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Suitability of biomass feedstocks for co-firing in large, pulverised coal, power plant boilers

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Direct biomass co-firing options for retrofit projects in large coal-fired boilers

- The co-firing of solid biomass by pre-mixing with the coal and processing the mixed fuel through the installed coal handling, milling and firing systems,

- The direct co-firing of milled solid biomass by pneumatic injection into the furnace, through dedicated biomass burners or through the existing coal burners.

The solid biomass materials utilised in large quantities in Northern Europe

- The solid wastes from agricultural industries, e.g. palm oil and olive oil production,
- Pellets made from dried sawdusts and other materials,
- Dried sludges,
- Wood materials in various forms, i.e. sawdusts, forestry residues, wood processing residues, SRC in chip and pellet form, etc.

- Baled materials e.g. cereal straws and other dry residues, miscanthus, perennial grasses.

- The majority of the biomass co-fired has been imported from other parts of Europe and from outside Europe.

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Biomass firing by pre-mixing and co-milling

Biomass co-firing by pre-mixing with coal and co-milling – general aspects

- Co-firing by co-milling is commonly the preferred approach for stations embarking on co-firing activities for the first time.
- The capital investment, at least for the initial trial work, can be kept to modest levels, and the expenditure is principally on the biomass reception, storage and handling facilities.
- The project can be implemented in reasonable time.
- This approach is particularly attractive when there are concerns about the security of supply of the biomass materials, and about the long-term security of the subsidy payments for co-firing.

Biomass co-firing by pre-mixing and co-milling

In general, this approach permits co-firing at levels up to 5-10% on a heat input basis.

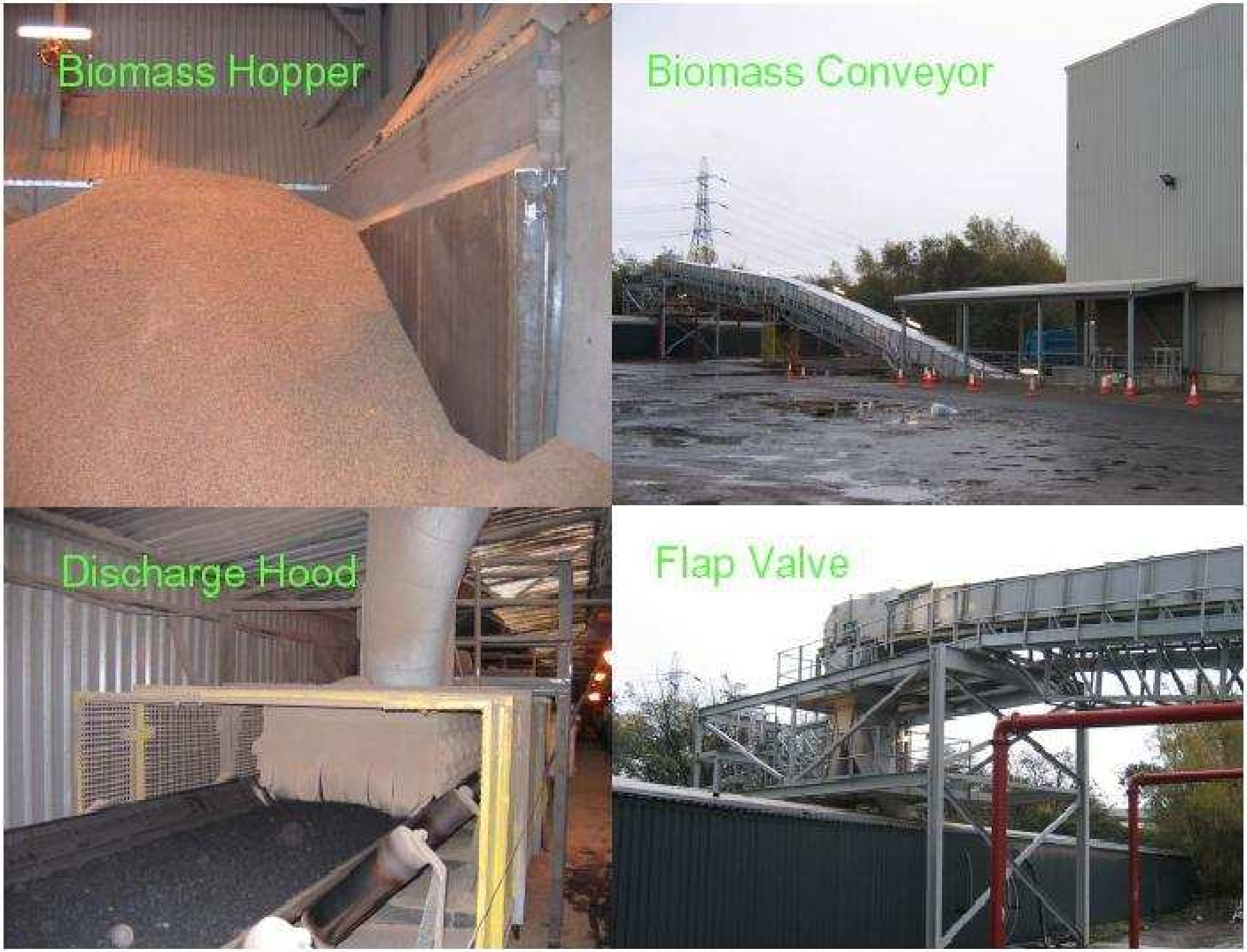
The key constraints are:

- The availability of suitable biomass supplies,
- The limitations of the on-site biomass reception, storage and handling facilities and
- The limitations associated with the ability of the coal mills to co-mill biomass materials.

There are also safety issues associated with the bunkering and milling of the mixed coal-biomass material.

Biomass storage shed

Biomass pre-mixing system



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Properties of biomass materials for co-firing by co-milling

- The biomass must be suitable for conventional solids handling equipment, i.e. hoppers, screw feeders, conveyors, etc.
- Generally biomass in dust, granular and pelletised forms have been co-fired successfully this way,
- Wet sawdusts, up to 60% moisture content have been co-fired, however there is an impact on mill performance and boiler efficiency.
- The power plant coal handling and milling systems are relatively robust and handle significant levels of ash and tramp material, within reason.
- The co-firing ratio is generally fairly low (<10%), so any particularly difficult biomass fuel constituent is diluted by at least a factor of 10.

- Straws and other baled materials are not suitable,
- Very dusty materials are less attractive, for materials handling reasons.

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Direct injection co-firing

Direct injection co-firing systems for biomass - basic options

- Direct injection co-firing involves by-passing the coal mills, and can increase the co-firing ratio.

- The biomass must be suitable for milling, normally using hammer mills, and for pneumatic conveying.
- There are restrictions on the moisture content, and levels of tramp material, because of the sensitivity of hammer mills and conveying systems to these materials.
- The milled biomass particles have to be small enough to be conveyed pneumatically and to combust efficiently in a pulverised coal flame.

All direct injection co-firing systems involve the pneumatic conveying of the pre-milled biomass from the fuel reception and handling facility to the boiler house.

There are three basic direct injection co-firing options:

- Direct injection into the furnace with no combustion air,
- New, dedicated biomass burners, and
- Injection of the biomass through modified burners or into the pulverised coal pipework.

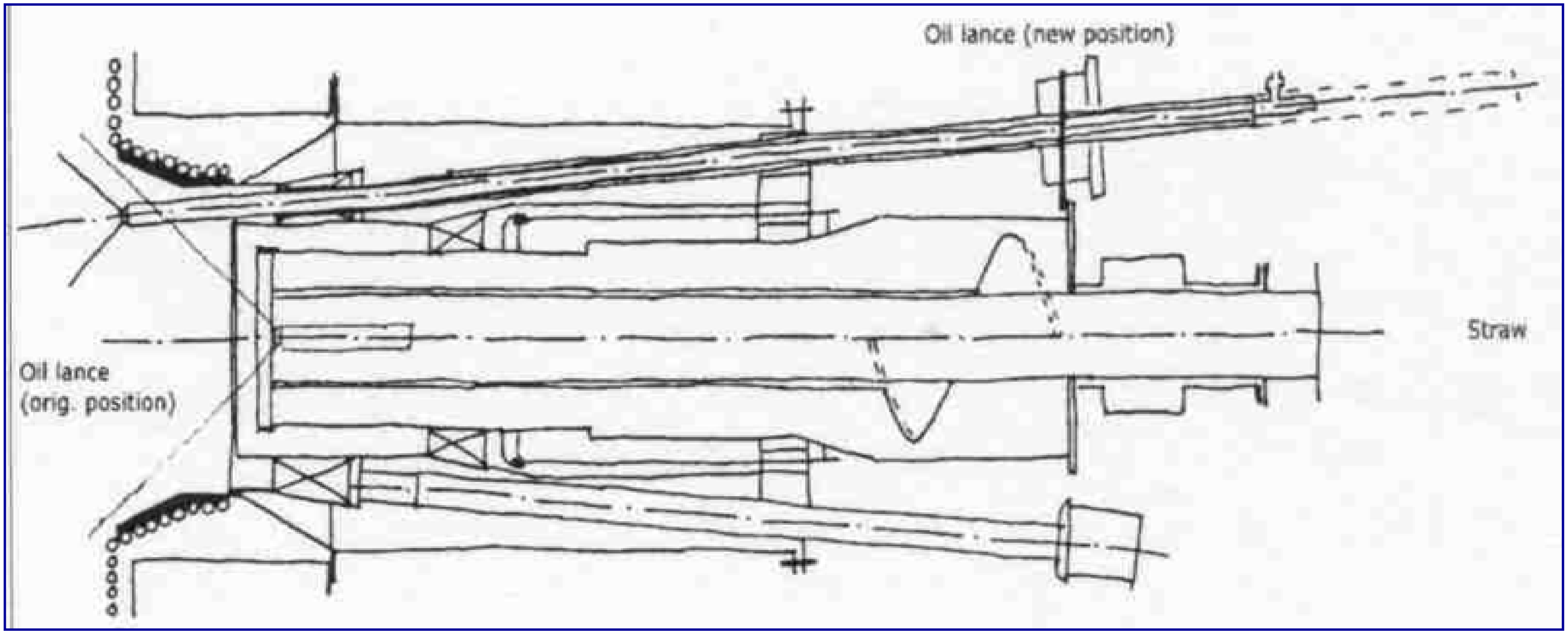
Direct injection to modified burners

- **May be necessary with some fuels, e.g. chopped cereal straws,**
- **Recent projects have involved modification of both wall-fired and corner-fired furnaces,**
- **Biomass metering and pneumatic conveying systems to each burner are required,**
- **The burner modifications involve significant additional cost,**
- **There are risks of interference with the coal combustion process and NO_x emission control,**

- **Successful applications include Studstrup in Denmark and Fiddlers Ferry in England.**

- **Overall, this is a viable, if relatively expensive, approach to direct injection co-firing.**

Modified Doosan Babcock Mark III LNB for Coal-Straw Co-firing at Studstrup



Direct injection into the pulverised coal pipes

- Direct injection into the existing coal firing system is relatively simple and cheap to install, and this is generally the preferred option.
- The preferred injection locations are into the pulverised coal pipework at the mill outlet or local to the burners.
- The mill air and fuel flow rates have to be reduced in line with the biomass conveying air flow rate, and the heat input to the mill group from the biomass.
- Both the mill and the burners are maintained within their normal operating envelopes for both the heat input and primary air flow rate.

- There are recent commercial demonstrations of direct firing system at Drax Power Station in Britain and at Langerlo in Belgium.
- These systems have been in successful operation since 2005, firing a wide variety of pre-milled biomass materials.

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Technical issues and impacts on plant performance

Technical issues with biomass co-firing at elevated levels

- The procurement of large quantities of biomass,
- Fuel quality/flexibility issues, and off-site biomass storage and pre-processing arrangements and costs.
- Fuel deliveries/reception, on-site handling, storage and pre-processing of very large quantities of biomass.

- Direct injection of pre-milled biomass at high biomass co-firing ratios, and the impact on combustion/NO_x control,
- The increased risks of excessive ash deposition, and fireside boiler tube corrosion.
- The production of mixed biomass/coal ashes and the risks to the normal ash utilisation/disposal routes.

Biomass ash effects

- Most biomass materials have low ash contents (<5%), compared to most power station coals.
- The biomass ashes are very different chemically from coal ashes, i.e. they are not an alumino-silicate system, but a mixture of simple inorganic compounds, of Si, K, Ca, P and S.
- There are concerns about increased rates of deposition on boiler surfaces and the surfaces of SCR catalysts.
- There are concerns about increased rates of high temperature corrosion of boiler components, with high chlorine biomass materials.
- Biomass co-firing tends to increase the level of submicron aerosols and fume in the flue gases, and may impact ESP collection efficiency.
- There may be utilisation/disposal issues with mixed coal/biomass ashes.

Biomass	Forestry residue	SRC willow	Cereal straw	Oil seed rape straw	Olive residue	Palm kernel	Poultry litter
Ash (%)	2	2	5	5	7	4	13
Ash Analysis (mg kg^{-1})							
Al	-	-	50	50	1,500	750	600
Ca	**5,000**	**5,000**	**4,000**	**15,000**	**6,000**	**3,000**	**20,000**
Fe	-	100	100	100	900	2,500	900
K	**2,000**	**3,000**	**10,000**	**10,000**	**23,000**	**3,000**	**5,000**
Mg	**800**	**500**	**700**	**700**	**2,000**	**3,000**	**5,000**
Na	200	-	500	500	100	200	3,000
P	**500**	**800**	**1,000**	**1,000**	**1,500**	**7,000**	**14,000**
Si	**3,000**	**-**	**10,000**	**1,000**	**5,000**	**3,000**	**9,000**

The effect of biomass ash on Ash Fusion Temperatures and fouling behaviour

Coal ash slagging

- For coals with high ash fusion temperatures, the addition of relatively small amounts of some biomass ashes can reduce the DT by as much as 200ºC.
- For low ash fusion temperature coals, the effect is much less dramatic.
- For predictive purposes, the normal coal Slagging Indices can be applied to mixed biomass-coal ash systems.
- Empirical correlations permit estimation of the Deformation Temperatures of mixed ashes.

Coal ash fouling

- Fouling indexes for mixed biomass/coal ashes are based on the alkali metal contents of the fuels.

Boiler tube corrosion factors

- The tube material – higher chrome alloys are more resistant.
- High flue gas and metal temperatures - generally superheater outlet elements are at highest risk.
- The chemical composition of the ash deposit material at the metal-deposit interface - high alkali metal and chloride contents are undesirable.
- The chemical composition of the flue gases - high chloride contents are undesirable.
- The operating regime of the plant – large numbers of start-ups and shutdowns are undesirable.

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Concluding remarks

Conclusions

- **Large scale biomass co-firing is one of the most efficient and cost-effective approaches to generating electricity from renewable sources.**
- **Biomass pre-mixing and co-milling at low co-firing ratio is being practised successfully by a number of coal plant operators in Britain and continental Europe.**
- **Direct injection co-firing projects are being installed as a means of increasing the co-firing levels.**
- **Project technical risks and costs (capital and operating) increase with,**
  - Increasing co-firing ratio, and
  - Increasing biomass fuel flexibility and quality variation.

The principal constraints on biomass quality/co-firing ratio

- Provided that the system is designed and operated properly, and there are no combustion-related issues, the main issues are:
  - Biomass materials with high nitrogen contents require careful consideration, because of concerns about NO_x emissions,
  - High chlorine biomasses require careful consideration, because of concerns about excessive metal wastage rates of high temperature boiler components,
  - Biomasses with high levels of potassium and phosphates require careful consideration because of concerns about increased fouling of boiler surfaces and SCR catalysts, and
  - Biomass materials with high levels of specific trace elements may need careful consideration.
  - For some specific biomass materials , the co-firing ratio may have to be limited.

Thank you for your attention

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