Small scale wood gasification coming of age?

TV Energy visited Biomass Engineering, Warrington on 24th May 2005 to view ongoing work with small-scale gasifiers. The trip was organised through Arup and forms a part of the continuing work towards sourcing an ESCo partner to design, build and operate the energy centre and supply energy services to the Bracknell town centre redevelopment. TV Energy was invited to join the visit with the aim of confirming whether the company has developed gasification technology sufficient to fill the gap in biomass to electricity generation plant in the 100s kW_e range. Confidence in the product would enable TV Energy to investigate the application of woodfuel gasification to the Bracknell project as well as a number of other potential end users in the SE of England region.

The visit comprised a presentation by Biomass Engineering of the company and its product followed by a tour of the grid connected gasifier and gas engine system at the Farm Project nearby.

Background

In the search for small scale (<1MW_e) generation plant, gasification combined with internal combustion engine or gas turbine technology is a high efficiency (~30%) process involving the conversion of biomass to electricity. Gasification is the conversion of biomass into a gaseous energy carrier by partial oxidation at elevated temperatures. There has been much development effort in recent years in an attempt to design a system which operates reliably and overcomes problems associated with tar contamination of the producer gas. There are a small number of installations in the UK which have experienced varying degrees of success in addressing these issues, however these are few and insufficient in experience to present a strong case to potential end users that this technology can reproduce the theoretical capability of the process in a practical application.

The woodchip fuelled combined heat & power (CHP) plant proposed for the redeveloped Bracknell town centre has taken established combustion and steam cycle technology to provide electricity, heating and cooling to buildings within the redevelopment area. At the scale envisaged (~1MW_e), this technology is on its lower limit of viability for reasons of low electrical efficiency (~10%) in comparison with heat output. This severely restricts the amount of revenue from the sale of electricity and ROCs (Renewables Obligation Certificates) which can be generated back into a scheme, given the high capital cost of such a plant and its associated energy distribution system. This type of technology is also relatively inflexible to varying heat demand, requiring large scale thermal storage in order to allow near continuous running through night periods when heat loads are reduced, in order to maximise year round energy efficiency and ROC revenue to claw back capital outlay. A biomass system which overcomes these difficulties can theoretically provide a more appropriate CHP solution at a lower lifetime cost with increased efficiency of CO2 saving.

Biomass Engineering and the Gasifier

Biomass Engineering, part of Shawton Engineering, is a British company based in Warrington and was set up in 1996 to develop a biomass gasifier to process clean wood and mixed organic wastes into producer gas of a quality suitable to fuel an internal combustion engine. Two test gasifiers have been built and since then a further five, four of these are operational and three more are under construction. Two of these are for projects in northern England and one for United Utilities in north Wales using briquetted sawdust as fuel, all to be commissioned by the end of 2005. There is a further 7MW_e of projects under planning. In total 30,000 hours of operating experience has been gained through existing units. The Ballymena ECOS Centre in Northern Ireland has a 75kW_e gasification and electricity generation plant installed by Biomass Engineering in 2000 with 4000 hours of operating experience. All gasifiers and associated key components are manufactured in house. Some funding has been received from the DTI for development of the process. Woodfuel applications account for 50% of business, the remainder is other waste products.

Technical

The key to the success thus far of operational units is the low tar (condensed hydrocarbon) content of the producer gas exiting the gasifier, around 13mg/Nm3 compared to typically ~200mg/Nm3. This has been achieved by continuously monitoring the pressure inside the gasifier and maintaining this pressure at the optimum level. The gasifier design is of the downdraught type, the producer gas leaves after the charcoal/ash bed leading to low tar carry over. Any tars in the producer gas must be filtered out prior to the gas entering an internal combustion engine otherwise contamination of the engine will take place leading to unreliability. High tar content post gasification results in the need for complex and expensive filtration systems. Tar removal in this process is achieved through reversible ceramic candle filters, elements are changed ever six months or so. Woodfuel can be fed into the gasifier with a moisture content of between 15 and 30%, heat energy from the generator engine exhaust can be used for fuel drying if necessary. Fuel feed is controlled by the variable parameters within the gasification process, and therefore is discontinuous.

The gasifier is around 80% efficient (producer gas out vs. fuel energy in), is able to handle a wide range of materials of varying quality and uses no fossil fuels in the process, apart from a small amount of propane on start up. The producer gas has around 20% of the energy value of natural gas, made up of N2, CO, H2, CO2 and CH4, in order of the largest component first. This gas can be fed to a modified internal combustion engine or gas turbine similar to the type usually fuelled by natural gas, to drive an electrical generator. From the producer gas stage of the process the system is very similar to other gas fuelled applications, for example involving electricity generation from landfill gas, biogas from anaerobic digestion and natural gas CHP processes. Ash content is typically 2 to 3% of fuel input by mass, this can be used as a soil improver (carbon positive), it is also possible to use the material in the manufacture of breeze blocks.

Emission levels are within EU legislation limits. A catalyst is used to remove a large portion of the NOx content of engine exhaust gas, resulting in a lower emission level figure than for an equivalent gas boiler. There is a small level of SOx present. Generally speaking the emission levels are slightly worse than for the equivalent natural gas CHP engine.

Commercial

Capital costs are around £2000/kW_e at 250kW_e scale, installed and commissioned but excluding site specific costs such as the fuel store and grid connection. System availability is essentially governed by the reliability of the engine, greater than 90% for the overall process is to be expected and a precise level is guaranteed on a contract by contract basis. The lowest size is 150kW_e for economic reasons, the capital cost is not very much lower than the larger scale. Systems can be built up as modular units of 250kW_e each. Second hand engines are often a good way of reducing capital costs, existing units with below 8000 hours of operation are worth considering. 48,000 operating hours (6 years) is the usual limit for internal combustion engines designed for this service before major refurbishment is required.

Typical lead time for a new project is 6 months, this is determined by the availability of engines if sourced as new units.

Annual maintenance costs from Biomass Engineering are around 1.3p/kWh_e of electricity generated, working out at roughly £18,000 per year for a 250kW_e system. The majority of this cost goes into the engines (1.2p/kWh_e). This typical contract rate would cover the first six years of operation, with renegotiation beyond this resulting in higher costs as equipment requires increased maintenance.

Farm Project Tour

This was an opportunity to see a gasifier system in operation and generating electricity supplying the national grid. Located on a farm on the outskirts of Warrington, this plant takes in woodfuel in the form of roundwood, chipped on site, stored in a bunker and loaded into a heated fuel feed hopper as required by the process. Woodchips range in size from 60cm x 30cm x 10cm to 100cm x 100cm x 30cm. The producer gas is fed into two 170kW_e engines located in acoustic enclosures. A separate control panel is located in a container. The system was connected to the grid in March 2005, the gasifier has been operating for 4000 hours however. Electricity is exported on a continuous basis, 24 hours/day. Ash is collected in a 250 litre drum and emptied periodically.

Fuel feed hopper

Gasifier with gas filter behind

170kW$_e$ gas engine

Ash collection

Heat from engine exhaust feeding woodchip hopper

Wood chip store

Acoustic enclosure, engine within. Gas feed shown.