BASIX Cogeneration Implementation Study
Quality Information

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Executive Summary

1.1 Approach

The BASIX Multi-Unit Residential Cogeneration Demonstration Project is an initiative of the NSW Department of Planning (The Department) and involves partnership with residential development companies Lend Lease GPT and Mirvac. The project features the installation of small-scale, gas-fuelled generators in a 7-storey Lend Lease development at Rouse Hill in western Sydney, and in Mirvac’s 25 storey Cambridge Lane apartment building at Chatswood in northern Sydney. The cogeneration projects aim was targeted to developers with the following objectives:

1. trial and showcase cogeneration technology in high-density residential developments, focussing on energy consumption and greenhouse reduction, as well as cost effectiveness

2. highlight the necessary technical issues to be considered when installing cogeneration systems

The NSW Department of Planning (the Department) engaged AECOM to review the two Department demonstration cogeneration projects at Chatswood and Rouse Hill, and other relevant residential applicable cogeneration projects in NSW. Cogeneration development in the residential sector is rare in NSW, however there is increasing interest from that sector and there are a number of systems installed in larger commercial buildings.

Each new residential dwelling development in NSW is allocated a mandatory target to achieve a quantifiable reduction in greenhouse gas emissions (energy target). The current BASIX energy target for apartment buildings is lower than the target for attached dwellings and detached dwellings. Monitoring by the Department has shown that apartment buildings use more energy on a per person basis than detached buildings due to common area lighting, common area ventilation (e.g. carparks) and greater use of air conditioning. It is intended that these projects demonstrate to the Department and industry that cogeneration can play a part in achieving further cuts to Multi-Unit energy use than those currently required by BASIX.

The objectives of this report are to:-

- Review the current energy usage and savings for the 2 BASIX cogeneration demonstration projects
- Review existing residential cogeneration installations and implementation
- Review the barriers to cogeneration
- Propose improvements to the BASIX tool given the outcomes of the study

1.2 Test Sites Results

Comprehensive Information was available from one demonstration site (Cambridge Apartments). Data from this site demonstrates significant carbon savings and financially beneficial returns.

The Cambridge Apartments save 118 tonnes Greenhouse Gas (GHG) Emissions every year compared to the same building without cogeneration. The returns could be improved through increased hot water storage provision and associated controls.

Unfortunately the other site (Rouse Hill) did not have sufficient data to allow an equivalent comprehensive analysis of the benefits of the cogeneration system due to lower user occupancy and generator being off for long periods from contract negotiation.

The table on the following page shows a summary of these results.
<table>
<thead>
<tr>
<th>Factor</th>
<th>Rouse Hill</th>
<th>Cambridge Apartments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Apartments</td>
<td>104</td>
<td>134</td>
</tr>
<tr>
<td>Operation Time Assumed</td>
<td>1 July 2008 – 30 June 2033</td>
<td>1 July 2008 – 30 June 2033</td>
</tr>
<tr>
<td>ELECTRICAL ENERGY GENERATED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generated power (kWh) per year</td>
<td>17,005</td>
<td>107,649</td>
</tr>
<tr>
<td>Imported power (kWh)</td>
<td>Insufficient data</td>
<td>675,842</td>
</tr>
<tr>
<td>Generated reactive power (kVARs)</td>
<td>~9,600</td>
<td>64,600</td>
</tr>
<tr>
<td>Installed power (kW)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Hours of operation (hours)</td>
<td>1563</td>
<td>6482</td>
</tr>
<tr>
<td>CARBON SAVINGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG savings (tonnes CO(_2)-e/yr)</td>
<td>~16</td>
<td>118</td>
</tr>
<tr>
<td>Lifetime GHG savings potential (tonnes CO(_2)-e)</td>
<td>Insufficient data</td>
<td>2,948</td>
</tr>
<tr>
<td>FINANCIALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Unit (excl GST)</td>
<td>$82,262</td>
<td>$72,433</td>
</tr>
<tr>
<td>Total Installation costs 2007 (excl GST)</td>
<td>$207,000</td>
<td>$165,000</td>
</tr>
<tr>
<td>Cost savings / year</td>
<td>Insufficient data ~$1000-$3000 currently</td>
<td>$17,380</td>
</tr>
<tr>
<td>Payback period - years (Undiscounted cash flow)</td>
<td>Unknown</td>
<td>12</td>
</tr>
<tr>
<td>Payback period - years (Discounted cash flow)</td>
<td>Unknown</td>
<td>25.8</td>
</tr>
<tr>
<td>SENSITIVITY ANALYSIS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon savings range (tonnes CO(_2)-e over 25 years)</td>
<td>Insufficient data</td>
<td>2,887 to 3,263</td>
</tr>
<tr>
<td>Cost savings range (NPV)</td>
<td>$-223,000 to $50,000</td>
<td>$-113,000 to $188,000</td>
</tr>
<tr>
<td>BENEFITS AND BARRIERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional benefits</td>
<td>, Greater hot water redundancy</td>
<td>, Greater hot water redundancy</td>
</tr>
<tr>
<td>Barriers</td>
<td>Lack of integrated storage</td>
<td>Solar preheat reduces cogeneration efficiency, lack of integrated cogeneration storage – majority of storage is fed from Raypak HWG only,</td>
</tr>
<tr>
<td>Issues</td>
<td>Low occupation, maintenance contract delays</td>
<td>Unit not running for 4 months of the year due to contract expiry</td>
</tr>
<tr>
<td>Suggested improvements</td>
<td>Increasing operational hours, increased storage</td>
<td>Increasing operational hours, increased storage</td>
</tr>
</tbody>
</table>

This shows that cogeneration provides significant GHG savings when the installation is operational and the building is close to full occupancy. The following points recommend strategies for optimising greenhouse savings based on these demonstration projects:

1. Cogeneration to be sized correctly for both heat demand and electricity usage (Correct for Cambridge)
2. Hot water storage to be incorporated to ensure the generator can run for long periods and operate mainly during high electricity price events (generally Monday to Friday 7am to 10pm) – Some storage included but not sufficient for ideal operation – The Royal provides an example of how this is achieved.
A cogeneration system can result in significant improvements to the BASIX Energy score - approximately 8-12% improvement compared to BAU.

In summary cogeneration in multi residential apartments and mixed use developments is a cost-effective way of saving greenhouse emissions and delivering a financial return on capital investment.

1.3 Proposed BASIX Improvements

It is suggested that the following three items are added to the BASIX tool data inputs and calculations as an initial step to improve the accuracy of the calculations:

- Heat Output (kWheat) - Fuel cells are very different for example from engines and heat output should be measured / recorded
- Storage (Litres). The amount of hot water storage provides a cogeneration backup, allows the generator to run for longer, allows a smaller unit to be selected and greater cost savings from running in peak electricity cost tariff times.
- Cogeneration supply temperature or operating temperature could also be one of the user inputs to allow kWheat storage to be calculated.

These items provide key inputs into the calculation and will allow better designed systems to make a higher contribution to the building’s BASIX score.
2.0 Introduction

2.1 Background

The BASIX Multi-Unit Residential Cogeneration Demonstration Project is an initiative of the NSW Department of Planning (The Department) and involves partnership with residential development companies Lend Lease GPT (now Bovis Lend Lease) and Mirvac. The project features the installation of small-scale, gas-fuelled generators in a 7-storey Lend Lease development at Rouse Hill in western Sydney, and in Mirvac's 25 storey Cambridge Lane apartment building at Chatswood in northern Sydney.

The cogeneration trial in 2007 was commenced to demonstrate that cogeneration was viable for multi-unit residential projects. The purpose of the trial was to determine the role of cogeneration in achieving greater greenhouse savings than the current 20% energy reduction target for multi unit residential buildings.

The cogeneration projects aim was targeted to developers with the following objectives:

1. trial and showcase cogeneration technology in high-density residential developments, focussing on energy consumption and greenhouse reduction, as well as cost effectiveness

2. highlight the necessary technical issues to be considered when installing cogeneration systems

The Department engaged AECOM to review the Department demonstration cogeneration project and other relevant residential applicable cogeneration projects in NSW. Cogeneration development in the residential sector is starting to increase and this information is proposed to be included in future BASIX tool updates.

The objectives of the report are to:

- Review the current energy usage and savings for the 2 BASIX cogeneration demonstration Projects
- Review existing Residential cogeneration installations and implementation
- Review the barriers to cogeneration for any changes
- Propose improvements to the BASIX tool given the outcomes

2.2 BASIX

The information below is taken from the BASIX website:

BASIX is a web-based design tool that ensures each new residential dwelling design meets the NSW Government's targets of up to 40% reduction in water consumption and up to a 40% reduction in greenhouse gas (GHG) emissions, compared with the average home. Introduced by the NSW Government, BASIX, the Building Sustainability Index, ensures homes are designed to use less potable water and be responsible for fewer greenhouse gas emissions by setting energy and water reduction targets for house and units. BASIX is one of the most robust sustainable planning measures in Australia, delivering equitable and effective water and greenhouse gas reductions across NSW.

How does BASIX work?

BASIX is an online program that is free and accessible to anyone. The user (usually the building designer) enters data relating to the house or unit design - such as location, size, building materials etc - into the BASIX tool. BASIX analyses this data and determines how it scores against the Energy and Water targets. The design must pass specific targets (which vary according to location and building type) before the user can print the BASIX Certificate.

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1 Source http://www.basix.nsw.gov.au/information/faq.jsp#about1
The BASIX Certificate

This lists all the commitments the user has agreed to, and the Certifying Authority will check these at various stages of construction. The BASIX Certificate must be attached to the development application before it can be processed.


It should be noted that, in general, multi-unit residential accommodation has a larger energy usage per person due to common area equipment operating 24 hours a day. This has resulted in a lower per person target under BASIX for multi-unit residential which is currently 20-35% GHG reduction compared to 40% GHG reduction for houses. The cogeneration demonstration project is seeking to determine the role that cogeneration can play in reducing the energy usage of multi-unit residential development.

BASIX is driving higher energy efficiency and lower carbon residential buildings. Cogeneration can be a useful strategy to lower the carbon emissions for multi-unit residential buildings given the large carbon emissions from electricity, heating and cooling usage.
2.3 Cogeneration

2.3.1 Cogeneration Definition

Cogeneration is simply defined as “multiple” generation, which generally means production of heat and electricity. The heat is generally “waste” heat from an engine-generator or other electric generating equipment such as turbine-generator sets or fuel cells.

Waste heat is mainly used for domestic hot water (showers, bathrooms, kitchen hot water). Other uses include space heating and pool heating. This is called ‘Cogeneration’ in the industry for the 2 outputs (heat and electricity).

The waste heat can be further converted into cooling through an absorption chiller. Absorption chillers usually use water as a refrigerant. Vaporisation of the refrigerant (water) under low pressure extracts heat from liquids such as water to produce ‘chilled water’. Lithium bromine is commonly used to absorb the refrigerant (water) vapour. Water is then recovered from the lithium bromide/water solution using the waste heat from the electricity generator in cogeneration. Chilled water production is sometimes called Trigeneration in the industry due to the three outputs (electricity, heat and cooling).

As Cogeneration is ‘multiple’-generation and the original generator produces heat and power, we will include ‘Trigeneration’ under the ‘Cogeneration term’ for this repo.

The co-generation/tri-generation plant modular concept as shown in the figure below with indicative % distribution:

Electrically led plants are sized to provide a particular level of electricity output and any thermal heating is utilised when there is a heating demand. Any surplus heat is rejected via an air or water cooled system.

2.3.2 Advantages of a Cogeneration System

One of the components of cogeneration is to improve energy efficiency by utilising waste heat in lieu of electricity or gas to produce domestic hot water, heating and cooling. A key item in this efficiency is providing local generation as a coal power station may only be 30% - 35% efficient in converting the usable energy contained within the coal to the energy used in the home.

Changing from the predominately coal based power generation to cleaner and greener methods of generation is also a significant benefit to NSW. The government is driving a change towards a more sustainable future. Fuel
change from coal to gas, biodiesel, ethanol and other fuels will result in lower emissions and/or more sustainable practices. Greenhouse Gas (GHG) reduction is significant for the implementation of cogeneration units. A carbon tax or Carbon Emission Trading Scheme (ETS) is a real possibility in the near future.

The key advantages of cogeneration are as follows:

- **Fuel cuts:** The successful installation of a Cogeneration plant leads to reduction of fuel consumption. The overall cogeneration plant efficiency can be as high as 85% (15% wasted energy) compared with Grid that is approximately 35% efficient (65% wasted energy).

- **Grid Energy produces approximately 900 kg CO2 emissions per MWh as compared with a Cogeneration plant which produces 550 kg CO2 emissions per MWh.**

- **Emissions reduction:** The reduction of atmospheric pollution follows the same proportion with gas a clearer fuel to burn than coal. With the use of natural gas, rather than oil or coal, the emissions of SO2 and particulates are reduced to zero. Emissions however tend to be closer to people and NOx emissions cause smog in cities such as Sydney. The NSW Government limits emissions for large engines. The size of residential CHP means that a high quality engine with flue exhausted to the roof will not require exhaust treatment.

- **Economic benefits:** Cogeneration units result in a higher gas bill for the development due to the increased usage of gas. Electricity use is lower as the unit will effectively provide ‘free’ electricity for the development. In NSW the price of gas is relatively cheap compared to electricity and hence provides a lower price during peak consumption periods. It should be noted that currently electricity prices are cheap at night so it is much more economic to run the plant during a week day. Storage systems can provide greater economic returns depending on customer gas and electricity prices.

- **Future proofing against potential carbon tax**

- **Increase of electricity networks stability:** Cogeneration units can offer significant load relief in electricity networks during the hot summer months.

- **Improved Reputation (the Green Brand)**
2.4 Cogeneration projects in NSW

2.4.1 Existing Projects

Cogeneration is not a new idea or technology and steam cogeneration units have been operating around 100 years. Recently in the last 10 years there has been a resurgence of gas power cogeneration units not just in large industrial uses but in buildings. This has predominately been in commercial buildings to achieve lower carbon emissions and achieve a Green Star or NABERS rating and meet the increasingly stringent energy standards in the Building Code of Australia (BCA). Despite the large increase in gas power generation in commercial buildings and industrial uses, there has been little use of cogeneration in residential buildings.

Local cogeneration can be achieved using a variety of fuels, but this is predominately gas due to the availability of gas reticulation in NSW.

Natural Gas is currently the fuel of choice but cities such as the City of Sydney are driving the change towards the creation of gas from waste (Syngas). Commercially viable technologies already exist for creation of Syngas and existing natural gas powered plants / cogeneration can be transferred to these new gas streams in the future.

Australian cogeneration plants have often been too large in size to run at optimum efficiencies. A large unit will need a constant large electricity and heat demand to operate at a high efficiency. Battery storage for excess electricity is problematic due to space and safety issues. Grid connection to sell excess electricity requires protection changes, metering changes and may require additional equipment to supply into the Electricity Supply 11kV network. While this is technically possible it is currently prohibitive given the low purchase price. If a feed in tariff similar to a solar tariff was provided, many more cogeneration systems may export power. In multi-unit residential buildings, the electricity demand is variable and is generally not timed with the heating demand. In extreme circumstances the units may not be able to run without purpose built load banks to waste energy and gas (reduced efficiency).

There are 2 main types of cogeneration selection and control:

1. Thermally Led
2. Electrically Led

Thermally led plants are sized based on the thermal DHW (domestic hot water), heating and/or cooling demand. Electricity is used by the base building lights, fans, etc. as a by product.

Electrically led plants are based on the electricity for the site, and any generated heat will be used with supplementary hot water generators or boilers required as a by product.

The system must be sized so it can meet the thermal and electrical demand. Residential systems tend to be small in terms of output capacity (3kWe - 25kWe) and size (unit is typically around a dining table size, compared to a large warehouse for some applications which can be over 100,000kW).

In order to prove that cogeneration is feasible and practical to install in apartment buildings two gas cogeneration plants were funded by the Department of Planning. The two locations of the operating test 25kWelectric (25kWe) plants are:

- Cambridge Apartments (Built by MIRVAC), Chatswood
- The New Rouse Hill Town Centre Apartments (Built by Bovis Lend Lease), Rouse Hill

The Chatswood and Rouse Hill project schematics are included in Appendix E.

Both of these plants are thermally led to provide hot water to the site. Electricity generated when the gas generator is operating is used by the base building.

The initial 12 months of results have already been published by MPI for both sites, along with the carbon emissions, energy and cost savings achieved. The results from these MPI reports, as well as more recent data are used in this report.
In NSW there are now a large number of cogeneration installations operating by a variety of companies, with an even greater number in construction. Examples include:

- 101 Miller Street, North Sydney (Commercial Building)
- Hornsby Library
- Parliament House in Sydney
- Hawkesbury City Council cogeneration system
- Blackmore cogeneration plant.

Some of these NSW cogeneration installations will also be discussed in this report as they are relevant to residential and multi-use developments.

- Macquarie University University Campus Cogeneration operating since 2001
- The Royal, Newcastle Hotel and Apartments due for completion 2010
- Willoughby Leisure Centre Council Pool with solar due for completion 2010

Some of the installed NSW cogeneration plants are summarised below:

<table>
<thead>
<tr>
<th>Cogeneration installation</th>
<th>Location</th>
<th>Design capacity (kW or kVA)</th>
<th>Equipment specifications</th>
<th>Application area</th>
<th>Year of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large capacity (range 1MWe – 6MWe)</td>
<td>Macquarie University</td>
<td>1.5MWe, 2.0MWth</td>
<td>2 x 760kWe Caterpillar Generators, 1 x York Absorption Chiller, 1 x 1250m³ chilled water storage, Backup electric chiller and integrated HWG</td>
<td>Multiple Building Heating, Cooling, Pool Heating, Library Power and Emergency Power</td>
<td>2001</td>
</tr>
<tr>
<td></td>
<td>Willoughby Leisure Centre</td>
<td>170kWe, 260kWth</td>
<td>Schmitt Generator</td>
<td>Pool Heating, Power</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>Hawkesbury Council</td>
<td>360kWe, 500kWth</td>
<td>Caterpillar Generator, Thermax Chiller, Basement Installation</td>
<td>Power, Cooling &amp; Heating cafe, gallery and office space</td>
<td>2004</td>
</tr>
<tr>
<td></td>
<td>Blackmore Pharmaceuticals</td>
<td>772kWe, 753kWr (cooling)</td>
<td>2 x 386kWe MTU Generators, 1 x 292kWth, 1 x 461kW Thermax Chillers,</td>
<td>Building Power, Heating &amp; Cooling</td>
<td>2008</td>
</tr>
<tr>
<td></td>
<td>The Royal Newcastle</td>
<td>130kWe, 190kWth</td>
<td>Camda Generator, 18,000 litres storage</td>
<td>Hotel Power, Domestic Hot Water(DHW)</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>101 Miller Street</td>
<td>2,332kWe, 750kWr (cooling)</td>
<td>2 x 1,166kWe MTU, 750kW Thermax chiller</td>
<td>Building Cooling and Emergency Backup</td>
<td>2008</td>
</tr>
<tr>
<td>Small capacity (range 3kWe – 80kWe)</td>
<td>Cambridge apartment, Chatswood, Sydney</td>
<td>25kWe, 47kWth</td>
<td>TEDOM Generator, 4000 litres storage</td>
<td>Common Areas Power, Domestic Hot Water(DHW)</td>
<td>2007</td>
</tr>
<tr>
<td></td>
<td>The New Rouse Hill Town Centre</td>
<td>25kWe, 47kWth</td>
<td>TEDOM Generator, 5000 litres storage</td>
<td>Common Areas Power, Domestic Hot Water(DHW)</td>
<td>2008</td>
</tr>
<tr>
<td></td>
<td>Hornsby Library</td>
<td>60kWe, 136kWth</td>
<td>60kWe Microturbine, Desiccant Dehumidifier</td>
<td>Library Power, Heating &amp; Cooling</td>
<td>2004</td>
</tr>
</tbody>
</table>
2.4.2 Cambridge Apartments Background

A 25 kW (25 kW of electricity generation) TEDOM gas generator cogeneration plant was installed in December 2007 along with solar thermal panel pre-heating and two Edwards SHX2000 storage vessels with a capacity of 2.20 kL (kilo litre).

The plant also had a fully redundant hot water system with 4 Raypak Model B06581D and 19 Model 610430 Rheem storage cylinders.

The site was commissioned in December 2007 and was close to 100% occupied from the start of the project. There are 132 units in the apartment block.

The following photos show some of the installation.
Cogeneration Hot Water Tanks

Cambridge Plant Unit before Final Installation and protective cover was installed.
2.4.3 Cambridge Apartments Project Costs

The Cambridge project cost (excluding GST) for the cogeneration system incurred by the Department of Planning was as follows:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST Excl GST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>$35,000</td>
</tr>
<tr>
<td>Generator Procurement &amp; Install</td>
<td>$110,000</td>
</tr>
<tr>
<td>Application</td>
<td>$11,000</td>
</tr>
<tr>
<td>Contracts</td>
<td>$9,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$165,000</strong></td>
</tr>
</tbody>
</table>

Incorporating a CPI for the period since installation (almost 3 years) this is results in an approximate:

- capital cost of $171,063 in 2010, or
- $6,1840 per kW installed

This cost is high per kW compared to larger plants due to the small scale.

2.4.4 The New Rouse Hill Town Centre Apartments Background

A 25 kWe (25 kW of electricity generation) TEDOM gas generator cogeneration plant was installed in December 2007 at the New Rouse Hill Town Centre along with a 5,000 litre storage tank and a dual Raypak gas hot water generator system with minimal water storage (around 750 litres).

The apartments were fully sold as recently as July 2010. The previous report for the site by MPI in March 2009 only had 70% of the units sold. Therefore over the last period 70%-100% units had been sold. However, occupancy of the units remains low and the expected savings are not yet realized. The project was also delayed resulting in lower usage information for the site. The following information is therefore based on limited information.

The number of apartments for Rouse Hill Apartments is 104. This is lower than the Cambridge 134 units business as usual (base case operating without cogeneration). In this instance the Business as usual case was based on Cambridge due to lack of gas data for Rouse Hill and to provide some commonality.
Rouse Hill Hot water Generator System

Rouse Hill Cogeneration Installation
2.4.5 The New Rouse Hill Town Centre Apartments Project Costs

The Rouse Hill project cost (excluding GST) for the cogeneration system incurred by the Department of Planning was as follows:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>$35,000</td>
</tr>
<tr>
<td>Installation</td>
<td>$178,000</td>
</tr>
<tr>
<td>Application</td>
<td>$11,000</td>
</tr>
<tr>
<td>Contracts</td>
<td>$9,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$233,000</td>
</tr>
</tbody>
</table>

It should be noted that this is significantly higher than Cambridge Apartments due to increased installation costs. It should be noted that an acoustic room was built for the unit. During running however the unit running was quieter than the Raypak Hot Water Generators in the carpark.

Incorporating a 3% CPI for 3 years this results in an approximate:
- capital cost of $254,000 in 2010, or
- $9,320 per kW installed

This cost is high compared to larger plants due to the small scale.

2.4.6 Macquarie University

Macquarie University is mentioned due to the long term operation and proven cost and GHG emission savings from cogeneration and generators operating over 25,000 hours each. This site also has chilled water storage and operates over multiple buildings and heats the Macquarie University Aquatic Centre. Storage of hot and cold water as well as installation of heated pools in residential buildings are key issues to be considered for cogeneration installation.

Macquarie University has proved that cogeneration is commercially viable with an estimated payback under 6 years even without government grants (a loan was provided) or a price on carbon. Pool heating due to the low temperature requirements is also a very good usage for heat that would otherwise be rejected directly to atmosphere.

2.4.7 The Royal Newcastle

The Royal Newcastle is a mixed development incorporating 3 towers which have residential and hotel uses. This provides a test case for cogeneration over multiple apartment blocks.

It provides electricity to the hotel along with 80°C water to be mixed to the required temperature for the hotel. Excess hot water is then distributed to the residential apartments for free. Each tower also has hot water generators to provide any temperature top-up for the system as required.

The expected domestic hot water hotel load is shown below (litres per hour). This shows 2 distinct peaks for shower usage in the morning and evening.
The cogeneration plant installed in the Royal Newcastle is shown below:
One key item to note is the usage of thermal storage in the system. This enables the generator to be used during expensive electricity purchasing time (gas does not have expensive operating times) and the hot water to be used as required by the residents. This load shifting increases the savings for the generation.

The hotel DHW layout is shown below. Showing 2 large 6000 litre cogeneration storage vessels (3 in the layout), 3 small mixing storage tanks (10), 2 hot water generators (HWG) (2b), and 1 cogeneration plant (1). Excess heat is provided to the apartments to the left of the diagram.

Please note that the above diagram is for indication purposes only and final flows and configuration were not complete as the system had yet to be commissioned.
2.4.8 Willoughby Leisure Centre

The Willoughby Leisure Centre is a recent cogeneration pool installation, which is due to be completed this year. This provides information on 24 hour a day cogeneration plant operation that is aimed at maximum GHG reduction and not focused on generating at peak periods only for maximum energy bill savings.

Demand is driven by:

- the pool area (approx 663 m$^3$) including main pool, spa, tots pool and learners pool,
- domestic hot water (showers in internal and external changing rooms), and
- winter demand from the fan coil units for heating

An intercooler and heat dump radiator are integrated into the system to allow for maximum power generation when tariff conditions allow.

The unit specifications are:

- Schmitt Enertec FMB-215-GSMK gas engine set (German Manufacture)
- 217 KVA of electrical energy
- 173 KWe (to be reduced slightly due to emission controls of NOx to be in line with the draft DECCW guidelines of 250 mg/Nm$^3$
- 235 kWth (heat)
- Storage size 3000 litres @ 50º∆T = 175 kW storage
- Expected carbon savings 650-750 tonnes per annum

Operational hours to be Peak and Shoulder (5 days x 15 hours a day) with option to run 24 hours if required to reduced carbon emissions.

The plant is to have solar incorporated into the system and be used for pool heating and cogeneration backup. Proposed completion is early December 2010.

The unit was selected to provide the highest electrical efficiency (35.8% at 100%) through a variable load rating (100% down to 50%).

These examples are mentioned through the report. In all these cases the cogeneration plant requires a standard plant and electrical supply for times the cogeneration unit is not operating. This allows the cogeneration plant to be used only when beneficial.
3.0 BASIX Demonstration Projects – Operational Results

The Department of Planning funded two cogeneration projects (2006 to 2008) to prove that cogeneration worked in multi-unit developments and encourage usage for BASIX compliance.

The two projects are Chatswood Apartments (Chatswood) and The New Rouse Hill Town Centre Apartments (Rouse Hill).

The units were monitored 12 months after installation. The data for the fully occupied Chatswood apartments was positive with the cogeneration unit providing high GHG reduction averaging 7.6 tonnes of GHG savings a month (based on the last 6 months July 2008 to December 2008 data). There was also a good financial payback averaging $815 a month. This site has a solar preheat to the cogeneration which while very beneficial for GHG or carbon reduction reduces the operational efficiency of the plant.

The Rouse Hill site (without solar preheat) in comparison had a low utilization initially due to slow Rouse Hill apartment sales, and only recently in July 2010 were all the apartments sold. This results in insufficient data to fully assess the cogeneration plant given the effect that the generator does not have enough load for designed operation.

Unfortunately, the full amount of information was not available at the time of writing this report. Previous reports and available data has meant that assumptions have been made as required based on previous information, efficiencies and averages over periods of time.

The most recent reports conducted for the two sites were as follows:

- Chatswood apartments: 9 Dec 2008 - 23 Jan 2009

This report builds on this information to provide up to date information on these two sites and expand the results with other cogeneration plants and the impacts in NSW and hence BASIX. Where possible the site gas usage was also updated to allow comparisons of cogeneration against normal hot water generator operation.

3.1 Sources of Information

The information used in the preparation of this document was obtained from the following sources. The accuracy of this report is limited by the information gained from these sources.

1. MPI Cogeneration Reports
2. Information provided by Urban Energy, Strata Managers and Operational Staff
   a. Generator run hours, operational data from Urban Energy (Cambridge Apartments & Rouse Hill)
   b. Gas readings from Pacific BMG (Cambridge Apartments)
   c. Gas readings from Pacific BMG (Rouse Hill Apartments – Cogeneration Off)
   d. Cambridge Apartments electricity bills – February 2009 – March 2010
   e. Cambridge Apartments gas bills – May 2009 to May 2010
   g. Rouse Hill gas bills – 15/12/2009-14/12/2010
3. Information from DECCW for the Royal Newcastle
4. Information from Willoughby Council on the Willoughby Leisure Centre cogeneration plant
5. 2009 NGA Factors Workbook (in line with Department of Planning Modelling)
3.2 Main Assumptions

The financial modelling for the demonstration projects has been based on the following key assumptions:

1. Total cogeneration efficiency based on MPI Calculations is 73% – it is noted that the solar preheat for the installation reduces the cogeneration efficiency
2. Heat rejection and gas usage assumed to be the same as modelled by MPI
3. Gas and electricity usage based on limited bills and data
4. 785 day period for Cambridge Apartments (since previous complete data point)
5. 525 day period for Rouse Hill Apartments (since previous complete data point)
6. Peak and Shoulder operation assumed to be as per previous reports (during peak, shoulder and off peak periods) 77% of operation was in peak and shoulder times based on MPI analysis. This results in approximately 44% of the electricity imported with cogeneration operating being during peak and shoulder times.
7. Electricity prices and gas prices based on the recent bills and usage
8. Gas usage increase assumed to be the same as per previous MPI reports
9. GHG emissions assumed to be as per NGA Factors (Jul-09)
10. Capital costs incurred by the Department of Planning covering project management, design and construction components
11. Upfront capital costs have been included (paid for by Department of Planning) and all costs and figures exclude GST in this report
12. Potential savings from not undertaking other BASIX options have not been included

3.2.1 Financial Assumptions

Annual cash flows for each cogeneration option and business as usual projections have been calculated as the net sum of the following line items:

- Capital expenses;
- Operating expenses (electricity and gas purchase, maintenance, carbon permits); and
- Value of tax shield (deductions due to operating expenses and depreciation but excluding interest expenses coupled with a 30% corporate tax rate).

Future cash flows are valued using a real discount rate of 7% p.a. post tax real with a base year of FY2009-10. An inflation rate of 2.5% p.a. has been assumed over the life of the project (except 1.5% 2010, 2.8% 2011, 2% 2012 as per Department of Planning modelling) and applied to capital, maintenance and other yearly factors.

Forward estimates of electricity prices are based on previous electricity invoices, IPART regulation determinations for 2010-2013 and the forecast increases in wholesale electricity prices published by the Australian Treasury as part of detailed modelling into the impacts of an Emissions Trading Scheme (ETS). The Treasury forecasts included price series under an ETS with several emission reduction targets as well as a reference case assuming no ETS is introduced.

It is anticipated that an ETS will increase grid supplied electricity prices in Australia due to the high emission intensity of the current grid creating large permit obligations for generators that will be passed through to electricity end users. AECOM has assumed that electricity prices will rise in line with that under an ETS introduced in 2015 with a 5% by 2020 emission reduction target but have undertaken sensitivity analysis varying this from a 0% to 15% ETS 2020 target.

The figure below shows the assumed electricity price escalation before inflation.
The introduction of an ETS would create an additional operating expense for cogeneration operations as emission permits would be required for each tonne of CO$_2$-equivalent through gas combustion. Gas prices have been assumed to rise with inflation only but sensitivity analysis has been undertaken assuming alternate gas prices.

### 3.3 Electricity and Gas Costs

The Electricity and Gas costs have been based on the below figures:

<table>
<thead>
<tr>
<th>Base Case – 2009/2010</th>
<th>Supplied Electricity average (excl GST) [$/kWh]</th>
<th>$0.112</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supplied Gas (excl GST) [$/GJ]</td>
<td>$15.67</td>
</tr>
</tbody>
</table>

This electricity price is low and averaged over the day. Typically usage is split into Peak, Shoulder and Offpeak tariffs which reflect greater expense during the day and early evening when most electricity is being used. It is therefore more cost effective to turn load off or run cogeneration plants when the electricity is more expensive in peak and shoulder periods.

Cogeneration control systems can be programmed to operate at certain times (Peak or expensive operation times) or run when heat demand is required (similar to boiler/hot water generator controls). The cogeneration plants in the demonstration projects do not select peak mode operation as a preference and generates based on hot water demand. This electricity cost is therefore well below the actual peak costs of electricity.

It should be noted that the gas cost is high compared to industrial or commercial sites due to the low gas volume usage by an apartment block. Larger gas plants above 1 TJ of gas a year have negotiated contracts and hence significantly lower. Gas price has a very significant effect on the payback of cogeneration. At this gas price it is not economic, and so the price of carbon is key in the result.

Combining multiple sites to provide larger collective gas purchase bargaining power or larger combined generation should be provided to reduce this gas price. The Willoughby Leisure centre 173 kWe generator for example can negotiate the gas price due to the higher usage.
We note that the analysis allows for all demand, consumption and network charges as detailed in the AGL, Integral Energy or Energy Australia Utilities bill.

The current status of the cogeneration demonstration sites are described below.

3.4 Cambridge Apartments

Since the unit has been installed including commissioning (between October 2008 and 2 July 2010 information courtesy of Urban Energy) the unit has:

- Generated 156,021 kWh electricity (the following data only includes recent operation)
- Generated 304,656 kW heat (estimated from unit specification sheet)
- Operated at around 73% total efficiency (heat + thermal)
- Run for 6480 hours of operation (7.2 hours per day on average)

The site has used:

- 61,270 m$^3$ of gas for the cogeneration plant
- 184,766 m$^3$ of gas for the gas hot water generators

The information on operational hours was not sufficient to provide an accurate operational time, but it was noted that the unit has run continuously on consecutive days and during normal operation has stopped for 2 hours in the middle of the day and stopped between 3am and 10am on another. This shows that the unit is capable of operating significantly more than currently. Gas usage also points to this.

Based on the gas bills it was noted that the unit was out of operation for 4 of the 12 months in the year. Upon further investigation, it was found to be due to the existing maintenance contract (paid for by the developer) expiring. It took time for the Strata to agree to another maintenance contract and during this time the unit stopped and waited for scheduled maintenance.

The unit would reasonably be expected to be non-operational for up to a month per year so this is unusual and contracts negotiated well in advance of contract or free maintenance period and should be closely monitored. As the units can be remotely monitored it is recommended that the Strata manager obtain a copy of the software to monitor the operation or provide an incentive for operational hours during the year.

Between 23/1/2009 and the 2/7/2010 the unit approximately produced (based on previous data):

- 154,840 kWh electricity
- 90,435 kVAr (reactive) electricity (absorbed, typically fixed using power factor correction capacitors)
- 302,350 kWh heat

This excludes operation during commissioning.

Maintenance costs this year for the unit included $5,160 as part of the yearly contract along with a $3,245 cost for the replacement of the catalytic convertor used for NOx and CO emission reduction. Depending on the operational hours and type of operation (similar to car servicing) the replacement part costs can vary considerably from year to year. High costs are expected after 5 and 10 years due to the large number of wearable parts requiring replacement. The Strata manager needs to be aware that large expensive services are approaching and save money to prepare for this.

It should also be noted that the depreciation against tax for the cogeneration unit is an additional factor to be considered and impacts on the rate of return.

3.4.1 BAU (Business as Usual)

In order to compare what the savings are from cogeneration the Business as Usual (BAU) case was calculated. If no cogeneration was installed, the BAU is the calculated gas and electricity usage for the Strata common areas. This was found to be:

- 783,473 kWe usage a year
- 1,568 GJ gas a year
$105,000 a year in electricity bills
$24,572 a year in gas bills
This base case was based on MPI reports and calculations and is considered reasonable.

3.4.2 Cash flow and GHG emission modelling

The yearly kWh based on current operation has been taken and used to create operational data from 2007 – 2033 the expected end of life for the unit.

Modelling of the above assumptions results in the cash flow and GHG emissions for the existing cogeneration installation shown on the following page and also a detailed yearly cashflow shown in Appendix D:
### Cambridge

**Present Value ($'000)**

<table>
<thead>
<tr>
<th></th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13-33</th>
<th>Total FY09-FY33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Expenditure</td>
<td>$165</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$165</td>
</tr>
<tr>
<td>Cogeneration Operating Costs</td>
<td>$0</td>
<td>$32</td>
<td>$29</td>
<td>$27</td>
<td>$25</td>
<td>$301</td>
<td>$415</td>
</tr>
<tr>
<td>Total Investment</td>
<td>$165</td>
<td>$32</td>
<td>$29</td>
<td>$27</td>
<td>$25</td>
<td>$301</td>
<td>$580</td>
</tr>
<tr>
<td>Net Operational Costs (Against BAU)</td>
<td>$0</td>
<td>-$4</td>
<td>-$7</td>
<td>-$7</td>
<td>-$8</td>
<td>-$162</td>
<td>-$189</td>
</tr>
<tr>
<td>Net Cash Flow (Against BAU)</td>
<td>-$165</td>
<td>$12</td>
<td>$11</td>
<td>$10</td>
<td>$9</td>
<td>$123</td>
<td>$0</td>
</tr>
<tr>
<td>Net Present Value (NPV)</td>
<td>$0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Rate of Return (IRR)</td>
<td>9.7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return on Investment (ROI)</td>
<td>0.2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Payback Period Undiscounted (Years)</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### GHG Emissions (t CO₂e Scope 1 & 2)

<table>
<thead>
<tr>
<th></th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13-33</th>
<th>Total FY09-FY33</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG Emissions</td>
<td>0</td>
<td>685</td>
<td>685</td>
<td>685</td>
<td>685</td>
<td>14,393</td>
<td>17,135</td>
</tr>
<tr>
<td>BAU GHG Emissions</td>
<td>803</td>
<td>803</td>
<td>803</td>
<td>803</td>
<td>803</td>
<td>16,869</td>
<td>20,082</td>
</tr>
<tr>
<td>Net GHG Emission Reduction</td>
<td>0</td>
<td>118</td>
<td>118</td>
<td>118</td>
<td>118</td>
<td>2,476</td>
<td>2,948</td>
</tr>
</tbody>
</table>
GHG emission reductions
The above results show consistent significant GHG reductions year after year.
The emission savings of 118 tonnes of GHG a year are the equivalent of:
- Permanently removing 27 cars off the road
- Planting of 707 trees
This is significant and approximately equivalent to each of the 132 apartments planting 5 trees each. This is a significant carbon emission saving and is more effective than an average home energy efficiency measure.

Cost Savings
Key results are:
- There is a nominal cash flow of $13,000 savings in FY2011 from the operation
- The results are significantly affected by the unit being switched off and not generating savings for 4 months of the year
- A 12 year undiscounted cash flow payback is reasonable given the expected 25 year life of the plant.

3.4.3 Results Summary
The Cambridge apartment results are summarised in the table below showing a comparison between the cogeneration operating and a base case without cogeneration:

<table>
<thead>
<tr>
<th>OPTION</th>
<th>Grid Electricity (kWh/year)</th>
<th>Generation (kWh/year)</th>
<th>Gas Consumption (kWh/year)</th>
<th>Energy + Cogeneration Operation Costs ($)</th>
<th>Carbon Emissions (Scope 1&amp;2) [t CO₂e/year]</th>
<th>Carbon Savings [t CO₂e/year]</th>
<th>Net Present Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU (No Cogeneration Installed)</td>
<td>783,473</td>
<td>0</td>
<td>435,587</td>
<td>$115,530</td>
<td>803</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cambridge Apartments (25kWe Unit)</td>
<td>675,824</td>
<td>107,649</td>
<td>455,176</td>
<td>$98,149</td>
<td>685</td>
<td>118</td>
<td>310</td>
</tr>
</tbody>
</table>

Note: Maintenance costs for non-cogeneration items have been excluded from the above figures as these are similar for both cases.

The table shows a significant electricity saving, cost saving and carbon saving. However the Net Present value is close to zero due to the installation costs.

For a strata manager the cost benefit for running the cogeneration plant is significant given the $13,000 savings taking into account taxation savings as well.

In summary the results show a:
- Close to Zero NPV (Net Present Value)
- 9.7% IRR (Internal Rate of Return)
- Approximately $13,000 saved each year
- Significant GHG reduction of 118 tonnes a year

It should be noted however that:
- Effects of solar heating on energy savings and efficiency of the cogeneration unit have been ignored.
- Plant operation over the last 1.4 years has been significantly impacted by maintenance contract negotiations (resulting in the plant only running 8 months in the last year)
- Large reactive power (90,435 kVAr over 1.4 years)
- Upfront capital costs are “sunk” costs that meet BASIX requirements and other options to meet the requirements may have been as or more costly.
While the NPV is close to zero it should be noted that BASIX requires certain targets to be undertaken on a residency. A building could undertake to install a cogeneration plant instead of a different measure. This means that the incremental cost of putting in a cogeneration unit over another option may be considerably less than what has been assumed and hence with a lower effective capital cost, the project would generate a better payback.

GHG savings per year are still considerable.

### 3.4.4 Sensitivity Analysis

In order to compare the values more accurately, various inputs were altered to give an indication of variability. The table below shows the sensitivity to various key factors. The key factors are organized into 4 scenarios as follows:

- **Active** is the current model given the existing conditions.
- **High** provides an estimate for a high return cogeneration installation
- **Medium** provides a more accurate cogeneration application in NSW
- **Low** provide an estimate for a low return cogeneration installation

Together these provide variability between sites in NSW for multi-unit residential apartments.

- **Gas Costs / BAU** provides % variability for the gas costs for the Base Case. Contracts over 1TJ a year
- **Capital Expenditure Costs / Cambridge** – shows the % variability for the installation capital cost. The high value is based on $/kW installation costs for other plants in NSW.
- **Gas Costs / Cambridge** – Shows the potential savings from increased gas usage on the site (lower negotiated contract)
- **CPRS (Carbon Pollution Reduction Scheme)** – shows the modelled carbon reduction target by the federal government as discussed previously
- **Cambridge Unit Efficiency** (73% from MPI report) – shows the cogeneration efficiency and variability. Some plants can reach above 90% total efficiency.
- **Cambridge Operation Hours per year** - Operational hours for the plant
- **% kWh at peak/shoulder times** - % of expensive electricity purchased from the grid (peak and shoulder times are significantly more expensive than off peak electricity. Normally this is 55% for a constant 24h load (peak and shoulder 7am to 10pm Monday to Friday).

The sensitivity table is on the following page.
As can be seen from the above table GHG-e savings of between 115 and 130 tonnes per year over the 25 year period is significant and reliable even with variation in cost savings for the site. The Net Present Value can vary from -$113,500 to +188,000 dollars pointing to the importance of design, setup, maintenance and contracts for the cogeneration system.

If the site had a Power Factor Correction unit installed and was available for operation all year round (not turned off for 4 months) for the full year it is expected that the results would have shown:

1. NPV of $49,426 (up from $310)
2. 12.7% IRR (up from 9.7%)
3. 9.8 year undiscounted payback period cash flow (down from 12 years)
4. 3,056 tonne GHG-e savings (total over the 25 years) (up from 2,947)

These are significantly better results; the next section provides some suggestions for improvement.

### 3.4.5 Improvement Suggestions

The following improvements are recommended:

- Increasing the operational hours by negotiating an operational contract in advance,
- Installation of larger hot water storage system and ensure cogeneration water storage temperatures are greater than gas hot water generators ignition temperature maximising the carbon reduction for the site, and
- Set the cogeneration plant to operate during peak and shoulder periods only (extra thermal storage required) to maximise cost savings

### 3.5 Rouse Hill

The information on operational hours was not sufficient to provide an accurate operational time, but it was noted that the unit has run for 1563 hours (2/7/2010) and generated 37,903 kWh including commissioning.

Between 8/5/2008 and the 2/7/2010 the unit approximately produced (based on previous data and information courtesy of Urban Energy):

- 36,572 kWh electricity
- 20,619 kVAr electricity
- 67,210 kWh heat (based on the unit specification sheet and electrical generation)
Operated at around 73% Total assumed efficiency (actual efficiency is probably higher than this but insufficient data to assess it)

Maintenance costs this year for the unit was $5,160.

3.5.1 BAU (Business as Usual)

There was insufficient data to assume a Business as Usual case for Rouse Hill Apartments. The Cambridge Apartments business as usual case was therefore used.

3.5.2 Cash flow and GHG emission modelling

This scenario does not have enough information to produce an accurate report on operational costs for the unit. The data in this report should be used in 2011 to produce an accurate 12 months worth of operational data and an estimate of the payback produced from this. The following results are only for guidance as to the current operational status of the cogeneration unit.

The operational data is not sufficient to provide any meaningful analysis but based on the 17,005 kWh per year operation indicated by hours and kWh output, 38 tonnes of GHG savings a year are being realised, indicating that it continues to provide real savings.

With a price on carbon these GHG reduction savings will also be passed into cost savings making the unit even more financially attractive to operate.

3.5.3 Results Summary

There is insufficient data to provide meaningful results for this site.

MPI Group report in March 2009 as shown in Appendix B indicated 11 tonnes of GHG savings and unit savings of $888.

The plant however does generate savings as shown by previous reports and these are now expected to be larger than the MPI reports and more in line with the Cambridge Results. As the Strata do not have to pay for the generator installation (this cost is assumed in the calculations) it makes sense to continue to run the plant and generate carbon and cost savings for the tenants.

3.5.4 Sensitivity Analysis

Whilst the site does not have sufficient information, a few key factors can have a significant effect on the financial return.

<table>
<thead>
<tr>
<th>Titles</th>
<th>Active</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Expenditure Costs</td>
<td>0%</td>
<td>-65%</td>
<td>0%</td>
<td>+20%</td>
</tr>
<tr>
<td>Gas Costs</td>
<td>0%</td>
<td>-50%</td>
<td>-20%</td>
<td>+20%</td>
</tr>
<tr>
<td>CPRS</td>
<td>CPRS 5%</td>
<td>CPRS 15%</td>
<td>CPRS 5%</td>
<td>CPRS 5%</td>
</tr>
<tr>
<td>[$ NPV]</td>
<td>-$152,057</td>
<td>$50,819</td>
<td>-$112,257</td>
<td>-$223,332</td>
</tr>
</tbody>
</table>

The sensitivity results below give an indication that the plant could provide a positive return and Net Present Value with combined large gas bills for the site, and capital costs savings for future projects combined with a Carbon Pollution Reduction Scheme. Increasing the utilization would increase the financial return further.
If the site had operated for the full year it is expected based on the Cambridge Apartment Results, that Rouse Hill would have shown a positive return.

3.5.5 Improvement Suggestions

The following improvements are recommended:

- Increasing the operational hours by negotiating an operational contract in advance,
- Installation of larger hot water storage system and ensure temperatures are greater than the gas hot water generators maximising the carbon reduction for the site, and
- Set the cogeneration plant to operate during peak and shoulder periods only (extra storage required) to maximise cost savings
- Minimise installation costs – Based on observation the cogeneration plant cannot be heard above the 2 installed Raypack hot water generator and so acoustic measures could have been reduced resulting in a lower capital installation cost. An official recorded sound level has not been provided.
4.0 Cogeneration Implementation Process

4.1 Design and Installation

While it has been proven that cogeneration can be implemented in residential buildings and provide both dollar and carbon savings, there are some other factors to discuss on the implementation side.

Cogeneration currently requires a specialist cogeneration contractor to deliver a quality integrated system with a combined building services consultancy practice to undertake the system design. As the industry develops and mechanical, electrical and hydraulic contractors become familiar with the technology, hydraulic or mechanical contractors should be able to manage the system and subcontract the electrical component as required similar to the provision of a mechanical switchboard. Electricity utilities need to be satisfied with the designed fault protection and connection. For the small 25kW units in the demonstration projects this protection is provided inside the generator sets, with settings designed by the design consultant and submitted to the electricity utility.

4.1.1 Design

In order to deliver a high quality cogeneration installation, the building systems incorporated must be fully combined and the system be sized between the various size constraints. A typical practice of over-sizing systems to provide safety or extra capacity does not result in full energy savings and in the extreme will mean that the cogeneration system is permanently switched off as it cannot operate without expensive and constant maintenance. Gas engines for example typically do not operate well/efficiently below around 50%.

Typical design considerations are:

- Building heating requirements (including total annual, peak hourly and average daily requirements)
- Building cooling requirements (including total annual, peak hourly and average daily requirements)
- Domestic hot water [DHW] (Showers, baths, washing machines, sink hot water etc)
- Pool heating
- Electricity requirements
- Electricity costs (to offset site usage, no export tariff currently for cogeneration)

For building heating and cooling detailed building thermal models are ideally carried out. The simplest solution and ‘lowest hanging fruit’ is typically domestic hot water production and electricity generation for common apartment areas. This is shown in the Cambridge Apartments and Rouse Hill Town centre apartments demonstration projects funded by the Department of Planning.

4.1.2 Installation

The installation requirements for cogeneration require working closely with all the contractors on the site to coordinate wall penetrations of cables, pipes or ducts, running of cables, piping, inlet air, exhaust air, heat rejection, noise requirements and structural requirements. There are a large number of items located in a small area.

Items to note are:

- Small units can take inlet air from the room, but usually this supply is ducted from outside the room to prevent the risk of gas being premixed in the intake air. Exhaust air is removed from the generator to remove heat off the metal body or sufficient space provided to cool and circulate air.
- Gas piping needs space for gas meter trains, 2 meters may be required (1 for cogeneration) and usually only 1 is a utility meter for billing purposes.
- Lagging is required on most pipes increasing diameters
- Exhaust from the generator is usually required to be 3m above roof level to disperse the emissions
- Cable trays need to be provided
- Hot water pipework and storage systems coordinated
- Unit control system is integrated into BMS for monitoring
• Installation submission to the Utility is undertaken well in advance as this can take many months to obtain generator connection approval.
• Reverse power protection may be required to stop unit if unit exceeds power use on the site or switchboard.

Cogeneration relies on a good synergy across all these factors and involves all the companies on site, resulting in a large coordination requirement and clear responsibilities.

4.2 Utilities and Planning Approvals

Utility requirements are increased for cogeneration mainly on the electrical side.
Gas requirement usage will typically be larger, and some units require a higher natural gas pressure for example. A higher gas pressure may therefore be required to achieve maximum cogeneration efficiency.

The generator produces higher electrical fault requirements for boards, creates additional safety issues from multiple sources of electricity that have to be addressed in the design.
For example a utility may require reverse power protection to guarantee that the building electrical protection will not be effected by the generator.

These factors take time to implement, but with increases in the installation of cogeneration plants these procedures would become less complex.
5.0  Cogeneration Benefits

It should be noted that cogeneration provides a number of benefits to a site and these are detailed below.

5.1  BASIX Compliance

Cogeneration installations contribute to BASIX compliance, providing a key driver particularly in the smaller cogeneration units. BASIX compliance saves energy and water as demonstrated in previous sections of this report. The BASIX scores for the cogeneration plants are shown for the 2 demonstration projects below (courtesy of the NSW Department of Planning).

5.1.1  Cambridge Apartments – Cogeneration BASIX Score

Background info

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of apartments:</td>
<td>132</td>
</tr>
<tr>
<td>Average occupancy (ABS), assuming 2 bedroom apartments on average:</td>
<td>2.03</td>
</tr>
<tr>
<td>Per capita annual GHG-e emission benchmark - kg(CO2)/(person.yr):</td>
<td>3292</td>
</tr>
</tbody>
</table>

BASIX score improvements from the base case

* Base case - 2 Raypak gas HWG providing hot water
(Source: MPI monitoring report 1, 7 March 2008)

Total GHG-e benchmark of the apartment building - kg(CO2)/yr: 882,124
Reported GHG-e savings from cogeneration unit - tonnes(CO2)/yr: 118
- kg(CO2)/yr: 118,000

BASIX score improvements from cogeneration: 13

5.1.2  Rouse Hill Apartments – Cogeneration BASIX Score

Background info

Note: this project has been entered into BASIX

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of apartments:</td>
<td>104</td>
</tr>
<tr>
<td>Total benchmark of the project - kg(CO2)/yr:</td>
<td>643,823</td>
</tr>
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</table>

Cogeneration inputs in BASIX

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel type</td>
<td>3</td>
</tr>
<tr>
<td>Electrical output (kW)</td>
<td>22</td>
</tr>
<tr>
<td>LHV Efficiency of fuel to electricity conversion (%)</td>
<td>28.4</td>
</tr>
</tbody>
</table>
BASIX score improvements from the base case

Method 1: Engine calculations

* Base case - 2 Raypak gas HWGs providing hot water  
(Source: MPI monitoring report 1 appendix, 18 April 2008)

Base case in BASIX - centralized gas-fired hot water generators (HWG)
- Total GHG-e - kg(CO2)/yr: 514,168

Cogeneration case
- Total GHG-e - kg(CO2)/yr: 456,403
- Difference: -57,765

BASIX score improvements from cogeneration: 9

Method 2: Reported savings

Reported GHG-e savings from cogeneration unit - 
- tonnes(CO2)/yr: 38
- kg(CO2)/yr: 38,000

Using 70% occupancy as reported, the 'corrected' total benchmark
- kg(CO2)/yr: 450,676

BASIX score improvements from cogeneration: 8

From the above calculations, GHG reduction provided by the cogeneration plant results in a good BASIX score and an effective GHG reduction measure.

Costs for cogeneration implementation should be compared with the costs of implementing other savings measures to give a more accurate benefit result.

5.2 Regulatory & Authorities

Regulatory requirements with energy authorities are strict and approval times for cogeneration systems can be lengthy. However, increased cogeneration system installation is reducing some strain on the electricity network.

The reduction in electrical losses and ability for the energy authorities to delay augmentation of the network provide a key benefit to energy retailers.

In terms of gas usage, cogeneration attracts limited additional regulatory requirements above those applied to gas hot water generators or boilers and therefore do not present significant regulatory complexities. Gas pressure requirements can be a little higher than gas hot water generators or boilers but this is not a significant factor for residential size units.

The increased gas usage has not impacted significantly on gas usage or availability; it will remain to be seen if this continues. The possibility of liquefied natural gas (LNG) on the east coast of Australia will be a greater factor than the current cogeneration trend. Into the future natural gas could be replaced with coal seam gas and Syngas (made from waste) as this is already commercially viable. However coal seam gas contributes to a positive carbon footprint, while the utilization of biogas from waste (Syngas) has a net footprint of zero.
5.3 Developer Benefits

Cogeneration provides Developers with:

1. Greater BASIX compliance Options (flexibility increased)
2. Greener Building Options
3. Easy integration with existing plant and does not impact significantly on the external aspects of the building.

5.4 Strata

Cogeneration provides lower energy costs to the Strata and hence residents. This is also a lower GHG emissions technology providing a greener, cheaper system for the Strata. Cheaper strata fees benefit the owner, these reductions in strata fees could be passed on to tenants or at least in the form of a lower GHG emission building.

5.5 Tenants

If the energy consumption by the DHW units is apportioned between the units, then tenants get the benefits of lower bills and GHG emissions for the site as well as a ‘green’ benefit and feel good factor of doing ‘their bit’ for the environment.
6.0 Barriers

The BASIX Cogeneration Report – Cogeneration for Residential Apartment Buildings in NSW – Challenges and Opportunities published in 2006 provides a good summary of the cogeneration barriers.

Since 2006 the following has occurred:

- Significant electricity price rises
- Significant discussion on GHG emissions and climate change – No definite price on carbon yet provided
- Increase in gas costs (but not significant)
- Increased cogeneration usage in Green Buildings
- Signs that developers and builders are designing more cogeneration systems into buildings but still minimal usage in Multi-unit apartments.

There are numerous reports on the barriers of cogeneration and this report does not seek to go into these barriers in detail. The below items are particularly targeted based on the experiences of some recent residential projects.

6.1 Regulatory & Authorities

6.1.1 Emissions

The following regulations are found to relate to air emissions and air quality in NSW:

- Ozone Protection Act 1989
  - Proposal will not be needed to be assessed against this Act
- Protection of the Environment Operations Act 1997
  - Defines scheduled activities in NSW and lists statutory obligation for these activities.
- Department of Environment and Climate Change and Water NSW Approved Methods for modeling and assessment of the Air Pollutants in NSW 2005
  - Lists statutory methods for modeling and assessing emissions of air pollutants in NSW

DECCW imposes limits on NOx emissions from electricity generation. It is understood that the present NOx limit mandated for reciprocating machines is 250 mg/Nm$^3$ though this could become more stringent in the future.

Currently units under 1MW are not required to meet the requirements for 250 mg/Nm$^3$ and hence the NOx requirement is not an issue for the TEDOM plants with a capacity of 25 kW or 0.025MW. This is therefore not a significant regulatory requirement. However as residents will no doubt prefer clean air quality and a large number of gas engines can meet the NOx requirement, it is recommended that the NOx requirement be met for residential sites as well.

6.1.2 Electricity

The regulatory barriers remain around contestability of electricity. This means that a plant cannot be built and expect to sell the power to the tenants in the building. In reality this results in the generated power being provided “for free” i.e. not measured (they will still pay for the electricity imported from the electricity grid) or sold at a reduced rate (10-20% below market rates). The Strata manager is normally in charge of the house services and typically will choose to run the generator based on the demonstrated savings.

For generators above 30 kW network suppliers may require system studies to assess impact on the network and protection or cable changes required to be undertaken depending on the network which adds additional cost to the system. Generators installed in apartment blocks are typically under this size (both demonstration projects had smaller units). Thermal storage can allow smaller units to be used.

The electricity supplier (EnergyAustralia, Integral and Country Energy) does however still provide some barriers in terms of acceptance, equipment approval and response times. If this process is managed well then it should not be a barrier. Using all electricity on site and the use of induction generators (which require the grid supply to be
present to operate at all) result in reduced risk and requirements on behalf of the suppliers. Typically generation needs to be around 70% of the connected load to reduce the risk of export to the grid (and hence protection and safety issues from this).

6.1.3 Gas

The gas network utilities (e.g. Jemena) do not present a barrier typically, but a dual supply may be required for some generators (for example 35 kPa supply for the Royal). Typical hot water generator supplies do not have such strict requirements and can have a 5-7 kPa supply.

Ideally the loads will be steady with little variability.

6.2 Developers & Builders

A developer or builder will typically wish to keep costs in a development low. The target market is also a factor and flexibility in how the BASIX requirements are met is also important.

Design and Installation requirements have typically required a separate cogeneration contractor to undertake the works due to contractual issues with pipework, ducts, motors, and breakers, cables etc. being incorrect sized, or not provided. This is due to the accurate heat and power matching requirements (size and operation) of the design and combined approach required. Consultants also have been learning the processes required to match the heat and power requirements accurately. It is expected that time involvement in the processes will be reduced as consultants and contractors become more familiar with cogeneration.

It should be noted that increased time for the builder to install cogeneration has not been factored into the $180,000 + GST average cost for design, installation and commissioning of a small 25 kW set.

6.3 Strata & Tenants

The Strata owners may turn off the generator due to technical issues or high maintenance costs in a building for the unit. As electricity costs rise, this risk may reduce. Using a display in the foyer of the units may provide a reminder to tenants and hence ensure the unit continues to operate throughout the design life.

Typically the Strata pay for the gas and often water together. While this is simple, it provides no incentive to tenants to reduce consumption. The volume of hot water can be metered for each tenant and total gas usage distributed through all the tenants. Cogeneration does not affect these methods significantly and is compatible with both options.

Increased cost to the tenants through maintenance and/or equipment replacement could be a barrier. This will presumably be a larger factor outside Sydney which has high housing costs already and a cogeneration unit (greener power) may be more of a benefit than a cost barrier. The cost barrier is only likely to impact slightly on the purchase of the unit. House prices in the area may be a more significant factor.

The higher complexity of the cogeneration system can also be a barrier to tenants/strata owners. Education needs to be provided and guidance shown as to the likely ongoing costs of the unit, money to be allowed for spare and replacement parts and ongoing maintenance cost requirements. Electricity is hard to see and so increased metering visibility may be required.
7.0 Proposed BASIX Improvements

After assessing the residential cogeneration systems installed, and the potential barriers and benefits of cogeneration, the BASIX tool cogeneration calculations were analysed to determine whether any further detail could improve the accuracy of the calculations.

The following section lists suggested improvements to the tool to improve the reliability, and effectiveness of installations in residential buildings in NSW.

7.1 Process

The BASIX tool currently incorporates the following options:

- **Fuel Type**
  - Biodiesel, Gas, Diesel
- **Electrical Output**
  - kW
- **Efficiency of fuel to electricity conversion**
  - %

The tool input screen is shown in the web screenshot below.
The tool assumes the following functions and efficiencies as shown in the table below:

<table>
<thead>
<tr>
<th>Functions</th>
<th>Efficiency of Waste Heat being harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water</td>
<td>70%</td>
</tr>
<tr>
<td>Pool and Spa Heating</td>
<td>75%</td>
</tr>
<tr>
<td>Space Heating</td>
<td>60%</td>
</tr>
<tr>
<td>Space Cooling</td>
<td>60%</td>
</tr>
</tbody>
</table>

Note: The COP (Coefficient of Performance) /EER (Energy Efficiency Ratio) of the space heating or cooling systems have not been taken into account here.

Internal BASIX calculations calculate the fuel and energy consumption and Net Greenhouse gas emissions. This provides a simplified system which allows for minimal inputs and hence accessible or "usable" tool.

### 7.2 Incentives and Drivers

The BASIX tool provides incentives to build sustainable housing with options for selection to allow a customisable solution. This provides flexibility for architects, designers, builders and developers to meet the requirements.

Through this the BASIX tool provides a driver (and also an ultimate penalty of not being able to build) to use cogeneration in the building.

### 7.3 Risks and Disadvantages

While the tool is currently simple there are a few disadvantages and presents certain risks:

- Some sites may (and have) installed cogeneration as a tick in the box type solution with limited operation and limited integration of the system
- It does not provide many options for the cogeneration plant and due to electrical generator size entry may give the impression that electrical energy is the driving factor when more commonly it is based on heat demand (thermally led)
- Installed capacity may not translate into later GHG or cost savings for the residents.

It is suggested that a little more detail could be provided to make the BASIX calculation more robust.

### 7.4 Potential Additions to BASIX

In order to improve the tool the following items are suggested to be added:

**User inputs:**

- Design heat output ($kW_{\text{heat}}$) - Fuel cells are very different for example from engines and heat output should be measured / input instead of calculated within BASIX. The assumed accuracy currently in the model (70% for hot water) will therefore be improved.
- Storage (Litres). The amount of hot water storage provides a cogeneration backup, allows the generator to run for longer, allows a smaller unit to be selected and greater cost savings from running in peak electricity cost tariff times. This provides more certainty in operation and better integration. This factor could also be in MJ (energy) which incorporates the temperature difference of the hot water. This is however harder to easily verify on site.
- Cogeneration supply temperature or operating temperature could be entered to allow $kW_{\text{heat}}$ storage to be calculated. This provides a calculated value that can be compared with the existing calculation for verification. A higher accuracy will result and an automatic check becomes possible.

Additional BASIX commitments for the cogeneration option:
- Alternative (e.g. Gas Boosted) Temperature – A check to confirm that the cogeneration is base load and will operate before any other hot water manufacturing item. Therefore increasing savings certainty.

Help notes material:
- Display – to encourage monitoring of the unit and engage tenants/residents. It is acknowledged that this in itself will not save energy, it may be appropriate for it to be a suggestion in a help note.

Feedback to the users:
- Usage – Provide the % of total demand for heating, cooling and/or electricity satisfied by the cogeneration unit. This provides a check to ensure that the cogeneration unit is not too large and is unlikely to run.
- Operation times – This combined with Storage gives an idea as to proposed operation and if the design is feasible. A standard profile can be used from either AS 4234 standard or the profile from the Royal Newcastle for example. The operational hours per year can be shown to the user as a check for them.

Storage is discussed further within the next section.

7.5 Storage

Storage of hot water enables a cogeneration plant to operate at full capacity during low periods and generate heat during the day when electricity is expensive and loads are high. The storage is then used during peak demand events and at night.

7.5.1 Heat Storage Formulæ

The formula for the heat requirement is

\[ Q \text{ (in kJ)} = \text{Temperature Difference (dT)} \times \text{specific heat capacity of water (4.1893kJ/kg K at 70}^\circ\text{C)} \times m^3 \text{ water} \times \text{density of water (975.5 kg/ m}^3\text{ at 74}^\circ\text{C)} \]

Note: 1,000,000 litres = 1,000 m³ and 1kWh = 3,600 kJ

7.5.2 Example Calculation Daily Use

As an example (similar to the Royal Newcastle) consider an average 150kW for an hour (150 kWh = 540,000kJ) 540,000 kJ x 24 h = 12,960,000 kJ is required for a day and the hot water is 15°C above the required temperature (80°C storage, 65°C requirement).

With the heat storage formulæ (in 7.5.1) \( Q = dT \times 4.1893 \times m^3 \times 975.5 \) we can calculate the storage (m³):

\[ m^3 = Q / (dT \times 4.1893 \times 975.5) \]

\[ m^3 = 12,960,000 / (4.1893 \times 15 \times 975.5) = 211.4 \text{ m}^3 \text{ of hot water for the day (or 211,419 litres)} \]

So storage requirement at 80°C is 211.4 m³ of hot water for the day.

If we assume 2% losses = 215.6 m³ or 215,650 litres per day required for site.

7.5.3 Cogeneration Plant Storage required

If a cogeneration plant is can provide 200kWheat * 15 hours (7am to 10pm) = 200 x 3,600 x 15 =10,800,000 kJ on average.

\[ m^3 = 10,800,000 / (4.1893 \times 15 \times 975.5) = 176 \text{ m}^3 \text{ of hot water or 176,183 litres for the day} \]

If we assume that the site requires 6 hours at half load during the day, then the cogeneration plant requires:

\[ 6 \text{ hours x 100kWh x 3,600} = 2,160,000kJ \]

\[ m^3 = 2,160,000 / (4.1893 \times 15 \times 975.5) = 35.2 \text{ m}^3 \]

or approximately 35,240 litres of storage (including losses) to keep the cogeneration operating at 100%. This is the recommended storage for this option.
7.5.4 Optional Storage to cover non-cogeneration day load

If additional backup/storage was required for the site then the cogeneration plant would not be able to provide the entire load (see 7.5.2, 7.5.3).

Gas boosted storage required for the remainder formulae is TOTAL REQUIREMENT – COGENERATION PROVISION = REMAINING STORAGE REQUIRED.

\[
215.6 \text{ m}^3 - 176.2 \text{ m}^3 = 39.4 \text{ m}^3 (39,400 \text{ litres}) \text{ or } (15 \times 4.1893 \times 975.5) = 2,419,200 \text{ kJ} \text{ or } (\text{divided by } 3,600) \text{ for } 672\text{kWh}.
\]

Total Storage for a single day operation (including the cogeneration storage in 7.5.3) is

\[
35.2 \text{ m}^3 + 39.4 \text{ m}^3 = 74.70 \text{ m}^3 \text{ or } 74,700 \text{ litres of storage}.
\]

This would provide storage redundancy for the site.

It is important to note that water used for showers etc. will be required to heat up from around 20 degrees. The actual Site Energy Input is therefore higher than the above calculation. The above calculation only looks at heating from 65 degrees to 80 degrees.

The expected hot water demand for the hotel at the Royal (mentioned in section 4.3.1.2) is below. This shows 2 distinct peaks driven mainly by showers in the morning and evening and around 6 hours in the middle of the day at low output.

The cogeneration system for the Royal is designed to operate during peak times. The generator size is 160kW electrical, and approximately 194kW thermal. The peak and shoulder electricity periods (where electricity costs are high) are generally 7am to 10pm in NSW. The thermal size of the unit and expensive electricity time lines are shown below:
To provide the greatest carbon savings the generator should be run to cover the blue shaded area which is the entire heat generation. Most gas engines can only operate down to around 50% of peak load effectively. This means that the generator cannot operate below 100kWth for a 200kW generator. The generator is also too small to provide the peak thermal loads during the day that are around 330kWth in the morning.

To remove these constraints water storage is used (in this case 12,000 litres for the hotel and then provision of hot water to the surrounding apartments. This maintains the generator operating at 100% during peak periods and ensures that greater carbon and energy savings are realised. It also has the benefit of providing more backup hot water in the case of interruption of services.

It is suggested that The Royal storage solution is monitored to show the cogeneration savings, which will assist the BASIX tool in accurate modelling of GHG emission reduction.
8.0 Conclusions

8.1 Existing Projects Summary

As shown in the report operation of the cogeneration units are feasible.

The table below shows a summary of the results:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Rouse Hill</th>
<th>Cambridge Apartments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Apartments</td>
<td>104</td>
<td>134</td>
</tr>
<tr>
<td>Operation Time</td>
<td>1 July 2008 – 30 June 2033</td>
<td>1 July 2008 – 30 June 2033</td>
</tr>
<tr>
<td>ELECTRICAL ENERGY GENERATED</td>
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<td></td>
</tr>
<tr>
<td>Generated power (kWh)</td>
<td>17,005</td>
<td>107,649</td>
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<tr>
<td>Imported power (kWh)</td>
<td>Insufficient data</td>
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</tr>
<tr>
<td>Generated reactive power (kVAr)</td>
<td>~9,600</td>
<td>64,600</td>
</tr>
<tr>
<td>Installed power (kW)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Hours of operation (hours)</td>
<td>1563</td>
<td>6482</td>
</tr>
<tr>
<td>CARBON SAVINGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG savings (tonnes CO₂-e/yr)</td>
<td>~16</td>
<td>118</td>
</tr>
<tr>
<td>Lifetime GHG Savings potential (tonnes CO₂-e)</td>
<td>Insufficient data</td>
<td>2,948</td>
</tr>
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<td>FINANCIALS</td>
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</tr>
<tr>
<td>Cost of Unit (excl GST)</td>
<td>$82,262</td>
<td>$72,433</td>
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<tr>
<td>Installation costs 2007 (excl GST)</td>
<td>$207,000</td>
<td>$165,000</td>
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<tr>
<td>Cost savings / year</td>
<td>Insufficient data ~$1000-$3000 currently</td>
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<td>Payback period - years</td>
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<tr>
<td>(Undiscounted cash flow)</td>
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<tr>
<td>Payback period - years</td>
<td>Unknown</td>
<td>25.8</td>
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<td>(Discounted cash flow)</td>
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<td>SENSITIVITY ANALYSIS</td>
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<tr>
<td>Carbon savings range (tonnes CO₂-e over 25 years)</td>
<td>Insufficient data</td>
<td>2,887 to 3,263</td>
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<tr>
<td>Cost savings range (NPV)</td>
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<td>$-113,000 to $188,000</td>
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<tr>
<td>BENEFITS AND BARRIERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional benefits</td>
<td>Greater hot water redundancy</td>
<td>Greater hot water redundancy</td>
</tr>
<tr>
<td>Barriers</td>
<td>Lack of integrated storage</td>
<td>Solar Preheat reduces cogeneration efficiency, lack of integrated cogeneration storage – majority is fed from Raypak HWG only,</td>
</tr>
<tr>
<td>Issues</td>
<td>Low occupation, maintenance contract delays</td>
<td>Unit not running for 4 months of the year due to contract expiry</td>
</tr>
<tr>
<td>Suggested improvements</td>
<td>Increasing operational hours, increased storage</td>
<td>Increasing operational hours, increased storage</td>
</tr>
</tbody>
</table>
The table on the shows that Cogeneration provides significant carbon savings and requires the following key items:

1. Cogeneration to be sized correctly
2. Hot water storage to be incorporated to ensure the generator can run for long periods and operate mainly during high electricity price evens (generally Monday to Friday 7am to 10pm)

8.2 Proposed BASIX Improvements

It is suggested that the following two items are added to the BASIX tool initially:

- Heat Output ($kW_{heat}$) - Fuel Cells are very different for example from engines and heat output should be measured / inputted
- Storage (Litres). The amount of hot water storage provides a cogeneration backup, allows the generator to run for longer, allows a smaller unit to be selected and greater cost savings from running in peak electricity cost tariff times.

Cogeneration supply temperature or operating temperature could also be one of the user inputs to allow $kW_{heat}$ storage to be calculated.

These items provide key inputs into the calculation and allow greater flexibility in design and installation.

In summary cogeneration in multi residential apartments and mixed-use developments is an effective way of saving greenhouse emissions and maximising the financial returns.