TOWN HALL TRIGENERATION PROJECT

Community Energy Efficiency Program

FINAL REPORT

“This activity received funding from the Australian Government.”
# Contents

Executive Summary ........................................................................................................1  
Project objectives ........................................................................................................5  
Energy efficiency activities ..........................................................................................8  
Demonstration and communications activities .........................................................20  
Project issues and learnings ......................................................................................22  
Outcomes and benefits ..............................................................................................28  
Project budget ...........................................................................................................32  
Project processes, mechanisms and operation .........................................................34  
Conclusions .................................................................................................................45  
Declaration ..................................................................................................................48  

## DISCLAIMER

“The views expressed in this report are not necessarily the views of the Commonwealth of Australia, and the Commonwealth does not accept responsibility for any information or advice contained herein.”
Executive Summary

Project development and delivery

Looking south towards Sydney Town Hall and Town Hall House. The civic precinct is in the heart of Australia’s largest CBD.

The Town Hall Trigeneration Project was conceived, investigated, designed and delivered to reduce primary energy usage and abate greenhouse gas emissions in the civic precinct at the heart of the City of Sydney.

Key requirements for the project included:

- Installation of a trigeneration facility that meets the electrical requirements of Town Hall House and Sydney Town Hall during operating hours, and is capable of exporting electricity to other premises via the electricity distribution network
- Engagement of a single supplier to manage all works and services associated with design/construction and operation/maintenance of the trigeneration facility
- Delivery of the project on a value for money basis and at appropriate levels of risk
- Development of a delivery model applicable to other commercial buildings.

An initial high-level business case for a trigeneration project based at Town Hall House was prepared and presented to Council in June 2013.
In July 2013, the City of Sydney executed an agreement with the Australian Government as part of the Community Energy Efficiency Program under which funding was awarded to the City in relation to this project. The amount of funds available under the agreement was $3,051,700.

A detailed preliminary business case was prepared at the beginning of 2014, taking into account the findings of a technical feasibility study by AECOM. Supplier market testing was conducted via EOI and commercial negotiations with potential thermal energy customers took place in April/May 2014. The results were presented to Council in June 2014, at which time Council selected the building-based option.

A preferred supplier (A E Smith) was established via a select tender process conducted in the second half of 2014. Detailed design, equipment purchase, construction and plant installation took place between March 2015 and May 2016. Commissioning of the trigeneration system was carried out progressively and operation started in June 2016.

The total value of the project is over $13 million inclusive of feasibility studies, pre-procurement activities, procurement, approvals, detailed design and technical studies, equipment purchases, delivery to site, installation and commissioning, associated building works and building services upgrades, project management and in-house supervision. The direct capital cost is inclusive of the cost of associated building service upgrades, primarily, replacing the main electrical switchboard.

**Choice of solution**

*Looking north over the trigeneration facility mid-way through installation.*

*Pre-assembly and modular construction helped ensure timely delivery of the project.*
The technology offered by the supplier (AE Smith) uses micro-turbines coupled to absorption chillers, instead of reciprocating engines. This technology has low emissions, is quieter and has lower vibration levels than reciprocating engines. It has been utilised in Australia and internationally for the past 10 years and is proven technology. The use of a low voltage connection from the roof-top power plant to the basement also simplifies the construction through avoidance of high voltage cables.

Because of shared requirements, delivery of the Town Hall trigeneration project was combined with replacement of the main switchboard servicing the civic precinct. The existing main electrical services switchboard had been installed when Town Hall House was constructed in the mid-1970s. Installation of trigeneration has provided Sydney Town Hall and Town Hall House with full electricity supply capability from both the trigeneration systems and by the normal electricity supply from Ausgrid.

**Project issues and learnings**

This project shows that substantial energy efficiency improvements and greenhouse gas emissions reductions can be achieved in in a large commercial building in a congested metropolitan centre while day-to-day operations continue. Success in such a project depends on paying regard to a number of factors:

**Comprehensive investigation and risk management** - Initial concept development was followed up by comprehensive investigation of both technical and commercial considerations prior to commencing project delivery. Based on the technical and commercial investigations, the City was able to develop a comprehensive listing of project risks and to develop a mitigation strategy that addressed each listed risk.

**Effective engagement and communication** - Three features of the engagement and communication activities associated with this project deserve mention. The first is the need to maintain transparency and accountability. The second is the need to engage with potential suppliers and with the energy efficiency sector generally. The third is the need to engage regularly with stakeholders in the immediate proximity of the project, including building service providers for the civic complex, building occupants, and service providers and occupants of adjacent buildings.

**Skills, capacities and time** - Successful implementation of this project required a mix of both in-house and external (consultancy) technical, commercial and project management skills. While smaller-scale energy efficiency projects can typically be carried within a window of 12 months to two years, the time from conception of the project to its completion was closer to four years. The willingness of the Commonwealth to lend support to such a longer term project is certainly appreciated.

**The courage to innovate, the willingness to adapt** - This project was conceived and executed because of the City’s vision for a low-carbon decentralised energy future. Achieving this vision requires a great deal of tenacity and a strong dose of innovation. It is the willingness to adapt in a disciplined and structured manner while staying true to the essential vision that has allowed a successful outcome.
<table>
<thead>
<tr>
<th>Name</th>
<th>Main civic complex - Sydney Town Hall / Town Hall House 456 Kent St, Sydney NSW 2000 and 483 George Street Sydney NSW 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of building, facility or site</td>
<td>Civic complex comprising major entertainment venue, reception and function rooms, high-rise offices, ancillary retail and underground car parks Office areas are primarily used on working weekdays; civic facilities and entertainment venues are in use up all days Buildings share common heating cooling and ventilation systems and service areas; following on from this project, buildings will share electricity supply</td>
</tr>
<tr>
<td>Sydney Town Hall</td>
<td>Total usable area in complex = 35,000 m² Historic town hall floor count = 4 public access levels Historic town hall construction date = 1867 onwards Hours of operation = 7am to midnight, all days Usage of civic/entertainment space varies seasonally</td>
</tr>
<tr>
<td>Town Hall House</td>
<td>High rise tower floor count = 25 (includes 2 basement levels) High rise tower construction date = 1977 Assumed occupancy = 95% Hours of operation = 6 am to 6 pm Monday to Friday</td>
</tr>
<tr>
<td>Activity Type and Measure</td>
<td>Installation of trigeneration system to supply electricity, heating and cooling to Town Hall House and Sydney Town Hall and to provide export of electricity via public grid to other City premises in the local area</td>
</tr>
<tr>
<td>Energy Efficiency Estimate Method</td>
<td>Energy efficiency improvement measure via reduction in primary energy use - expressed as GJ per m² per year - based on metered gas and electricity supply - amount of primary energy is derived via publicly available energy efficiency/conversion benchmarks</td>
</tr>
<tr>
<td>Current Energy Usage</td>
<td>61,500 GJ per year (2012-13 is baseline) (This is equivalent to 61,500,000 MJ per year or 17,083,333 kWh per year)</td>
</tr>
<tr>
<td>Current Energy Efficiency</td>
<td>1.75 GJ of primary energy per m² per year (This is equivalent to 1750 MJ per m² per year or 486 kWh per m² per year)</td>
</tr>
<tr>
<td>Energy Efficiency Improvement</td>
<td>In terms of energy usage, reduction of up to 12,300 GJ per year (20% of baseline) in total primary energy used (This is equivalent to reduction of up to 12,300,000 MJ per year or reduction of up to 3,416,667 kWh per year) In terms of energy efficiency, reduction of up to 0.35 GJ per m² per year (20% of baseline) in average primary energy usage (This is equivalent to reduction of up to 350 MJ per m² per year or reduction of up to 97.2 kWh per m² per year)</td>
</tr>
</tbody>
</table>
Project objectives

Community Energy Efficiency Program

The Community Energy Efficiency Program (CEEP) provides co-funding to local governing bodies and non-profit community organisations to implement projects that deliver a range of energy efficiency measures in council and community owned buildings, facilities and sites. This includes council buildings such as town halls, chambers, libraries and administration buildings; council facilities such as bores, depots and sewerage treatment centres; community buildings such as museums, theatres, libraries, hubs and arts centres; as well as sporting and recreation facilities, aquatic and leisure centres, parks, ovals and reserves.

The Community Energy Efficiency Program has two key objectives - to support local councils and community organisations to increase the energy efficiency of different types of non-residential buildings; and to demonstrate and encourage adoption of improved energy management practices within councils, organisations and the broader community.

Town Hall Trigeneration Project

The Town Hall trigeneration project actively contributes to the delivery of the objectives of the Community Energy Efficiency Program.

1 – By providing reliable and energy efficient business hours electric and thermal energy supply to Town Hall House and Sydney Town Hall at an acceptable cost

The recommended solution fully meets the projected business hours electric and thermal energy (heating hot water, chilled water) for Town Hall House and Sydney Town Hall on a reliable and energy-efficient basis.

A reduction in energy-related operating costs for Town Hall House and Town Hall is projected over the project lifetime.

2 – By increasing energy efficiency and delivering significant carbon abatement

By installing a trigeneration plant, the City improves the efficiency of its civic buildings while also achieving substantial levels of carbon abatement.

The preferred solution achieves significant carbon emissions reductions. Over the project lifetime, namely 30 years, the amount of carbon abatement is calculated at more than 42,000 tonnes.

Annual abatement equals 3 per cent of the City’s estimated baseline (business as usual) emissions for 2030.
The cost of abatement is estimated to be broadly comparable to the benchmark cost of abatement which has been set as the extra cost (premium) for GreenPower.

Using trigeneration also has two additional benefits.

The first is proximity - electricity will be generated close to where it is used, which is essential to achieve sharing of energy between buildings. This is beneficial to electricity (especially at network peaks) by reducing load on the network.

The second is additionality – the project is predicated on the assumption that low-carbon generation will directly increase in the City area. This would not occur if GreenPower were to be purchased through the wholesale market (which trades power from existing renewable generators) or via carbon offsets.

3 – By ensuring proper management of risks associated with energy efficiency and carbon abatement improvements

Major risks of this project have been managed as follows:

Operational performance – The design/construct contract was linked to a performance-based operate/maintain contract for up to 10 years to ensure that operating results meet expectations. Equipment has been modelled to run in the most cost efficient manner throughout business hours, and high operating reliability were embedded in the tender selection criteria.

Capital cost and operating cost risks - A fixed price has been obtained for construction and for operation/maintenance for up to 10 years. There is proactive project governance during both construction and operational phases.

Electricity and gas price risks - Price path forecasts have been provided by a leading energy price specialist and sensitivity of cost of abatement to departure in electricity and gas commodity prices from forecasts has been modelled.

Constructor/operator financial failure - This risk has been minimised by determining that City will own the plant, purchase the gas (as it already does for its own buildings) and manage the sale of export electricity.

Reputation risks - Reputation risks are minimised by ensuring that high-reliability equipment is installed, a reputable constructor/operator is selected; ownership of equipment and systems remains in City hands; and an ongoing connection to the public electricity grid is retained.

4 – By demonstrating a delivery model that can apply to other buildings

The chosen solution provides a model for trigeneration that may be appropriate for other commercial buildings such as office blocks and mixed use developments in the City area, and for commercial buildings in CBDs elsewhere in Australia.

It is recognised as being low-impact in terms of noise and air pollution, and suits retrofits as well as new builds.
The selected technology mitigates some of the technical complexities that can arise when connecting generators direct to CBD grids. As well, the chosen solution can generate sufficient electricity to help power other nearby buildings.
Energy efficiency activities

Precedents

Trigeneration (both as combined power/heating and as combined power/heating/cooling) is a well-established technology both overseas and in Australia. Over 3000 MW of trigeneration capacity is present in Australia, both as isolated on-site projects and connected to the public power grid. This includes both industrial settings (e.g. sugar mills, food processing) and commercial settings (education campuses, shopping centres, district centres, office blocks).

There are already a number of well-known trigeneration installations in the Sydney CBD supplying single sites, such as Central Park and Westfield Sydney. Numerous councils in NSW have installed trigeneration plants, including North Sydney, Leichhardt, Willoughby and Marrickville. So have major community organisations such as RSL and sports clubs.

Schematic view of the trigeneration plant on the roof top of Town Hall House
Micro-turbines have been used in a wide range of settings, both overseas and Australia. This includes office buildings (e.g. Darling Park) and community facilities (e.g. Leichhardt Pool). Reliability and durability is demonstrated by their use to provide power in remote settings such as gas fields and military settings.

**Project development**

In 2013, Council endorsed a revised strategy for delivery of decentralised energy across the City area.

A key element of the revised strategy was delivery of trigeneration at some of the City’s own facilities, including Town Hall House and Sydney Town Hall.

A feasibility study and preliminary business case for trigeneration at Town Hall House was prepared in late 2013.

The study recommended a staged approach which would manage development risks by installing trigeneration in Town Hall House to initially service Town Hall House and Sydney Town Hall (“Stage 1”).

This could potentially be expanded to supply surrounding buildings with thermal energy as part of a small precinct in a second stage, when demand for thermal energy from these buildings is established.

Key requirements for the project included the following:

- The trigeneration facility should fully and reliably meet electrical requirements of Town Hall House and Sydney Town Hall during plant operating hours;
- The trigeneration facility should include capacity for export of electricity to other premises via the Ausgrid distribution network; and
- A single supplier should be responsible for all works and services associated with the design/construction and operation/maintenance for up to 10 years.

By installing a trigeneration plant, the City would own infrastructure which improves the efficiency of its buildings; in contrast, were carbon abatement funds to be allocated to the purchase of GreenPower, Council would not benefit from these efficiency improvements.

The City sought expressions of interest from organisations capable of design, build operate and maintain services for both Stage 1 and Stage 2.

The EOI process confirmed that the market could offer the technical and commercial capabilities and relevant experience to provide competitive design, construct, operate and maintain services for the project.

Council accordingly approved proceeding to Request for Tenders (RFT) to design, construct, operate and maintain Stage 1 of the Town Hall trigeneration project.
Consideration of options

A range of options were considered in the development of the trigeneration project.

These include both the use of energy from renewable sources, and the use of other low carbon technologies. Some use is already made of renewable energy from solar PV at Sydney Town Hall and Town Hall House, through the installation of a significant array of roof top solar panels.

For the purpose of this project, however, the use of energy from on-site renewable sources is not seen as suitable, as the absolute quantity and reliability of on-site wind and solar PV generation would be insufficient to fully and reliably meet the electrical and thermal energy needs of Town Hall House and Sydney Town Hall.

It is noted that this situation is typical of high rise office development and other intensive development in CBD settings, hence the importance of this project in demonstrating that suitable low-carbon solutions are available.

As to low-carbon electricity and thermal energy generation, a number of technologies have been considered, including fuel cells, reciprocating engines and micro-turbines.

The technical feasibility study established that a solution would be achievable at reasonable cost in a way that would meet regulatory and other requirements. This technology would be suitable either as part of a building-based project (primarily to meet the energy needs of Town Hall House and Sydney Town Hall) or as part of a small thermal precinct (exporting electrical energy and supplying thermal energy to third party buildings).

For the purpose of market testing (EOI) and receiving firm offers (tender), a performance based approach was adopted, leaving the selection of proposed technology to suppliers and incorporating appropriate technical due diligence to ensure that supplier proposals met performance requirements (which include such factors as reliability and durability and environmental acceptability as well as technical performance).

In the event, the preferred solution incorporates micro-turbine technology rather than reciprocating engines. The suitability of this solution was confirmed by independent engineering advice.

Identification of preferred option

The following steps were involved in identifying a preferred option for the project:

- Preliminary consideration of a range of options based on a range of strategic and technical characteristics
- Review of preliminary options and more detailed investigation of a preferred two-stage option that allows for optimisation of technical/commercial viability over time and increased scale of carbon abatement over time
• Development of a revised financial model

• Detailed financial modelling of a potential two-stage option.
  
  o Stage 1 - Town Hall/Town Hall House with Electricity Export
  o Stage 1&2 – Small Precinct with Electricity and Chilled Water Export
  o Technical and commercial assumptions for the financial model for Stage 1 and for Stage 1&2 are listed in the Preliminary Business Case.

**Diagram: Two-stage option considered in the Preliminary Business Case**

- Initial testing of the supplier market via EOI

- Commercial negotiations as to likely short-term third-party thermal demand

- Determination of Stage 1 (only) as the preferred option, after taking into account the outcome of commercial negotiations with third parties

- The scope of the project is now limited to the building-based project and this has been reflected in the tender process.

- Finally, selection of a preferred supplier via select tender and optimisation of the operational model to reflect the technical solution proposed by the preferred supplier

The revised scope is summarised in the diagram on the next page.
Project sizing and specification

Town Hall House (THH) is located in Sydney’s Central Business District (CBD) with frontages to Kent Street (west) and Druitt Street (north).

The site also has a frontage to an open plaza linked to George Street.

The building has:
- Four levels of basement parking;
- Level 1 and 2 entrance foyer;
- 8 levels of low rise office floors;
- A mid-level plant room;
- 13 floors of high rise office floors;
- A roof plant room (level 24);
- A lift motor room (level 25);
- A cooling tower plant room (level 26), now only occupied by water tanks.

The City occupies most of these levels, providing accommodation for approximately 1,000 staff and contractors, with the balance of the building being commercially leased.
Sydney Town Hall (STH) is located at 483 George Street and is a landmark sandstone building located in the heart of Sydney. It is listed on the Register of National Estate and State Heritage Register.

The building has:

- A basement floor, which is connected to the loading dock of THH;
- Lower ground floor, which is connected to level 2 of THH;
- Mezzanine floor;
- Ground floor, which is connected to level 4 of THH;
- First floor, which is connected to level 6 of THH;
- Second floor;
- Upper roof

THH & STH are both supplied from a main switchboard (MSB) located within Town Hall House.

The seasonal average electrical load profile of the site prior to the commencement of the project is shown on the next page:
Below are the electrical load duration curves of the site:

Figure 1 Site Electrical Load Working Weekday Averaged Profile July 2012 - June 2013

Figure 2 Site Electrical Load Duration Curve July 2012 - June 2013 (Working Hours)
Below is the hourly profile within one year period:

![Hourly Load Profile](image)

**Figure 3 THH/STH Hourly Load Profile (July 2012 – June 2013)**

Site cooling requirements are supplied through electric chillers located in mid-level plant room of THH and chilled water pipe reticulation. When the main chillers are not operating, STH cooling demand is serviced from a 129kW electric chiller located within STH. THH data centre also has additional air cooled chillers which operate when the main chillers are not operating.

The seasonal load profile of the main chillers in the mid-level plant room is:

![Seasonal Load Profile](image)

**Figure 4 Site Cooling Load Working Weekday Averaged Profile July 2012 - June 2013**
Below is the chilling load duration curve of the main chillers:

![Chilling Load Duration Curve](image)

**Figure 5 Site Cooling Load Duration Curve (Working Hours)**

The heating requirement of Town Hall House and Sydney Town Hall is via gas boilers and hot water pipe reticulation based in the boiler room, located on roof plant room level (level 24) of THH. Existing natural gas service to THH is supplied from Jemena secondary natural gas mains located in Kent Street.

The monthly gas consumption profile of Town Hall House and Sydney Town Hall prior to commencement of the project is shown below:

![Monthly Gas Consumption](image)

**Figure 6 THH + STH Natural gas consumption July 2012 to June 2013**
**Technical solution**

The works that are part of the technical solution include:

- supply and installation of absorption chiller, cooling towers, heat exchangers as well as associated pumps, valves, fittings, instrumentation and pipework
- integration of the trigeneration facility into existing mechanical / HVAC system
- installation of thermal energy meters to enable monitoring and verification
- allowance for future installation of additional Combined Heat & Power (CHP) plant and an additional absorption chiller
- supply and installation of new main switchboards and distribution boards for integration of the trigeneration facility to the existing electrical system of the building, as well as associated cables, fire rated enclosures, electrical protection, control and earthing systems
- replacement of the Town Hall House main switchboard (MSB) and relocate to a new switchboard room and consolidation of all building load under a single revenue meter
- establishment of a new main switch room in the basement of Town Hall House to accommodate the replaced MSB and associated electrical equipment
- upgrade of the existing cooling tower plant room
- new internal service risers shall be established for new cables and pipes associated with the trigeneration plant
- equipment hoists as necessary to facilitate plant maintenance, as well as establishment of acoustic and vibration attenuation/isolation
- upgrade of existing fire protection services to serve all new rooms proposed including but not limited to provision of smoke detectors, sprinklers, emergency warning, signage and fire extinguishers
- Ausgrid substation works as required.

**Essential operational and performance requirements**

Key operational requirements include the following:

- fully meet site electricity demand, taking into account displacement of electric chiller load
- produce/supply sufficient chilled water from absorption chillers to meet a specified percentage of annual cooling load
- ensure maximum demand for electricity from grid does not exceed 600kW during network peak hours for more than 0.5% annually
- be able to operate at 45% of total nameplate capacity during periods of low electrical or thermal demand without noticeable reduction in electrical or thermal efficiency
- meet vibration, noise and air quality standards
- be suitable for connection to Ausgrid’s electricity distribution network
- integrate with existing site hot water system and chilled water systems in such a way that produced thermal energy is prioritised to displace heating demand first,
before use to displace electric chillers via absorption chillers. Use of chilled water from absorption chillers must take priority over chilled water from the existing electric chilling plant.

- be able to operate in electricity load following mode as well as maximising exports of electricity to the grid.

Key performance specifications are summarised below:

<table>
<thead>
<tr>
<th>Category</th>
<th>As supplied</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical generation capacity</td>
<td>1267 kW – electrical</td>
<td>Provided via 7 micro-turbines, each with a net effective maximum generation of 181 kW (total 1257 kW)</td>
</tr>
<tr>
<td>Refrigeration capacity (absorption chillers)</td>
<td>1200 kW – refrigeration</td>
<td>Provided via 2 absorption chillers with a maximum output of 600 kW</td>
</tr>
<tr>
<td>Design life</td>
<td>At least 30 years</td>
<td>Fixed cost cycle covers first 10 years. Major refurbishment occurs each 10 years or after 40,000 operating hours</td>
</tr>
<tr>
<td>Annual net electrical energy generation during operating hours</td>
<td>Capacity to generate 4000 MWh (max export) Specified by the City to generate 2800 MWh (load following mode)</td>
<td>Generated electricity (inclusive of any export to grid) is net of parasitic load</td>
</tr>
<tr>
<td>Plant operating hours</td>
<td>7 am to 10 pm</td>
<td>Working week days</td>
</tr>
</tbody>
</table>

**Operating regime**

The mode of operation that is initially being adopted is the load following mode, and the recommended hours of operation are the standard peak and shoulder hours for large commercial consumers in the Ausgrid electricity network i.e. 7 am to 10 am local time on working week days.

This means that (as closely as practicable given fluctuation in instantaneous loads) the level at which generation occurs will be the same as the electricity demand of the building (base load and tenant load combined), taking into account the reduction in electrical demand due to the use of thermal energy (waste heat) to run absorption chillers.

The reduction in average electrical load is close to 150 kW (electrical) i.e. nearly 20 pc of the average electrical demand prior to installation of the trigeneration plant (the load prior to trigeneration averaged about 870 kW during proposed hours of operation).

In practical terms, a small amount of electricity exports will occur. Based on the site energy demand characteristics and taking into account prevailing costs of electricity
and gas, it is planned to export around 5 per cent of the average generation in the short term. This decision will be reviewed periodically.

This mode of operation optimises the balance between:

- primary energy savings (through more efficient use of primary energy inputs such as natural gas and coal)
- carbon abatement (which increases in almost linear fashion up to the point where the building’s own electricity needs are met, after which it increases only slowly, owing to the choice of generation technology i.e. micro-turbines)
- unit cost of abatement, which is a function of both fixed costs (upfront capital and ongoing operational) and variable costs/savings (gas consumed, electricity avoided).

The operational efficiency of the proposed micro turbine solution remains relatively constant and near peak efficiency throughout the entire load range.

As the electrical demand drops, individual turbine modules will be cycled off, leaving the remaining turbines to operate at their peak efficiency.

The use of multiple absorption chillers, cooling towers and variable speed drives on all water systems and cooling towers will enable the production of chilled water and/or heat rejection into the existing HHW loop based on load following operation, with no adverse impact on the maintenance requirements of the equipment.
Demonstration and communications activities

This project includes the following demonstration activities:

- The project demonstrates the benefits of sharing local energy between buildings

  The chosen solution meets the requirements of proximity (sharing of energy between buildings requires electricity generation to take place close to where it is used) and direct additionality (the level of low-carbon and renewable generation should be increased, which is not achieved through purchase of GreenPower or carbon offsets.)

- The project provides a business model for on-site generation that is attuned to the changing environment for low carbon initiatives and ensures effective mitigation of risk

  The chosen solution is low-impact in terms of noise and air pollution, well suited to retrofits as well as new builds and minimises technical challenges involved in connecting on-site generation to existing CBD electricity grids.

  The design/construct contract has been linked to performance-based operate/maintain contract for up to 10 years to ensure that operating results meet expectations.

  Equipment has been modelled to run in the most cost efficient manner throughout business hours, and high operating reliability has been embedded in the tender selection criteria

The project includes the following communication activities:

- Targeted engagement during the course of the project with key groupings such as the energy efficiency sector, the commercial property sector, internal stakeholders, neighbouring building, study tours visiting the City and international organisations that have an interest in urban carbon abatement

- Publicly directed information via council reports, periodic media briefings, inclusion in the City’s green report and other ongoing community activities

  Observed feedback from the communication activities is generally positive and testament to the growing motivation amongst stakeholders to achieve the benefits as mentioned above within their respective portfolios.

Demonstration and communication activities will continue after the completion of the capital works through public announcements (e.g. media alerts), material on websites and other media aimed to reach as wide an audience as possible. Efforts will be
made to use the project as a vehicle for educating all socio-economic groups on the need for and benefits of energy efficiency and the type of technologies to achieve this (described in a manner appropriate to the audience).

One possibility being pursued is the use of interactive touchscreens. The public information counter for Town Hall House is on Level 2 of the building. The foyer also contains the City’s three dimensional city wide model. People from all walks of life can come to this foyer for information and advice. Subject to resolving technical issues, it may provide a good site for an interactive touchscreen that people can use to gain information about the trigeneration scheme and other low carbon power generation systems, as well as the City’s renewable energy installations (for example the photovoltaic installation on the roof of the Sydney Town Hall).

More detailed information on the project and its learnings will be disseminated via professional development events, conferences and the like.
Project issues and learnings

Successful completion of this project demonstrates that it is feasible to deliver substantial energy efficiency improvements and to make substantial reductions in green house carbon emissions in a large commercial building in a congested metropolitan centre. Achieving the expected project outcomes depends on paying sufficient regard to a number of factors, each of which is discussed below.

Resolving electrical network connection issues

One of the major risks for a cogeneration or trigeneration project revolves around the issue of obtaining a grid connection agreement to enable local power generation. Such an agreement is needed whether power is exported to the grid or not. In the case of the current project the process of gaining a grid connection agreement started in December 2013. A formal application was lodged in August 2015 and a connection offer was made and accepted in June 2016 just before the project was due for completion.

Consultants in this field typically advise that at least one year should be allocated to the task of obtaining a connection agreement. Due to this length of time project design and construction runs in parallel with the connection process and that was the case with this project.

This process creates two major risks. The first is that the project may be ready for commissioning, but cannot proceed because the connection agreement has not been resolved. The second risk is that the project scope needs to change significantly to accommodate the conditions of connection. The business case and plant control strategy may be predicated on, for example, a certain level of power export which is not permitted in the final connection agreement. In the worst, but less likely case, the trigeneration project scale or technology may not be compatible with the network utility’s requirements.

Network utilities handle applications for connection within what is effectively a regulatory framework. They carefully follow the required process, but are also constrained by it. There is potential to improve the framework to reduce risks to trigeneration project proponents without transferring risk to the network utility and/or other network customers. The City of Sydney would like to put forward some matters for consideration, while acknowledging that the City is not privy to all the relevant matters that would need to be considered when looking at changes to process and that ultimate responsibility for managing the electricity network rest with the utility.

One of the challenges with the present process is that effective information exchange between the project proponent and the network utility does not start until a connection application is lodged. The application, understandably needs to contain detailed information about the specifications and performance characteristics of the
proposed power generation plant. That means key project decisions and investment in design need to be made without a good understanding of the network utilities likely requirements. This crate risk which could be avoided, if for example the network utility adopted a resource allocation or planning model.

In water management for example, discharges to waterways and abstraction of water from rivers and streams is usually guided by planning framework. Similarly property developers are guided before they lodge their development applications by the local authority’s policies and plans such as the Local Environment Plan. Network utilities could similarly produce network capacity plans based around zoning or substation/other network nodes that describe such matters as: the ability of various parts of the network to accommodate and wheel power exported from local generation; the presence or other wise of power quality issues in various parts of the network; any geographic variation in protection requirements; and base or starting point connection requirements for different power generation technologies.

These capacity plans could also identify areas on the network where suitable local generation could support the network by reducing peak demand on lines reaching capacity or ameliorate localised power quality issues. The networks in the course of their normal condition assessments and capital works programing have this type of information and it would be a matter of collating it and making it accessible to potential trigeneration, cogeneration photovoltaic and battery storage proponents. With a planning framework, connection applications could be lodged with less risk to trigeneration proponents around outcome. Both parties would also have a better idea of the information required to accompany applications and the network utility would have a head start on assessing applications because it had already reworked capacity information in anticipation of connection applications.

These improvements would address another major issue for project proponents, namely not knowing in advance what detailed information the network utility requires. Failures in this area under the current process can lead to the application processing stretching out over very long periods of time – six and up nine months or more. Currently if the network utility decides more information is needed then the clock for the normal turnaround can be restarted. Several iterations of this process leads to extended processing times.

Time extensions should really only relate to the time required to process the new information. With greater transparency up front, as suggested above, consideration should be given to setting an absolute timeframe for resolution, such as 120 days. This in turn leads to a further issue, namely the ability of the network utility to resource the application process both in terms of absolute staff time and expertise.

The risks associated with large cogeneration and trigeneration projects can, in some cases, create a willingness to pay on the part of the project proponent for measures to expedite the process. This might be the case where a costly project involved novel technologies or evoked complex technical issues and is evident that it would
normally take quite a while to work through these matters. One useful mitigation measure might be tapping into extra technical resources.

Expertise in high voltage matters and network matters does not solely reside in the network utilities, but can be found in consulting firms and universities (inter alia). It should be possibly for the project proponent and the network utility to recognise the need for and mutually agree to engage independent consulting services on a cost sharing basis. Presently it is fair to say that bringing in outside assistance is problematic.

Finally taking the planning analogy to its conclusion, a case could possibly be made for having an appeals process (other than through the courts) should the project proponent believe that connection requirement are onerous or unnecessary. The City of Sydney’s experience indicates that this would not be necessary if steps were taken to provide more information up front and modify the process to one that is a bit more collaborative with the possibility of using outside expertise.

**A comprehensive approach to investigation and to risk management**

Initial concept development was followed up by comprehensive investigation of both technical and commercial considerations prior to commencing project delivery.

Technical issues considered included a detailed study of existing building energy loads, both electrical and thermal. Engineering issues such as plant siting were also investigated. In terms of the proposed technical solution, a range of options were considered and there was detailed consultation with utility services (electricity, gas).

Commercial issues covered focused on the procurement model and the operating strategy.

Based on the technical and commercial investigations, the City was able to develop a comprehensive listing of project risks and to develop a mitigation strategy that addressed each listed risk.

This lead to the development of a risk allocation table that specified the breakdown of risks between the City and the project deliverer (supplier), which was incorporated into the procurement process.

**Effective engagement and communication**

Three features of the engagement and communication activities associated with this project deserve mention.

The first feature is the need to maintain transparency and accountability. In the case of this project, that meant regular and comprehensive reports and briefings to Council, from the time that the project was conceived until the time that the project was delivered.
The second feature is the need to engage with potential suppliers and with the energy efficiency sector generally. The Local Government Act provides a firm discipline as to how local councils can manage procurement of works and services.

Within the discipline imposed by the Act, however, it was still essential to understand both what was technically feasible and what was the appetite for risk amongst contractors in the energy efficiency sector. Through a management process of supplier engagement, the City was able to establish that it was likely to be able to retain suppliers on terms acceptable to the City (and duly did so).

The third feature is the need to engage regularly with stakeholders in the immediate proximity of the project, including building service providers for the civic complex, building occupants, and service providers and occupants of adjacent buildings.

Weekly meetings were held with key stakeholders and periodic updates were provided to building occupants and managers of adjacent buildings. There was also a publicly advertised and exhibited approval process for the trigeneration plant.

**Skills, capacities and time**

Successful implementation of this project required a mix of both in-house and external (consultancy) technical, commercial and project management skills.

Assembling the right combination of skills (through staff recruitment and through consultancy engagement) took time, and ensuring that both technical and commercial investigations were completed competently and thoroughly took time.

Additionally, sufficient time needed to be allowed in the project timetable for stakeholder engagement and for preparation of reports and briefings to Council.

While smaller-scale energy efficiency projects can typically be carried within a window of 12 months to two years, the time from conception of the project to its completion was closer to four years. Of course, the scale of the eventual outcome is correspondingly greater.

The point is, to accommodate projects like this, a grant program must be able to accommodate a longer timetable. The willingness of the Commonwealth to lend support to such a longer term project is certainly appreciated.

Finally, successful delivery of the project was dependent on engaging a capable and competent head contractor with substantial financial capacity and prior experience with trigeneration in large commercial buildings. AE Smith fitted this bill well.

For this particular project, the contractor needed to be not just competent, they needed to be somewhat ingenious and very capable problem solvers. Delivering over
100 tonnes of plant and materials to the rooftop of a more-than-20 storey building in the middle of a busy CBD requires both.

**The courage to innovate, the willingness to adapt**

This project was conceived and executed because of the City’s vision for a low-carbon decentralised energy future. Achieving this vision requires a great deal of tenacity and a strong dose of innovation.

At the same time, the initial conception for this project was somewhat different (and on a different scale) to the eventual outcome. Initially it was thought that a single large reciprocating engine generator set would meet project objectives. Further consideration of a number of factors such as environmental impacts (e.g. noise), structural issues (roof capacity) and electrical network connection considerations (power quality) indicated that a micro-turbines would be a better solution in this case.

Without a degree of flexibility, it may be difficult to achieve a successful outcome within the available time frame.

The business case process was essential to define what could be achieved on a value for money basis at an acceptable level of risk.

As constraints in the operating environment were incorporated into the project, so the business case process was revised and reviewed. In this way, the City was able to adjust its expectations while ensuring that the essential requirements of the project were adhered to.

It is the willingness to adapt in a disciplined and structured manner while staying true to the essential vision that has allowed such a successful outcome to be achieved.

**A trigeneration project is an electrical as well as a mechanical project**

The head contractor for trigeneration or cogeneration projects often has a background in mechanical services such as HVAC. One of the lessons learned is that trigeneration projects require as much focus on the electrical aspects as the mechanical/HVAC aspects. The electrical skills needed extend beyond just the ability to deal with low voltage work. Having an understanding of the local electricity network and its associated issues and processes is also crucial to the success of these types of projects.

The head contractor may try to cover both mechanical and electrical disciplines through use of suitably qualified sub-contractors, but the City’s experience is that it would be advantageous for the head contractor to have strong in-house expertise in the electrical discipline as well as mechanical services.

Procuring a head contractor who possesses strong knowledge of both disciplines in-house is considered important.
Early engagement vs confirmation of technology

Integration of trigeneration plant to the electricity distribution network requires agreement from the power utility and involves a complicated process, which often become the critical path of the project.

On the other hand, having certainty of the technology selection and detailed technical data and specification of the system is as crucial to ensure smooth connection agreement process between the parties involved.

It is important to strike the balance on these two conflicting elements for successful project delivery.
Outcomes and benefits

**Energy efficiency outcomes and benefits**

The Town Hall Trigeneration Project has achieved the anticipated outcomes:

- **It provides a reliable and secure local supply of electrical and thermal energy to Town Hall House and Sydney Town Hall**

  The recommended solution fully meets the projected business hours electric and thermal energy (heating hot water, chilled water) for Town Hall House and Sydney Town Hall on a reliable and energy-efficient basis.

- **It achieves a range of objectives, including reducing future energy bills at least overall project cost**

  The project had multiple objectives, principally energy efficiency, peak demand reduction and carbon abatement, rather than just a single financial objective. The project was, designed and its construction managed, however, to minimise costs and maximise all benefits including a reduction in future energy costs.

  Over the project lifetime, the annual reduction in energy-related operating costs for Town Hall House and Sydney Town Hall is projected to average around $150,000 to $200,000. The net present value of the project is estimated to be a cost of between $1.9 and $2.6 million (depending mainly on the future trajectory of energy cost and electricity network charges). As indicated below, this net result represent a good balance of cost-benefits.

- **It achieves a significant level of carbon abatement at a unit cost that is competitive with other technologies**

  Over the project lifetime, which is forecast as 30 years, the amount of carbon abatement is calculated at more than 42,000 tonnes equal to 1400 tonnes per year.

  Annual abatement equates to 2.7 per cent of the City’s baseline emissions for 2030 (note that 2030 baseline emissions are higher than current emissions, on account of growth in population and business activity).

  The unit cost range for abatement is expected to be competitive with the City’s benchmark cost of abatement i.e. the cost of voluntary GreenPower.

  The cost of voluntary GreenPower fluctuates from time to time, but at the time of project completion was in a band of $50 - $90 per tonne of carbon abated.
The control panel for the trigeneration facility maintains a record of electricity generated.

- It has acted as a driver for further energy efficiency initiatives in Town Hall House and across the rest of the City’s building portfolio

The project brought an energy efficiency focus to the existing energy services in Town Hall House; water heating and chilling for HVAC and the electrical reticulation. Opportunities to rationalise the electrical reticulation, to improve the operation of the chillers and to increase the level of metering and monitoring have been recognised and are being actioned.

The successful implementation of this project has demonstrated the benefits of local power generation to the City. There may be one or two opportunities in the future for further trigeneration projects, but meanwhile focus has turned to opportunities for a closely related technology - cogeneration. The City intends to install a cogeneration unit in its new Gunyama Park Aquatic and Recreation Centre. The Council will shortly consider tenders for a cogeneration unit installation at the Ian Thorpe Aquatic Centre, while a cogeneration unit installation is being investigated as part of a wider upgrade of heating services at the Cook and Phillip Park Aquatic Centre.

As this project current was reaching completion the City embarked on a major energy efficiency project covering its property portfolio. Referred to as the Major Properties Efficiency Project (MPEP) this new project has an allocation of $8.22 million over 5 years. Additional staff resources have been brought on board to assist with project roll-out. The MPEP involves systematic energy audits of properties and take up of the opportunities for improvement that are identified.

**Demonstration and communication outcomes and benefits**
The Town Hall Trigeneration Project has achieved the anticipated outcomes:

- **It demonstrates the benefits of sharing local energy between buildings**

  The chosen solution meets the requirements of proximity (sharing of energy between buildings requires electricity generation to take place close to where it is used) and direct additionality (the level of low-carbon and renewable generation should be increased, which is not achieved through purchase of GreenPower or carbon offsets.)

  Even though the level of energy exports will be lower than originally anticipated, the very fact that electrical energy can be exported to other buildings is essential to the adoption of the load following mode. As has been shown, this allows the greatest amount of carbon abatement to be achieved at an acceptable cost. Adoption of the load-following mode achieves a vast improvement over the level of carbon abatement that can be achieved through base building operation, which many other projects have applied.

- **It provides a business model for on-site generation that is better attuned to an increasingly challenging environment for low carbon initiatives (lower electricity prices, fewer climate change signals) and which ensures effective mitigation of risk**

  The chosen solution is low-impact in terms of noise and air pollution, well suited to retrofits as well as new builds and minimises technical challenges involved in connecting on-site generation to existing CBD electricity grids.

  The City will own the plant, purchase the gas (as it already does for its own buildings) and manage the sale of export electricity.

  Design/construct contract has been linked to performance-based operate/maintain contract for up to 10 years to ensure that operating results meet expectations.

  Equipment has been modelled to run in the most cost efficient manner throughout business hours, and high operating reliability has been embedded in the tender selection criteria.

- **It has increased the level of technical skill and experience in the local building services industry.**

  The building works to accommodate the project, such as the rooftop steel support structure, pump-set frames, acoustic walls, equipment shelters etc., were all fabricated locally. While the turbine gen-sets and the absorption chillers used on the project were necessarily imported, all the plant and equipment was installed and, importantly, commissioned by local companies.

  The head contractor and their electrical subcontractor, in particular, have been able to enhance their mechanical and electrical engineering skills and gain valuable experience in trigeneration technology and retrofitting this to existing
down town high rise buildings. This is important as opportunities exist for other building owners to have trigeneration units installed on their CBD properties.

- It has provided a vehicle for raising awareness of energy efficiency technologies and the way they can be used reduce carbon emissions, reduce the load on energy distribution networks and save future costs.

This matter was elaborate in the earlier section on Demonstration and Communication Activities. Various media will be used to communicate positive and informative messages about the project.
## Project budget

### Summary of project budget

<table>
<thead>
<tr>
<th>Expenditure Items</th>
<th>Department Funding (GST Exc)</th>
<th>Other Contributions (GST Exc)</th>
<th>Total Cost (GST Exc)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finalise plan, design and procurement</strong></td>
<td>$0</td>
<td>$585,000</td>
<td>$585,000</td>
</tr>
<tr>
<td><strong>Develop high level technical specification associated with the Town Hall House trigeneration installation, including supply assessment to Sydney Town Hall, Queen Victoria Building and street lights.</strong></td>
<td>$0</td>
<td>$168,750</td>
<td>$168,750</td>
</tr>
<tr>
<td><strong>Seek Expressions of Interest. Undertake further utility connection studies and pay associated fees for Ausgrid and Jemena connections, prepare detailed technical specifications and tender documents, prepare development application studies, pay lodgement fees and assess heritage impacts, call tenders.</strong></td>
<td>$0</td>
<td>$345,000</td>
<td>$345,000</td>
</tr>
<tr>
<td><strong>Receive tenders, complete engineering and commercial review of submissions, recommend preferred supplier.</strong></td>
<td>$0</td>
<td>$71,250</td>
<td>$71,250</td>
</tr>
<tr>
<td><strong>Purchase</strong></td>
<td>$1,381,900</td>
<td>$4,232,650</td>
<td>$5,614,550</td>
</tr>
<tr>
<td><strong>Contract initiation</strong></td>
<td>$0</td>
<td>$1,338,710</td>
<td>$1,338,710</td>
</tr>
<tr>
<td><strong>Complete purchase of major equipment for the tri-generation system</strong></td>
<td>$1,381,900</td>
<td>$2,893,940</td>
<td>$4,275,840</td>
</tr>
<tr>
<td><strong>Installation and Commissioning</strong></td>
<td>$1,669,800</td>
<td>$5,517,815</td>
<td>$7,187,615</td>
</tr>
<tr>
<td><strong>Complete installation of tri-generation unit for electricity supply to Town Hall House and associated equipment and export of electricity to street lights and other buildings.</strong></td>
<td>$1,391,524</td>
<td>$4,174,571</td>
<td>$5,566,095</td>
</tr>
<tr>
<td><strong>Complete installation of insulated pipework to connect tri-generation unit to Sydney Town Hall</strong></td>
<td>$57,500</td>
<td>$172,500</td>
<td>$230,000</td>
</tr>
<tr>
<td><strong>Complete commissioning and testing of the tri-generation unit as per manufacturer specifications and requirements and provide report to the Department.</strong></td>
<td>$347,880</td>
<td>$1,043,640</td>
<td>$1,391,520</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$3,051,700</td>
<td>$10,335,465</td>
<td>$13,387,165</td>
</tr>
</tbody>
</table>
Key funding information

The total value of the project is over $13 million inclusive of feasibility studies, pre-procurement activities, procurement, approvals, detailed design and technical studies, equipment purchases, delivery to site, installation and commissioning, associated building works and building services upgrades, project management and in-house supervision.

Some unexpected costs were encountered during the project. It emerged that the system would benefit from some additional metering and monitoring. It was anticipated from the outset that the operation of the trigeneration unit needed to be integrated with the existing set of three chillers. As chiller operation was further investigated, it became apparent that a condenser water bypass should be installed on the existing chiller system. This was to enable the chillers to operate over a wider range of conditions and thus work better with the new trigeneration absorption chiller. Unexpected costs were dealt within the project contingency.

The direct capital cost is inclusive of the cost of associated building service upgrades, primarily, replacing the main electrical switchboard.

The contract awarded to the main contractor comprises both the cost of capital works and an additional cost to operate/maintain costs over the first 10 years of the project operating life.

Costs of major overhauls by the original manufacturer have been ascertained as part of the tender process.

A single supplier is responsible for all works and services associated with the design/construction and operation/maintenance of the trigeneration facility.

Substantial energy-related operational savings are expected over the project lifetime.

The City entered into a funding agreement with the Australian Government under the Community Energy Efficiency Program (CEEP).

The funding agreement contains targets relating to energy efficiency and a number of delivery milestones.

The maximum value of the grant (as per finalised project objectives and outcomes) is $3,051,700
Project processes, mechanisms and operation

Procurement model and market testing

Three high-level procurement options were considered:

- **Multi-stage (separate design, construct and operate/maintain) option**
  - Several separate sequential stages
- **Single-stage (design/build/operate/maintain) option**
  - Single-stage supplier selection process
  - Costing based on preliminary information/concept design only
- **Single-stage (energy service company) option**
  - Design/Build/Long-term O&M/Long-term energy supply

A high level analysis was carried on these three options. As well as the balance of risk, ability to deliver the project within a reasonable time frame was taken into account.

Multi-stage (separate design, construct, operate/maintain)

The multi-stage (separate contracts) procurement option carries the following risks:

- **High integration risk**
  - City is exposed to the risks of integrating services provided by various contractors

- **Less control over construction costs**
  - Driven by design spec, not performance outcome

- **Less control over O&M costs**
  - Driven by design outcome, not performance outcome

- **Likely to take longer to deliver**
  - Multi stage supplier selection takes extra time

- **Higher risk of non-completion**
  - Cost to deliver approved design may prove to be too high

- **Less likely to match results to objectives**
  - Initial analysis may not capture some market options
Design/build/operate/maintain (DBOM)

The design/build/operate/maintain (DBOM) option carries the following benefits and risks:

✔ Better connect is likely between project objectives and project results than is the case for the multi-stage option
  - Driven by performance specs, not technical specs
  - Design/build integrated with O&M

✔ Timely delivery is more likely than for multi-stage option
  - Single supplier selection process

✔️ Some pricing risk applies to both design/build and O&M phases
  - Potential suppliers must base package price on preliminary information

Build – own – operate model (BOO)

✘ Based on previous experience, it was considered that the build own operate model may not deliver good value within an acceptable timeframe.
  - A particular concern about the model is that a substantial price premium may be built in to associated long-term energy off-take contracts.

Supplier assessment

For this project, supplier market assessment was carried out as follows:

- meetings with suppliers hosted by the City in combination with procurement representatives.
  Such meetings have occurred at the request of potential equipment and/or service providers. Procurement representatives participated in these meetings.

- independent assessments from KPMG (City’s commercial advisor) and AECOM (City’s technical advisor) prepared on an arm’s length basis

- conduct of an open market EOI process in between April and May 2014

- conduct of an RFT process in between July and October 2014.

The City called for expressions of interest via a publicly advertised EOI process. Key provisions of the draft contracts included as part of the EOI documentation were an extended defaults liability period and an increased level of public liability and professional indemnity insurance commensurate with the project risks.

The City called for tenders via a select tender process. A request for tender was issued to each of the parties shortlisted via the public EOI process. The tender documentation included the proposed design/construct contract and the proposed operate/maintain services agreement, to be signed by the same party.

Bids were considered according to the following criteria:

- Demonstrated recent experience completing similar projects
• Expertise and capability demonstrated through proposed key personnel, subcontractors and suppliers

• Ability to complete design/construction within required timeframe, demonstrated through proposed program; Design/construct methodology is project specific and addresses key project risks

• Tenderer’s proposal meets performance requirements

• Operate/maintain methodology demonstrates long-term capability to operate and maintain facility; Demonstrated understanding of requirements for major plant overhaul; Demonstrated flexibility to operate in different scenarios

• Environmental management: Provision of certification or in house system

• Quality Assurance: Provision of certification or in house system

• Workplace Health & Safety

• Financial and commercial trading integrity including insurances

Management of commercial and corporate issues

A summary of how the City managed key commercial/corporate issues for this project is set out in the table below:

<table>
<thead>
<tr>
<th>Issue</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL ISSUES</strong></td>
<td></td>
</tr>
<tr>
<td>Sensitivity of changes in operating environment感性于变化在运行环境</td>
<td>Sensitivity of unit cost of abatement to changes in operating environment has been modelled e.g. variations in capital costs, changes in unit gas and electricity prices敏感性于变化在运行环境的单位成本到变化的环境建模例如变化在资本成本，变化在单一气体和电力价格</td>
</tr>
<tr>
<td>Impact on unit cost of abatement影响于单一成本的单位</td>
<td></td>
</tr>
<tr>
<td>Performance Assurance that the project as constructed operates in a manner consistent with project objectives性能保证项目作为建设操作在与项目目标一致的模式下</td>
<td>Design/construct contract has been linked to performance-based operate/maintain contract for up to 10 years to ensure that operating results meet expectations.设计/建设合同与性能为基础的运行/维修合同已连接到长达10年的期间以确保操作结果符合期望。</td>
</tr>
<tr>
<td>Grant funding Level of grant received meets City’s expectation赠款水平与收入缴纳到市的期望一致</td>
<td>There will be proactive project governance for the selected option. Negotiation with Commonwealth as/when any changes that affect project outcomes are identified.将有主动的项目治理对于所选的选项。与联邦政府谈判当任何影响项目结果的变化被识别时。</td>
</tr>
<tr>
<td><strong>COST ISSUES</strong></td>
<td></td>
</tr>
<tr>
<td>Capital cost estimate</td>
<td>Fixed price for capital works and ongoing operation have been obtained via tender process.</td>
</tr>
<tr>
<td>Quantum and variance</td>
<td></td>
</tr>
<tr>
<td>Delivery within budget Competitiveness of market offers</td>
<td>The City has sought and obtained a firm price via tender process for project delivery that includes linked performance based contracts for design/ build and operate/maintain.市已寻求并获得一个通过招标过程为项目交付的固定价格包括与设计/建设及运行/维护相关的性能基线合同。</td>
</tr>
<tr>
<td>Operating costs Adverse impact of relatively small scale,</td>
<td>Equipment will operate in most efficient mode (load following) and at time when highest cost of supply from grid applies (business hours)设备将运行在最有效模式（负荷跟随）和在时间当最高成本的供应从电网申请（工作小时）</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
costly operating mode and/or unreliable equipment

<table>
<thead>
<tr>
<th>High operating reliability was specified in tender criteria Supplier performance responsibility is embedded in the operate/maintain contract linked to the design/build contract</th>
</tr>
</thead>
</table>
| Switchboard upgrade Switchboard upgrade costs more than expected
| Cost of replacement has been established via tender process |
| Continuity of operation Constructor/operator financial failure
| The City will own the plant, purchase the gas (as it already does for its own buildings) and manage the sale of export electricity. This obviates the risk of non-supply that might occur due to third party owner/operator experiencing trading difficulties. |
| Future gas and electricity prices Reliability of forecasts
| The City purchases the gas required or generation (the main operating cost) as it does for other City buildings and facilities. The business case is based on up to date forecasts for wholesale electricity and gas from energy pricing specialist ACIL Allen |

**REVENUE ISSUES**

| Electricity sales Value of export electricity
| Electricity sales are minimal and can be dealt with by way of sales to wholesale market or via energy buy back |

**CORPORATE ISSUES**

| Liability Liability arising from export electricity sales
| Liability is avoided by limiting electricity sales to wholesale market or energy buyback pending more flexible local energy retail |
| Reputation Non-performance, poor performance, interruption to on-site supply
| High-reliability equipment and a reputable operator will be selected The City will retain ownership of equipment and systems Ongoing connection will be maintained to the electricity grid |

**Contracted works and services**

The main works and services required up to start of commercial operation were:
- Project Design
- Generator & emission treatment works
- Cooling and mechanical works
- Ausgrid substation upgrade
- Electrical works
- Network connection – electricity
- Hydraulics/gas
- Building upgrades and Modifications (THH)
- Environmental approvals modifications (if required)
- Development approval modifications (if required)
- Utility approvals
- Cranage and scaffolding
- Plant commissioning

The major services required subsequent to start of commercial operation were:
- Ongoing operation (5 years + 5 years)
- Ongoing testing/maintenance (5 years + 5 years)
- Handover at end of operate/maintain agreement

**Risk allocation**

A comprehensive risk allocation table was developed for the project and included in the tender documentation.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Description</th>
<th>Allocation</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership of plant and equipment</td>
<td>Take owner's responsibility for trigeneration plant</td>
<td>City</td>
<td>Always</td>
</tr>
<tr>
<td>Planning approval (Part 4, EP&amp;A Act)</td>
<td>Obtain development consent for operation of trigeneration system at Town Hall House</td>
<td>City</td>
<td>Until consent is granted</td>
</tr>
<tr>
<td>Modification of planning approvals</td>
<td>Modify approvals for trigeneration system or building façade works</td>
<td>Supplier</td>
<td>From award of tender</td>
</tr>
<tr>
<td>Obtain Ausgrid connection offer</td>
<td>Obtain offer to connect embedded generator to Ausgrid network and obtain Design Information Package detailing Ausgrid connection requirements</td>
<td>City</td>
<td>Up to award of tender</td>
</tr>
<tr>
<td>Modify Ausgrid connection offer</td>
<td>Obtain modifications to connection offer necessary to accommodate the tenderer’s proposal, including cost variation and change to design requirements</td>
<td>Supplier</td>
<td>From award of tender</td>
</tr>
<tr>
<td>Obtain Jemena connection upgrade offer</td>
<td>Obtain offer to upgrade connection to gas network, including cost of upgraded connection and technical requirements</td>
<td>City</td>
<td>Up to award of tender</td>
</tr>
<tr>
<td>Modify Jemena connection upgrade offer</td>
<td>Obtain modifications to connection offer necessary to accommodate supplier’s proposal, including cost variation and change to design requirements</td>
<td>Supplier</td>
<td>From award of tender</td>
</tr>
<tr>
<td>Off-take of electricity</td>
<td>Negotiate agreement between City of Sydney and electricity retailer to purchase electrical energy exports</td>
<td>City</td>
<td>Always</td>
</tr>
<tr>
<td>Purchase of grid electricity</td>
<td>Negotiate agreement between City of Sydney and electricity retailer to purchase electricity outside business hours and for supply to other Council premises</td>
<td>City</td>
<td>Always</td>
</tr>
<tr>
<td>Activity Description</td>
<td>Responsibility</td>
<td>Timeframes</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>-----------------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td>Purchase of gas, and gas price</td>
<td>City</td>
<td>Always</td>
<td></td>
</tr>
<tr>
<td>Regulatory change</td>
<td>Supplier</td>
<td>Always</td>
<td></td>
</tr>
<tr>
<td>Regulatory change</td>
<td>City</td>
<td>Always</td>
<td></td>
</tr>
<tr>
<td>Scheduling</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Equipment procurement</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Commissioning of plant</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Operational performance</td>
<td>Supplier</td>
<td>From award of tender</td>
<td></td>
</tr>
<tr>
<td>Environmental compliance</td>
<td>Supplier</td>
<td>Always</td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td>All parties</td>
<td>Always</td>
<td></td>
</tr>
</tbody>
</table>

**Project works delivery timetable**

The tenderer’s proposed timetable is shown under “Projected date”.

This was reviewed by independent engineering advisors, who confirmed that the timetable was achievable.

Actual delivery against timetable is reported under “Achieved date”.

---

*CEEP PROGRAM - TOWN HALL TRIGENERATION PROJECT – FINAL REPORT – PAGE 39*
<table>
<thead>
<tr>
<th>Milestone</th>
<th>Projected Date</th>
<th>Achieved date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tender recommendation considered by Council</td>
<td>December 2014</td>
<td>December 2014</td>
</tr>
<tr>
<td>Selected tenderer executes design/construct contract and operate/maintain agreement</td>
<td>December 2014</td>
<td>March 2015</td>
</tr>
<tr>
<td>Selected tenderer commences design and construction work</td>
<td>January 2015</td>
<td>March 2015</td>
</tr>
<tr>
<td>Major equipment purchase committed</td>
<td>March 2015</td>
<td>March 2015</td>
</tr>
<tr>
<td>All major equipment delivered to site</td>
<td>November 2015</td>
<td>February 2016</td>
</tr>
<tr>
<td>Commissioning/Operation</td>
<td>April 2016</td>
<td>June 2016</td>
</tr>
<tr>
<td>Operate/maintain agreement commences</td>
<td>April 2016</td>
<td>July 2016 (estimate)</td>
</tr>
</tbody>
</table>

**Managing Future Projects**

The model described above provides a step-by-step process and a checklist of parameters for consideration should the City wish to undertake future similar projects. Of the matters under the City’s direct control, a little more attention would be paid in future to making sure existing systems were very well understood when designing a trigeneration or cogeneration retrofit. The operation of the existing HVAC system, the location of all air intakes and exhausts and the exact nature of the existing electrical reticulation all need to understood in detail.

As a result of the project the City has increased its experience with major energy efficiency projects, in house capabilities have improved markedly and the City is better equipped to undertake future similar projects.
Record of construction

Rooftop of Town Hall House in 2015 (looking north) prior to start of construction and installation activities.

Renewal of the roof membrane took place prior to installation of the rooftop plant.
Cranage had to be managed in stages, with progressively larger cranes transported to the roof in component form. This is the second and larger of the rooftop cranes.

Construction of a rooftop platform to spread the weight of the equipment evenly over a number of columns was an essential prerequisite to installation of the plant itself. Due to CBD congestion, it was necessary for delivery of major components to occur at night and on weekends.
The scale of the rooftop crane structure is indicative of the challenges facing the contractor in delivering materials, plant and equipment to the rooftop.

Two banks of micro-turbine sit atop the rooftop platform, awaiting the next stage of the project. After final positioning of the generators, a noise reduction enclosure was constructed and wiring and pipework were installed to link the generators to other elements of the trigeneration facility.
A key part of the overall trigeneration facility is a series of pumps and other ancillary systems to export thermal energy (both as hot water and chilled water) to Town Hall House and Sydney Town Hall.

The installation process attracted considerable interest from City staff and other building occupants and stakeholders.
Conclusions

The Town Hall Trigeneration Project was conceived, investigated, designed and delivered to reduce primary energy usage and abate greenhouse gas emissions in the civic precinct at the heart of the City of Sydney.

As a consequence of this project, a trigeneration facility is in place that fully and reliably meets electrical requirements of Town Hall House and Sydney Town Hall during plant operating hours, and is capable of exporting of electricity to other premises via the public electricity distribution network.

The City has been able to deliver the project on a value for money basis and at appropriate levels of risk. Along the way, it has developed a delivery model that is applicable to other commercial buildings.

The technology provided by the supplier uses micro-turbines coupled to absorption chillers, instead of reciprocating engines. This technology has low emissions, is quieter and has lower vibration levels than reciprocating engines. It has been utilised in Australia and internationally for the past 10 years and is proven technology.

The project shows that substantial energy efficiency improvements and greenhouse gas emissions reductions can be achieved in in a large commercial building in a congested metropolitan centre while day-to-day operations continue.

Success in this project has depended on paying regard to a number of factors:

**Comprehensive investigation and risk management** - Initial concept development was followed up by comprehensive investigation of both technical and commercial considerations prior to commencing project delivery.

**Effective engagement and communication** - Three features of the engagement and communication activities deserve special mention. The first is the need to maintain transparency and accountability. The second is the need to engage with potential suppliers. The third is the need to engage regularly with stakeholders in the immediate proximity of the project.

**Skills, capacities and time** - Successful implementation of this project required a mix of both in-house and external (consultancy) technical, commercial and project management skills. The willingness of the Commonwealth to lend support to such a longer term project is certainly appreciated.

**The courage to innovate, the willingness to adapt** - This project was conceived and executed because of the City’s vision for a low-carbon decentralised energy future. It is the willingness to adapt in a disciplined and structured manner while staying true to the essential vision has allowed a successful outcome.
<table>
<thead>
<tr>
<th><strong>PROJECT TITLE</strong></th>
<th>Town Hall Trigeneration Project</th>
<th><strong>FUNDING RECIPIENT</strong></th>
<th>The Council of the City of Sydney</th>
<th><strong>DATE</strong></th>
<th>23/6/2016</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROJECT ID</strong></td>
<td>CEEP1161</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NAME OF BUILDING, FACILITY OR SITE</strong></td>
<td>Sydney Town Hall/Town Hall House complex</td>
<td><strong>LOCATION (ADDRESS)</strong></td>
<td>456 Kent St, Sydney NSW 2000 and 483 George Street Sydney NSW 2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TYPE OF BUILDING, FACILITY OR SITE</strong></td>
<td>Civic complex comprising major entertainment venue, reception and function rooms, high-rise offices, ancillary retail and underground car parks</td>
<td><strong>ACTIVITY TYPE AND MEASURE</strong></td>
<td>Installation of trigeneration system to supply electricity, heating and cooling to Town Hall House and Sydney Town Hall and to provide export of electricity via public grid to other City premises in the local area</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ENERGY EFFICIENCY ESTIMATE METHOD</strong></td>
<td>Method of measuring energy efficiency improvement is improvement in primary energy use: - expressed as GJ per m2 per year - based on metered gas and electricity supply - amount of primary energy is derived via publicly available energy efficiency/conversion benchmarks</td>
<td><strong>CURRENT ENERGY USAGE</strong></td>
<td>61,500 GJ per year (2012-13 is baseline) (This is equivalent to 61,500,000 MJ per year or 17,083,333 kWh per year)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Baseline Energy Efficiency | 1.75 GJ of primary energy per m² per year  
(This is equivalent to 1750 MJ per m² per year or 486 kWh per m² per year) |
|----------------------------|---------------------------------------------------------------------------------|
| Energy Efficiency Improvement | In terms of energy usage, reduction of up to 12,300 GJ per year (20% of baseline) in total primary energy used  
(This is equivalent to reduction of up to 12,300,000 MJ per year or reduction of up to 3,416,667 kWh per year)  
In terms of energy efficiency, reduction of up to 0.35 GJ per m² per year (20% of baseline) in average primary energy usage  
(This is equivalent to reduction of up to 350 MJ per m² per year or reduction of up to 97.2 kWh per m² per year) |
| Reporting Data (Measuring Energy Efficiency and Additional Data) | Sydney Town Hall  
Total usable area in complex = 35,000 m²  
Historic town hall floor count = 4 public access levels  
Historic town hall construction date = 1867 onwards  
Hours of operation = 7am to midnight, all days  
Usage of civic/entertainment space varies seasonally  
Town Hall House  
High rise tower floor count = 25 (includes 2 basement levels)  
High rise tower construction date = 1977  
Assumed occupancy = 95%  
Hours of operation = 6am to 6pm Monday to Friday |
| Cost of Activity | Estimated cost of activity = $13.4m  
This is full project cost including project management and contingency allowance. Irrespective of the source of funds. It also covers some ancillary work to facilitate the project but which provides extra-project benefits. The figure is not net of the CEEP grant. |
| Estimated Cost Savings | Average $140,000 to $200,000 savings per year over 30 year life of the project. |
DECLARATION

The Authorised Officer of the organisation makes the following declarations:

☐ I declare that I am authorised to submit this Final Report (including any attachments) on behalf of the City of Sydney
☐ I declare that the information provided in this Final Report is true and accurate.
☐ I understand, and acknowledge that giving false or misleading information in this Final Report is an offence under the Criminal Code Act 1995.
☐ I understand that final payment will only be made in accordance with the Funding Agreement including on satisfactory completion of Milestones.

Authorised Officer Signature: ..............................................................

Date: 16/6/2016
Name: KIM WOODBURY
Position: CHIEF OPERATING OFFICER
Organisation: CITY OF SYDNEY

Witness Signature: ..............................................................

Date: 16/6/2016
Name: CHRIS COLLINS
Position: MANAGER, GREEN INFRASTRUCTURE IMPLEMENTATION
Organisation: CITY OF SYDNEY

The use and disclosure of information provided in this Final Report is regulated by the relevant provisions and penalties of the Public Service Act 1999, the Privacy Act 1988, the Freedom of Information Act 1982, the Crimes Act 1914 and the general laws of the Commonwealth of Australia.

Information contained in the Final Report may be disclosed by the Department for purposes such as promoting the program and reporting on its operation and policy development. This information may also be used in answering questions in Parliament and its committees. In addition, the selected project information will be made publicly available. Public announcements may include the name of the grant recipient and of any project partners; title and description of the project and its outcomes; and amount of funding awarded.