Biomass Conversion as an Emissions Control Technology

Graham Welford

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Biomass Conversion as an Emissions Control Technology

- How does biomass control emissions?
- Doosan Babcock experience
- Focus on Lynemouth conversion
How Does a Switch to Biomass Control Emissions?

- Conventional Pollutants
  - Biomass has lower levels of pollutant causing elements such as sulphur and nitrogen
  - Biomass burns with a cooler flame reducing NOx

- Carbon Dioxide
  - Biomass is renewable
  - Biomass can lead to net carbon removal from the atmosphere in combination with CCS
How Does a Switch to Biomass Control Emissions?

<table>
<thead>
<tr>
<th></th>
<th>Coal use 1990</th>
<th>Coal use 2015</th>
<th>Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur % ar</td>
<td>1.5</td>
<td>0.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Nitrogen % ar</td>
<td>1.4</td>
<td>1.2</td>
<td>0.11</td>
</tr>
<tr>
<td>Ash % ar</td>
<td>15</td>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>Chlorine % ar</td>
<td>0.3</td>
<td>0.02</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Cleaner fuels = lower emissions

<table>
<thead>
<tr>
<th></th>
<th>Coal use 1990</th>
<th>Coal use 2015</th>
<th>Biomass</th>
<th>Equipment</th>
<th>Reason for effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂ mg/Nm³</td>
<td>3750</td>
<td>1250</td>
<td>25</td>
<td>No FGD</td>
<td>Fuel S ratio</td>
</tr>
<tr>
<td>NOₓ mg/Nm³</td>
<td>650</td>
<td>500</td>
<td>200</td>
<td>Low NOₓ burners</td>
<td>Fuel ratio &amp; cooler flame</td>
</tr>
<tr>
<td>Dust mg/Nm³</td>
<td>50</td>
<td>35</td>
<td>~20</td>
<td>ESP</td>
<td>Fuel ratio &amp; efficiency</td>
</tr>
<tr>
<td>HCl mg/Nm³</td>
<td>400</td>
<td>25</td>
<td>15</td>
<td>No FGD</td>
<td>Fuel Cl ratio &amp; CaO in ash</td>
</tr>
</tbody>
</table>

Typical values for UK market
ar is “as received”
All emissions at standard 6% O₂ dry conditions
How Does a Switch to Biomass Control CO$_2$?

<table>
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<th>Coal</th>
<th>Biomass</th>
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<tr>
<td>CO$_2$ is renewable</td>
<td></td>
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</tr>
<tr>
<td>Emitted CO$_2$ g/kWh, net</td>
<td>825</td>
<td>140</td>
</tr>
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CO$_2$ is renewable

Typical values for UK market, subcritical plant

Typical Volume and Revenue from a Harvest

Source: INRS
**CO₂ Game Changer: Biomass + CCS**

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<td>CO₂ is renewable</td>
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<tr>
<td>Emitted CO₂ g/kWh, net</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ is renewable, plus CCS</td>
<td>160</td>
<td>- 830</td>
</tr>
<tr>
<td>Emitted CO₂ g/kWh, net</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- CCS with biomass offers net removal of CO₂ from atmosphere
- Uses very effective and natural photosynthesis to filter low CO₂ concentrations from the air
- CCS permanently stores the CO₂
- Power generated as a “by-product” of filtering the atmosphere
- Net CO₂ removal may be necessary to meet 2050 climate temperature rise targets

*Typical values for UK market, subcritical plant
CCS – Carbon Capture & Storage*
Doosan Babcock Biomass Experience
## Doosan Babcock Biomass References

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Scope</th>
<th>Units x MWe</th>
<th>Contract Award</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynemouth UK</td>
<td>100% biomass conversion</td>
<td>3 x 140</td>
<td>2016</td>
<td>EPH</td>
</tr>
<tr>
<td>Yeong Dong Korea</td>
<td>100% biomass conversion of downshot boiler</td>
<td>1 x 110</td>
<td>2015</td>
<td>KOSEP</td>
</tr>
<tr>
<td>Gardanne France</td>
<td>Biomass conversion and turbine upgrade</td>
<td>1 x 150</td>
<td>2013</td>
<td>E.ON</td>
</tr>
<tr>
<td>Drax UK</td>
<td>Conversion of mills and associated burners to biomass</td>
<td>3 x 660</td>
<td>2010 to 2012</td>
<td>Drax Power</td>
</tr>
<tr>
<td>Tilbury UK</td>
<td>100% biomass firing</td>
<td>3 x 300</td>
<td>2011</td>
<td>RWE</td>
</tr>
<tr>
<td>Ironbridge UK</td>
<td>100% biomass conversion</td>
<td>2 x 370</td>
<td>2011</td>
<td>E.ON</td>
</tr>
<tr>
<td>Atikokan Canada</td>
<td>100% biomass conversion</td>
<td>1 x 220</td>
<td>2011</td>
<td>Ontario Power Generation</td>
</tr>
<tr>
<td>Rybnik Poland</td>
<td>Biomass unloading, storage and milling</td>
<td>1</td>
<td>2010</td>
<td>EDF</td>
</tr>
<tr>
<td>Drax UK</td>
<td>Direct injection biomass co-firing systems</td>
<td>6 x 660</td>
<td>2009</td>
<td>Drax Power</td>
</tr>
<tr>
<td>Hasselby CHP Sweden</td>
<td>Conversion of coal mills and burners to 100% biomass</td>
<td>1</td>
<td>1992</td>
<td>Hasselby Power</td>
</tr>
</tbody>
</table>
Lynemouth Combustion & Emissions Systems Upgrades
**Lynemouth Power Station: a Good Candidate for Biomass**

<table>
<thead>
<tr>
<th><strong>Closure at the end of 2015 due to lack of SOx and NOx controls to meet IED TNP limits</strong></th>
<th>Biomass conversion offered a way to meet emissions limits because biomass is cleaner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power station was becoming uneconomic due to rising price of carbon</strong></td>
<td>Biomass conversion offered a way to avoid the carbon floor price because the fuel is renewable</td>
</tr>
<tr>
<td><strong>Biomass is an expensive fuel and efficiency is important</strong></td>
<td>North Sea cooling, upgraded turbines &amp; condensers; despite moderate size and steam conditions probably UK’s most efficient coal station</td>
</tr>
<tr>
<td><strong>Benefit of a CfD from the UK government of £105/MWh, ratified by EC, for 10 year period</strong></td>
<td>Drive to maximise availability, efficiency and power output and extend life</td>
</tr>
<tr>
<td><strong>3x140 MWe size made logistics manageable</strong></td>
<td>Helped gain EC approval</td>
</tr>
<tr>
<td><strong>Power station can reuse most of the systems and components which have good residual life</strong></td>
<td>Reducing capital cost for green electricity</td>
</tr>
</tbody>
</table>
Lynemouth: Comprehensive Conversion

- 40% unit efficiency to be maintained
- 140MWe power output to be retained
- IED minimised emissions
- Maximum safety
- 10 year life

- New fuel feeding system
- Mill modifications and new dynamic classifiers
- Replacement PF piping
- Heat balance correction by PA cooler
- New low NOx bespoke biomass burners
- New BOFA system for further NOx control
- Upgraded oil system
- Furnace and heating surface cleaning extension
- No heating surface changes
- 36 new fans across the 3 units
- New dry bottom ash system
- ESP upgrade
- New fly ash system

BOFA  Boosted over-fire air
PA    Primary air
ESP   Electrostatic precipitator

Doosan Babcock
Milling Plant Upgrade

- Vertical spindle mills are robust and can be easily converted to biomass with some capacity reduction

- Low biomass CV and density overcome by using spare mill
  - Lynemouth has 4 mills with one spare at full load giving 33% spare capacity, enough for biomass

- Particle size for biomass PF is ~1mm, 10 times larger than for coal

- Mill velocities have to increase

- Control of particle size is critical leading to the use of new dynamic classifiers

- Mill air inlet temperature has to be reduced to prevent ignition with wood

- Explosion suppression added with other safety measures eg, to avoid fuel hang-up

- Larger particles need higher conveying velocities to prevent saltation

- Replacement PF piping
Biomass Burners

- Replacement low NOx burners based on Doosan Babcock low NOx heritage optimised for biomass
- Milled biomass has a large particle size (top-size in 1-3 mm), so particles take longer to heat up and ignite, and flame stands off a standard burner
- For low NOx operation a rooted flame is required through lower fuel injection velocities to allow particles time to ignite
- Biomass burner proven on full-scale single burner test facility
- Low NOx biomass burners with over-fire air can achieve IED/BREF NOx levels
Boosted Over-Fire Air (BOFA)

- Over-fire air reduces NOx via low oxygen levels in the burner zone and creates a CO risk
- Lynemouth furnaces pre-date NOx control and are small by modern standards
- BOFA increases turbulence and mixing through higher velocity jets designed to penetrate and mix the flue gas and allows longer residence time at reduced stoichiometry
- BOFA offers:
  - 20% less NOx than low NOx burners alone
  - Better combustion efficiency
  - Lower CO emissions
Conclusions

- Wood pellets used in coal fired power stations dramatically reduce emissions of NOx and SO₂.
- Biomass is renewable and cuts CO₂ emissions by 85% compared to coal.
- Biomass with CCS gives a net absorption of CO₂ from the atmosphere equal to a coal fired power station CO₂ without CCS.

- Lynemouth has good fundamentals for conversion to biomass.
- Doosan Babcock has applied its extensive experience of bespoke solutions to deliver a comprehensive highly specified combustion and emissions system:
  - 40% unit efficiency to be maintained
  - 140MWe power output to be retained
  - IED minimised emissions
  - Maximum safety
  - 10 year life
Thank you

Questions?

graham.welford@doosan.com