THE BUSINESS CASE FOR COGEN & TRIGEN

TECHNOLOGY OVERVIEW

In cogeneration (cogen) systems (also referred to as combined heat and power systems), a fuel is burnt in an engine to produce electricity, with waste heat from combustion captured and used to drive thermal processes. In industrial settings, this heat is used as process heat, while in commercial buildings this heat can be used for space heating or cooling.

Trigeneration (trigen) extends this concept by using the heat to also drive a cooling process. The cooling part of the plant will be supplied using an absorption refrigeration cycle, like the ammonia-water absorption system used in "three-way" camping fridges, or "thermal wheel" systems, which exploit the cooling effects of evaporation.

When linked with an in-vessel anaerobic digester[1], the waste heat can be used to heat the digestion process, which improves the operation of the digester.

An example theoretical integrated energy from waste system for meat processing sites could be assembled as follows: waste streams are collected in a large concrete tank where they undergo anaerobic digestion to produce methane/biogas. This gas is collected and used to fuel an engine, which drives a generator and produces electricity. Combustion heat, captured in the engine jacket water, is used to heat the digester and speed the anaerobic digestion process. Gas supply can be buffered in the tank using expanding bladders or floating lids, which allows the generator to meet the plant electricity load. The hot water from the engine will not be hot enough for rendering or sterilization, but could be heated further using biogas in an instant gas heater.

IS IT SUITABLE FOR YOUR FACILITY?

As a rule of thumb, conventional cogen systems convert incoming energy (fuel) into one third electricity and two thirds heat. Therefore, the key determinant of the economic feasibility of a cogen project is whether a sufficient heat load exists at the site, or near the site (i.e. in the form of a district/community heating scheme).

[1] See the AMPC Factsheet "The Business Case for Methane Capture and Reuse"

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Please note that where commercial services providers are referred in this report, this is for industry guidance only and should not be considered an exhaustive list of available service providers.

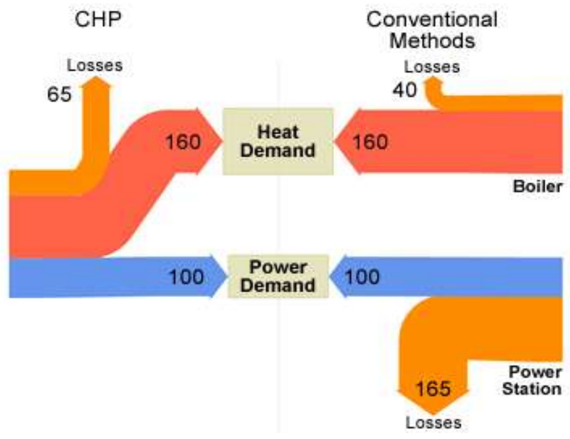

Figure 1 Energy flow diagram comparing conventional methods and cogeneration (CHP)[2]

If a use for the waste heat does not exist, the heat generated by the cogen system would not be utilised and the project could be economically unviable.

As shown in Figure 1,[2] generating electricity via a cogen enables waste heat usually vented to atmosphere to be collected and used for process heating applications such as rendering and sterilising.

Similarly, the economics of trigen systems are most attractive when a constant cooling load exists, in addition to some need for low-grade heating. Electricity can be provided on-site by the generator and the waste heat can be utilised by an absorption chiller to reduce the refrigeration load, as well as heat water to reduce boiler use.

HOW TO DEVELOP YOUR BUSINESS CASE

The main factors to consider when developing a business case for a cogen or trigen system include:

- Electricity use and demand profile at the site
- Generator fuel – i.e. biogas, natural gas, LPG or fuel oil
- Energy savings – electricity cost and pricing profile, boiler fuel reductions
- Future prices of generator fuel
- Revenue generated through financial support mechanisms such as a carbon pricing scheme
- Heating and cooling loads at the site.

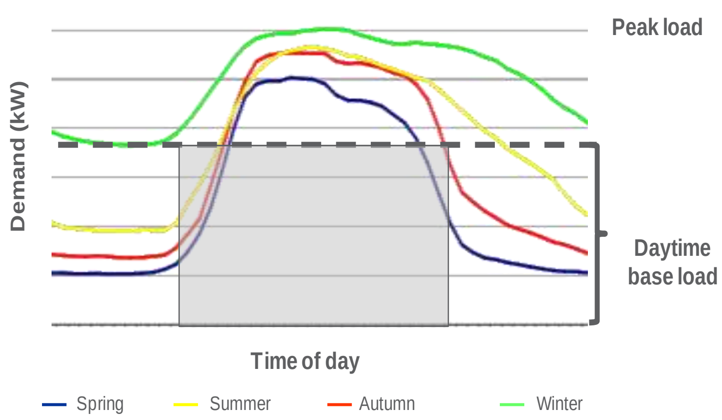

Figure 2: Illustrative seasonal load profiles

ELECTRICITY USE AND DEMAND PROFILE

Maximum economic value for any onsite generation of electricity is realised through onsite use (to offset more expensive grid-sourced electricity), rather than electricity export. The first step is to determine how much electricity is used on site and when the usage occurs.

Half-hourly interval metered data, obtainable from your electricity supplier, can be used to determine the site's load profile and consumption. The generator should be scaled to provide no more than the maximum power required by the site (see Figure 2).

Over-sizing the cogen/trigen system can decrease the profitability of the project because it is rarely economic to export the generated power. This is due to the current low price of power purchase agreements on offer from energy suppliers.

FUEL AVAILABILITY

The economics of cogen/trigen systems is most favourable when the generator runs constantly. Consider whether you have a stable supply of fuel to meet this demand. Sites connected to a gas grid are unlikely to experience a fuel supply problem, sites who rely upon biogas captured from the onsite wastewater treatment facility may experience fuel supplies problems if the wastewater system ceases to produce biogas.

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[2] Diagram from http://chp.decc.gov.uk/cms/chp-benefits/?phpMyAdmin=ff232c1d3b302ac6e951f554eeeaefdf

ENERGY SAVINGS

Energy savings in cogen/trigen projects can be found across multiple sources; including electricity, heating and refrigeration loads, as outlined in the cost benefit analysis below.

FUTURE PRICE OF FUEL AND CARBON CREDIT PRICES

Gas prices are forecast to rise in the coming years, driven by export competition on the global market. This could have a significant impact on the economics of a cogen/trigen project. Similarly, markets for carbon credits change over time and changes to the values of these credits impact upon the economic viability of a project.

HEATING AND COOLING LOADS

A site's heating load can be estimated using thermal modelling techniques, or by determining the capacity of the existing hot water heater(s) or boiler(s), their efficiency, and their period of operation.
A site's cooling load can be estimated using thermal modelling techniques, or by determining the cooling capacity of the existing refrigeration plant, their efficiency, and their period of operation.

FINANCIAL INCENTIVES

A coge/trigen project may be eligible for funding under Government incentive programs targeting energy efficiency and greenhouse gas mitigation.

A project which is fuelled by biogas may be eligible for Renewable Energy Certificates (RECs) for the electricity created. More information on renewable energy power stations and Renewable Energy Certificates (RECs) can be found at the link below. RECs generated for biogas projects are discussed in the AMPC factsheet "Anaerobic digestion".

EXAMPLE COST-BENEFIT ANALYSIS

An abattoir uses about 700MWh of electricity annually, with a peak load of about 100kW, and wants to reduce energy costs. A modest heat load exists at the site, which is currently met with about 10,000GJ of natural gas a year. Of the 700MWh of electricity used each year, about 300MWh is used in refrigeration.

The abattoir engineering manager discovers an 80kW (electric) genset that looks suitable for the site. In weighing up the costs and benefits of the genset, the annual costs are considered, based on an electricity price of $0.25/kWh and a gas price of $8/GJ. These costs are shown in Table 1.

Electricity ($)	Natural Gas ($)
175,000	80,000

Table 1 - Current costs p.a.

It is assumed that the genset will operate with an 80% utilisation factor and is 25% efficient at converting gas to electricity. Electricity will not be exported from the genset to the grid. Waste heat from the genset is sent to the boiler. It is assumed that 20% of the heat generated is unrecoverable, so 80% of the waste heat goes to the boiler. The energy and financial inputs and outputs of the project are shown in Table 2. The existing boiler will use less natural gas because of the waste heat recovered from the genset. It is assumed that boiler energy use will be reduced by the same amount as the heat sent from the engine; the boiler captures heat to water at the same rate regardless of the source. The overall cost saving per annum are shown in Table 3.

Gas required for the engine (GJ input)	Cost of gas for cogen ($)	Electricity generated by the engine (kWh output)	Electricity cost saving ($)	Waste heat to boiler (GJ output)	Saving of gas at boiler ($)
8,064	64,500	560,000	140,000	4,838	38,700

Table 2 - Cogeneration inputs and outputs p.a.

	Electricity cost ($)	Gas ($)	Total ($)
Existing system	175,000	80,000	280,000
Cogen system	(175,000-140,000) **=60,000**	(80,000+64,500-38,700) **=105,800**	**165,800**
Change	-115,000	+ 25,800	**- 89,200**

Table 3 - Scenario cost comparison

A conservative estimate of $20,000 per annum is used for maintenance and spare parts, leaving an annual saving of $69,200 ($89,200 - $20,000). The estimated capital cost of the project is $400,000, therefore the simple payback of the project is less than 6 years.

In this scenario the waste heat has the same value as the gas it offsets; 4,838GJ of waste heat is captured, achieving a $38,700 reducing in gas costs each year. If an absorption chiller were installed, this heat could be used to provide cooling for refrigeration. As this heat would have to be diverted from the boiler where it is offsetting gas use, its value is the same as the gas use that could be offset.

Adding a trigeneration cooler to reduce their refrigeration load is estimated to cost an extra $200,000. The cooler is evaporative and has a coefficient of performance of 0.5, so 1GJ of heat captured from the genset offsets 0.5GJ of coolth from the refrigerator. The existing refrigerator uses electricity and has a COP of 4, so requires 0.25GJ of electricity per 1GJ of cooling.

The absorption chiller could provide cooling at $1.36/GJ less than the existing refrigeration system ($17.36 - $16, as shown in Table 4). The current system uses 300MWh of electricity each year. The refrigerator has a COP of 4, so 300MWh electricity provides 1,200MWh cooling, or 4,320GJ, each year. Assuming the absorption chiller could provide all of this, it would save $5,875 each year, indicating a payback on the capital cost of the absorption chiller ($200,000) in the order of 40 years.

	Coefficient of Performance	Fuel cost ($/GJ)	Cost of cooling ($/GJ)
Existing Refrigerator	4	69.45 (based on an electricity tariff of 25c/kWh)	17.36
Absorption chiller	0.5	8 (cost of natural gas avoided in boiler)	16

Table 4 - Trigeneration chiller