Biomass Conversion as an Emissions Control Technology

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APG TF
cleaner fuels for power and industry

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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?

	Coal use 1990	Coal use 2015	Biomass
Sulphur % ar	1.5	0.5	0.01
Nitrogen % ar	1.4	1.2	0.11
Ash % ar	15	10	0.6
Chlorine % ar	0.3	0.02	0.01

Cleaner fuels = lower emissions

	Coal use 1990	Coal use 2015	Biomass	Equipment	Reason for effect
SO_2 mg/Nm^3	3750	1250	25	No FGD	Fuel S ratio
NOx mg/Nm^3	650	500	200	Low NOx burners	Fuel ratio & cooler flame
Dust mg/Nm^3	50	35	~20	ESP	Fuel ratio & efficiency
HCl mg/Nm^3	400	25	15	No FGD	Fuel Cl ratio & CaO in ash

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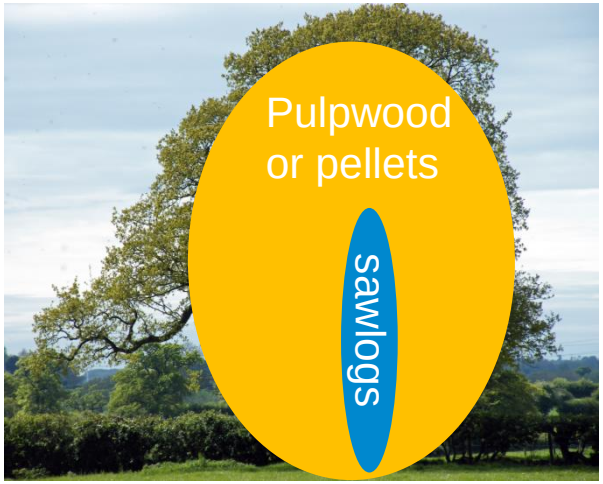
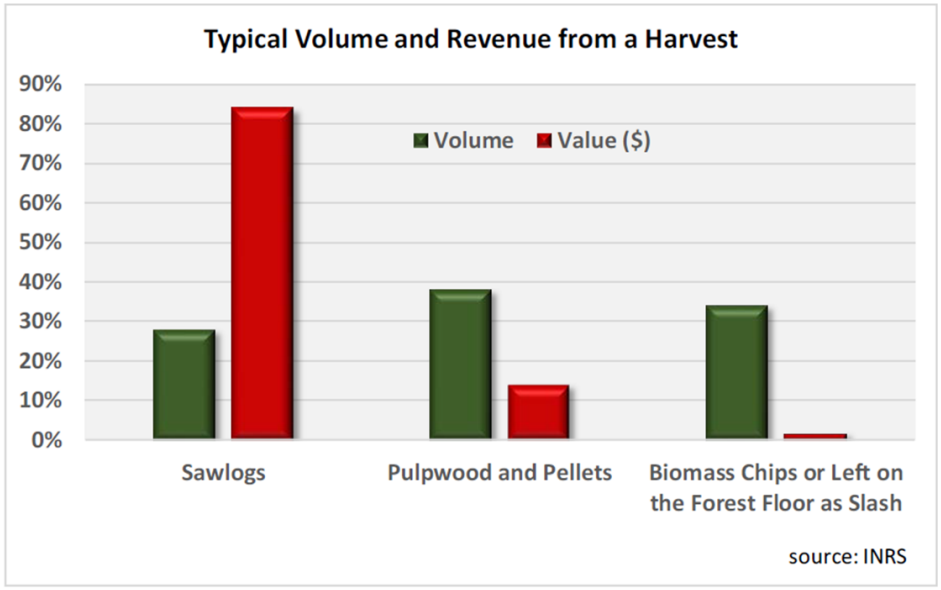
Typical values for UK market
ar is “as received”
All emissions at standard 6% O_2 dry conditions

How Does a Switch to Biomass Control CO_2?

	Coal	Biomass
CO_2 is renewable Emitted CO_2 g/kWh, net	825	140





Typical values for UK market, subcritical plant

CO_2 Game Changer: Biomass + CCS

	Coal	Biomass
CO_2 is renewable Emitted CO_2 g/kWh, net	825	140
CO_2 is renewable, plus CCS Emitted CO_2 g/kWh, net	160	- 830

- CCS with biomass offers net removal of CO_2 from atmosphere
- Uses very effective and natural photosynthesis to filter low CO_2 concentrations from the air
- CCS permanently stores the CO_2
- Power generated as a “by-product” of filtering the atmosphere
- Net CO_2 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

Project Name Country	Scope	Units x MWe	Contract Award	Customer
Lynemouth UK	100% biomass conversion	3 x 140	2016	EPH
Yeong Dong Korea	100% biomass conversion of downshot boiler	1 x 110	2015	KOSEP
Gardanne France	Biomass conversion and turbine upgrade	1 x 150	2013	E.ON
Drax UK	Conversion of mills and associated burners to biomass	3 x 660	2010 to 2012	Drax Power
Tilbury UK	100% biomass firing	3 x 300	2011	RWE
Ironbridge UK	100% biomass conversion	2 x 370	2011	E.ON
Atikokan Canada	100% biomass conversion	1 x 220	2011	Ontario Power Generation
Rybnik Poland	Biomass unloading, storage and milling	1	2010	EDF
Drax UK	Direct injection biomass co-firing systems	6 x 660	2009	Drax Power
Hasselby CHP Sweden	Conversion of coal mills and burners to 100% biomass	1	1992	Hasselby Power

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Lynemouth Combustion & Emissions Systems Upgrades

Lynemouth Power Station: a Good Candidate for Biomass

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

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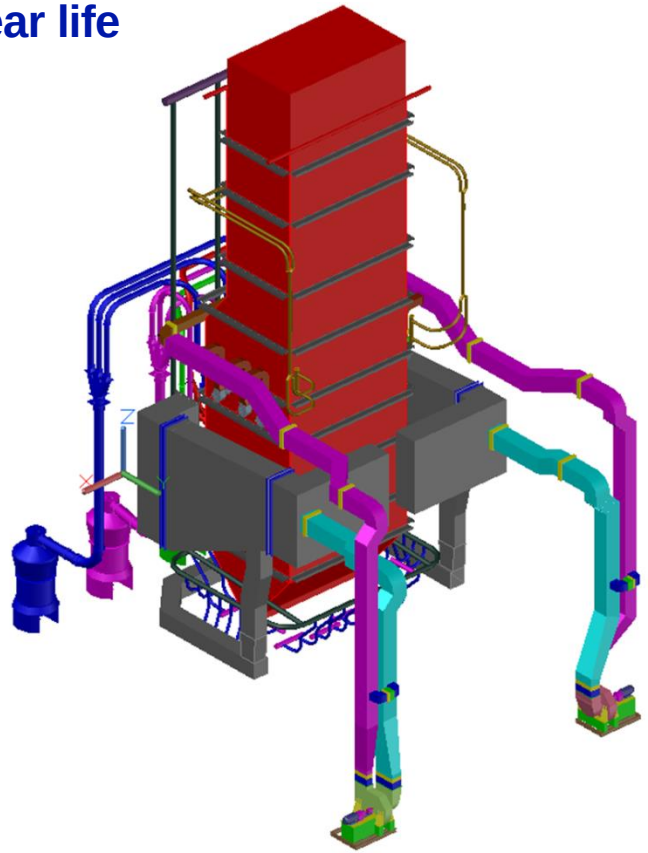
CfD Contract for Difference
EC European Commission

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

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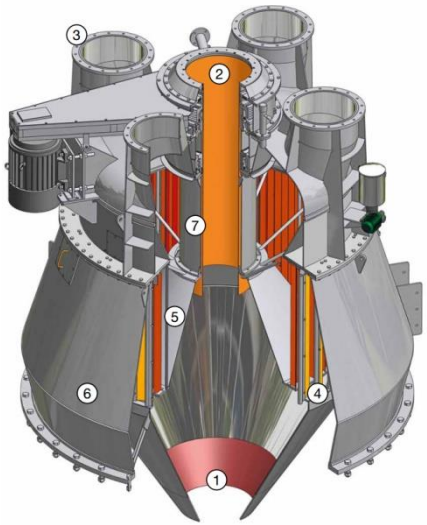
Milling Plant Upgrade

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



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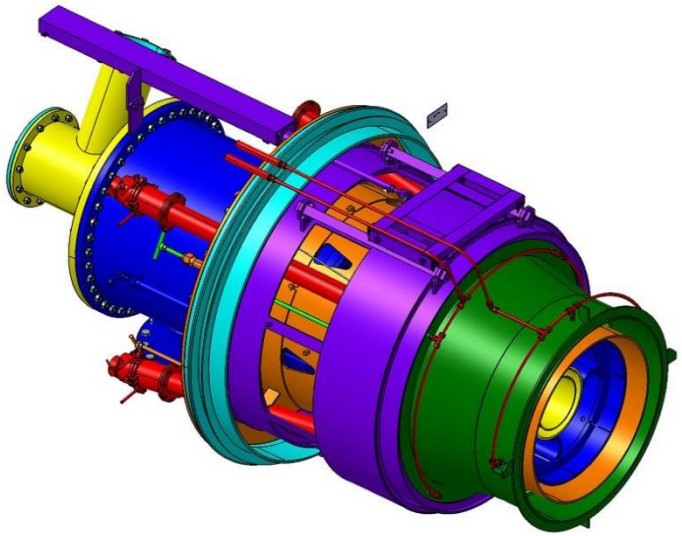
- Low biomass CV and density overcome by using spare mill
  - Lynemouth has 4 mills with one spare at full load giving 33% spare capacity, enough for biomass
- Particle size for biomass PF is ~1mm, 10 times larger than for coal
- Mill velocities have to increase
- Control of particle size is critical 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

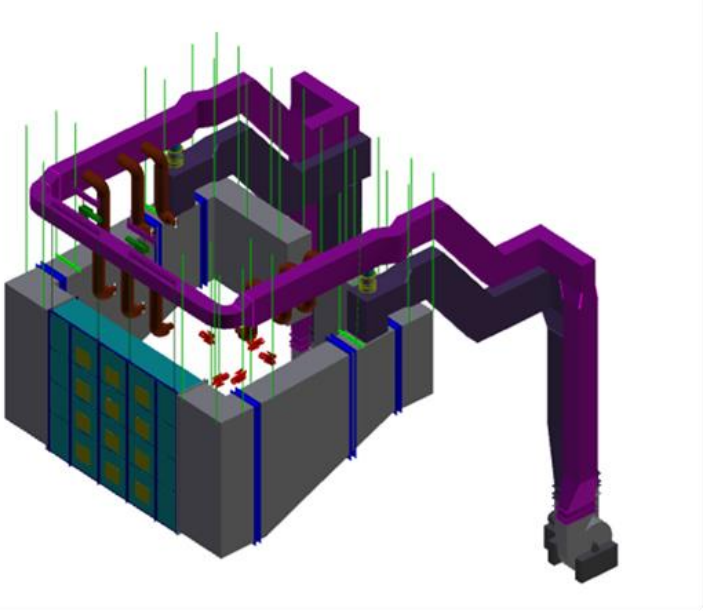
Biomass Burners

- 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

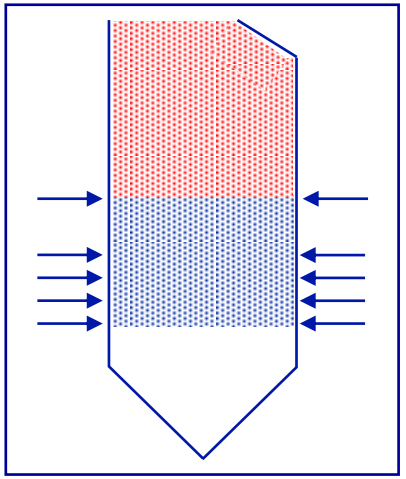


Boosted Over-Fire Air (BOFA)

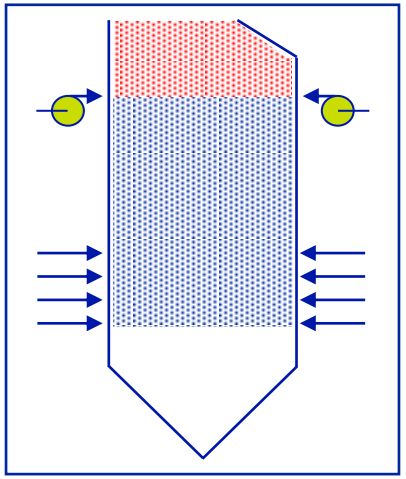
- Over-fire air reduces NOx via low oxygen levels in the burner zone and creates a CO risk
- Lynemouth furnaces pre-date NOx control and are small by modern standards
- BOFA increases turbulence and mixing through higher velocity jets designed to penetrate and mix the flue gas and allows longer residence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



Normal over-fire air



Boosted over-fire air



Conclusions

- Wood pellets used in coal fired power stations dramatically reduce emissions of NOx and SO_2
- Biomass is renewable and cuts CO_2 emissions by 85% compared to coal
- Biomass with CCS gives a net absorption of CO_2 from the atmosphere equal to a coal fired power station CO_2 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?

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