Design snap shot 21: Cogeneration

Summary

Introduction

The CH2 building provides a proportion of its own electricity for use on site, through a small scale gas combined heat and power (or micro-CHP) generation unit.

Figure 1. Example of a cogeneration system – Capstone

The generation of electricity produces heat and in a cogeneration system this heat is used to assist heating and cooling the building - directly for the building's heating hot water system and through an absorption chiller for cooling.

Drivers and objectives

To reduce the greenhouse gas emissions of the building, natural gas is used as the fuel source of the generator. This replaces grid electricity which predominately comes from brown coal fired power stations in the La Trobe Valley, east of Melbourne.

In addition to augmenting the energy use of the building the generator acts as a back up power system for critical building systems, in case energy supply from the grid fails.

Costs and benefits

The micro-CHP provides a degree of autonomy from the electricity grid, and could be extended in capacity at a later date.

The size of the plant was determined by the amount of waste heat that could be utilised.

Using gas reduces the use of high grade energy (electricity) used for low grade purposes such as heating and cooling. The return on investment in the plant is 7-8 years, as implemented with the cooling option. The cogeneration system will also help the building to achieve an 85% reduction in energy use compared to Council House, while significantly reducing greenhouse intensity of the electricity used. Reduction is expected to be 1773 tonnes of CO_2 per annum.

Outcomes

The peak demand on electricity is reduced.

The electricity generation capacity of the system is sized for the needs of the computer systems and associated ventilation system. The by-product of the generation is waste heat which is passed through an absorption chiller and used to supplement cooling as well as heating.

Lessons

The combined cooling and heating and power plant provides the opportunity to avoid distribution losses associated with energy production.

The micro-CHP unit provides a 'future-proofing' mechanism and could be replaced at a later date with a carbon neutral source, such as a fuel cell powered from renewable sources.

To be cost effective the system runs when the waste heat can be harvested and used by the building. For this reason the unit is not operated at night and runs only during working days.

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More detail

The co-generation plant proposed for CH2 will contribute to the building's electricity requirements and provide heating and cooling from efficient, low grade energy sources. The use of natural gas for co-generation also has a lower greenhouse intensity than grid power. The key to maximising energy efficiency is the utilisation of the waste heat, as it reduces the energy consumption of the building as a whole. This heat will be used to heat and cool fresh air constantly entering the building, as well as to heat water for hydronic heating.

Figure 2. Example of a gas fired co-generation plant at Macquarie University, NSW. Source SEDA.

Fuel source

In choosing the generation plant, various sizes and fuel sources were investigated. Diesel was discounted, as although the plant size is smaller for a given capacity, fuel tanks would be required and a high maintenance regime. A diesel engine has a high running cost for not a great deal of environmental gain over grid power.

Although a fossil fuel source of natural gas was opted for, this was deemed acceptable compared to the traditional electricity fuel source of brown coal used in the Melbourne region. A natural gas turbine was chosen as it could be connected to the mains supply. In addition, the generator has relatively few moving parts, so the maintenance requirements are low. The system requires the minimum of intervention, so has a low operating cost.

To make the plant as viable as possible, it was integrated with other energy systems. If a traditional HVAC (heating, ventilation, air conditioning) system of ventilation was used, the plant would have had to be so large that there would not be space in the building for the system.

Backup generator vs full time generator

The way in which the generator was to be used was determined by it's capacity to deliver cogeneration. Co-generation, in this case micro-combined heat and power (CHP), is the simultaneous production of electricity and heat using a single fuel such as natural gas. A typical generator will produce electricity, with heat as a waste product. However cogeneration captures the heat, for use in heating (or cooling if combined with an absorption chiller). The efficiency of a 30% generator is boosted to 70-80% when the waste heat is used in a cooling system, energy that would otherwise have to come from additional electricity. That is a typical micro turbine unit can produce three times as much thermal energy as electrical energy which is usually wasted to the environment by cooling towers.

Due to regulatory problems of exporting energy to the grid, (the building had to pass regulations concerning power stations), it was decided to provide the base load of a back up system for the electricity use of computers and associated building services. This meant that the energy would always be used and the system could be shut down in times of low occupation such as over Christmas.

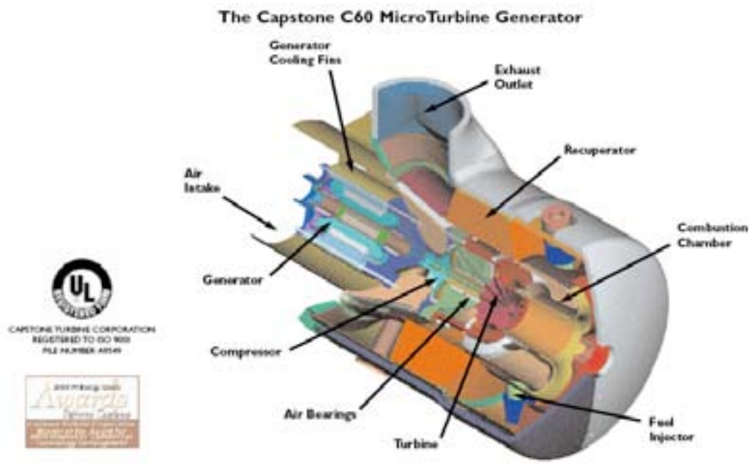

Figure 3. Example of a cogeneration system – Capstone

Process

The generator uses hot air warmed up by the burning gas to pass through a turbine to produce electricity. Usually, this heat is wasted. In the case of CH2, this air is sent to a heat exchanger, where hot outgoing air preheats the incoming air so the minimum amount of heat energy is lost. This heat is then used in a low pressure evaporator to provide cooling for the building.

This process of cooling using waste heat is termed absorption chilling, and uses the same principle as a fridge to provide coolth to the building. Although less efficient than an electric chiller, it uses waste heat to produce cooling of the building and so is more energy efficient overall.

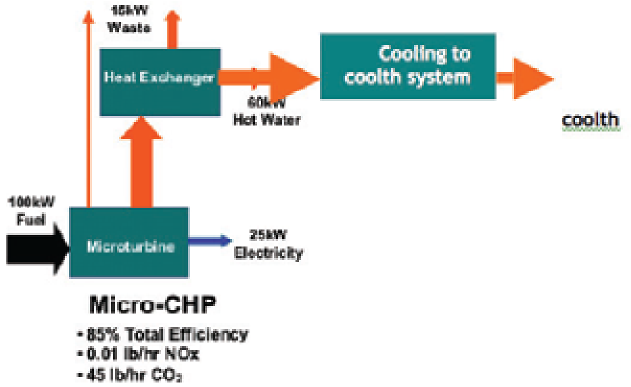

Figure 4. Advantages of a cogeneration system – Capstone

Micro-CHP (Combined Heat and Power) plants are typically 75% to 85% efficient, compared to coal-fired electricity at around 35-40%. An indication of the emission savings is provided in the following table, which shows the kilograms of CO_2 emitted per Mega-watt-hour of energy produced (CSIRO).[1]

Technology	kgCO2/MWh
Gas engine alone	550-580
Fuel cell alone	400-500
Gas engine + hot water[2]	280-300
5 MW gas turbine + steam	370-400
Coal[3]	920-940

System installed

The installed system has a capacity of 60kVA (kilovolts amps, equivalent to kilowatts) electrical supply, and 180kW heat supply (equivalent to 72kW of cooling load when passed through the heat exchanger). This provides enough electricity for the computer rooms. It was decided that it is better to have a system that runs efficiently to provide the base load than provide the whole electrical load of the building, which would produce excess heat.

The system installed is a modular system, so as the electricity and thermal requirements of buildings around CH2 are determined the plant can be added on, to providing additional power and cooling.

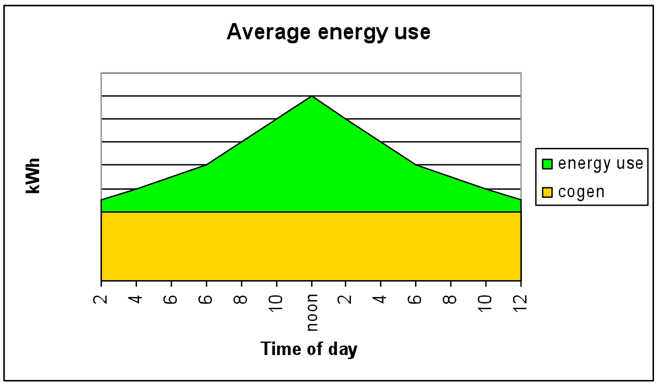

Figure 5. Illustration of how cogeneration can reduce total load in a typical building

Calculating the system

From the graph below it can be seen that at a load of 100kW efficiency starts to decrease therefore beyond 100kW any increase in heat load capacity would be inefficient – i.e. give less benefit for extra investment.

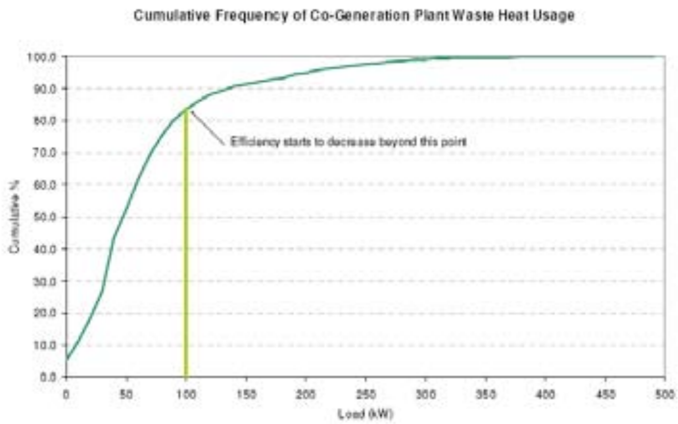

Figure 6. Examination of waste heat efficiencies (AEC)

Therefore, the optimum size for the system was set at 100kW. With this unit, 80% of the building's heating or cooling requirements can be satisfied by the co-generation plant's waste heat. The AEC team then checked to make sure that the system was not over-sized or under-sized looking at heat and cooling requirements for specific periods, rather than cumulative yearly needs.

1 table from http://www.det.csiro.au/factsheets/gas_de_csiro.html
2 waste heat utilisation offsets new generation (emissions are on equivalent basis)
3 pulverized fuel combustion - current power station technology

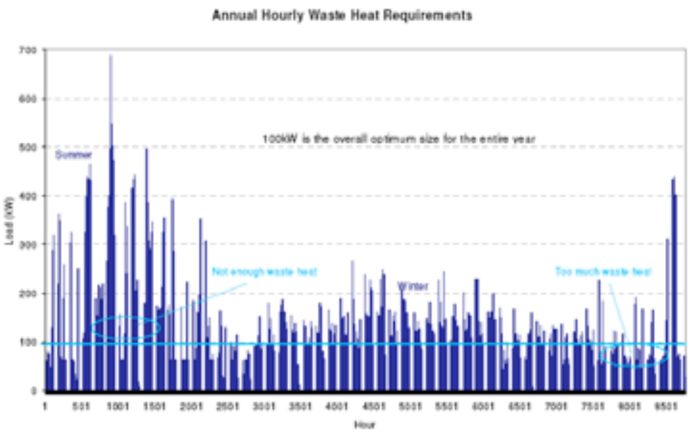

Figure 7. Examination of constant waste heat requirements (AEC)

This showed that indeed the 100kW system provided a good balance between insufficient and too much waste heat.