33 high-rise towers located adjacent and nearby. • Further information can be viewed at <http://www.asla.org/meetings/awards/awds02/chicagocityhall.html>. Other Australian examples: • Freshwater Place, Southbank. • Parliament House, Canberra. • M-Central, Sydney.
Other considerations to implementation	The decision on what type of green roof to install can be based on the structural capacity and/or functional requirements. If for instance, the sole objective is to achieve environmental benefits, an extensive green roof best meets these demands. In contrast if it were desired to provide public amenity for the building occupants or to grow food produce, then an intensive green roof would be more beneficial. Green walls, which have plants growing on or within them, exhibit many of the same integrated benefits to sustainable development as green roofs outlined above; however their water management benefits are minimal and as such are not discussed further.
Links to further information and key references	American Society of Landscape Architects, c2002. *Chicago City Hall Green Roof*. Viewed 7 October, 2009. <http://www.asla.org/meetings/awards/awds02/chicagocityhall.html>. Appl, R., Ansel, W., 2004. *Future Oriented and Sustainable Green Roofs in Germany:* Proceedings from Green roof tops for sustainable communities conference, Portland, 2004 Augustenborgs Botanical Roof Garden, c2006, viewed 7 October 2009. <www.greenroofs.se>. Capital Region District, 2009, Vancouver, Canada, viewed 14 October, 2009. <http://www.crd.bc.ca/watersheds/lid/roofs.htm>. Carpenter, S., 2008. *Green roofs: a review*. Green roofs forum: turning buildings green, literally! 26 August 2008. Melbourne, Australia. City of Sydney, c2008. Green Roof Resource Manual. Viewed 9 October, 2009. <http://www.cityofsydney.nsw.gov.au/Environment/Overview/GrantFundedProjects/GreenRoofRetrofitDesignModel.asp>. Eleftheria, A., Jones, P., 2008. *Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates*. Building and Environment 43 (2008) 480-493. Getter, K., Rowe, D. B., 2006. *The Role of Extensive Green Roofs in Sustainable Development*: HORTSCIENCE 41(5):1276–1285. 2006. Green Roofs Australia 2009. Toronto Green Roof by-lay a model for Australian Councils. Blog

Element	Description
	entry 9 June, 2009, viewed 14 October, 2009. <http://greenroofs.wordpress.com/>. Green Roofs 2007. *Ford Plant*. Viewed on 14 October, 2009. <http://www.greenroofs.org/index.php/grhccommittees/290?task=view>. Living Roofs, 2009, UK, viewed 14 October 2009. <www.livingroofs.org> O'Loan, T., 2007. *The Green City*. Woods Bagot Public Paper, issue 0904, viewed 7 October 2009. < http://www.woodsbagot.com/en/Pages/TheGreenCity.aspx>. University of Melbourne, 2008, Australia, viewed 7 October, 2009. <The University of Melbourne Voice Vol. 3, No. 6>. VanWoert, N., Rowe, B., Andresen, J., Rugh, C., 2005. *Green roof stormwater retention: Effects of roof surface, slope, and median depth*. Journal of Environmental Quality. Volume 34. Wong, N.H., Chen, Y., Ong, C. L., Sia, A., 2003. *Investigation of thermal benefits of rooftop garden in the tropical environment.* Building and Environment 38:261–270.