Supergen WP1 Workshop on Environmental and Operational Aspects off Bioenergy Plant

Tuesday 20 June
13.00-17.00

Room H18
Pariser Building
University of Manchester

1. Welcome and Introduction

Patricia Thornley outlined the main objectives of the meeting:

- To examine factors influencing environmental emissions from different bioenergy systems more closely
- To establish what information/expertise was available within the Supergen consortium in relation to plant performance/operation
- To assist in filling data gaps in WP1 analysis
- To ensure that other partners were comfortable with assumptions and activity going on in WP1 modelling

2. Background – Summary of Cases

John Brammer outlined the 25 cases being considered as part of the WP1 analysis, covering a range of plant types, 4 scales for operation and 3 feedstocks. More detail is available in the presentation slides, which accompany the notes below:
The 250 kWe gasifiers are all downdraft with warm air drying.
Three CHP configurations are being modelled:

- Hot water/space heating
- Low pressure steam
- Medium pressure steam

The 2 and 5 MWe gasifiers are based on the Gussing, twin fluidised bed concept, with no drying.
Case 9 (atmospheric gasifier) is similar to Arbre.
Case 10 (pressurised gasifier) is similar to Varnamo, Sweden.
Case 11 (FBC) takes 30% moisture feedstock with no drying.
Models of pyrolysis systems with gas turbines will draw heavily on experience being gained on a plant in Canada.
Co-firing is at 5% of thermal input.

Jim Campion pointed out that at the 1-2 MWe (and up to 8 MWe) scale Biomass Engineering were using multiple 250 kWe modules as no commercial systems were available, whereas 250 kWe engines had sufficiently experience to be bankable

3. Background – Reception, Handling And Feeding Systems

Patricia Thornely explained that the design of these front-end components did not significantly influence mass, energy or environmental balances, but was important for costing, as well as the relationship between manning levels and availability.

An outline of the sort of systems applicable to large plant was given: automated weighbridges, CCTV, automated sampling, enclosed tipping, oversize exclusion, cranes for automated fuel mixing/management, hazardous area management etc, multiple conveyors and screw feeders.

This was contrasted with the sort of system that might be used at smaller scale (up to 2 MWe): a simple silo with screw conveyor from the side. Jim Campion said that walking-floors directly onto the gasifier were OK at 1-2 MWe and even at 500 kWe were cost competitive with hoppers and silos.

Storage is client-dependent: typically 4-5 hours for a small farm project, with up to 1 days storage for larger, more automated projects e.g. 6t hopper required for 25kg/hr. When more than 2t storage was required push and walking floors were best for wood chip, with a belt/tipping conveyor direct to a local feed lock hopper, which was driven by hopper demand. A 20t truck could tip directly onto a walking floor. Sampling on small scale ops is difficult and expensive to do in detail: typically, handheld probes are pushed into sample for moisture, and there is a physical size and contaminant check.

WP1 could work with modelling systems similar to these for the small and large scale cases, but input was sought on what to assume for intermediate scales (say 5 MW). It was suggested this was also linked to manning levels and design philosophy, with JC pointing out that fuel-feed systems are the biggest Achilles heel of bioenergy plants. Fuel expectations are important e.g. if you have a reliable supplier you need less up-front exclusion design. Suggestions included a front loader manually operated on a tipping floor (JB), four entrances with computer-controlled merging of the feed streams (JC), pellets (NS).

Parts of the attached presentation: “Biomass feeding systems 2”, provided by Sina Rezvani of University of Ulster were also reviewed during this discussion.

4. Flue Gas Treatment And Abatement Measures

Patricia Thornley outlined the emissions abatement measures that were being assumed for the systems being modelled. These were generally being guided by the requirement to comply with relevant UK and EU legislation, while taking account of best practice, particularly at existing reference plants. Below 20 MWth (about 5 MWe) schemes in the UK come under local air pollution control (LAPC), unless the plant is >3MWth and uses waste as a fuel, in which case it comes under WID and EA control. LAPC does not have uniform emission limits across different regions and installations, making identifying typical levels for WP1 difficult. The main small systems are either grates or gasifier/engine combinations. No significant emissions problems are expected with the grates; the main FGT requirement being a bag filter. For the engines the NOx is naturally low but CO is high. This can be addressed with a catalyst (a 2-way catalyst will also address unburnt hydrocarbons), but should this be incorporated in SUPERGEN analysis if not required under legislation. Jim Campion advised that they had put some 2 stage oxy-catalysts in anyway on Perkins engines of 250 kWe size because the additional cost was not that prohibitive at £2500. The catalyst should last 7 years.

Cyclones were recommended at the outlet of rotary dryers, but odours and visual appearance can be a problem. JC: assumes no volatiles in his plants, as temp. 40-50C Gussing use biodiesel to scrub the gases and then burn the tars.

For atmospheric pressure gasifiers a scrubber and bag filter prior to the gas turbine was used. With pressurised gasifiers only a hot gas filter was used prior to the gas turbine. To facilitate this cooling to about 450C is necessary For filtration prior to turbines/engines Nigel Simms confirmed that a hot gas filter takes out anything above a micron and has good reliability when used up to about 400 C. Hot gas filters can be either ceramic or metal. Both were used at Varnamo, but metal proved superior in terms of durability. Jim Campion uses ceramic and it works fine if there is low tar from the gasifier. For larger plants filters would be self-sealing for on-line detection of failures and replacement.

For pyrolysis plant a filter in line prior to the engine is sufficient. This results in a small amount of water with trace phenols etc e.g. <5litres/hr (?) from a 250kW plant – needs collection and treatment (e.g. active carbon) and the discharge to sewer.
A catalyst (two-way or three-way) may be required for gas turbines and engines operating with pyrolysis oil.

5. Impacts Of Agronomic Production On Feedstock Properties

See notes in separate file: "General properties of biomass affecting processing", supplied by Simon thain of IGER

Discussion ensued around the variability of feedstock composition. To date WP1 have used an average feedstock composition for each fuel being considered. It was agreed that some consideration of sensitivity of the power plant to the range of possible compositions/properties was necessary. It would be important to consider issues such as how boiler fouling might be affected by variations in composition and Cranfield have models that can predict this for combustion systems.

6. Relationship Between Fuel Chemistry And Environmental Releases For Combustion And Gasification Plant

See notes in separate file: "Emissions", supplied by Alan Williams of Sheffield University

In highlighting the variability of biomass samples, Alan recommended a paper that was available from the Victoria biomass conference proceedings.

The following general trends were noted from chemical compositional data presented:

- Ca is significant in wood, but not straw
- Coal contains Ca, but not much K
- Coal and straw have significant ash contents, but wood is much lower
- Cl levels can vary with different straws and can be HCl or KCl

The relative amounts of Ca, S, K and Cl are important in determining which fuels would release/retain more S or Cl, but there were no simple rules for predicting this. Complex calculations were possible to predict these aspects of fuel chemistry and followed curves illustrated in a paper by Klaus Hein in "Fuel". These were dependent on the temperature in the flue gas duct.

It was suggested that it might be possible to carry out one such calculation to, say, predict release levels for miscanthus under combustion conditions if the compositional data was available and flue gas conditions were known.

7. Predicting Performance Of Large Scale Furnaces From Small-Scale Rig Data Using CFD Techniques

This presentation is detailed in the separate file Large-scale simulation, provided by Dr Yang of Sheffield University.

Discussion ensued on what modelling work had been done to date within Supergen in this area and the potential for any future work. Kinetic data for the Supergen feedstocks is available from Leeds and Sheffield could model eg. a small grate system for a particular fuel, but the detailed plant data would have to be provided. WP1 members will consider whether or not this is possible – perhaps for a small grate system, if sufficient design data of the furnace itself could be provided.

8. Practicalities of Small Scale Plant Operation

Jim Campion of Biomass Engineering discussed this area with those present.

- At small scales (250/500 kWe) installation is often farm-based, with non-technical users, so maing the system user friendly and providing a high level of remote monitoring was key to ensuring good availability. Farmers are key users, so the system must be user-friendly with remote monitoring for any problems, such as impending fuel shortage: text sent to farmer automatically in that case. Expect farmer to check on it once per day only. Sensible design features included eg. allowing 4-5 days ash storage.
- At all scales fuel handling and fuel delivery are the key problems/issues. Biomass Engineering standard specification is 10-20% moisture. The process can tolerate up to 25%, but much above this level the process will stop and

require flushing out, taking a few days interruption. While having one person supervising several plants in a locality is fine, better ways of monitoring input characteristics (moisture level/HHV) were desirable. Fuel size is of order 75mm x 40mm; briquetted wood would be ideal. Above this size bridging can occur in feeders/hoppers. BE generally subcontract design of the fuel handling plant.

- Availability was not generally impacted by ash removal/blockages and JC has reports on ash analyses, which give carbon in ash levels. Many farmers spread it on fields. BE gasifiers can achieve >97-8% availability; engines 93-4%; >90% is required of overall system for commercial guarantees. The engine is most likely to be the constraint on this, as they require an oil change every 1000 hrs for current warranties (as per landfill gas) and start-up took a long time after this interruption.
- When 3-4 plants are in operation unmanned operation is feasible, with remote centralised monitoring.
- A spare grate could be held on site to minimise downtime.
- Plant operation is relatively quiet, but, in rural areas noise can still be a constraint. For example 35 dBA at site boundary is achievable, but this is not acceptable at night
- BE will have about 20 UK gasifier sites next year: 3 now and 17 units in NW England planned for next yr for an Energy Service Company, using waste wood at £20-25/t and generation at 8.5p kWh.
- 14-16 wks build time for a gasifier now.
- JC would be willing to share turnkey costs with WP1 work.
- On emissions CO is the most difficult/sensitive parameter. Catalysts are required as standard in the German market and this drives volume production therefore they tend to be used in BE installations in UK as well. Raw CO levels could be 1500-2000 mg/Nm3, but the German TA Luft regulations require 500 and WID requires 50.
- In future typical plant size is envisaged as 1-2MW due to economies of fuel movement

9. Operation of CHP Plant

John Rogers of Aston University discussed CHP operation with attendees. He emphasised that in the current energy climate CHP needed to be considered as a boiler that could also provide some electricity and not the other way around. Hence the plants operation tended to be heat led and sized to the winter heating load, so that it was oversized in summer. Few plants run with a dump condenser and this led to small IC engine CHP plants for space heating having availabilities of only 40% and even larger combined cycle plants only managing 60%. Plants operating with waste fuel would have much higher availabilities as there was a financial imperative to dispose of waste continuously. The fact that biomass-fired CHP was eligible for ROC's might encourage operation in electricity only mode but there was no evidence of this to date.

Reports form an EPA programme had estimated annual O&M costs as 4-5% of capex for LFG plants. For comparison purposes contracte out maintenance costs on gasifier/engine systems were 0.6-0.8 p/kWh and 0.4-0.5 c/kWh for turbine systems running on natural gas, in CHP mode at around 500 kWe – 2 MWe scale. However, a World Bank report concluded that firing on crude increases maintenance requirement by a factor of 3.

10. Operating Large Scale Plant – Impacts Of Corrosion And Fouling

This presentation is detailed in the separate file "WP1 workshop – corr+dep v2", provided by Nigel Simms of Cranfield University.

Discussion of the presentation at the meeting was unfortunately limited due to time constraints.

11. Technology Ranking

Stakeholders and the general public involved with WP1 work had in some cases expressed concerns over the extent to which bioenergy plants utilised proven technology or more novel systems. A group exercise during the meeting provided an "expert ranking" of all 25 systems being considered in WP1, on the basis of the extent to which the technology could be considered proven in each case. This is summarized in the separate file "ranking".