Report for the Global Water Research Coalition (GWRC) - Energy Efficiency Compendium of Best Practice for Australia and Singapore

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1. Introduction

This Australasian energy efficiency report has been compiled by Water Services Association of Australia (WSAA) in partnership with PUB Singapore. The report showcases 26 energy efficiency initiatives which were collected as case studies to a consistent pro-forma from WSAA Members (Large Australian urban water utilities) and PUB Singapore.

The 26 case studies represented in this report will be submitted to UKWIR and Black and Veatch, for potential inclusion in the Global Water Research Coalition (GWRC) global compendium of best practice case studies. The aim of the GWRC compendium is to identify the promising developments and future opportunities to help deliver:

- Incremental improvements in energy efficiency through optimisation of existing assets and operations.
- More substantial improvements in energy efficiency from the adoption of novel (but proven at full scale) technologies.

The GWRC compendium will be a global reference document for best practice and will ensure representation is as complete as possible across the following typical subject areas:

- Scope – to cover incremental and significant changes
- Process – to cover all important parts of the water cycle
- Geography – to cover flat and steep catchments and various environments
- Climatic – to cover regions with cool, temperate and tropical conditions
- Regulatory – to cover public, private, regulated and non-regulated utilities
- Scale – to cover large and small works in rural and urban areas
- Technology – to cover simple low-tech and complex high-tech solutions

The 26 case studies are plotted to the energy saving matrix provided by Black & Veatch

Figure 1 – Water Cycle Energy Saving Matrix

WATER CYCLE ENERGY SAVING MATRIX				Green boxes show priority areas				
		Raw Water	Treatment	Distribution	Sewerage	Treatment	Disposal	Re-use
Current Energy Usage estimate (%)		25	10	65	25	60	15	
Demand	Conservation							
Management	Leakage Reduction			SW5				
Pumping	Optimise Gravity Flow				HW2			
	Transfer Pumps, Ops	HW1 SA1		PUB1 SA1	HW3 PUB1 SA1			
	Transfer Pumps, Plant	MW1		PUB1	PUB1			
	Catchment Transfer							
	Aquifer Recharge							
Treatment	Screens / Preliminary							
	Sedimentation / PSTs							
	Aeration, Blowers					BW1 BCC2		
	Aeration, Others					PUB2 SW1		
	Mixing							
	Filtration SSF / RGF							
	Nutrient Removal							
	Nitrate Return Pumping							
	RAS Pumping							
	Intermediate Pumping		MW2					
	Filtration GAC							
	Membrane Treatment					PUB3		
	Desal. Membrane/ Therm							
	Disinfection / UV							
	Ozonation							
	Enhanced / Tert Treatmt.							
	Optimise Ops/Process							
Sludge	Sludge Thick/Dewatering							
	Sludge Digestion					BCC1 PUB4		
	Sludge Drying							
	Disposal to Land							

WATER CYCLE ENERGY SAVING MATRIX					Green boxes show priority areas			
		Raw Water	Treatment	Distribution	Sewerage	Treatment	Disposal	Re-use
Building Services		**SW2**	**SW2**	**SW2**	**SW2**	**SW2**	**SW2**	**SW2**
Generation	Mini Hydro-Turbines	**SA2 SE1**		**MW3**	**SA2 SW4**		**SW4**	
	Wind Turbines							
	Biogas / Cogeneration					**MW4 PUB5 PUB6 SA3 SE2 SW3 SW4**		
	Incineration							

2. Study Environment

2.1 Singapore

Singapore is a small island city-state with a land area of about 710 km^2 and a population of 4.8 million. It enjoys an equatorial climate with relatively uniform temperatures, high humidity, high evaporation and an average annual rainfall of 2400 mm. The daily water consumption is 1.36 million m^3, about 50% of which is for industrial, commercial and other non-potable use, and the remainder for domestic use.

Being a small island nation, collection of rain that falls over most parts of Singapore throughout the year will have to be balanced with land uses for socio-economic growth. Currently, although half of Singapore's land area is already allocated as water catchment, water is still a scarce commodity on the island. The population in Singapore was about a million in 1950, and its water demand about 142,000 m^3 per day. Today its water demand has increased 10 fold to 1.36 million m^3 per day, a rate that is 2.5 times that of population growth. With active water conservation efforts, water demand has been kept consistent over the recent years. In spite of demand control, it is still not possible for Singapore to depend solely on rainwater collection in its surface reservoirs as its only drinking water source.

In order to achieve a sustainable and robust water supply to meet increasing water demand, Singapore has diversified its water sources, namely:

- Imported water from Johor, Malaysia;
- Local catchment water;
- NEWater (recycled water); and
- Desalinated water

Water purchased from Johor and local catchment water have been the traditional sources of water for Singapore. There are currently a total of 15 reservoirs in Singapore. However, these would not have been sufficient for the rapidly expanding population. With advancement in membrane technology and decreasing membrane prices, recycled water came online in 2003. Desalination is a process that was also recently included as a water source, with the opening of a 136,000 m^3 desalination plant in 2005.

Water from the catchment is treated in waterworks through either conventional processes involving coagulation, flocculation, sedimentation, filtration and disinfection or advanced processes that include membrane or ozone technologies, before the treated water is pumped to the distribution system and service reservoirs to be supplied to the consumers.

As Singapore is 100% sewered, wastewater is then collected and transported to wastewater treatment plants, where the conventional activated sludge process is used to treat the wastewater. A multi-barrier process using membranes and ultraviolet disinfection is then used to produce NEWater from the treated used water.

Some of the improvements made in energy efficiency include recovery of energy from biogas for in-plant use, as well as optimised plant operations to minimise energy usage.

Figure 2 - Singapore Electricity Tariff
Source: http://www.singaporepower.com.sg/

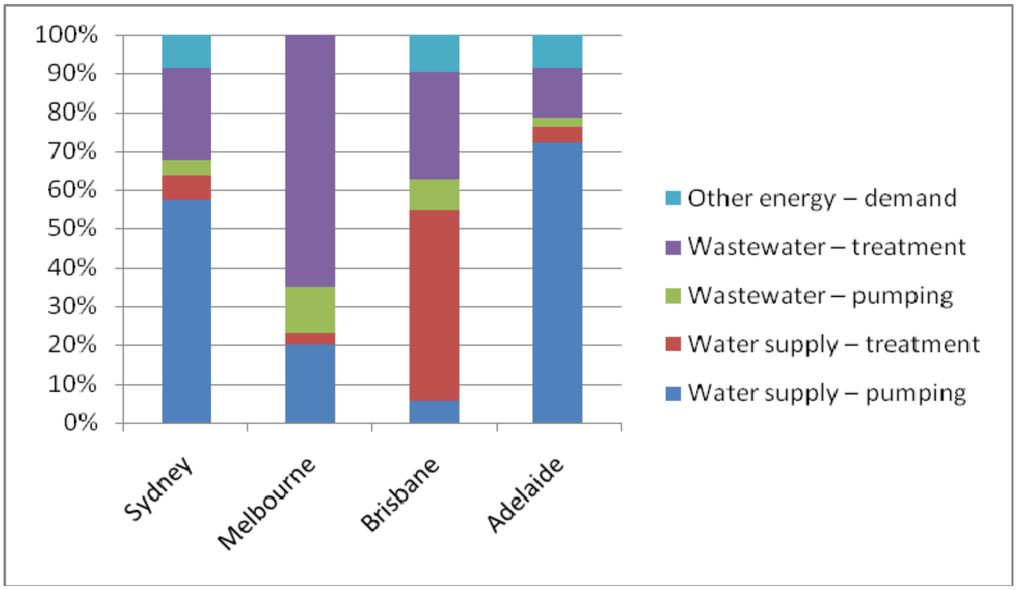
HIGH TENSION LARGE (HTS) SUPPLIES	
Contracted Capacity Charge $/kW/month	6.96
Uncontracted Capacity Charge $/chargeable kW/month	10.44
kWh charge, ¢/kWh Peak period (7am to 11pm) Off-peak period (11pm to 7am)	 15.31 9.07
Reactive power Charge ¢/chargeable kVARh	 0.59

2.2 Australia

Australia's climate is varied from tropical in the north of Australia with high rainfall to temperate in the southern parts and Mediterranean-like in the south-west. Over the last ten years, Australia has experienced changing rainfall patterns due to climate change. Adapting to climate change continues to be the major driver of activity in the urban water industry.

The industry is in the midst of a massive capital investment program and will be overseeing projects with a value greater than $14 billion during the 2009-10 year. This is on top of record capital expenditure of $2.75 billion in 2007-08. The majority of the capital expenditure being undertaken is related to developing new water sources to mitigate the risks associated with climate change. It is essential that the industry diversify its portfolio of water sources so that it reduces its reliance on surface runoff from rainfall. Projects being constructed include desalination plants, recycled water schemes, aquifer storage and recharge and establishment of water grids. It is estimated that by 2012 30% of capital city water needs, based on 2007-08 consumption will be supplied by desalination (WSAA Report Card 2008-09).

The areas in Australia that submitted case studies were major urban areas in the south east corner of Australia and included Sydney, Melbourne, Brisbane, Adelaide, Newcastle and Geelong. Energy consumption within these utilities varies according to local circumstances and regulations. Whilst for the purposes of this study, it was intended for WSAA to align this breakdown with the energy saving matrix (Figure 1), the response to WSAA's request for energy consumption and potential energy savings data was sparse. In lieu of this some data was taken directly from a WSAA-sponsored study titled "Energy Use in the provision and consumption of urban water in Australia and New Zealand", (Kenway et al, 2008) which is an appropriate substitute.



Melbourne data (2008-09) – supplied by Melbourne Water
Sydney, Brisbane and Adelaide data (2006-07 FY) – CSIRO study 2008

Figure 3 – Average Australia electricity prices ($/MWh)

Year	*NSW*	*QLD*	*SA*	*SNOWY*	*TAS*	*VIC*
1998-1999	33.13	51.65	156.02	32.34		36.33
1999-2000	28.27	44.11	59.27	27.96		26.35
2000-2001	37.69	41.33	56.39	37.06		44.57
2001-2002	34.76	35.34	31.61	31.59		30.97
2002-2003	32.91	37.79	30.11	29.83		27.56
2003-2004	32.37	28.18	34.86	30.80		25.38
2004-2005	39.33	28.96	36.07	34.05	190.38	27.62
2005-2006	37.24	28.12	37.76	31.09	56.76	32.47

2006-2007	58.72	52.14	51.61	55.19	49.56	54.80
2007-2008	41.66	52.34	73.50	45.49	54.68	46.79
2008-2009	38.85	34.00	50.98		58.48	41.82
2009-2010	27.69	25.27	24.77		23.52	24.32

http://www.aemo.org.au/data/avg_price/averageprice_main.shtm

2.2.1 Brisbane (eastern Australia)

The vast majority of Brisbane City Council's (Water Distribution) energy requirements are supplied by electrical power, with only a relatively small amount of energy (10 000 GJ or 2%) generated from biogas for internal purposes (digester heating). Brisbane City Council has relatively high energy intensity for water supply mainly due to the need to pump water to the Mt. Crosby and North Pine treatment plants. The requirement for tertiary treatment of wastewater before discharge to Moreton Bay is also a significant driver of energy use, resulting in an energy intensity for wastewater disposal and a contribution of approximately 40% of total energy requirements.

2.2.2 Melbourne (south-eastern Australia)

Melbourne Water provides bulk water and wastewater treatment and bulk transport services for Melbourne. Yarra Valley Water, South East Water and City West Water are the retail water companies providing water delivery and wastewater collection services for Melbourne.

Melbourne Water's energy use is characterised by a low energy requirement for water supply, with about eight times more energy being used for wastewater disposal (0.14×10^6 GJ versus 1.2×10^6 GJ respectively). This relationship is easily understood as most of Melbourne's water is gravity fed from protected mountain catchments, and only a small percentage is treated while the wastewater is pumped long distances and requires extended levels of treatment. In 2006/07, Melbourne used about 4051 GJ/GL to treat and dispose of its wastewater, although about 40% of this energy was internally generated through biogas production at the wastewater treatment plants.

2.2.3 Adelaide (southern Australia)

Adelaide's energy requirements for water supply depend significantly on the percentage of supply pumped from the Murray River at Mannum, which increases in drought conditions (i.e. the last ten years). The increased pumping is reflected in the energy intensity of water supply of 6901 GJ/GL in 2006/07 – some 20 times the energy required per volume for Melbourne's water supply.

Energy consumption for wastewater pumping and treatment in Adelaide was about 20% of that for water supply pumping and treatment at around 217 258 GJ/a. This is largely due to a very low pumping energy requirement of only around 32 000 GJ/a (note: there is a 20 m fall between Adelaide city and Bolivar Wastewater Treatment Plant). The other interesting fact is that a high proportion of the energy for wastewater treatment is generated in gas turbines fed either by biogas generated in the treatment plant or imported natural gas resulting in about 30% of the energy used in wastewater treatment coming from on-site generation sources. The energy intensity of wastewater management in Adelaide is a relatively small figure compared to other utilities, while the use of biogas and imported natural gas further reduces the greenhouse gas footprint for wastewater management in Adelaide.

2.2.4 Sydney (eastern Australia)

Sydney Water and the Sydney Catchment Authority jointly manage Sydney's urban water supply system. Sydney's water supply comes mainly from Warragamba Dam and is mostly gravity fed. However in drought periods (e.g. 2006/07) extensive pumping from the Shoalhaven system occurs sharply lifting Sydney's water supply energy consumption. Sydney also has 14 water filtration and/or chlorination plants of which four are privately operated. Sydney has 29 wastewater treatment plants with the three major coastal plants processing about 75% of the total volume of wastewater. These plants provide primary treatment, with deep ocean outfall disposal. One of these plants, North Head Sewage Treatment Plant (STP), requires all wastewater to be lifted 50 m to the plant on the top of the headland. The ocean outfalls require sufficient pressure to enable dispersal of the effluent.

2.2.5 Geelong (south-eastern Australia)

Barwon Water (Barwon Region Water Corporation) provides water and sewerage services to more than 275,000 permanent residents over 8,100 square kilometres. Barwon has an asset base of $1.024 billion wich includes more than 5,640 kilometres of pipes, 10 major reservoirs, 10 water treatment plants and nine water reclamation plants.

Geelong region's water is supplied by three major sources - the Barwon River, East Moorabool River and West Moorabool River. Domestic customers comprise 92% of the customer base, with industrial and commercial customers accounting for the remaining 8%. However, non-domestic customers use around 35% of metered consumption.

Barwon Water has nine water reclamation plants governed by Environmental Protection Authority (EPA) Victoria licensing requirements. All water reclamation plants produce water suitable for recycling. More than 14% of their recycled water is committed to a variety of users, including wineries, golf courses and turf, flower, tomato and potato growers.

2.2.6 Newcastle (eastern Australia)

Hunter Water is a State-owned Corporation providing water and wastewater services for over half a million people in the lower Hunter region in NSW. There are 220,600 properties connected to the water network and 208,660 to the wastewater network. Total assets are valued at approximately 2.2 billion dollars. The area of operation covers 5,366km^2 with a population of 517,273 in the local government areas of Cessnock, Lake Macquarie, Maitland, Newcastle, Port Stephens, Dungog and small parts of Singleton.

Water comes from 3 main sources – Grahamstown and Chichester Dams and Tomago Sandbeds. The water is distributed to customers via a network of 76 service reservoirs, 84 pumping stations and 4,548 km of water mains. The average water delivery is 205 ML per day. Hunter Water operates 17 wastewater treatment works and maintains 4,477 km of sewer main systems, which require 380 pumping stations.

3. Methodology

The first stage of the Australasian effort in compiling energy efficiency case studies involved utilities preparing abstracts as a screening process. The abstracts were reviewed by WSAA / PUB (Singapore) and an Advisory Committee (made up of four water utility energy specialists) as well as UKWIR and Black and Veatch. Most abstracts were invited to submit more detailed case studies, and only those that were out of scope or not proven at full scale were excluded. At this stage, WSAA also held an energy workshop with its Members to attempt to get more coverage of case studies across the water cycle.

More detailed information (to a specific pro-forma) was then elicited from the successful abstracts, which were again submitted to WSAA and reviewed by WSAA / PUB (Singapore), the Advisory Committee as well as UKWIR and Black and Veatch. This review identified consistency issues and any significant gaps in the case studies where more information was sought.

4. Incremental Improvements

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
Clean Water					
Raw water - pumping	Newcastle (eastern Australia)	HW1	Installation of Variable Speed Drive Pumps (VSDs). 3 out of 7 pumps. In process of converting 2 of the remaining 4	735 MWh p.a. (8% saving) From 0.236 to 0.182 KWh/m^3	The initial project had a benefit to cost ratio of 1.42 using $0.08/kWh and discounting costs and benefits by 7% p.a.
	Adelaide (southern Australia)	SA1	Epoxy coating of pump impellers and casings. Upgrade to mechanical seals on early pumping units	From 0.468 to 0.378 kWh/m^3	Total cost of pump refurbishment including impeller coating (excluding rotating element replacement) is approximate $20,000. Payback period of this pump is about 3.2 yrs. Annual energy saving $6,220 p.a. based on annual running hrs of 1,910.

Area of water cycle	**Location**	**Code**	**Description**	**Energy efficiency savings**	**Investment**
	Melbourne (south-eastern Australia)	MW1	Mechanical pump overall on 30 year old pump	*See Observations and, Figures 1 and 2 in appendix*	N/A (completed as part of maintenance programme)
Treatment – intermediate pumping	Melbourne (south-eastern Australia)	MW2	Changed reuse pump control algorithm to flow pressure control from pressure control	During 07/08 the pumps were operational for 11,325 hours consuming 2,573 MWh (0.227 MW) and pumping 13.1 GL (195 MWh/GL). During 08/09 the pumps were operational for 13,908 hours consuming 2,631 MWh (0.189 MW) and pumping 14.2 GL (185 MWh/GL)	<1 month payback period
Distribution – leakage reduction	Sydney (eastern Australia)	SW5	Active water leak detection on reticulation pipes and customer service pipes. 21,000 km of pipes surveyed per year. Improved response times to customer reported water leaks	An estimated 6,617 MWh has been saved across the 5-year water leak reduction maintenance program (02/03 – 07/08).	Active water leak detection is justified on a break even basis (Economic Level of Leakage) Pressure Management is justified on a NPV basis with benefits of water leakage reduction, reduction in main breaks and asset life extension.

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
Distribution – pumping	Singapore	PUB1	Pump refurbishment program (pump sandblasting and epoxy coating)	The energy savings is attributed to the improvement in the average efficiencies of these pumps by some 5.5% following their refurbishment.	Increase in "useful" lifespan of some 107 pumps results in significant capital expenditure savings of up to $25.6 million. Estimated annual energy cost savings of $1 million from refurbishment of some 130 pumps.
	Newcastle (eastern Australia)	HW2	Cured In Place Pipe (CIPP) to reduce groundwater infiltration in low-lying area		$30,000 p.a. (electricity savings) NPV analysis over 50 years resulted in a marginally positive B/C ratio of 1.08

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
	Newcastle (eastern Australia)	HW3	Retrofitting flap valve to stop infiltration reducing pump run time	Average pump run hours per day from 7.26 to 2.27 hours per day (after the flap valve was installed). Total energy saving is estimated to be 281 MWh p.a, including 149 MWh p.a. at the pump station plus secondary power savings from downstream pumping.	The cost to inspect all constructed sewer overflows within the network was $200,000 over three years. The example described at Windale 2 WWPS is just one of several problems found within the network by undertaking an inspection of all overflows. It is impossible to determine a true Benefit to cost ratio but we can calculate that the leak need only have remained undetected for a further 5 years in order to have accumulated a present day net present value of $200,000 in electricity costs.

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
Treatment – aeration blowers	Brisbane (eastern Australia)	BCC2	Modification and optimisation of bioreactors The last section of the aerobic zone and the secondary aerobic (re-aeration) zone were converted into dissolved oxygen die-off and anoxic zones respectively. Ammonia feed back was provided for dissolved oxygen set point control and nitrate feedback was provided for mixed liquor (ML) recirculation control.	13% reduction in air supply for aeration (3000 m^3/hr per stage) and thus an approximate reduction of 100 MWh/month.	$2.1 million capital cost. $60,000 savings in electricity per year. Ensures no fines for effluent non-compliance.
	Sydney (eastern Australia)	SW1	Improve dissolved oxygen (DO) control on the aeration system at one of Sydney Water's sewage treatment plants.	An estimated energy saving of 5% on the same time last year. Exact values are due to be calculated as part of the project review.	

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
	Geelong (south-eastern Australia)	BW1	Reduced sewage flows from drought led to process rationalisation	20-23% of aeration blowers Overall saving of 1600 MWh per annum	In the 08/09 financial year there was an overall saving of approximately A$150,000 in budgeted electricity costs. The payback time for this project is immediate as the cost to implement were in the order of A$25,000.
Treatment – sludge digestion	Brisbane (eastern Australia)	BCC1	Waste activated sludge Thermal hydrolysis increases biogas and reduces sludge volumes	Annual generation increases from ~4100 MWh to ~6200 MWh. Sludge imports from other plants may further increase biogas to over ~8400 MWh.	Reduction in sludge mass leads to a reduction in transportation fuel costs and consumption. There is potential for a 70% reduction in sludge mass across the plants, which leads to 2173 less truck movements and a 52% reduction in transport and dumping costs.

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
	Singapore	PUB2	Optimisation of aerobic sludge retention time of nitrification (warm climate)		\$1.3 million savings in transport and dumping costs per year. \$0.6 million savings in grid based electricity avoided. 20 year NPV is -\$41.6 million compared to -\$39.2 million for alternative option (ultrasonic).
	Singapore	PUB3	Optimisation of membrane bioreactor demonstration plant, through process design and energy efficient equipment selection	From 0.7 to 0.4 kwh/m^3	

5. New Technologies

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
Clean Water					
Raw water – Generation	Adelaide (southern Australia	SA2	Adelaide's water supply system, replacing dissipater valve	Average output - approx 5,000 MWh p.a.	Project Investment approx $3 million. Electricity generated of approx 5,000 MWh p.a. (on average) since commissioning in 2003/04. Recent output has been impacted by introduction of water restrictions and consequent reduced water volumes flowing through the turbine. Electricity produced is sold at market rates available at the time of generation.

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
	Melbourne (south-eastern Australia)	SE1	Replaces pressure reduction valve, electricity fed into grid	988 MWh in 2008/09 – SE Water receives in form of additional Green Power – accounts towards 4% of SE Water's total renewable energy use.	The payback period is estimated to be around 20 years.
Distribution – Generation	Melbourne (south-eastern Australia)	MW3	Construction of 6 mini-hydro generating plants at service reservoirs on pressure reduction valves and discharge valves	37,200 MWh (combined) *See Observations (Table 2) in full case study*	NPV (for all 6 sites): $15.5 million (NPV for individual sites not available)
Sewerage					
Treatment – Sludge digestion	Singapore	PUB4	Pre-treatment of de-watered secondary sludge by sonication, increasing sludge digestion rate and improving methane yield	~2 kWh net energy gain for each 1 kWh energy input.	~8-12 years varying with price of electricity and cost of sludge disposal

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
Treatment – Biogas-Cogeneration	Singapore	PUB5	Biogas from anaerobic digesters, dual fuel engines (biogas and diesel) and sludge drying	0.4-0.6 kwh per m^3 sewage 6.6776 GWh annually	The annual saving due to the electricity recovery is around S$11 million
	Singapore	PUB6	Co-digestion of sludge and oil grease. Mixing of oil grease with dewatered sludge to increase biogas production	About 4.2 GWh of energy is generated annually from the biogas of FOG digestion and meets about 15% of the total energy consumption	About S$ 660,000 annual saving is achieved due to the co-digestion of FOG
	Sydney (eastern Australia)	SW3	Optimising biogas production – Chemically Assisted Sedimentation (CAS)	The average daily gas production with CAS was around 13% higher than without CAS. If a short period of time is selected with no plant operating issues, with CAS, the average gas production was approximately 20% higher with CAS operating.	$50,000 saving from increased generation. It should be noted that without other benefits of CAS, reduced ferric chloride to secondary process, reduced sludge production and reduced air use, the increased gas production would not be cost effective.

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
	Sydney (eastern Australia)	SW4	Construction of new biogas cogeneration facilities at five Sewage Treatment Plants. Three hydro-generation facilities will also be installed.	The existing four cogeneration engines currently operating on Sydney Water sites have generated 24.5 GWh in the 08/09 financial year. When all plants under construction are finished they are expected to supply 60 GWh over 15% of Sydney Water non-desalination electricity load.	
	Melbourne (south-eastern Australia)	SE2	Biogas previously flared, now have co-generation	Re-using methane in place of purchasing LPG results in energy savings of 53,10 GJ (or 1,475,000 kWh p.a.) in 2007/08 and 1714.25 tCO_2^{-e}	Upgrade cost of $250,000. Payback period dependent on price of LPG
	Melbourne (south-eastern Australia)	MW4	Installation of 7 Green Energy electricity generators (sludge and natural gas). Waste heat is also used for heating sewage digesters	28,000 MWh from biogas 36% of total electricity needs of the plant	NPV: 26.6 million (this includes the conversion of three of the five outfall pump engines to electric motors to facilitate the utilisation of the increased power generating capacity).

Area of water cycle	Location	Code	Description	Energy efficiency savings	Investment
	Adelaide (southern Australia)	SA3	Biogas generated to produce electricity. Heat recovery system capturing waste heat for use in sludge digestion tanks	Digester gas: 5057 MWh with 2313 ML equals: 2.2 kWh/kL Natural gas: 3145 MWh with approx. 650 ML	
Building services					
Building services	Sydney (eastern Australia)	SW2	New head office at One Smith Street, Parramatta (built and owned by Brookfield Multiplex) features water and energy efficiency and recycling. The building is forecasted to perform to 5 star NABERS.	Old Office Annual KWh/NLA (m^2): 46 New Office Annual KWh/NLA (m^2): 14.5 (Forecast). The new head office is expected to use over 60% less energy then the old head office.	

References

List of all references used in the report text, by section in order of occurrence.

"Energy Use in the provision and consumption of urban water in Australia and New Zealand", (CSIRO Kenway et al, 2008)
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Appendices (full case studies)