Investigation into cogeneration systems for abattoirs using micro-turbines, organic Rankine cycle units or reciprocating engines.

Project Report Reference: 2016.1002 **Date: February 2017**

Project description

Energy costs for heat and power represent major operating costs for abattoirs. These costs have increased more than the consumer price index (CPI) in recent years and are expected to increase further in coming years. Cogeneration (or CHP, combined production of heat and power) is increasingly seen by the meat processing industry as a way of improving energy efficiency, and thus reducing costs and also greenhouse gas emissions. MLA and AMPC have investigated cogeneration on several occasions over recent years, with a number of reports prepared on its various aspects. Most recently, work on AMPC project 5011 identified micro-turbines and organic Rankine cycle (ORC) units as equipment worthy of further consideration relative to reciprocating engines for the provision of cogeneration in abattoirs.

Cogeneration is already used widely around the world. The targeted technologies show commercial viability at a range of scales and across a variety of applications. The applications for micro-turbines are often different to those for ORC units. This project has reviewed several different sizes and configurations for cogeneration using these units, combining data from experienced vendors with operating conditions for a typical meatworks. Cost benefit analysis has been used to assess commercial viability.

For each of the technologies considered (organic Rankine cycle (ORC) units, reciprocating engines and micro-turbines) budget pricing for supply, installation and operation was gathered from experienced Australian vendors, along data from industry reports and technical literature. These provided the basis for cost benefit analyses to examine the commercial viability of the cogeneration systems at a range of scales and operating situations.

Project content

The analysis was completed for a "typical" red meat process facility, which processes 625 head of cattle per day[1], running a 2 shift per day roster for 250 days per annum. The principal assumptions made for the base case cost-benefit analysis were:

[1] www.mla.com.au/download/finalreports?itemId=3112, accessed 3 August 2016.

	Assumption	Information / Reference
1	Natural gas lower heating value (LHV) 47.13 MJ/kg	http://hydrogen.pnl.gov/tools/lower-and-higher-heating-values-fuels
2	Natural gas price $12 / GJ.	Approximate median commercial rates
3	Electricity – Peak: $ 0.1269 / kWh Electricity - Off Peak: $ 0.0876 / kWh Network Charge: $ 262.308/kVA/yr	Approximate commercial rates for businesses on 11 kV grid power feed
4	Operation during peak power cost periods: 3,500 h/yr	Peak 7am - 9pm M-F Off-peak: 9pm – 7am M-F, plus weekends
5	Operation during off peak power cost periods: 4,924 h/yr	
7	Power factor for facility of 0.9	Integrated industrial facility without power factor correction
8	688 kWt of hot water, or 5830 kWt of 6 bara steam can be utilized on-site during operating hours	Mass and energy balance result for a “typical” facility based on industry data.
9	Up to 2661 kWe of power can be consumed during operating hours	
10	No indexing (CPI), discounting, tax considerations or depreciation applied to future revenue / costs.	

For some meatworks, biogas produced on site may be an alternative to natural gas. The typical meatworks is anticipated to produce sufficient biogas for operating the 250kWe ORC unit, 633 kWe reciprocating engine and 200 kWe turbine at full capacity, and the biogas option was considered for these smaller systems. Operation of larger systems on a mix of biogas and natural gas was not investigated. Biogas was assumed to be “free issued” from a co-located anaerobic digester. This biogas can be used to create large scale renewable energy credits under the Australian Government’s Renewable Energy Target (RET) scheme, which were valued at the spot price of $86 / MWh[2].

Project Outcomes

For cogeneration units operating consistently at capacity and with natural gas as feed, reciprocating engines were found to provide better payback periods than either micro-turbines or ORC units. We attribute this primarily to the ability of the engines to achieve more efficient electricity generation than micro-turbines or ORC units, resulting in significantly improved revenues from an equivalent quantity of gas.

While the modeling done for this project assumed constant operation at capacity, in real-world applications it is likely that units will be required to operate at partial loads. For such operation micro-turbines and ORC units both offer greater flexibility than reciprocating engines. The ambient temperature for operation has an effect on system efficiency, and reciprocating engines appear to be less sensitive to temperate than micro-turbines.

All cogeneration systems considered were capable of generating hot water at 90 ^{O}C, which can contribute to the meatwork’s process heating needs, but is potentially limited by the actual plant requirements for hot water and its existing availability from other sources within the plant. ORC units also offer an alternative approach. When coupled with new heat plant, the combined

[2] http://greenmarkets.com.au/, accessed 20 Oct 2016.

system can provide process steam instead of hot water, potentially offering greater flexibility for such systems when the meatworks requires a new heat plant. Micro-turbines can also be used to generate steam, via a purpose-built heat recovery unit capturing waste heat from the turbine. We were advised that 5 bar steam could be produced in this way.

Larger cogeneration systems were found to offer economies of scale, with lower capital cost per unit of energy output. However this did not always mean that such systems achieved shorter payback periods. While small cogeneration systems are able to target peak electricity replacement, the larger systems rely more on the replacement of cheaper, off-peak electricity and this was found to have an adverse effect on their profitability that was greater than any capital cost benefits achieved through economy of scale.

Most of the cogeneration systems modeled using the base case assumptions did not show a feasible payback period. Sensitivity analyses were undertaken. When electricity prices were increased relative to the price of fuel used for cogeneration the payback periods improved for all systems. Similarly, lower fuel prices had a positive impact on payback periods. It would appear unlikely that natural gas prices will reduce in the future. However, alternative fuels may offer lower fuel costs in specific situations:

- If waste management at a meatworks necessitates anaerobic digestion, all forms of cogeneration that are partly or completely fuelled with the digester gas could show a better payback than the same system operating only on natural gas. This is based on the premise that the cost of the digester gas is lower than the cost of equivalent natural gas.
- If a new heat plant is required, a plant that uses biomass (e.g. local wood wastes) as a fuel could show improved economic viability over a gas-fired unit. Such plants will have greater capital costs, however the lower cost of fuel may mean that the whole of life costs are better for a biomass system than a natural gas system. Selection of a sustainable biomass fuel that

Benefit for industry

All of the engines have strong economics when run on low cost biogas (4 - 6 year payback). Further, when an ORC unit is coupled to a new heat plant that can utilize a low cost (wood chip) fuel that is renewable a payback of approximately 6 years could be obtained.