IS THERE VALUE IN COGENERATION?

Alex Sanbrook 1, Greg Appleby 1, Phil Woods 1
Sydney Water, Sydney, NSW, Australia

ABSTRACT
Sydney Water has been utilising biogas to operate cogeneration assets for 15 years. In 2013-14, Sydney Water’s cogeneration plants produced around 15% of the organisation’s energy needs, with significant financial benefits from avoided electricity costs and green commodity value. Sydney Water has followed a staged approach in implementing cogeneration. Key factors for successful installation, operation and maintenance of cogeneration assets have been identified. Sydney Water has gained significant value from cogeneration and continues to invest in it. While the primary benefit of cogeneration is the financial returns achieved, ongoing value from cogeneration also extends to the environment and plant performance. This paper explores these benefits and lessons learned from Sydney Water’s cogeneration plants.

INTRODUCTION
Sydney Water has been utilising biogas to operate cogeneration assets (which produce electricity and heat) since 1999. Biogas is produced in anaerobic digesters at Wastewater Treatment Plants (WWTPs), and contains between 55-65% methane. Sydney Water’s renewable energy program has expanded over the last 15 years, with new cogeneration assets installed in 2009 and 2014. Sydney Water now has cogeneration units at 8 WWTPs with an installed capacity of 9.8 MW, as shown in Table 1. This paper describes Sydney Water’s staged approach, our lessons learned and future plans to get the best value from cogeneration.

<table>
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<tr>
<th>Plant</th>
<th>WWTP Discharge (ML/d)</th>
<th>Cogeneration Engine Capacity</th>
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<tbody>
<tr>
<td>Malabar 498</td>
<td>1,060 kW 1,200 kW 1,200 kW</td>
<td></td>
</tr>
<tr>
<td>North Head 308</td>
<td>1,415 kW 1,063 kW</td>
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The installed cogeneration plants have a capacity to generate over 60,000 MWh electricity per year thereby reducing over 60,000 tonnes of greenhouse gas emissions, which is the equivalent of removing 15,000 cars from the road.

PROCESS
Sydney Water has followed a staged approach in implementing cogeneration. The technology was first implemented at Sydney Water in 1999. In 2007 a renewable energy program commenced. Several sites were identified where cogeneration was calculated to be financially feasible. Cogeneration was installed at these sites during 2009 and 2010. Optimisation was undertaken between 2010 and 2012, aiming to realise the full potential of both its new and existing cogeneration fleet. The increased generation since 1999 is shown in Figure 1.
A second program examined sites with excess biogas or sites with anaerobic digestion and no cogeneration unit. This resulted in further expansion of cogeneration in 2014 at two sites. Some sites remain unviable and will be reviewed again as key success factors change. Sydney Water will continue to investigate ways to get more value from cogeneration in future. This includes gaining a better understanding of co-digestion and other technologies including Organic Rankin Cycle.

**DISCUSSION**

**Lessons learned from installing cogeneration**

Sydney Water has gained experience installing cogeneration assets at 8 sites over 15 years. Post implementation reviews of these projects have built our understanding of the key success factors to ensure value from cogeneration, including:

- Understanding capital investment requirements (e.g., appropriate engine sizing, plant type, biogas supply/optimisation and measurement, biogas pre-treatment requirements, high voltage connections for large engines, allowing for site factors such as corrosion, emission requirements, access and maintainability of engine, triggers to review decisions for new installations).
- Understanding operation and maintenance costs (e.g., true maintenance costs, maintenance strategies versus manufacturer recommendations, auxiliary equipment costs, complexity of operation).
- Correct assumptions during evaluation process (e.g., costs, onsite power utilisation and minimising export, electricity price and green commodity value forecasting, engine downtime, timing for implementation).
- Optimising performance as soon as possible (e.g., good biogas measurement, performance monitoring and continuous improvement).
- Identifying additional value from co-generation assets beyond financial benefits from electricity. The focus on optimising gas production can lead to better biosolids management.

The main limiting factors to ensure financial benefits from cogeneration at Sydney Water are engine size (dependent on quantity of biogas), understanding full capital and operating costs to deliver reliable generation performance and the value of electricity. For Sydney Water sites, engines below 200kW are generally not financially viable.

**Lessons learned from operating cogeneration**

During an optimisation program between 2010 and 2012, Sydney Water increased generation from cogeneration by 10% in the first year and a further 5% in the second year. We have continued to incorporate improvement planning into our management of renewable energy assets. Lessons include the following:

- Root cause analysis showed that downtime is the greatest cause of lost generation (without standby units, any downtime represents lost revenue).
- Maintenance planning remains the biggest challenge in reducing downtime (a high level of unplanned maintenance is required on biogas engines and coordinating these needs across 10 sites with a small team is very challenging).
- Technical expertise of the maintenance provider is essential (fast diagnosis and innovative solutions are important elements of reducing downtime).
- Parts management is crucial because waiting for delivery of engine parts can cause significant delays.
- Good performance monitoring provided the foundation for identifying and monitoring improvements – performance was constantly challenged by others ensuring issues were followed until root causes were found and resolved.
- Cogeneration units running on biogas do not all respond equally (there are differences between maintenance requirements depending on engine model and biogas composition).
- Biogas pre-treatment for removal of hydrogen sulphides and siloxanes needs to be considered on a site by site basis to determine whether the cost of biogas cleaning is offset by reduced engine maintenance.
- Optimisation of digester gas production and accurate gas flow measurement is important and can be done before cogeneration is installed to ensure appropriate sizing of engines and the full potential of the asset is realised.
- Stakeholder engagement can improve performance (e.g., operator training, sharing of lessons, identifying causes of lower biogas production).
- Maximising the onsite usage of electricity produced from cogeneration prevents electricity being exported to the grid (exported electricity receives a much lower return than the savings generated by offsetting imported grid electricity). Electrical load studies have provided data to allow Sydney Water to reduce export over the last few years.

Practical limitations on operating and maintaining cogeneration units are now well understood. These limitations include operator capability, realistic downtime and major periodic maintenance requirements. These limitations can now be built into business cases for future investment in cogeneration units, which gives business owners greater confidence in achieving a positive financial return.
A case study – Utilising excess biogas

In 2012, Sydney Water carried out an investigation into the feasibility of new or additional cogeneration capacity at 4 sites; Shellharbour, West Hornsby, Cronulla and North Head WWTPs.

Installation of cogeneration at West Hornsby WWTP was not considered feasible due to technical constraints and existing site design. The plant had low gas production and no boiler for the sludge heating system. Heat recovery from the generator would therefore not provide any benefit and biogas would still be required to heat sludge directly.

Installation of cogeneration at Shellharbour WWTP is not currently cost effective as a result of low biogas production (<200kW) and low electricity rates, however a future business case may be submitted if a more cost effective solution or a method to increase biogas production can be implemented. Lower cost engines were considered, however, they were unable to meet emission requirements.

A $6 million project was approved to utilise excess biogas at Cronulla and North Head WWTPs. The project upgraded the existing cogeneration unit at Cronulla WWTP from 475kW to 835kW and installed an additional 1MW cogeneration unit at North Head WWTP. The project was aligned with Sydney Water’s Energy and Greenhouse Gas Mitigation Strategy to provide cost effective reduction of greenhouse gas emissions by on-site generation of renewable energy. The project’s business case provided a net present value of $3.5 million. The capital costs are broken down into categories in Figure 2.

Sydney Water’s lessons from installing and operating cogeneration were incorporated into the business case including; improved biogas quantity and quality measurement to accurately size the engines and to determine the impact of siloxanes and sulphur compounds on design and maintenance, realistic generation targets based on past performance, optimising operation and maintenance costs without impacting reliability and understanding electricity and green certificate forecast rates with factors such as government policy, current price trends and electricity demand forecasts considered.

Minimising export at North Head WWTP was an important consideration as the site had two existing renewable energy assets; a 1.4MW cogeneration unit (shown in Figure 3) and a 2.1MW mini-hydro plant. Both these units were attached to a pair of incoming electricity feeders. The remainder of the load was distributed across 4 other feeders. The cost of an 11KV ring main unit to enable more versatile utilisation of power from the new engine to the site was incorporated into the business case to help minimise the export of renewable power.

Sydney Water gained input from our specialist operation and maintenance contractor to provide design input before the final business case was approved. There were a number of factors that were incorporated into the design to ensure all capital costs were captured upfront to deliver reliable performance and minimise operation and maintenance costs, including:

- Electrical considerations (low voltage/ high voltage connections, electrical protection settings)
- Engine room ventilation and cooling
• Fire detection and suppression
• Oil storage and management (clean oil, waste oil and day tank)
• Gas conditioning requirements (new chiller required at North Head)
• Heat recovery (exhaust heat recovery installed at Cronulla only, North Head had sufficient heating from existing cogeneration)
• Paint specifications to prevent corrosion of container (particularly important due to coastal environments)
• Platform access and stairs to the roof of the container (shown in Figure 4)

The project was delivered under a Design and Construct Contract during 2014. This method of project delivery and preparing an advanced concept design prior to tendering helped manage capital costs.

A large component of the capital costs were electrical and an electrical engineer with local site knowledge was engaged to provide support to the contractor during design, construction and commissioning. Electrical issues included:

- Site load studies to maximise onsite utilisation of generated electricity and minimise export to the grid
- Step up transformer and high voltage cabling required at North Head WWTP to allow connection to high voltage network due to capacity limitations of the low voltage network and allow better utilisation of the power from the new engine without having to export
- Physical size of sites and layout impacting cable runs and electrical connection points
- Review of electrical protection settings to ensure faults at cogeneration will not impact plant or electrical network
- Connection agreements with Ausgrid
- Fault limiting reactor required at Cronulla
- Earth grid and earthing connections

Installation of the engine at Cronulla WWTP required removal of the existing unit (shown in Figure 5) prior to installation of the new unit in a space restricted area (shown in Figure 6). There were multiple site contractors at Cronulla during implementation of the cogeneration project due to a high voltage upgrade which also added to the project’s complexity.

Improved value from cogeneration in the future
Sydney Water is looking for innovative ways to achieve further benefits from cogeneration, including:

- Treatment process improvements are being implemented as a result of digester audit recommendations. Studies are underway to improve gas production, storage and distribution at some sites.
- Sydney Water is trialling the co-digestion of trucked organic waste with sewage sludge. This involves receiving trucked organic waste for a fee and adding it to a sludge digester to increase biogas production. Glycerol is currently being trialled at Bondi. Other waste materials including beverage waste, pulped food waste, dairy, bakery and fats oils and grease will be trialled at other sites over the next 3 years. Co-digestion has the potential to double biogas generation, which could see some WWTPs become energy neutral and make cogeneration cost effective at WWTPs that were previously not viable.
- The Organic Rankin Cycle technology makes use of waste heat from the cogeneration units to produce additional electricity. This process requires higher temperatures and is more suitable from exhaust heat recovery rather than the
lower temperature engine jacket water. Sydney Water is currently investigating the technology. One study showed that an additional 100kW could be generated using heat from the new 1000kW cogeneration unit at North Head.

CONCLUSION

Sydney Water has gained significant value from cogeneration and continues to invest in it. While the primary benefit of cogeneration is the financial returns achieved, ongoing value from cogeneration also extends to the environment, plant performance as well as contributing to a liveable city. Financial benefits are more difficult to achieve with smaller engines (<200kW), due to limitations in construction and operating costs, achievable production rates and the market value of energy. However, all these limiting factors are constantly changing and there are innovative ways to improve value from cogeneration in the future. Therefore decisions on sites where cogeneration is not currently feasible should be regularly reviewed.

ACKNOWLEDGMENT

The authors wish to thank our Renewable Energy Generation contractors who work closely with Sydney Water to maximise the benefit from renewable energy assets. Technical expertise provided by our contractors has resulted in Sydney Water gaining value from cogeneration.

REFERENCES