BASIX Cogeneration Report

Cogeneration for Residential Apartment Buildings in NSW – Challenges and Opportunities

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PREPARED FOR

NSW Department of Planning

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PREFACE

This report has been commissioned by the NSW Department of Planning.

Currently, in NSW, the Building Sustainability Index (BASIX) policy requires new homes to use up to 40% less potable water and produce 25% less greenhouse emissions than the average home (20% for apartment buildings greater than 6 storey). From 1 July 2006, BASIX requires all new homes in NSW to use up to 40% less potable water and produce up to 40% fewer greenhouse gas emissions than the average home. The BASIX Energy target varies according to building type and location; however, over 80% of all new homes will have to meet the maximum energy targets. The average greenhouse gas reduction for all building types in NSW will be 36%.

Large common area demands such as ventilation and lighting, combined with limited roof space for solar hot water, will mean that developers are likely to investigate cogeneration systems (which generate electricity and make use of the waste heat for applications such as hot water and swimming pool heating) as an economical way to achieve BASIX compliance.

A cogeneration system, acting as a centralised source of hot water and pool heating, is estimated to cost between \$500 - \$3,000 per dwelling for a typical high rise. By reducing per-capita greenhouse emissions by between 10 to 25%, such a system would, alone, score 10 - 25 points in BASIX. In comparison, an energy efficient refrigerator in each apartment is expected to score 8 points in BASIX at a cost of approximately \$1,500 per dwelling.

Whilst cogeneration systems are a proven technology and have been implemented widely in commercial buildings in Australia and in residential applications overseas, cogeneration has not been installed in a residential apartment building in Australia. This report aims to identify barriers and other considerations to the use of cogeneration in residential multi-unit buildings, and options for overcoming these barriers. It should assist in demystifying cogeneration for all stakeholders, but primarily to key stakeholders in the property sector, including property developers, building owners, energy utilities and government. It is expected to assist the Department of Planning's future policy direction regarding residential multi-unit development.

SUMMARY

The simultaneous production and use of electricity and heat, or cogeneration, is well suited to assist in reducing greenhouse gas emissions associated with residential multi-unit buildings in NSW. The use of cogeneration to provide hot water for domestic use and electrical power for use with common area loads is feasible, and is becoming increasingly economic with changes in electricity tariffs.

Cogeneration plant should be sized according to domestic and common area hot water demand rather than electrical load. Using industry guides for hot water usage, the cogeneration plant size, even for very large multi-unit buildings, is likely to be less than 300 kWe.

Any power produced should be used by common area loads. Supplying power to residents is complicated by retail contestability and not recommended at this stage. Export of excess power to the grid is possible but unlikely to be economic. The most economical mode of operation is for power (and hot water) to be produced during peak tariff periods, to offset electricity purchases by the owners corporation during these times. Hot water can be stored for use during periods when the plant is not operating.

Commercial cogeneration packages in the size ranges suitable for multi-unit residential buildings are available, including both reciprocating gas engine and microturbine technologies. There is scope for third-party involvement, such as the use of Energy Services Companies, to manage the installation and operation of cogeneration systems if desired.

Billing for energy services provided by cogeneration, such as domestic hot water and common area electricity use, is complicated because a single fuel, purchased by the owners corporation for example, is being used to provide energy services to both residents and the owners corporation. While an owners corporation might be willing to manage billing, a more feasible solution could involve a third party experienced with meter reading and billing.

While there are clearly a number of challenges to the introduction of cogeneration in multi-unit residential buildings, as there would be with any new technology, none are considered undue, and the industry appears capable of meeting them. A lot of the uncertainty would be removed by a demonstration project that could provide actual figures for installation and running costs for a multi-unit building.

1 Introduction

Cogeneration is the simultaneous production of electrical or mechanical power and useful thermal energy from a single fuel stream such as natural gas, oil and coal. It differs from the generally accepted concept of large-scale power generation in that the heat produced (and normally wasted), is deliberately captured and used, for example, to provide hot water or steam. Cogeneration, also known as Combined Heat and Power or CHP, has been used industrially for many decades, especially where energy costs are high, but is not commonly used in the residential sector.

Cogeneration has a number of attractions, principally that it can be configured to provide very high energy efficiency. This arises because the energy normally lost as waste heat, is utilised in cogeneration. This is illustrated in Figure 1 below.

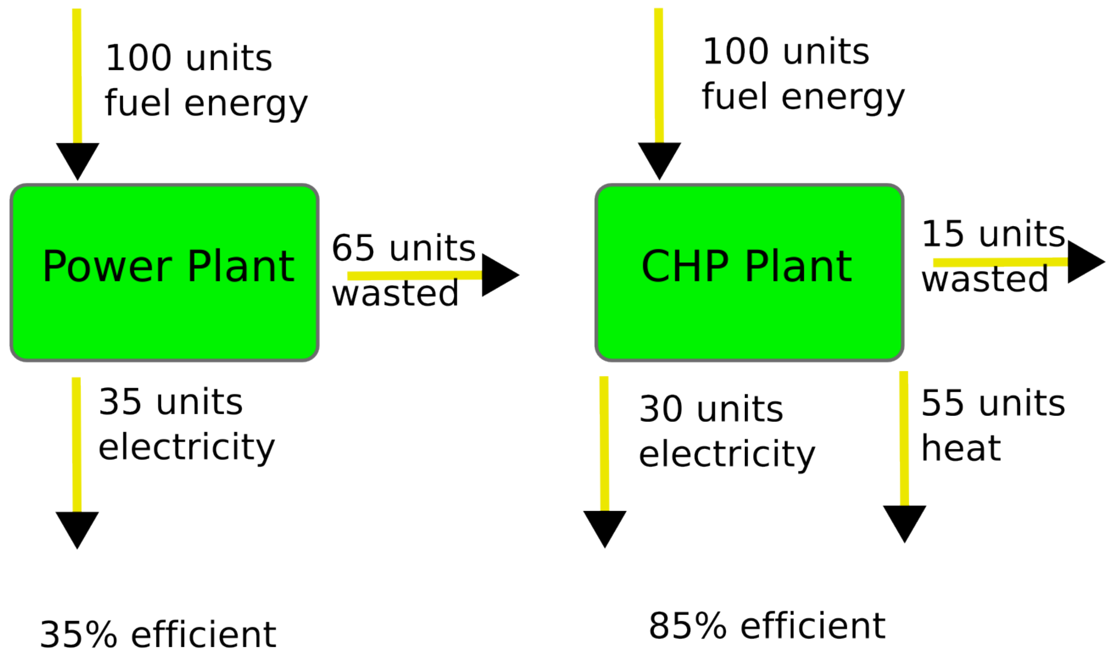

Figure 1: Efficiency of conventional power plant and cogeneration

Cogeneration is often used industrially and commercially where there is a significant demand for heat as well as power, such as in chemical and mineral processing, food processing and hospitals.

Cogeneration plant is typically based on either turbine or reciprocating engine technology, with turbines commonly used at the large end of the scale and reciprocating engines at the smaller end of the scale. Plant size can range from as small as 1 kWe[1] to 100's of MW for a major industrial complex. There is no 'typical' industrial cogeneration installation, as each plant has specific requirements for heat and power, available fuel source, and operating conditions, for example. While many manufacturers provide engines and associated heat recovery equipment, almost every industrial cogeneration plant is purpose built. However at the smaller end of the power scale, it is now possible to purchase standard cogeneration equipment designed to operate over a limited range of electrical and heat output. Turbines are now available in the 30-200 kWe range, and are usually referred to as microturbines.

A cogeneration system usually consists of a reciprocating engine, connected to an electrical generator, with the engine operating at a rotational speed set by the generator design and the electrical frequency of the power system (50 Hertz, or cycles per second, in Australia). This normally means an engine speed of 1500 or 3000 RPM. Microturbines operate at very high speeds (such as 60,000-90,000 RPM) and need a different generator and electrical system. They typically use a permanent magnet generator, which provides very high frequency power that must be converted to 50 Hertz. This is achieved using an inverter.

In general, cogeneration plant is sized to meet either the electrical power demand and/or the heat demand of the host. It is usually not cost-effective to oversize the plant and export electricity, although in some cases it can be economic.

Cogeneration has been used for residential applications in other countries, especially where energy costs are high and in cold climates where heating is needed for a large part of the year. In Australia, cogeneration has not been used for residential purposes, other than in a few trials, principally because it has not been cost effective under Australia's energy tariffs. However with an increasing focus on greenhouse gas emissions and more efficient use of energy infrastructure, cogeneration has much to offer. It can provide power and heat with much lower greenhouse gas emissions than using centralised (coal-fired) power generation, but it comes with extra needs and requirements that must be taken into consideration, such as service and maintenance, safety, noise, and reliability. The NSW Government's BASIX legislation, which requires all new residential buildings to produce 20-40% less greenhouse gas emissions compared to the NSW state average, will make it more cost-effective to install cogeneration in new residential buildings. Beyond installation, it is not straightforward to compare cogeneration running costs to existing centralised hot water systems as cogeneration provides power as well as heat. The factors influencing running costs, such as gas and electricity tariffs are discussed in Section 3.

1 kWe = kilowatt electrical output, kWt = kilowatt thermal output

2 Design & Installation Issues

2.1 Engine Heat And Power

All cogeneration equipment needs to be matched to the heat and power requirement of the building. It is a characteristic of combustion engines that the electrical power output and the heat produced cannot be independently varied past small limits. That is, for any particular engine the ratio of power to heat is a function of design, and operation away from that design point will reduce fuel efficiency and may damage the engine. In general, internal combustion engines operate with a fuel efficiency in the range of 20-40% depending on engine size and technology (turbine or reciprocating engine). Larger engines are generally more efficient than smaller engines, and reciprocating engines are often more efficient than simple turbines.

A typical natural gas fired reciprocating engine suitable for residential cogeneration might have a fuel efficiency of 30%. This indicates that for every 100 units of fuel energy burnt, 30 units of useful output power (electricity) are obtained. The other 70 units go to heat in the exhaust gas, lubricating oil, jacket cooling water heat, vibration and noise. The exhaust and cooling water heat can be recovered through heat exchangers, and depending on the application, up to 90% of this heat might be captured and used (more typically 70-80% of the heat is recovered so 70% of 70 units = 49 units). In some systems, heat from the lubricating oil circuit is also recovered.

Using established terminology, the above generator would be rated at 30 kWe, using 100 kW of fuel, with 49 kWt (thermal) recovered heat, for a fuel efficiency of 79%. The ratio of (recovered) heat power to electrical power is 49/30 or approximately 1.6. For each installation, optimal use of this 'typical' system will provide heat and power in this ratio. If more heat but not more power is needed, it would not be efficient to use a larger engine, as the power would be wasted. If more power and less heat is needed then a larger engine would necessitate wasting heat. When connected to the grid, it is possible that excess power can be exported, however it may not be economic to do so in all circumstances.

Cogeneration plant can be designed to provide heat and power in different operational modes. For example, the system could be sized to provide for a certain heat demand with the electricity used to partly offset normal grid supply, or if the electricity is in excess of demand, exported to the grid. Alternatively the plant could be sized to provide a certain electrical demand, while the heat could be used to reduce or eliminate energy needed for hot water or space heating. In this case, if the heat produced by the cogeneration system is in excess of that required locally, it might need to be wasted.

For residential apartments in Australia, the major use of heat is expected to be for domestic hot water and swimming pool heating, although for some installations engine heat could also be used to provide cooling.

The following sections are based on the use of cogeneration in multi-unit apartment buildings, where the thermal output is used for domestic hot water and the electricity used to offset community property load, that is, the electricity is not provided to individual apartments.

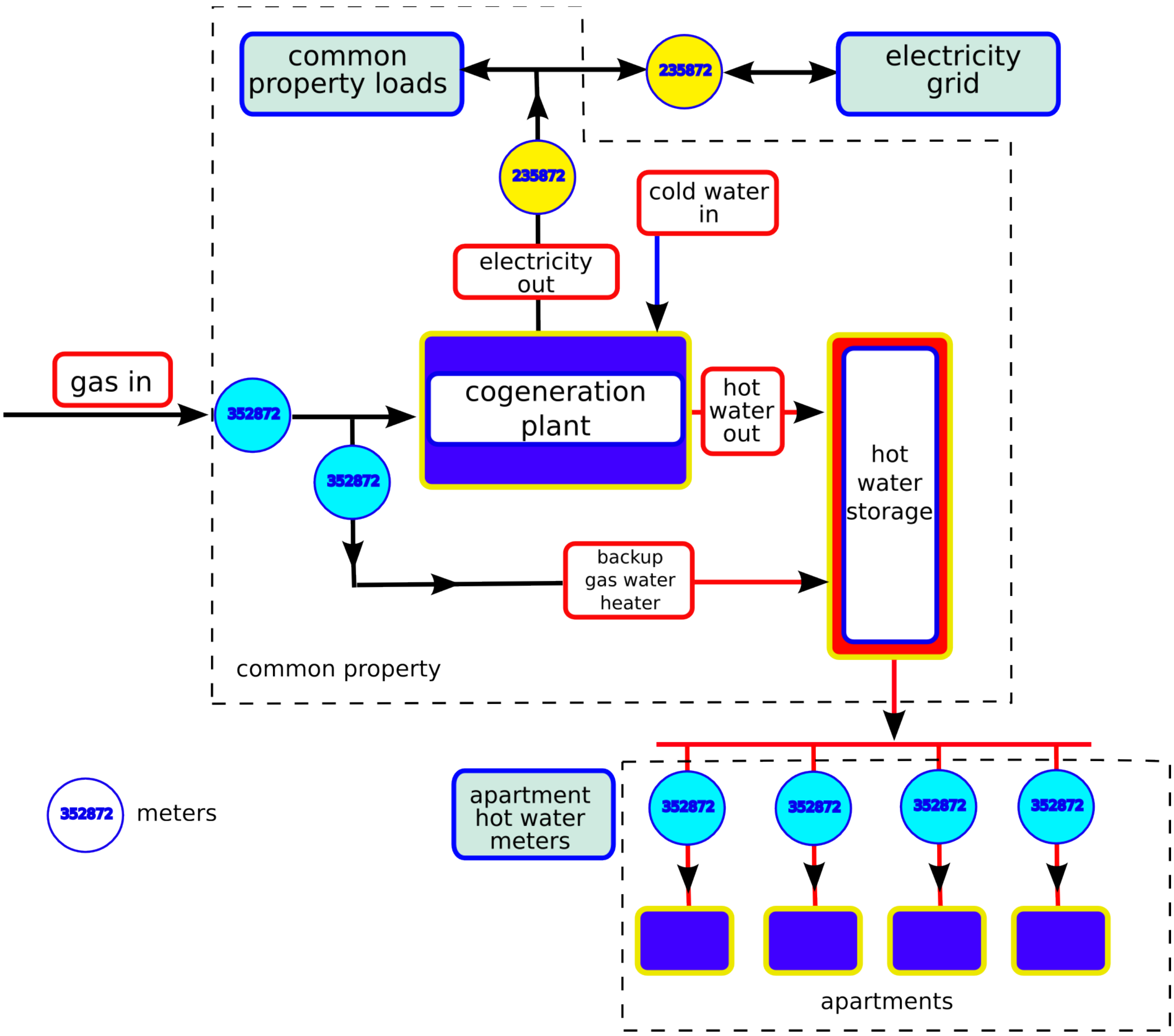

Figure 2: Schematic of possible cogeneration installation

A schematic representation of such an installation is shown in Figure 2. In this configuration, a gas fired cogeneration plant produces electricity which is either used in common areas or exported to the grid, while the heat is used to produce domestic hot water which is then provided to individual apartments. Although not shown in this simple representation, the hot water could also be used for swimming pool heating, space heating (and cooling) and clothes drying.

2.2 Common Property And Residential Energy Consumption

The total energy consumption in a multi-unit building comprises the energy used by individual apartments and that used by the common property. The common property loads may include lighting and ventilation for areas such as foyers, community property such as swimming pools, gymnasium, car park, and lifts, as well as fans for common risers for bathroom and laundry ventilation and other electrical loads. The energy cost for the common property is paid by the owners corporation from the strata levies. Energy consumed in individual apartments is usually metered and paid for by the owner or tenant. In NSW, all consumers have the right to choose their energy supplier ('Full Retail Contestability').

For hot water and air-conditioning, centralised systems are often used. For example, an apartment block may have a centralised gas-fired hot water system which provides each apartment with hot water on demand. The energy costs can be handled in two ways:

1 The owners corporation pays for the gas (and often the water as well) and passes on the cost through the strata levy. While this is simple to implement, it provides no incentive for individual tenants to reduce their energy/water consumption, effectively subsidising high users. It is also up to the owners to recover these costs from tenants.

2 The volume of hot water is metered in the apartment, and in conjunction with the total amount of gas used by the centralised hot water service, an apportionment is calculated for each apartment. The gas utility then bills the resident for the energy use. This is more equitable when all apartments are occupied, but can result in very high energy bills when occupancy is low, for example when a new building is being populated.

For cogeneration, there are a number of possibilities for how the energy will be used and for how costs are recovered. Assuming that the capital cost of the equipment has been incorporated into the building cost, the operating costs consist of fuel (gas) and maintenance (and ultimately end-of-life replacement). The hot water and electricity produced may be used by individual apartments or common property, or a mix of both. For example, the heat may be used for domestic hot water and for pool heating, while the electricity could be used for common property or individual apartments. While the options will vary for each installation, the most attractive mode of operation is largely constrained by the characteristics of the cogeneration plant.

2.3 Optimum Plant Sizing

Optimum plant sizing is critical to avoid shortfalls in supplied heat, or wastage of energy. Ideally, a cogeneration plant would produce heat and power in the same ratio (and with the same time demand) as the building it supplies. Each building is likely to have a different ratio, due to differences in location, design (high, mid and low-rise) common property, apartment size and many other factors, so it is not possible to provide a 'typical' ratio. In some cases electricity use is greater than energy for hot water and heat, while in other buildings the reverse is true.

Another major consideration is the daily load profile for electricity and hot water. While the engine's heat output can be stored as hot water for some time, the electrical output cannot be easily stored (battery storage is possible but not currently economic). This places some restriction on how the plant is operated. For example, if the plant is to supply power to individual apartments, then it would need to be operational during peak times when power demand is high; this is generally in the mornings and late afternoon and evenings, depending on the season. However it is likely to be more economic to operate the plant during those times when the peak electricity tariff applies, which is approximately 2.00 pm to 8.00 pm weekdays, depending on the utility. Cogeneration during peak tariff periods means less electricity needs to be purchased at the most expensive rate.

The cogeneration plant should be sized so that all the heat output is used (it is assumed that all power can be used at any time). This will result in the most efficient use of fuel. Any heat that is not used (that is dumped via a radiator) corresponds to wasted fuel. The plant should also be sized so that the engine operates for a minimum number of hours per day (for example 8-14 hours). Oversized plant that produces all the required heat in one hour of operation for example will represent a poor use of capital as larger engines are generally more expensive to purchase. Undersized plant that has to run continuously will be providing power during off-peak periods when it would be cheaper to buy power from the grid and will require an overhaul more frequently than larger plant.

Reciprocating gas engines and turbines are designed to run, and have an efficiency quoted at, full or rated power. Operation at less than full power (or 'part load' operation) will usually result in lower efficiency, and may increase wear, so part load operation is usually not recommended.

2.4 Cogeneration And Hot Water Requirements

The hot water demand for a multi-unit building will largely depend on the number of residents and their age group. An example may help illustrate the variables that need to be evaluated. For domestic hot water an average value of 110 litres per apartment per day has been suggested by AGL in their design guide (AGL Design Guide, 2006).

Assume a building with 60 apartments and 115 residents (a mixture of 1, 2 and 3 bedroom apartments). Using typical values for centralised gas-fired hot water systems, approximately 6600 L/d of hot water will be required, using an estimated 1700 MJ/d of energy. If this were to be provided by natural gas-fuelled cogeneration, a guide to engine size and operating hours is indicated in Table 1. Note this doesn't take into account flow rates, heat losses and peak demand – it only reflects the daily energy required to heat this volume of water from 15° to 65 °C.

Table 1: Notional cogeneration characteristics

Electrical output (kWe)	**Assumed fuel efficiency (%)**	**Thermal output kWt**	**Operating h/d (time to heat 6600 L)**
20	25	48	10
50	30	93	5
100	33	162	3

For this example, a 100 kWe cogeneration plant will only need to run for three hours a day to provide sufficient hot water to the residents (neglecting losses), while a 20 kWe plant would need to run for 10 hours. The electrical output will be 100 kWe for 3 hours or 20 kWe for 10 hours. This time corresponds to how long the system needs to run to heat up 6600 litres of cold water to 65 °C.

While this simple example demonstrates the approximate scale of cogeneration plant for use in residential multi-unit apartments, it doesn't take into account the hot water demand profile or heat losses that occur in real systems, which must be considered. In general, demand for hot water peaks in the morning and the evening and any hot water system must be able to provide for the maximum demand. Without storage, the cogeneration plant would need to be able to start up and provide sufficient heat to quickly meet the peak demand, which is unrealistic. As with most centralised hot water systems, storage is a very effective means of providing almost instantaneous hot water.

Average hourly peak demand depends on usage but industry guides recommend sizing between 75 to 110 litres of 65 °C hot water per hour (or 25 litres per person) per apartment

(65 °C hot water will be mixed with cold water to provide 45 °C to 50 °C water at the outlet). For a 60 unit building this implies a peak hourly demand of between 4500 and 6600 litres which would require a cogeneration plant of approximately 300 kWe. In practice, hot water storage is almost always used with a centralised hot water service to provide instantaneous hot water and to level the peak demand, and in this example, would allow the much smaller engine to be used.

AGL have developed guidelines for the design of gas-fired centralised hot water systems. These guidelines introduce a benchmark energy performance indicator called a 'Common Factor'. The common factor (CF) is calculated by dividing the total daily gas consumption in MJ/d (for hot water generation) by the volume of hot water used in L/d, and so has units of MJ/L. For a system with a heater that is 80% efficient in converting fuel energy to hot water, heating water from 15° to 65 °C would result in a CF of 0.262 MJ/L. AGL note that a well designed centralised hot water system should have a CF of 0.4 or less. This implies a maximum standing heat and piping loss of 0.11 MJ/L. For a cogeneration system that may be 55% efficient in converting fuel to hot water (assume 30% to electricity and 15% losses), the corresponding common factor would be 0.58 MJ/L.

Using these assumptions, a guide to the approximate size of cogeneration plant (operating for 10 hours per day) that would meet the hot water demands of multi-unit apartment buildings is shown in Table 2.

Table 2: Guide to engine sizing for multi-unit residential buildings

Number of 'average' apartments	Hot water		Reciprocating engine size for 10 h/d (kWe)
	L/d	MJ/d	
20	2,200	1,276	11
50	5,500	3,190	27
100	11,000	6,380	53
200	22,000	12,760	106
300	33,000	19,140	159
400	44,000	25,520	213
500	55,000	31,900	266

Based on 110 L hot water per apartment, 0.58 MJ/L, water from 15 °C to 65 °C, 30% engine efficiency

Compared to industrial cogeneration plants, which are frequently multi-MW, these engine sizes are small. Increasing the operating time to 20 hours per day would allow even smaller engines. While useful as a guide, the engine sizes above are notional, and in practice each project should undertake detailed modelling of the likely hot water demand, load profile, storage capacity and engine characteristics which may indicate a very different engine size. Furthermore, it is unlikely that a commercially available engine could be found with exactly the right size.

2.5 Optimal Time Of Operation

To obtain the maximum economic benefit from cogeneration, it is desirable to operate the plant during electricity network peak tariff periods so that the power produced captures the greatest value (by reducing the quantity of electricity purchased during peak times). In NSW this period is generally between 2.00 pm to 8.00 pm. Extending the time to include shoulder tariffs expands this period from 7.00 am to 10.00 pm. The Country Energy peak is from 7.00 am to 9.00 am and 5.00 pm to 8.00 pm on weekdays and shoulder from 9.00 am to 5.00 pm and 8.00 pm to 10.00 pm on weekdays. Electricity and gas tariffs are discussed further in section 3.2.

2.6 Australian Standards, BCA And Other Requirements

There are no codes or standards specific to cogeneration, however there are many codes and standards that apply to generating plant and centralised hot water systems. As with existing centralised gas-fired hot water systems, there are gas, building and plumbing codes that must be considered, however a cogeneration system should not require any significant departure from these codes. To a moderate approximation, a gas engine can be considered as a lower efficiency gas heater that also produces electric power.

The generating aspect of a cogeneration plant may be an area that is unfamiliar to those in residential property development. Any person or organisation seeking to connect generating equipment to the electricity network must have approval from the distribution network service provider (DNSP) prior to connection to the electricity grid. In NSW, the DNSPs are Country Energy, EnergyAustralia and Integral Energy. Each DNSP provides their own requirements for connection of generating equipment to their network and should be consulted prior to design (see section 3, Utilities, and Frequently Asked Questions).

Some cogeneration systems use inverters to provide power output. If the power output is up to 10 kVA per phase (nominally a 30 kWe machine) the inverter must be compliant with the Australian Standard AS 4777 'Grid Connection of Energy Systems via Inverters'. For inverters with a greater output than 10 kVA per phase each installation might require individual assessment. In any case, the installation must be undertaken by a licensed electrician in accordance with the NSW Service and Installation Rules (currently under review), and will be inspected by an officer from the DNSP before connection is allowed.

In general, with the size of systems likely to be connected in residential cogeneration (say <100 kWe) the requirements are less stringent than with larger generators, however approval to connect cannot be taken for granted. You should ensure that the specifications of the equipment are acceptable to your DNSP prior to installation. Some imported systems have been designed for operation in the northern hemisphere and may need additional testing before approval is granted to connect.

2.7 Cogeneration Plant Designers, Manufacturers & Installers

There are a number of companies that have experience in designing and installing cogeneration systems, but many of these are at the larger, industrial scale, such as installations in Parliament House, Macquarie University, CSIRO, Newcastle University, and Griffith Hospital. Some of these companies have indicated that they can design and advise on the installation of small cogeneration systems. The Australian Business Council for Sustainable Energy is developing a services directory on its website that will provide a tool for consumers and business to locate services provided by BCSE members, including cogeneration (www.bcse.org.au navigate to item 12 - services directory). This facility is expected to be fully operational by mid August 2006.

2.8 Costs For Plant Design And Installation

The installation of a cogeneration plant will require additional design beyond normal gas supply, hot water and electrical design work.

Additional installation costs will depend on the specific site, but should cover items such as foundations if needed, anti-vibration mats or springs, soundproofed enclosure, lifting equipment, gas leak detectors, exhaust, possible condensate removal, ventilation, electrical switchboard, gas connection and metering, and water supply and metering. Depending on design, larger than normal hot water storage tanks might be used. Cogeneration systems at the smaller end of the scale (say <150 kWe) may include the electrical switchboard and control system into a single enclosure, while larger units (>300 kWe) would generally have a separate switchboard.

Figure 3: A packaged 22 kWe cogeneration system

Based on international experience, it would be prudent to expect design and installation costs to be at least 30-50% of the hardware costs, however in many cases, these installations did not use commercially available packages but were engineered from component parts. This will generally be more costly as each installation will be unique and require much more detailed design and modelling. The use of commercially available packaged systems is growing worldwide and a number of these are now available in Australia through local distributors. These packages provide standard fuel, water and electrical connections simplifying installation and removing a large part of the design work normally associated with a new cogeneration installation. An example of a packaged commercially available system is shown in Figure 3.

2.9 Backup Systems

The percentage of time over a year that a system could operate if called upon—the availability, of most cogeneration plant should be at least 95% or better, which includes downtime due to maintenance and breakdown, however this demonstrates that a backup hot water heater will be required when the cogeneration plant is not operational. This backup system could form part of the total cogeneration system, such as a boost heater for example, used to maintain water temperature between engine operating periods or could be a separate hot water system designed for occasional or emergency use.

2.10 Plant Siting Issues

For medium and high rise multi-unit apartment buildings, roof installation is the obvious option due to exhaust and water storage requirements. Other locations may be viable depending on the building design. Attention will need to be given to engine noise and vibration, exhaust and air intakes. Modern reciprocating engines and microturbines in the size range suitable for cogeneration can be very well soundproofed so that noise and vibration need not be an issue, however this should be included in the design phase so that rubber vibration dampers for example are included. Acceptable noise levels from air intake and exhaust should be specified. Microturbines will require different soundproofing to reciprocating engines.

One issue with rooftop installation that is of concern to developers is the height of any plant. For best utilisation, the cogeneration plant must be below the height of the lift motor room. This shouldn't be a problem with most systems. Commercially available, fully packaged reciprocating engine based systems of up to 150 kWe electrical output (226 kW thermal) can be found with a height of less than 2 metres. The 65 kWe Capstone microturbine based cogeneration unit is 2.4 m high.

Sufficient space should be provided around the plant to allow for access during maintenance and repair. During maintenance it may be necessary to remove and/or replace heavy items so consideration should be given to how these items can be moved on and off the site.

2.11 Plant Type And Related Issues

The choice of plant begins with a consideration of prime mover – the engine. While there are a number of technologies for producing power and heat, the practical alternatives are gas reciprocating engines and gas turbines. Both technologies are widely used for cogeneration, but small turbines (called microturbines) have only been commercially available since 1999. Turbines have many attractive features for cogeneration, including long life, low maintenance, high temperature exhaust (and so high quality heat) and simple heat recovery. The disadvantages include lower efficiency (for small units), the need for higher gas pressures (a fuel gas compressor might be required), poor part load efficiency and noise. Lower efficiency means less power and more heat, which may not be problematic where a high heat demand exists. However where economic operation relies on power production, fuel efficiency may be critical. Turbine output is also very dependent on the ambient air temperature and pressure, and can fall significantly as the air temperature rises. Microturbine output is normally specified at ISO conditions, which is sea level and 15 °C ambient air temperature. With ambient air temperatures of 30 °C and air inlet temperatures of 35 °C, microturbine output could drop by 20% for example.

The market leader in microturbines is Capstone, based in California. Capstone produce two microturbines rated at 30 kWe and 65 kWe. The 65 kWe unit is available as a cogeneration package. A small number of other companies also provide microturbines. Currently, microturbines are more expensive than reciprocating engines of similar output.

Reciprocating gas engines are widely used in cogeneration systems, especially below about 5 MWe. Reciprocating gas engines are generally cheaper than turbines to purchase, but may cost more to operate and maintain. The advantages of reciprocating engines are their generally higher electrical efficiency for comparable size, quick start, good part-load efficiency, maintenance of efficiency and output at increasing altitude and ambient conditions, and generally higher reliabilities. They can also usually be maintained with in-house or locally sourced staff. Their downside is the need for more frequent maintenance.

In addition to providing heat for hot water, it is possible, and in some cases economically viable, to provide chilled water or air from the waste heat. This can be achieved using absorption chillers or desiccant systems for example. Absorption chillers are in use in a number of larger cogeneration plants, such as Macquarie University, where they provide chilled water for air conditioning. A desiccant system is in use at Hornsby Council Library where waste heat from a microturbine is used to provide chilled air for the library's air conditioning. Systems that provide power, heating and cooling are termed 'trigeneration' and can be highly energy efficient, however the economics of its use in residential multi-apartment dwellings has not been well studied.

In the future, fuel cells may also be considered as the prime mover for residential cogeneration systems, since they also produce heat during the conversion of fuel to electricity. In fact, high temperature ceramic fuel cells, which can use natural gas, are being demonstrated in Australia, Japan, Europe and North America in cogeneration applications. However it will be some years before economical, commercially produced systems will be available.

3 Utilities

Under the National Electricity Rules, all generators must be registered by NEMMCO (the National Electricity Market Management Company) unless exempted. Currently, generators below 5 MW are exempted. Licensing requirements for generators are generally managed at the jurisdictional level and vary between states. In NSW the regulatory entities are the Independent Pricing and Regulatory Tribunal (IPART) and the Department of Energy, Utilities and Sustainability (DEUS). The NSW Electricity Supply Act 1995, does not require the issuance of a license for generation, however each distribution network service provider will require the owner of the generator to meet certain standards for connection of generating equipment.

The Ministerial Council on Energy (MCE) Standing Committee of Officials – the Utility Regulators Forum, has been asked to develop a Code of Practice for embedded generation. A consultation paper and a draft Code of Practice have been prepared, and it is expected that the Code of Practice will eventually be adopted as the minimum standard across the National Electricity Market (NEM). This should assist in providing more uniform regulations nationally.

3.1 Natural Gas Connections

The prime movers in a cogeneration plant require natural gas fuel supplied from the gas network. Reciprocating gas engines can utilise low pressure (101 kPa) gas supplies. Microturbines however, require high pressure gas (+400 kPa), which if not available necessitates a gas compressor which reduces overall efficiency and adds to the cost and maintenance schedule, but are readily available. The natural gas network covers the Greater Sydney region and over 45 regional areas across NSW including coastal centres between Newcastle and the Hunter Region north of Sydney and Wollongong and Shellharbour south of Sydney. The Network also extends to the Riverina, Blue Mountains and the major centres of the Central Tablelands.

3.2 Gas And Electricity Tariffs And Demand Reduction Potential

Gas and electricity tariffs are crucial to how a cogeneration system is economically operated. The cost of any electricity produced is directly related to the cost of the gas fuel. In terms of energy content, gas tariffs in NSW are typically comparable to off-peak electricity tariffs (at the level of usage corresponding to residential and multi-apartment loads). Converting gas to electricity in an engine or turbine based generator is only 25-35% efficient, so the cost of the electricity produced is three to four times greater than the gas cost, if the by-product heat is not used and valued as in cogeneration.

A selection of gas and electricity tariffs is provided in Table 3, however owners corporations should be able to negotiate tariffs with energy retailers. Gas tariffs are quoted on the basis of c/MJ or $/GJ, while electricity tariffs are quoted as c/kWh (1 MJ = 3.6 kWh). These tariffs do not include supply fees, and were current as of June 2006.

Table 3: A selection of NSW gas and electricity tariffs as of June 2006

Plan	Tariff (incl GST)	
	electricity c/kWh	gas c/MJ
Residential		
AGL residential 'everytime Plus'		1.53
EnergyAustralia residential 'domestic all time' - first 1,750 kWh/quarter	11.63	
thereafter	13.56	
Commercial		
AGL Industrial & Commercial NSW standard first 50,000 MJ/month		1.47
thereafter		1.32
EnergyAustralia Load Smart Tariffs (>40 MWh/y)		
peak (2 pm - 8 pm)	17.22	
shoulder (7 am - 2 pm & 8 pm -10 pm)	11.67	
off peak (all other times)	5.90	
EnergyAustralia - General supply all time, first 2,500 kWh	11.30	
thereafter	13.50	

All new multi-apartment buildings will be equipped with time-of-use (TOU) meters, which record electricity consumption according to the time period. This allows for differential pricing, encouraging consumers to reduce consumption during peak periods. TOU tariffs provide a strong financial incentive to minimise consumption during peak periods. For multi-unit residential buildings with constant loads, there is limited opportunity to reduce demand during peak periods. However, if domestic hot water and other heat loads are met with cogeneration which operates during peak periods, then very substantial savings in electricity purchases can be achieved. For example, using the AGL industrial tariff of 1.47 c/MJ, a cogeneration plant operating at 33% efficiency will produce electricity at approximately the same cost as the EnergyAustralia peak LoadSmart tariff, while also providing domestic hot water. In effect, the cogeneration system provides free hot water when operating during peak times.

Note: Almost all engine suppliers quote fuel efficiency using the Lower Heating Value (LHV) of the fuel, however gas is purchased using the Higher Heating Value (HHV). The different values derive from whether the combustion products are cooled back to standard (ambient temperatures) conditions or not. In almost all engines, the exhaust is kept well above the temperature at which water will condense, to avoid corrosion. This corresponds to using the Lower Heating Value of the fuel. However the gas is purchased using the Higher Heating Value, and this is what should be used to calculate fuel costs. For natural gas, the difference is about 10%. So an engine efficiency of 30% (LHV) is actually about 27% efficient at the HHV.

3.3 Residential And Owners Corporation Billing Options

Customer billing for most centralised gas hot water systems in multi-unit residential buildings in NSW operate using a calculated 'common factor'. The gas needed to provide hot water to all residents is centrally metered at the hot water system. Each apartment is now usually fitted with a water meter in the hot water entry point which registers the volume of (hot) water flowing into the apartment. A water meter on the centralised hot water plant also records the volume of cold water entering at the inlet. The energy retailer is provided with the meter readings and uses them to calculate the common factor. Individual apartments are billed according to the amount of hot water they consume, by using the common factor to calculate the energy apportioned to their metered volume. Standing losses and pipe losses are therefore shared accordingly. Some older buildings don't meter individual unit consumption and apportion gas costs according to unit entitlements. This is obviously less satisfactory as it is not based on use.

If the hot water is provided by a gas fired cogeneration plant, the same means of billing could be used in principal. The substitution of a gas heater with a gas engine should not require significant alteration of the common factor approach to metering. However in the case of a cogeneration plant, the gas fuel also provides power. Common factor metering would also apportion some of those costs to each customer according to their hot water consumption. In the absence of any additional adjustment residents may pay more for their hot water. In comparison with a modern centralised hot water system utilising a heater of approximately 80% efficiency, a cogeneration plant recovering 55% of the fuel energy in hot water (with approximately 30% going to electricity) would result in a 45% increase in hot water costs.

If the electricity output is being used to power common area equipment, the owners corporation however is reducing the need to purchase electricity and owners will be compensated.

Resident owners will benefit from lower strata levies, but tenants may not see a direct benefit if they can only view their hot water bill in isolation.

Alternative billing arrangements could be considered, but where a utility is involved, there is little likelihood of accommodating adjustments for individual buildings. This is not unreasonable given that most billing processes are fully automated to minimise costs and mistakes.

An option that might evolve in step with the introduction of residential cogeneration is the use of non-utility third parties to manage billing. This is now occurring in some other Australian states for electricity and gas sales in residential apartment buildings. Under this scenario, a third party would be responsible for managing the costs and revenue of the cogeneration plant. As a commercial operation, the third party would be able to aggregate usage and negotiate a better gas tariff. For example, the third party could be contracted to operate and maintain the cogeneration plant, purchase gas, provide hot water to residents and electricity to the owners corporation (not residents). From the gas retailers perspective, this is a single commercial supply point and may be eligible for lower (bulk) gas tariffs. This type of operation would require that individual apartment hot water meters be owned and read by the owners corporation or a third party (under current arrangements, these meters are owned and read by the gas supplier).

3.4 Contact People In Each NSW Distribution Utility

There are four main utilities in NSW that might be involved in a residential cogeneration application. These utilities provide the electrical and gas distribution networks and depending on the location, at least one will require notification and undertake an approval process. Some of the guidelines and agreement forms refer to NEMMCO Registered Participants. Generators below 5 MW output are exempt from registration however some utilities still require exempt generators to comply with the National Electricity Rules (the 'Rules', currently 774 pages in length). In practice this is likely to be relaxed as many of the requirements are not applicable to small generators.

EnergyAustralia

In the first instance contact should be initiated with the Customer Service Office in your locality. A standard connection agreement is available from the EnergyAustralia website (www.energy.com.au) made up of two parts, the *Generator Connection Agreement: General Conditions*, and the *Generator Connection Agreement: Instrument of Agreement*.

Integral

In the first instance, contact should be made with:

The Major Network Customer Manager
Network Connections
Integral Energy
PO Box 6366, Blacktown NSW 2148

A document titled *Customer Guidelines for the Connection of Private Generation to Integral Energy's Distribution Network* is available and should be consulted prior to any design or construction. Following this, it is likely that Integral will require completion of *The Standard Form Connection Contract for Connection Points with Exempt Generation.*

Country Energy

For potential installations in the Country Energy network, contact should be made with the Local Area Planning Coordinator.

The Manager - Infrastructure Development & Utilisation
Country Energy
PO Box 718 Queanbeyan NSW 2620

A set of guidelines is available; *Code of Practice: Co-Generation Protection Guidelines* document CEK8012.

AGL

Physical connection to the gas distribution network and the installation of gas metering is normally undertaken by Agility at the request of the energy retailer involved in the project. The process for connection to the gas network is generally straightforward and requires completion of a load summary. Enquiries specifically concerning cogeneration equipment should be directed to:

Mr Graeme Fox
Energy Applications Specialist
Agility
PO Box 6300, Frenchs Forest, NSW 1640

4 Implementation Issues

4.1 Plant Ownership Options

There are a number of options regarding ownership of the cogeneration plant, as there are with other types of generating plant equipment. The most obvious is that the owners corporation assumes ownership after the building is sold and occupied, as occurs with other items of plant such as lifts, swimming pools and centralised hot water. The owners corporation may then engage a building manager to supervise and manage the plant, usually via specialist third-party contractors. This is often the model used for lift maintenance and centralised air-conditioning systems, however this model would be more suitable to reciprocating engine based, rather than microturbine based, cogeneration systems because of the more widespread availability of technicians trained in reciprocating engine technology.

Other ownership models could include third-party ownership, such as utilities or other organisations, often referred to as ESCOs (Energy Services Company). In these models, a utility for example, would install and own the equipment and provide electricity and hot water to residents and building services. The attractiveness of this model to a utility would depend on the income stream from the sale of hot water and electricity and the benefits, if any, of embedded generation in their network. There are many variations in how an ESCO might be involved, but it will usually require the preparation of an energy performance contract, which sets out the conditions under which the energy services are provided. These may require a minimum energy saving, a fee for service approach or a shared savings approach for example. The Australasian Energy Performance Contracting Association provides a Best Practice Guide to energy performance contracting, which is available from their web site (www.aepca.asn.au). The AEPCA can also provide a list of organisations that specialise in energy performance contracting.

4.2 Performance Monitoring And Maintenance Providers

Most modern cogeneration equipment will come with automatic control systems which, once set, should ensure operation continues within the set band of operation. Regular checks should be undertaken, perhaps quarterly, correlating gas consumption with hot water and electricity production to observe any movement away from the set point and to fine tune the operation. This could be included in the service agreement or undertaken by a building manager if available. Remote monitoring of the cogeneration plant is usually possible via modem connection, however this might not include meter readings unless access was provided by the utility during installation.

Although there are currently no multi-unit cogeneration installations in Australia, equipment suppliers have indicated that ongoing maintenance can be arranged through themselves or with independent contractors familiar with reciprocating engine technology. Microturbine suppliers can provide servicing of their microturbine based cogeneration plant. There is a large installed base of stationary engines, used for emergency power backup and other support, ensuring an adequate pool of service technicians.

4.3 Plant Life And Replacement

Plant lifetime typically depends on actual operating hours, quality of maintenance and the equipment design. Microturbine manufacturers are targeting a 40,000 hour life (continuous operation) with major overhaul at 25,000 hours, however microturbine lifetime is strongly dependent on the number of starts and more than one start per day will significantly reduce engine lifetime. Reciprocating gas engine life is very dependent on maintenance, oil quality and air quality. Long-life gas engines are specially designed (and are not simply modified motor vehicle engines, which would not last more than 12 months under cogeneration conditions). Most suppliers of reciprocating gas engines indicate that engine life should exceed 30,000 hours providing service schedules are adhered to.

The responsibility for plant replacement when it is eventually necessary will depend on the ownership model, however as long as cogeneration is providing cost savings, it should be in the interests of the owners corporation to pursue replacement either through normal suppliers, or via the services of an energy services company.

4.4 Cost Of Maintenance And Ongoing Operations

As with all mechanical equipment, ongoing maintenance is required to ensure safe and reliable operation over the life of the equipment. Maintenance costs will vary with the type of equipment and hours of operation, and are conventionally expressed as a cost per kilowatt-hour (kWh) of electrical output.

For reciprocating gas engines, typical maintenance will include oil changes, spark plug replacement, air cleaner replacement, primary cooling water quality, and general mechanical checks. Usual maintenance intervals are of the order of 800-1000 hours operation and consist of oil and filter changes, spark plug replacement (depending on interval) and engine adjustments. Typically the cylinder head would be overhauled at 12,000 hours, and the engine rebuilt or replaced at 30,000 hours. Turbocharged engines have additional service requirements relating to the turbocharger, with repair or renewal of the turbocharger likely between 7000-8000 hours.

For reciprocating gas engines, routine maintenance costs might range from 1-3 c/kWh. This would cover replacement of engine oil, air cleaners, and spark plugs for example, and labour. For a 30 kWe cogeneration plant operating 10 hours per day, maintenance costs of 2 c/kWh would total about $2000 per year. This doesn't include the major overhauls usually needed at 12,000 and 30,000 hours.

For microturbines, routine maintenance is confined to checking and replacing air cleaners and replacement of the igniter and fuel filter every 8000 hours, with inspections every 4000 hours or every six months. Replacement of injector assemblies, thermocouples and other filters is recommended every 20,000 hours. If a gas compressor is used it should be included in the maintenance schedule. Maintenance costs are estimated to be about 5 c/kWh over 5 years including spare parts and labour for the major services, but not including an engine change, possible at 40,000 hours or more. For a nominal 60 kWe based system, which could theoretically provide sufficient hot water for 100 or more apartments, the maintenance cost, using the estimate above, would be of the order of $10,000 per year. (This maintenance is for air-bearing based microturbines, which are the most popular.) Better estimates of maintenance and running costs would be available once a demonstration project has been running for 12-18 months.

In addition to the engine and generator, the heat exchangers will also require inspection and water quality testing and this should be included in the ongoing maintenance schedule.

5 Barriers to Implementation

There are a number of perceived and actual barriers to the use of cogeneration in residential multi-apartment buildings. These include:

Regulatory

Current electricity and gas regulations are not conducive to ease of installation and provide substantial market impediments through metering, connection and pricing requirements. For example there is no standard process for gaining approval to connect the (co-)generator to the electrical network across the three network service providers in NSW. It is possible that three different procedures will be required to install the same cogeneration equipment in each of the three network areas. In some cases, the DNSP may require the installation of prohibitively expensive equipment in the distribution network to accommodate increased fault levels even though network demand may well be reduced through cogeneration.

In NSW all electricity customers have retail contestability which provides them with the right to chose their electricity supplier. This mitigates against the option of supplying residents with power from the cogeneration plant, however it is still attractive to use the power to provide for common area requirements such as lighting, ventilation and lifts.

Perceived added burden for Owners Corporations

The incorporation of cogeneration plant will add to the list of equipment that will require service and repair. For many multi-apartment buildings this equipment might already include fire safety equipment (including hydrant diesel and electric booster pumps), air conditioning and ventilation systems including cooling towers, hot water heaters, lighting, security hardware, car park roller shutters, car wash pumps and oil separators, communication systems, lifts and swimming pools.

Most medium to large multi-apartment buildings already engage service contractors to maintain this equipment. Cogeneration plant should not require levels of service beyond what is already expected and provided for equipment commonly found in most new multi-unit buildings.

It is expected that a well designed and operated cogeneration system will result in lower overall energy bills for owners, even after maintenance costs are taken into account. Energy costs make up a substantial component of most strata levies (typically 10% or more) so reduced energy bills would be welcome.

Complex greenhouse credits scheme

One of the reasons cogeneration is so effective under BASIX requirements is that it provides very substantial reductions in greenhouse gas emissions compared with conventional hot water and electricity supply. It achieves this through the use of a lower emission fuel (natural gas) and the capture of waste heat, normally lost at a centralised power station, for the production of hot water. These emissions savings have a financial benefit through the NSW Greenhouse Gas Abatement Scheme (GGAS) which provides a market for certificates which can be generated and traded. The value is approximately $10-15 per tonne of carbon dioxide equivalent abated. For a building with 60 apartments, meeting its hot water demand with cogeneration, the annual value of the credits would be in the range of $1000-1500. However the effort required to capture this value would probably exceed the benefit. Nevertheless some organisations are now offering a service where they will undertake the GGAS application on a commission, and will aggregate small generators.

Little knowledge of cogeneration in the building industry, unfamiliarity with technology, requirements and benefits

There is, understandably, little knowledge of cogeneration in the building industry and a general reluctance to commit to a new technology given the need to ensure that the plant must operate for at least 7 to 10 years without major problems. However cogeneration has been used in industry and commercially for many decades and the underlying technology is well proven. Residential cogeneration has been implemented in Europe, Japan and North America.

A demonstration program would go a long way to alleviate the uncertainties and provide confidence that systems of this size and operational requirements can be implemented with minimal risk.

6 Benefits to Developers and Owners Corporations

6.1 Benefits To Developers

Cogeneration can provide very significant energy savings and help meet BASIX targets. Modelling by the NSW Department of Planning shows that cogeneration is one of the most cost-effective means of reducing greenhouse gas emissions from energy use in multi-apartment buildings, which is consistent with studies from the industrial and commercial sectors on the benefits of cogeneration. Cogeneration can provide developers with greater flexibility in how they meet BASIX requirements.

6.2 Benefits To Owners Corporations

When considering both hot water and electricity generated by the system, a well designed cogeneration system which maximises use of waste heat, will result in lower energy costs as well as lower greenhouse emissions when compared to existing buildings using a centralised hot water system. These lower costs should be reflected in lower strata levies for owners. In addition, a BASIX compliant multi-unit building will have far greater energy and water efficiencies integrated into the building compared to a pre-BASIX multi-unit building. This will also result in lower energy and water costs for common areas, centralised systems and individual units for body corporates and tenants.

Financial benefits from schemes such as the NSW Greenhouse Gas Abatement Scheme may also provide some income to the owners corporation. The owners corporation might also be able to receive additional payments from the local DNSP for provision of demand reduction during certain hours of operation. Cogeneration will provide additional means to an owners corporation to better manage their energy consumption and demand, either directly or through a third party.

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FAQ

General

What exactly is cogeneration, or combined heat and power (CHP)?

Cogeneration or CHP is the simultaneous generation and use of electric power and heat, using an engine such as a reciprocating gas or diesel engine, or turbine. While all combustion engines produce heat, in cogeneration this heat is used to provide space heating, hot water or other service. In almost all cases, both the heat and electricity are used by the owners of the cogeneration plant.

What are the component parts of a cogeneration system?

Typically a cogeneration system will consist of a 'prime mover', which is the engine or turbine, a generator that converts the rotary engine power to electricity, a system for capturing and using the heat from exhaust gases and cooling water (heat exchangers), and a control system. Most commonly, the engine is a reciprocating gas engine, but new very small turbine generators - 'microturbines' - are now commercially available. The generator can be a separate unit, as is typical for reciprocating engines, or integrated as in some microturbines.

Usually there are two heat circuits, so that heat exchangers transfer heat from the engine or turbine to water through separate circuits, ensuring that engine jacket water or exhaust never comes into contact with the water being heated for domestic or other use.

What are the possible uses for 'waste' heat in a residential building?

Common uses for 'waste' heat could include domestic hot water supply, heat for swimming pools, clothes drying, space heating and even air-conditioning. With the right technology, waste heat can be used to provide both heating and cooling to a building.

How does CHP work?

CHP works by capturing the waste heat from a combustion engine while it is generating power. All power stations using fuel (coal, gas oil) convert the fuel energy to electrical energy through combustion. Unfortunately, most of the fuel energy is lost as waste heat at the power station, where typically more than two thirds of the energy is lost. Some modern gas-fired combined cycle power stations may reach 50% but most coal-fired power stations run at about 35% efficiency. The attraction of cogeneration is that a large proportion of the normally wasted heat can be used for other purposes such as process heat in industry, or hot water and space heating in hospitals or large commercial buildings. There is little use for this heat at the power station, so it is dumped via cooling towers.

A cogeneration plant, located at a hospital for example, would consist of an engine running on natural gas, producing power from a generator with the exhaust and cooling water heat recovered using heat exchangers. Cogeneration plants have been designed and built to run on many different types of fuels, ranging from biomass (e.g. sugar cane waste), to landfill gas, and almost any combustible fuel. For residential cogeneration, the only practical fuel is natural gas.

Why is cogeneration so effective in helping to meet BASIX targets?

BASIX benchmarks new dwellings on the basis of their greenhouse gas emissions compared to average per capita emissions for NSW. Technologies and practices that result in lower per capita greenhouse gas emissions will score highly in BASIX.

BASIX accords cogeneration a high ranking because the electricity produced has a much lower greenhouse impact than the NSW state average (with cogeneration, electricity is produced from natural gas, while in NSW almost all electricity is produced from burning coal, which has higher greenhouse gas emissions). Additionally, the heat produced by the engine is used to provide hot water which would otherwise have required a gas burner anyway (the waste heat at the power station is just rejected to the environment). So the combination of electricity production from natural gas, and waste heat utilisation effectively reduces emissions by about 40%.

What are the different kinds of engine that can be used?

In general the engines that are used are reciprocating (that is piston engines) or turbines. Reciprocating engines for cogeneration are normally fuelled from natural gas and are specially designed for long life, minimum maintenance and heat recovery. Gas turbines are generally used for larger installations and where the temperature of the heat needs to be higher than that provided by a piston engine, but new microturbines are now available that would work well in residential cogeneration. A 65 kWe microturbine with cogeneration could fit in a floorspace of 1 x 2 m and have a height less than 3 metres.

How much does cogeneration cost?

The system cost will depend on the size and type of the plant (turbine or reciprocating engine), the fuel efficiency, the sophistication and design life. In general, the cost per kWe rises as the size of the generator goes down. A very approximate guide is that a high quality 30 kWe reciprocating engine based system costs about $90,000, including heat exchangers, control system and installation to a prepared site (that is with gas and electricity connections available).

Hot water storage tanks may also be required, depending on how the system will be operated. If the cogeneration plant will be operational only during peak electricity tariff periods then sufficient hot water storage and boost heaters will be needed to ensure adequate supply for morning peaks.

How much does installation cost?

Installation costs will vary according to each location, but need to cover foundations, fuel (gas) connections, electrical connections and meters, water connections, exhaust gas piping, enclosure and sound proofing. Experience from overseas installations indicate a budget of approximately 30-50% of the equipment cost should be provided for installation and an additional 15% for project management and contingencies.

Maintenance

Who will maintain the plant?

Maintenance will generally be contracted to third parties, as is often done with other plant such as lifts, hot water systems and air-conditioning systems. Simple maintenance tasks could be undertaken by the building manager, if present.

How much maintenance will it require?

For reciprocating engines, routine maintenance involves changing of engine oil, air and fuel filter, coolant and spark plugs, often carried out for every 800-1,000 hours of operation. A rebuild of the engine cylinder head might be needed after 12,000 hours with a major overhaul or replacement of the engine after 30,000 hours. Heat exchangers should be expected to last as long as the engine, provided the water quality is maintained.

Microturbines can have fewer maintenance requirements, especially those that use no lubricating oil. For these microturbines, the routine service is to clean or replace the engine air filter and replace the igniter and fuel filter every 8000 hours, with inspections every 4000 hours or every six months. Replacement of injector assemblies, thermocouples and other filters is recommended every 20,000 hours. As these are relatively new products, the lifetime before major overhauls are needed is still not well established, however some early units have exceeded 45,000 hours of near continuous operation.

What are the projected maintenance costs?

Maintenance costs will vary with the type of equipment and hours of operation, and are conventionally expressed as a cost per kilowatt-hour (kWh) of electrical output. For reciprocating gas engines, routine maintenance costs might range from 1-3 c/kWh. This would cover replacement of engine oil, air cleaners, spark plugs and labour. For a 30 kWe cogeneration plant operating 10 hours per day, maintenance costs of 2 c/kWh would total about $2000 per year. This doesn't include the major overhauls usually needed at 12,000 and 30,000 hours.

For microturbines, the maintenance costs are estimated to be about 5 c/kWh over 5 years including spare parts and labour for the major services, but not including an engine change, possible at 40,000 hours or more.

How can the plant be designed to avoid service interruptions while under maintenance?

The most likely mode of operation for a cogeneration plant in a residential apartment block would be for a certain number of hours each day, for example 6, 8 or 12 hours per day. It would be possible to schedule maintenance during periods when the equipment was not operating. For longer periods, a backup source of heat might be needed for hot water production. As long as the building is still connected to the electricity grid, no backup of the system's power output would be needed.

How does cost vary with size of system?

In general the cost in dollars per kWe of output reduce as the size of the plant increases, meaning that a 60 kWe plant would be less than twice the cost of a 30 kWe plant. There are very few systems commercially available below about 20 kWe (the smallest microturbine is 30 kWe) although 1 kWe and 5 kWe reciprocating engine units are now being offered for single homes in Japan and Europe, and a 1 kWe Stirling engine is being trialled in hundreds of homes in the United Kingdom (a Stirling engine is an external combustion engine). A very approximate guide is that plant costs could range from $2000-3000/kWe in the 20-200 kWe size range.

Operation

How will the residents or owners be billed?

This depends on how the system is operated and what the residents use. The simplest option is that the owners corporation owns the plant (as with most existing equipment such as lifts), pays for the fuel and maintenance and passes the costs on to owners through the quarterly levies. In this instance, residents (not necessarily owners) would not pay for hot water use, but owners would have increased levies. This is unlikely to be popular with owners and is inconsistent with the trend to user pays for energy and water services.

Another option is for the owners corporation to bill each resident for the amount of energy used for their hot water, which can be calculated from the individual hot water meters in each apartment and the amount of gas used by the cogeneration plant to provide the hot water (the energy used to produce electricity could be netted out of the gas consumption and charged directly to the owners corporation). This might not be feasible for small owners corporations so the process could be contracted out to a third party.

By-laws would need to be formulated for each strata so that owners understand, agree and are bound by the apportionment process.

What is the best operational strategy for minimum costs?

This depends on how the plant is configured. In the simplest case, the plant is configured to provide residents with hot water and the electricity is used to power the common property services only (such as common lighting, ventilation and lifts) with no power provided to individual apartments. In this case, and with the current structure of gas and electricity tariffs, and using typical cogeneration plant efficiencies (fuel to electricity and the fraction of waste heat recovered for hot water) the most economic operating strategy would be to minimise the amount of electricity needed from the grid during peak tariff periods (for example from 2.00 pm to 8.00 pm in the EnergyAustralia network). This means operating the cogeneration plant during these hours and using the generated power to reduce or eliminate any power consumption from the grid. The hot water produced would then need to be stored for consumption during the evening and morning periods.

Operating the plant continuously is possible but it would be more economical to use low price electricity for the common property during off-peak periods than to use power from the cogeneration system. A 25% efficient gas engine will convert natural gas at 5.3 c/kWh (1.47 c/MJ) to electricity costing 21.2 c/kWh whereas off-peak electricity can be purchased at about 5 c/kWh (commercial tariffs) depending on usage. Electricity prices during peak and shoulder periods may be double or more compared to off-peak prices, so it makes sense to run the plant during peak periods. Larger engines tend to be more efficient (fuel to electricity) so large multi-unit apartment blocks can have better economics than smaller buildings, especially if they use more than 10 TJ of gas a year.

How will plant operation be monitored for fault as well as for performance?

Most modern cogeneration equipment can be configured to be remotely monitored via telephone or internet connection. If this is not available from the manufacturer, third party suppliers can usually provide the necessary hardware and software. If the owners corporation has appointed a building manager then monitoring of operation and performance would be a responsibility of that person or organisation. For buildings without a manager or services supervisor, a service contract with an organisation should include regular monitoring as well as maintenance and repair.

Annual performance checks should be undertaken by the building manager or contractor to ensure ongoing efficient operation. This could entail meter readings of operation hours, gas consumption, electricity production and hot water delivery for example. Total plant efficiency should be checked and maintained at the suppliers specifications.

Is utility control an option?

Utility control involves an agreement between the plant owner and the power utility whereby plant operation is under the control of the utility. This is used in some industrial cogeneration installations when it is of benefit to the utility to be able to call on local power generation in times of high demand, network constraints or other circumstances. The plant owners usually negotiate a payment from the utility for this control. While it is technically possible, the small power output available from most residential installations would make it impractical for the utility, unless a number of buildings were to be aggregated. Utility control means that the engine might need to be operated beyond what is needed for hot water production and so extra cooling and heat rejection equipment would need to be installed adding considerable extra cost for the owner. Nevertheless, utilities may be interested and should be approached during the design phase.

Design & installation

'*I only need a plant that will supply domestic hot water and generate electricity at an efficiency of at least XX%. From the point of view of reliability and maintenance, what is the best choice of prime mover?*'

While there are a number of technologies that could be used to provide both electricity and hot water, such as fuel cells, solar thermal heat engines, Stirling engines, gas engines and gas turbines, only gas engines and gas turbines are commercially available, economically viable and proven for residential cogeneration. Microturbines are themselves quite new and have yet to establish an installed base and demonstrated lifetime operation.

Comparing microturbines with reciprocating engines is not as straightforward as expected. Microturbines typically have only one moving part (the turbine) and don't require lubricating oil or cooling water so their maintenance can be very simple and infrequent. However in real life operation, especially with frequent starts, breakdowns and malfunctions increase. They also incorporate sophisticated power electronics and inverters which can and do fail. These systems require specialist repair facilities currently not available in Australia, and there has been lengthy delays in the repair of the few units operating in Australia. This is expected to improve as the installed base grows.

Reciprocating engines, with lubricating oil, cooling systems and many moving parts, require much more maintenance than microturbines with more opportunity for breakdowns. However there is a large base of service and repair skills available from the automotive industry and modern internal combustion engines have become very reliable, provided preventive maintenance is carried out according to the manufacturers guidelines.

The fuel efficiency of the prime mover is important because it determines the ratio of electricity to heat output of the system, however it is not easily altered, being a product of the thermodynamics and design of the engine. While low efficiency might be acceptable when the most important product is heat, it is usually the case that higher efficiency is more desirable as electricity is a higher value product (if no electricity is needed then a simple gas burner is the best solution).

Who can design the plant and advise me on optimum size with lowest running and maintenance costs.

There are a number of companies that have experience in designing and installing cogeneration systems, but most of these are at the larger, industrial scale, such as installations in Parliament House, Macquarie University, Newcastle University, and Griffith Hospital. However some of these companies have indicated they can design and advise on the installation of small cogeneration systems. The Australian Business Council for Sustainable Energy (BCSE) has a search facility on its website for BCSE member companies that offer cogeneration services.

Where should the plant be sited in view of service access, noise and exhaust discharge requirements?

In most cases, rooftop installation will be the preferred location, as it is with centralised gas-fired hot water systems. Gas fuelled engines require a well ventilated location to comply with gas codes, which becomes difficult in basement and other internal locations. Hot water storage and distribution is also most conveniently undertaken from a rooftop location. The space required for the plant will obviously vary with the size of the building that it serves, but as a guide, a 70 kWe cogeneration plant might have a footprint of approximately 2 x 3 metres.

Engine noise and vibration can be mitigated using acoustic enclosures and rubber or spring based supports, however equipment suppliers should be consulted for the range of measures that might be needed in each location. Particular attention needs to be given to exhaust and air intake silencers. Microturbine based cogeneration systems also need well designed enclosures to avoid unacceptable noise.

Utilities

What are my options for grid connection?

The simplest and lowest cost connection would be to not connect the generation system to the grid at all, for example, just using all the electricity generated to power loads on the common property such as lighting and ventilation. However this means that when the cogeneration plant is not operating, no power would be available for those loads. This is unlikely to be acceptable, or safe, in normal circumstances.

The next option is to connect the generator to the building's electricity supply but designing and operating the system so that the generator output is always less than the minimum load. For example, if the load from common property never drops below 80 kWe, a 50 kWe generator will never export power to the grid. When the cogeneration system is not operating, the full common property load would be met from grid supplied power, but when operating, only 30 kWe need be supplied from the grid. Providing all the installation, safety and other electricity code requirements are met, the distribution network service provider and energy retailer would not be further involved as no power would ever flow back into the grid from the building.

A more involved option is to provide power for local consumption, such as for common property loads, but to size the generating system so that excess power is exported to the grid. For example a 150 kWe cogeneration plant might meet all common area property loads and still be able to export 50 kWe to the grid. For this to occur, an agreement needs to be reached with both an energy retailer to purchase this power, and the distribution network service provider to manage the power flow. The ease or difficulty of the network connection will depend on the location and the capacity of the local network. For example, if the network is near capacity it may not be able to safely accommodate the exported power without some modification. These modifications could include transformer upgrades and fault level equipment upgrades which may be prohibitively expensive for a small generator. The energy purchase agreement may also be unattractive.

How can the plant be used to maximum effect for reduction of site loads and as leverage for reduced electrical tariffs?

The most effective way of reducing electrical tariffs is to use the power provided by the cogeneration plant to offset any purchases of electricity during peak and shoulder tariffs. This could be achieved by sizing the plant to be able to produce the required amount of hot water over the time period of these tariffs. The power generated during this time would go to meeting the common area load and so reduce demand from the grid by the amount of generated power. For example, if the average common area load is 80 kWe and a 65 kWe microturbine is operating, then only 15 kWe need be met from the grid while the plant is operating. A properly sized cogeneration plant would run for at least 10-14 hours per day, which should coincide with peak or shoulder tariffs for maximum saving. A system sized so that it only needed to run for 2 or 3 hours a day would imply a larger than necessary engine, and therefore be more costly to purchase.

Is electricity export desirable?

Exporting electricity (selling it back into the distribution network) produced with cogeneration is possible in most locations, however the price received from the electricity retailer is subject to negotiation. Additional equipment such as meters and safety devices might be required. In some locations where the existing electricity supply is already near capacity, the distribution network service provider might be willing to provide extra payment for a guaranteed amount of exported power, usually during peak periods. With current gas and electricity tariffs, it is unlikely that a gas-fuelled cogeneration plant could economically export power except under a negotiated agreement for peak periods. In almost all cases, the most economical operation would be to use the generated power to meet the common area loads such as lighting and ventilation.

How can an attractive gas tariff be negotiated?

Under current metering arrangements, customers using a centralised gas-fired hot water system are individually metered and billed. Aggregation of usage (by building or strata for example) to access lower tariffs is not permitted, as long as individual apartments are metered and read by the utility. However if hot water meters were installed and read by a third party, then it should be possible to aggregate all usage and perhaps qualify for a lower tariff. For example, if the owners corporation, or an energy services company, purchased the gas and managed the billing process, access to bulk usage discounts might be available.

Under NSW regulations, commercial and business customers using less than 1 TJ of natural gas per annum can accept a regulated tariff or request a market contract with their supplier. Customers using between 1-10 TJ per annum can request a market contract. As an indication, a 30 kWe cogeneration system operating for 10 hours a day supplying hot water to approximately 60 apartments (say 120 residents) could consume about 1.4 TJ per annum. Using current regulated tariffs this corresponds to approximately $1600 per month for gas consumption. Significant tariff reductions may be available for customers using more than 10 TJ per annum, however this level of usage would be unlikely to be reached in all but the largest buildings.

What is the process for obtaining consent to connect to the electricity grid?

Any person or organisation seeking to connect generating equipment to the electricity network must have approval from the Distribution Network Service Provider (DNSP) prior to connection to the electricity grid. In NSW, the DNSPs are Country Energy, EnergyAustralia and Integral Energy. Each DNSP provides their own requirements for connection of generating equipment to their network.

Some cogeneration systems use inverters to provide power output. Inverters are used to electronically transform the generator's output to match the mains requirements and are typically used on microturbines. If the power output is up to 10 kVA per phase (nominally a 30 kWe machine) the inverter must be compliant with Australian Standard AS 4777 *Grid Connection of Energy Systems via Inverters*. For inverters with a greater output than 10 kVA per phase, each installation might require individual assessment. In any case, the installation must be undertaken by a licensed electrician in accordance with the NSW Service and Installation Rules (currently under review), and will be inspected by an officer from the DNSP before connection is allowed.

For non-inverter connected generating equipment there may be additional protection and operational requirements which must be met before connection is approved. These requirements cover issues such as:

- disconnection of the generator in the event of loss of network supply
- operational procedures for automatic connection and synchronisation of generator output to the network
- protection to avoid 'islanding' when network supply is absent
- voltage and power quality standards

In general, with the size of systems likely to be connected in residential cogeneration (say <100 kWe) the requirements are less stringent than with larger generators, however approval to connect cannot be taken for granted. You should ensure that the specifications of the equipment are acceptable to your DNSP prior to installation. Some imported systems have been designed for operation in the northern hemisphere and may need additional testing before approval is granted to connect.

What is the process for obtaining consent to connect to the gas distribution network?

In NSW customers can choose from a number of energy retailers:

Locality	Utility
Sydney, Newcastle and Wollongong and other regional areas in NSW	AGL Gas Networks
Wagga Wagga, Tumut, Adelong, Cooma, Bombala and Gundagai	Country Energy Gas Pty Ltd
Albury and other townships near the NSW and Victorian border	Envestra and Origin Energy
Nowra, Bomaderry and Queanbeyan	ActewAGL
NSW north coast border towns	Allgas/ENERGEX

The process for obtaining consent to connect varies depending on the energy retailer but typically involves completing an application form that requires details including the location of the nearest gas path valve, the required metering pressure, and a load summary consisting of the equipment's hourly gas consumption rate (MJ/h) and usage pattern.

What protection measures are needed for grid-connection and how much do they cost?

This depends on too many conditions to be able to give a comprehensive answer, as the protection measures depend on the type and size of generating plant, whether it is connected via an inverter, the local electricity network conditions and the requirements of the DNSP. However the sorts of measures needed could include automatic disconnection during loss of network supply, automatic re-synchronisation, automatic fault detection and disconnection, protection measures from over and under voltage conditions. Some or all of these requirements may already be met with packaged equipment from suppliers but each system would need to be checked according to the local network requirements.

Where on the Internet can I find more information on cogeneration?

The Australian Building Council for Sustainable Energy <www.bcse.org.au>

Cogen Europe - The European Association for the Promotion of Cogeneration <www.cogen.org>

The World Alliance for Decentralized Energy (WADE) <www.localpower.org>

Midwest Cogeneration Association <www.cogeneration.org>

Combined Heat and Power Association UK <www.chpa.co.uk>

Natural Resources Canada <www.retscreen.net>

IEA/ECBCS Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems <www.cogen-sim.net>