Real world burning issues on the road to conversion

In terms of potential emissions reduction and financial benefits, burning biomass appears to be an attractive proposition for many coal plants and they should all be converting as quickly as possible. But in the real world it's not that straightforward.

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With governments across the developed world committed to decarbonising their economies over the medium to longer term, the spotlight is firmly on fossil-fuelled power stations to play their role in terms of reducing their carbon dioxide emissions. It is also recognised that biomass firing on existing coal-fired power stations is a 'fast track' route to large scale renewable generation that, unlike wind, does not suffer from intermittency and can consistently deliver reliable power on demand.

As a consequence, many European governments have introduced schemes to incentivise biomass firing on existing stations. This means that plants that can generate a certain percentage of their power from biomass fuels benefit from an immediate financial uplift that can overcome the higher costs of biomass.

In the UK, this consists of the following:

- Renewable Obligation Certificates (one per MWh for conversions or enhanced co-firing) typically worth in the region of £45 per MWh.
- Climate Change Levy Exempt Certificates (LECs) worth in the region of £4.50 per MWh.
- EU ETS carbon credits.
- Protection from the impact of the UK carbon floor price, predicted to be £16 per tonne in 2013, rising to £30 per tonne by 2020.

These financial aspects have a considerable impact on plant economics, hence the current drive for biomass conversion or increased co-firing.

In addition to the financial benefits from renewable generation, further benefits may be gained through biomass firing in terms of emissions reductions, primarily relating to SO_x and NO_x.

For NO_x in particular, allowable emissions limits are being further tightened via the introduction of the Industrial Emissions Directive (IED). A coal-fired station in the EU essentially has two options:

- Cut emissions of NO_x to 200 mg/Nm^3 in line with the timescales set out in the IED. To achieve this limit, it is likely that the installation of SCR will be required, costing in the region of £30 million to £60 million per boiler.
- It can opt out of the IED, in which case operation beyond 2016 is limited to 17 500 generating hours before enforced closure.

The lower NO_x emissions obtained when firing or co-firing biomass may reduce the scope of post-combustion NO_x control equipment required and therefore provide a lower cost IED compliance route.

In addition to IED compliance and reduced NO_x, the reduced SO_x emissions obtained with low sulphur biomass can allow a station that had opted out of the earlier Large Combustion Plant Directive (LCPD) to achieve the new-plant standards set out in IED without excessive capital investment in SCR or FGD plant; in this way, the station can continue operation beyond its closure date of 2015.

Back in the real world

In an ideal scenario therefore, every fossil-fuelled power generator would immediately convert to 100% biomass combustion or move to a high percentage of co-firing, but back in the real world, it's just not that easy.

Coal, oil and gas have a higher energy density when compared to typical biomass fuels, such as wood pellets. This means that to achieve the same output in terms of generated MW, the station will require a much greater volume of biomass to be fired in the furnace. Depending upon the type of biomass used, twice the volume of fuel can typically be required to maintain that given power output.

So straightaway, we have a number of knock-on effects that need to be addressed. Critical to this is fuel storage capacity. Greater volumes of fuel are required and due to the nature of most biomass fuels this must be stored indoors in a weather-protected environment. Fuel storage controls, especially temperature monitoring of the fuel and first in/first out stocking procedures must be implemented to protect against the risks of self-heating and fuel degradation.

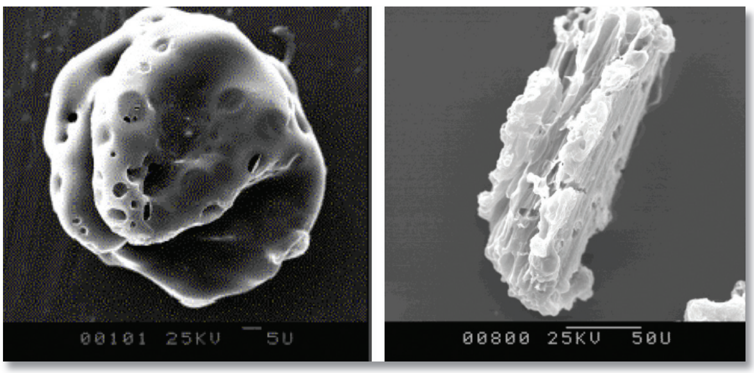

Figure 1

Left: **milled coal, 0.1 mm in diameter.**

Right: **milled wood, 1.5 mm in length**

(Images: University of Leeds)

Similarly, how has the biomass got there? Doubling up on volume means twice the road or rail movements. How does this sit with other environmental issues such as noise/nuisance to the local community? And is there spare capacity in the transport network to enable such an increase in road or rail movements, and can the site's off-loading facilities handle this increase?

Also, the potential for fire is a real hazard, as demonstrated in February 2012 at the 750 MW Tilbury biomass plant in the UK, where two wood pellet hoppers caught fire (see p 41).

Aside from storage and delivery, there's the whole question of how the biomass fuel is physically broken down into particles small enough to be fired into the furnace. Coal mills are purpose-built and produce very fine particles of coal dust that are typically below 100 µm in diameter.

In contrast, biomass fuel is typically spongy in texture and cannot be processed by coal mills in any great volume. Dedicated mills are therefore required, but even these will only reduce the size of the biomass particles to 1-2 mm.

The larger biomass particle size has a negative impact on combustion and whilst this is partially offset by the much higher volatiles content of the biomass (approximately 80%wt for biomass compared to 22%wt for coal), there are many other critical differences in the fundamental combustion process that must be understood.

The different shapes of the milled particles, illustrated in Figure 1, whilst appearing insignificant, also change fundamental combustion kinetics.

Plant operators need to understand the science of how biomass actually combusts in a coal-fired boiler and second, they need to be able to optimise burner design and operation to ensure safe and stable combustion. This is particularly important as flame stability and burnout have both caused problems on every large-scale biomass conversion trial undertaken, when firing via conventional, radially-staged low NO_x coal burners.

Problems may also be encountered with ash deposits building up on critical boiler heat transfer surfaces. These impact on boiler performance and whilst the ash content of biomass is much lower than that of coal, the

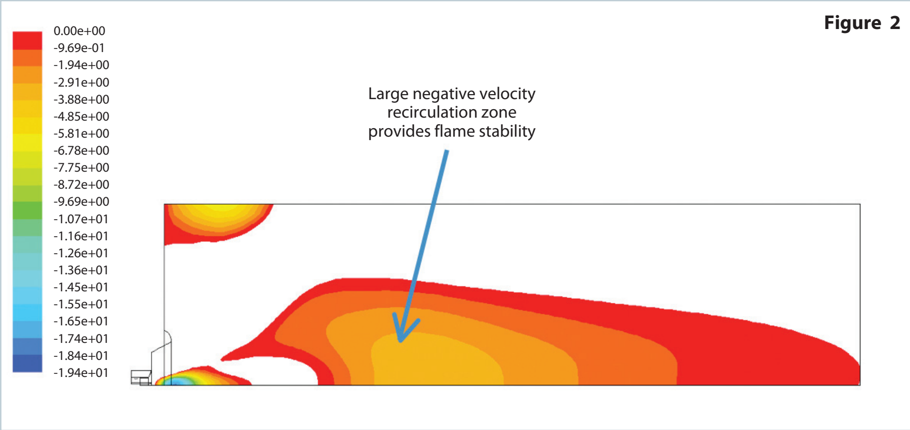

Figure 2

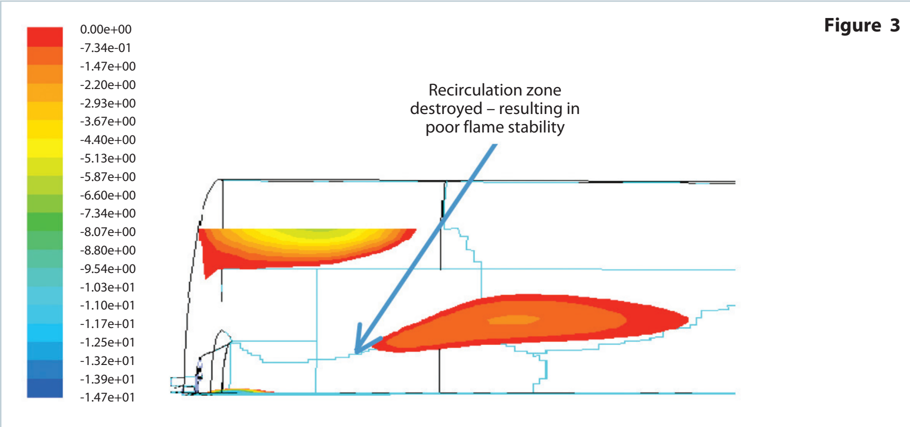

Figure 3

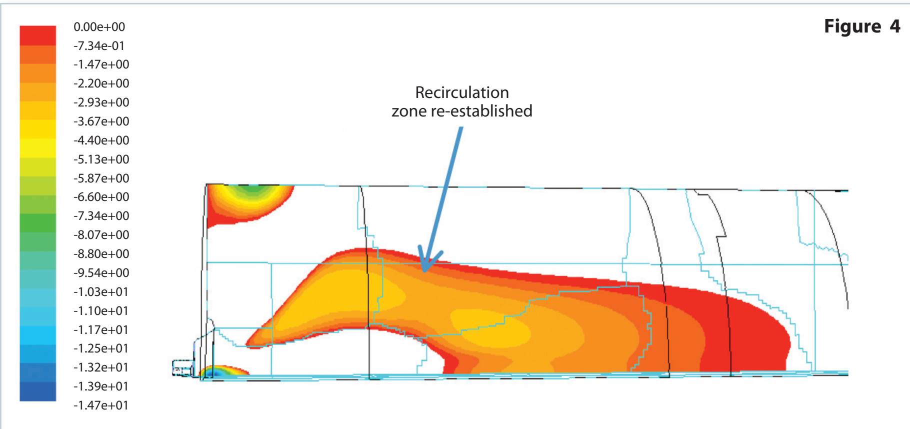

Figure 4

propensity for slag build-up with a typical biomass fuel is higher. The nature of these deposits can be very different to that of coal, in that they are formed of metal chlorides rather than metal sulphates. This presents an increased corrosion risk, with a knock-on impact on superheater element life.

With coal, these slagging risks are generally predicted by means of empirically-derived indices and this approach works well within the existing coal fuel boundaries. These indices are not however applicable to biomass.

CFD modeling and biomass-optimised burners

This may make biomass conversion seem like one long headache, but the reality is that plants all over the EU and the USA are dipping their toes in the water with co-firing and full conversion projects. The primary technical challenges as described above, remain however, as plant operators endeavour to ensure the safe and efficient combustion of a range of biomass materials whilst minimising impact on boiler performance.

Of considerable benefit here are CFD modelling techniques we have developed and adapted to accommodate the different combustion characteristics inherent in biomass fuel. This sophisticated biomass CFD modelling work has been led by RJM's partner business in the United States, SAS Inc, a company that has a strong track record in the field of CFD analysis and one that is at the forefront of developing CFD software and analysis for biomass and co-fired plants. To enable accurate predictions to be made using CFD, the combustion algorithms encompassed in the CFD code have been rewritten to match biomass combustion kinetics measurements obtained through laboratory and pilot plant testing. Further enhancements of the code have been required to enable modelling of biomass co-fired with coal on a single burner.

Figures 2-4 provide some visual examples showing how biomass CFD modelling is informing the engineering process of adapting RJM's field-proven ultra-low-NO_x coal burner for biomass firing.

Flame stability with large biomass particles is a key concern. Figure 2 shows the anticipated negative particle velocity plots obtained firing coal in an ultra-low-NO_x burner.

Firing exactly the same burner design and configuration with larger particle size wood of cylindrical/flake-like shape produces the flow pattern shown in Figure 3. The absence of a recirculation zone indicates poor flame stability and uncontrolled combustion.

With further CFD-based redesign and operational optimisation, firing biomass results in the situation shown in Figure 4, regaining flame stability and controlled combustion.

The biomass CFD model also accommodates particle burn-out and NO_x predictions, allowing us to provide a comprehensive view of combustion performance and pollutant formation when firing biomass.

RJM's biomass CFD model has also been expanded to include the entire combustion chamber, thus allowing the prediction of flue gas emissions data and, in conjunction with a boiler thermodynamic model, the prediction of boiler efficiency.

In addition, slagging and fouling issues can also be tackled, using CFD modelling techniques, in this case via a post-processor add-in. This technique has been validated for co-firing boilers and ensures that risks are assessed and minimised.

By exploiting the accurate findings produced by its CFD biomass model, RJM is currently in the process of designing a suite of biomass-optimised burners to retrofit into existing coal-fired boilers.

These burners will utilise the axial staged design techniques that form the basis of RJM's ultra-low-NO_x coal burners, but incorporate additional features to control flame stability and char burn-out. This overcomes many of the limitations of more conventional radially-staged low-NO_x burners.

Our ultra-low-NO_x burners are already delivering NO_x levels down to 250 mg/Nm^3 on 100% coal-firing in conjunction with overfired air systems and the CFD model is already predicting NO_x levels below 200 mg/Nm^3 on a single burner firing 100% biomass at similar burner stoichiometries. Clearly, other factors influencing NO_x emissions must be taken into account on a multi-burner boiler, however, these results are extremely positive.

Economically viable and technically realisable

What this means in practice is that the technology that is available from RJM – state-of-the-art combustion systems hardware supported by CFD modelling capability – can provide generators with an economically viable and technically realisable solution for compliance with the new IED NO_x limit of 200 mg/Nm^3 using a realistic co-firing mix of biomass and coal.

What's more, they can do so without the high capex and ongoing operating costs associated with bolt-on SNCR or SCR units and at the same time, get the benefit of whatever government incentives are available for moving to lower carbon generation. MPS