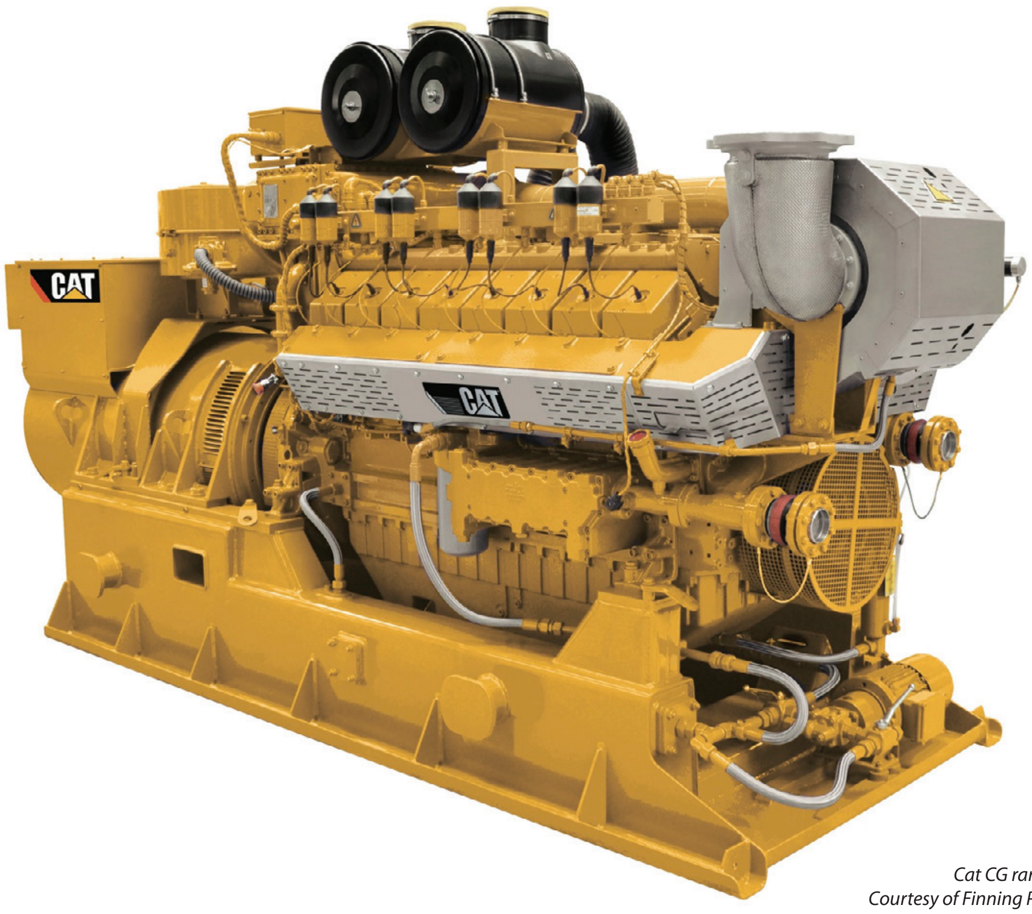
Biogas Engines in the Wastewater Industry

The search for efficiency - the key areas to consider when specifying gas engines to achieve the lowest cost of ownership

by David Hatherill BEng PhD CEng FIMechE

Efficiency ... Selecting the right engine to use with biofuels can be a complex engineering challenge. Quite apart from specifying the correct engine size for the application, there are a number of other factors which all compete with each other in the trade off, while other figures simply confuse. David Hatherill, Engineering Manager and Head of Technologies at Finning Power Systems discusses the key areas to consider when specifying gas engines to enable an installation that delivers the right level of efficiency for the best overall cost of ownership.



Cat CG range of engines
Courtesy of Finning Power Systems

The efficiency puzzle

Traditionally the pursuit of efficiency in the generator set has been something of a key performance target and manufacturers in this area have made significant gains. However increases in efficiency can be brought about by a variety of factors so it is important to understand how these are linked to real world operability and whether these paper improvements translate into bottom line savings.

First operators should consider that engines are tested in accordance with ISO 3046/1, which specifies requirements for power, fuel and oil consumption among others. This provides a 'best efficiency' figure, not the nominal or actual efficiency users may achieve in operation, which may vary by several percentage points.

It is always worth checking which efficiency figure is being quoted in headline figures. Further to this it is worth noting that engine manufacturers usually quote fuel consumption based on the net calorific value (also called lower calorific value) of the fuel since this is the useful energy it contains. Some regulatory paperwork requires that gross calorific value (or higher calorific value) is used, despite the fact that some of the energy content is not realisable.

Another item to consider is that some engines use ancillaries such as pumps and fans, which are engine driven, so these will already be deducted in the net engine output figure.

Other engines may incorporate separate electrically driven items that impose an additional parasitic load, and therefore need to be deducted from the generator output. Given that this mode of operation will result in a loss of metered green electricity, the lost revenue can be much higher than normal market rates.

Sophisticated control

Historically, and until comparatively recently improvements in efficiency have been brought about by improvements in control: typically more sophisticated fuel metering valves, advances in instrumentation and the introduction of integrated and sophisticated software and electronics.

In most cases biogas engines are now fitted with a single electronic control module with integrated software controlling all engine activities.

This is a step change from twenty years ago when engines incorporated many simple mechanical systems comprising springs and dampers, which were unable to communicate to other parts of the engine. Even early electronic modules of the time had quite discrete functionality and could not interface to other engine controls, although they provided some advances in specific areas.

Nevertheless the introduction of electronic control brought about significant improvements to not only efficiency, but also the ability to monitor, offering a change in the way engines could be managed and maintained at reducing cost. Efficiency savings of this type reduced variability in operation and did make a positive impact on the bottom line.

In more recent years, further improvements in efficiency have resulted from the use of increasingly high boost pressures from larger turbochargers coupled to larger aftercoolers, which increase the cylinder pressure and therefore power output. This means that for the same power output a smaller engine can be used.

The same principle has been applied to the automotive industry where smaller engines have been used to improve economy with no loss of performance. The quid pro quo for this high level of tuning has been that the engines are much less tolerant of variations in fuel and operating conditions. Since automotive engines burn a highly refined and clean fuel this change has been largely invisible to the user.

Fuel source

In the case of a biogas engine the situation is rather different since the fuel is neither refined nor clean, although in some cases a degree of gas treatment takes place to remove particulates. The result is a fuel that can, and often does, adversely affect engine performance and, the less tolerant an engine is about its fuel the greater the effect will be if it falls outside tolerance. It should also be noted that the size of this tolerance varies from manufacturer to manufacturer.

In practice this means that a high efficiency engine may have to derate more often, or may need certain components replacing at a higher frequency, which tends to negate the benefits of the efficiency gains.

Further increases in efficiency therefore come at some cost, and the cost is either in engines that are more prone to shutdown due to fuel variability, or in some cases, fail to deliver the expected savings due to increased maintenance cost.

It is also true that building efficiency into engine packages increases up front capital cost. Electrically driven fans for example can have their parasitic load reduced by the increased use of natural cooling, but this requires equipment to have increased cooling surface areas and sizing.

Power and heat

As if the above wasn't complicated enough, we have to take into account that many engines, and gas engines in particular, are used in combined heat and power (CHP) applications, so we are not necessarily only interested in electrical efficiency, but also in recoverable waste heat.

On a basic level, by making the unit more efficient electrically the amount of waste heat available to recover is reduced. Therefore the saving made in terms of efficiency is only really the difference in the cost of electricity versus heat, not the whole cost of the lost electrical output.

Added to this manufacturers may offer different jacket temperature engines, which mean the temperature of the waste heat available can vary by as much as 40ºC. In this case a more electrically efficient unit may in fact have much less usable waste heat, and if recovering exhaust waste heat the whole proposition becomes more complicated still. This is because the exhaust outlet temperature, at which no more heat can be recovered, varies according to the fuel type, whether biogas, natural gas or diesel, due to material corrosion limits.

Operational efficiencies

The third age of improvements in engine efficiency will not come about through advances in combustion or related headline efficiencies but through efficiency of operation. This component in the efficiency equation is related to data collection, analysis and management based not only on the machine in question, but also against other similar engines. This will enable precise benchmarking so that component lifecycle, oil life and service history can be managed more effectively and maintenance routines are more precisely aligned to individual engines.

This transformation is as much a consequence of our increasingly connected world as it is related to specific engine developments, although it will naturally tend to favour larger manufacturers who can invest in such schemes over greater installed equipment estates.

It should also be said that larger output engines tend to be more efficient than smaller units, and this can sometime leads to CHP being oversized. This invariably results in a lower efficiency since if the engine runs at part output its actual efficiency will be below that of the smaller unit.

Efficiency in the balance

Combining all the above points, we come to the conclusion that the pursuit of electrical efficiency on its own does not necessarily provide a very good indication of overall operating benefits.

It is necessary to consider not only the electrical output, but also factors including the heat output, maintenance cost, fuel cost, cost of existing heat, debt cost, green energy payments, risk and a number of other factors, or in other words the investment efficiency; in simple terms, how much has been put in versus the return on investment. This is the real measure that determines the success or otherwise of schemes.

The Editor & Publishers would like to thank David Hatherill, Engineering Manager and Head of Technologies with Finning Power Systems, for providing the above article for publication.

Engine control - Courtesy of Finning Power Systems