

Reinhold Environmental Ltd.



2010 NO_x-Combustion Round Table & Expo Presentation

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Biomass Co-firing Experience in PC Boilers

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February 8, 2010

Presentation Summary

- **General Comments**
- **Principal Direct and Indirect Biomass Co-firing Options**
- **Logistical and Technical Issues**
- **Concluding Remarks**



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Biomass Co-firing –General Comments

Biomass Co-firing –General Issues

- **To date, biomass co-firing activities worldwide have almost exclusively been associated with retrofit projects to existing coal power plants**
- **There have been concerns about the availability of biomass, the long term security of subsidy incomes and about impacts on power plant performance and integrity**
- **The emphasis has been on the minimization of the risk of significant impacts on the coal plant operations, performance and integrity**
- **The biomass co-firing activities are additional to the installed coal-firing systems**
- **A number of the ‘new build’ coal power plant projects currently being developed in Europe and elsewhere have a requirement for a co-firing capability, generally at the 10-20% level, on a heat input basis.**

The Current Status in UK

- In April 2002, the UK government introduced the 'Renewables Obligation', which provides financial incentives to the generators of electricity from renewable sources, including co-firing
- This produced a relatively dramatic increase in biomass co-firing involving all of the large coal-fired power plants in the UK
- Co-firing has been mainly by pre-mixing the biomass with the coal and co-milling and, more recently, by direct injection of pre-milled biomass
- To date, the cumulative power generation from co-firing biomass is in excess of 11 million MWh
- The level of activity at individual Stations has varied significantly

General Approach in the UK

The general approach at a number of the Stations has been as follows:

- Establish co-firing by pre-mixing and co-milling on the preferred fuel at minimum capital cost, and with short project lead times
- Integrate biomass co-firing into the normal station operations
- Upgrade biomass reception, storage, handling and mixing facilities, to increase throughput and reduce mechanical handling constraints, dust generation, etc.
- Start consideration of the direct firing of biomass to permit higher co-firing ratios
- Installation of direct biomass co-firing facilities

Biomass Co-firing at Coal-fired Stations in the UK

Station	Capacity (MW _e)	Generator	Cumulative GWh
Aberthaw	1,455	RWE npower	431
Cockenzie	1,200	Scottish Power	217
Cottam	2,000	EdF	571
Didcot	2,100	RWE npower	417
Drax	4,000	Drax Power	2,262
Eggborough	1,960	British Energy	741
Ferrybridge	2,035	SSE	2,132
Fiddlers Ferry	1,995	SSE	1,410
Ironbridge	970	E.on UK	178
Kingsnorth	2,034	E.on UK	769
Longannet	2,400	Scottish Power	680
Ratcliffe	2,010	E.on UK	38
Rugeley	1,000	Int. Power	337
Tilbury	1,085	RWE npower	100
West Burton	1,980	EdF	392
			10,675

Biomass Materials Utilized in Large Quantities in Europe

- The solid wastes from agricultural industries, and principally palm oil and olive oil production
- Pellets made from dried sawdust and other materials,
- Dried sludges
- Wood materials in various forms, i.e. sawdust, forestry residues, wood processing residues, short rotation coppice wood, etc
- Cereal straws and other dry agricultural residues in baled form
- The majority of the biomass material co-fired has been imported from other parts of Europe and from outside Europe



Biomass Pre-treatment

As with all fuels, biomass material may require significant pre-treatment prior to firing. This may include:

- **Chipping or shredding,**
- **Dewatering and/or drying**
- **The removal of tramp material, normally by air classification or magnetic separation**
- **Milling**
- **Pelletization or other densification**
- **Torrefaction or pyrolysis, with pelletization**

The infrastructure for the supply and pre-treatment of biomass materials in very large quantities for co-firing is still under development in most countries.

Materials Handling Issues – General

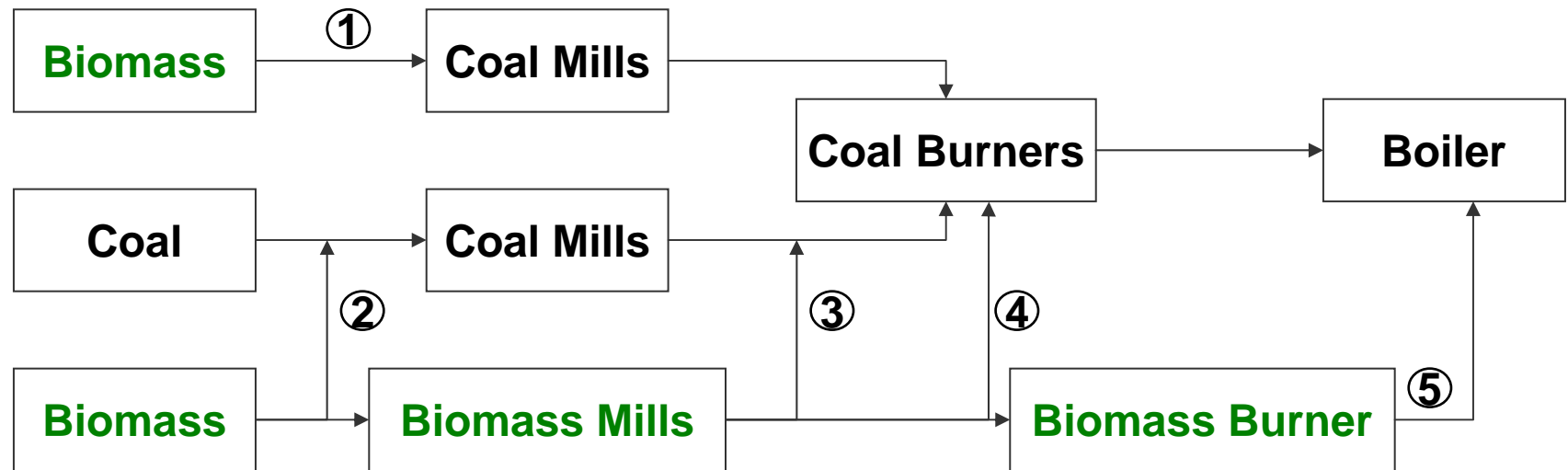
- **Biomass materials are generally delivered as pellets, granular materials or dusts, or as baled materials**
- **In the UK to date, the costs of the specialized storage, handling and feeding equipment required for baled materials have been prohibitive for co-firing projects**
- **Most biomass materials are easy to ignite and have self-heating tendencies**
- **Most biomass materials generally require covered storage, although the open storage of sawdust and wet wood chips is practised**
- **The biggest single problem has been associated with the tendency of many biomass materials to generate dust, with the associated health and safety/fugitive emissions issues**



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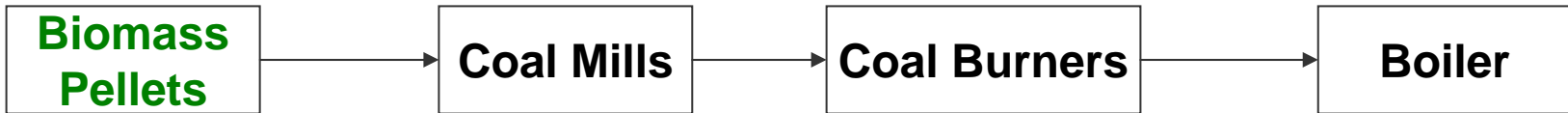
Principal Direct and Indirect Biomass Co-firing Options

Principal Direct and Indirect Biomass Co-firing Options



1. Milling of biomass (pellets) through modified coal mills
2. Pre-mixing of the biomass with the coal, and the milling and firing of the mixed fuel through the existing coal firing system
3. Direct injection of pre-milled biomass into the pulverised coal pipework
4. Direct injection of pre-milled biomass into modified coal burners or directly into the furnace
5. Direct injection of the pre-milled biomass through dedicated biomass burners

1. Milling of Biomass (pellets) Through Modified Coal Mills



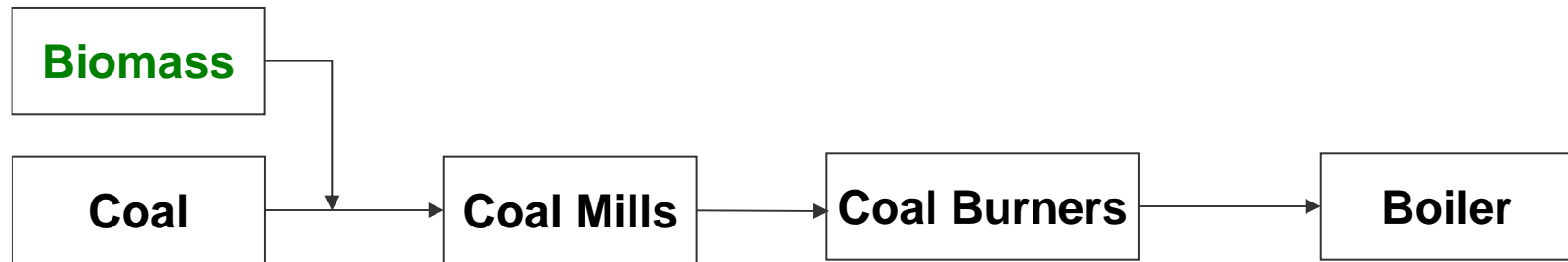
**Example: Hasselby CHP – 3x100 MWt Operating since 1994
1,500 t/day pellets**



1. Milling of Biomass (wood pellets) Through Modified Coal Mills

- **The milling of biomass pellets in coal mills, and the firing of the mill product through conventional burners, is done at a small number of Power Stations in Europe**
- **This has the attraction that the coal mills are very robust and have high availability and low maintenance requirements, compared to the more conventional biomass attrition mills**
- **At best, the action of the coal mill breaks the pellets back to the original dust size distribution**
- **The mill has to be modified to operate with cold primary air, i.e. there are requirements for throat and classifier modifications**
- **There are generally no modifications to the grinding elements**

2. Pre-mixing Biomass with Coal, Milling and Firing the Mixed Fuel Through Existing Coal System



2. Pre-mixing Biomass with Coal, Milling and Firing the Mixed Fuel Through Existing Coal System

- **Co-firing by co-milling is the preferred approach for Stations embarking on co-firing activities for the first time**
- **Capital investment 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 of the subsidy payments**



2. Pre-mixing Biomass with Coal, Milling and Firing the Mixed Fuel Through Existing Coal System

This approach permits co-firing at levels up to 5-8% on a heat input basis.

The key constraints are:

- **Availability of suitable biomass supplies**
- **Limitations of on-site biomass reception, storage and handling facilities**
- **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.



2. Pre-mixing Biomass with Coal, Milling and Firing the Mixed Fuel Through Existing Coal System

- In the UK, a range of biomass materials is being co-milled with coal in ball and tube mills and in vertical spindle ball and ring and roller mills
- These mills depend on the coal particles being subject to brittle fracture, and this does not apply to most biomass materials
- There is a tendency for the biomass particles to accumulate in the mill, during normal operation, and to take longer to clear from the mill during shutdown
- With vertical spindle mills there is a tendency for the mill differential pressure and the mill power take to increase when co-milling biomass
- The mill product topsize tends to increase, due to the lower particle density of the biomass, i.e. larger biomass particles can exit the classifier
- When co-milling wet biomass materials there will be an impact on the mill heat balance, and this may be a limiting factor

2. Pre-mixing Biomass with Coal, Milling and Firing the Mixed Fuel Through Existing Coal System

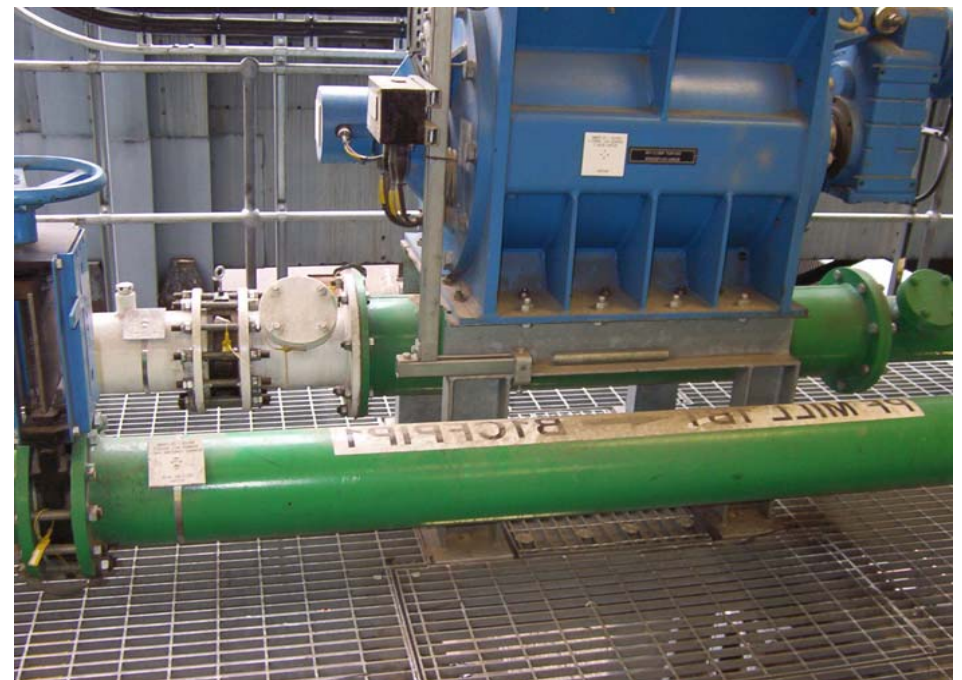
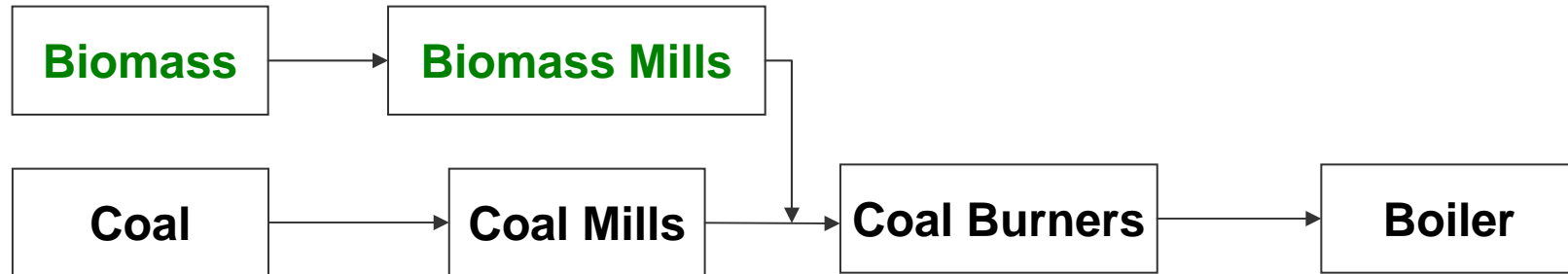
Safety Issues When Co-milling Biomass in Vertical Spindle Coal Mills

- The key issue in mill safety is avoiding hot primary air coming into direct contact with dry fuel
- This is particularly important during certain mill operations such as:
 - planned and emergency shutdowns,
 - restarts after emergency shutdowns,
 - loss of coal or intermittent coal feed incidents, etc
- Biomass has high volatile matter content and combustible volatiles are released in significant quantities at temperatures above 350°F, i.e. at much lower temperatures than for bituminous coals
- It is usually advisable to reassess and modify the mill operating procedures to allow the co-milling of biomass safely

2. Pre-mixing Biomass with Coal, Milling and Firing the Mixed Fuel Through Existing Coal System

- **This approach has been employed successfully at a number of Power Plants across Europe for the co-firing of a range of solid biomass materials**
- **The incidence of significant mill safety issues when co-milling biomass has been fairly modest**
- **In general, this approach has permitted the co-firing of up to 8% biomass on a heat input basis, although 5-6% or less is more common**
- **The most common problems have been associated with the reception, storage and handling of the biomass, with the most important problems being associated with the generation of biomass dust**

3. Direct Injection of Pre-milled Biomass into PF Pipework

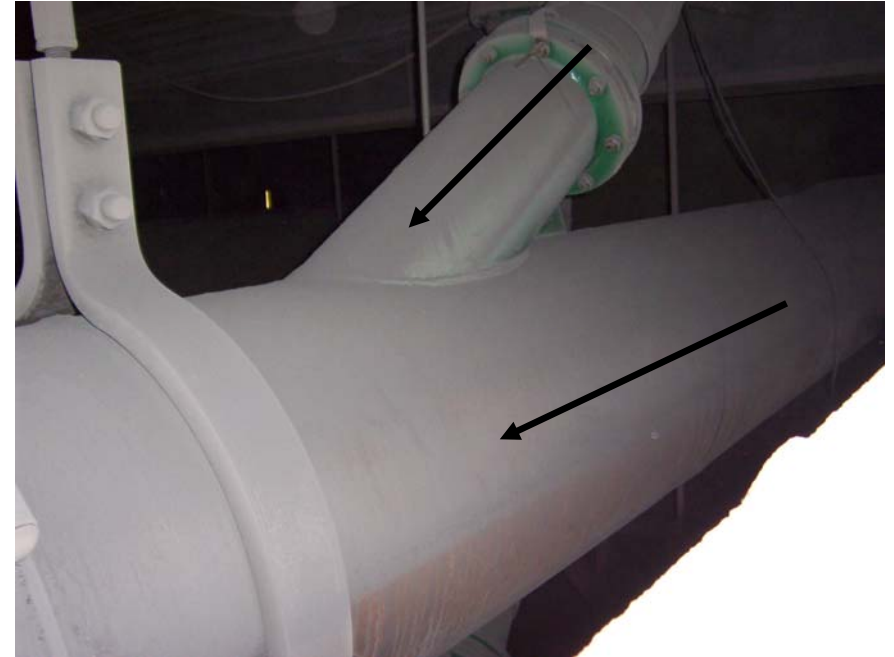


3. Direct Injection of Pre-milled Biomass into PF Pipework



- **Direct injection into the existing coal firing system is relatively simple and inexpensive to install and this is generally the preferred option**
- **Pulverizer primary air and fuel flow rates have to be reduced in line with the co-fired biomass and associated conveying air**
- **Both the pulverizer and the burners are maintained within their normal operating envelopes for both the heat input and primary air flow rates**
- **The maximum heat input from the mill group is not affected, and can be increased in some cases**
- **There are new interfaces between the mill and biomass conveying system controls, covering permits to operate, biomass system shutdowns, start-ups and trips, etc**

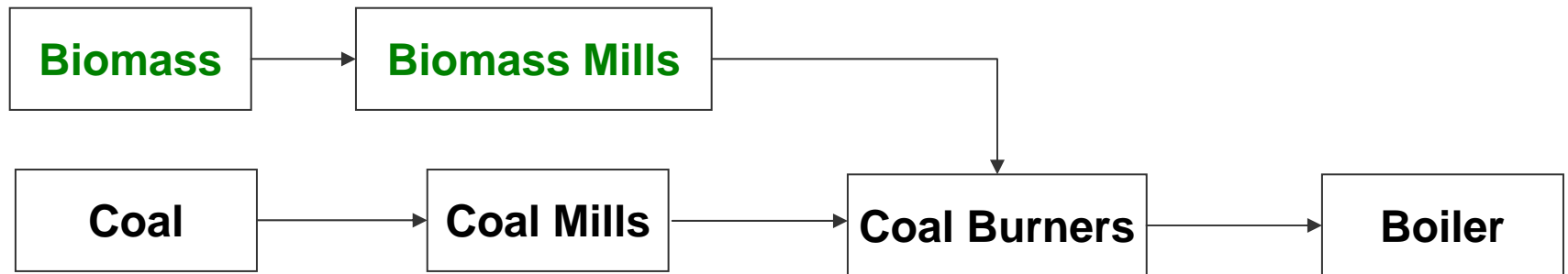
3. Direct Injection of Pre-milled Biomass into PF Pipework



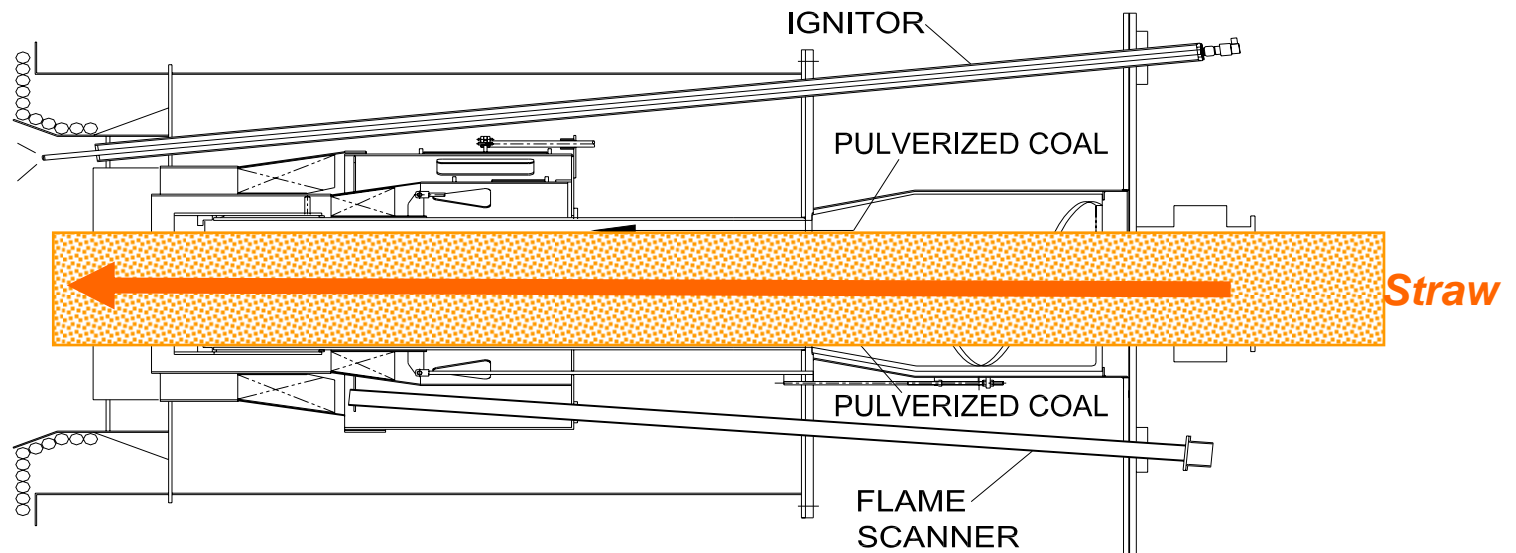
The Kinetrol automatically shuts the fast acting ball valve (<2sec) in the case of an emergency. A local knife gate valve allows system isolation.

This is normally on the same level as the coal feeders and adjacent to the biomass rotary valve level.

4. Direct Injection of Pre-milled Biomass into Modified Coal Burners



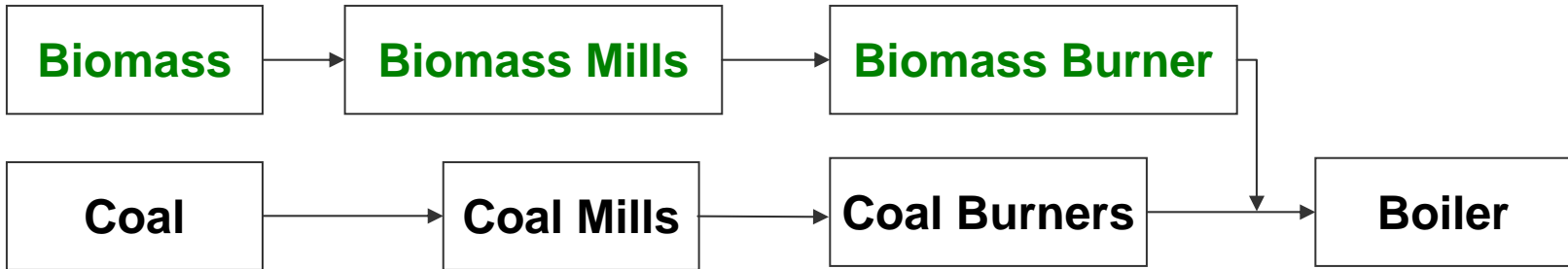
- **Modified Doosan Babcock Mark III LNB for Coal-Straw Co-firing (to 50% heat input/burner) at Studstrup, Denmark**



4. Direct Injection of Pre-milled Biomass into Modified Coal Burners

- **This has been achieved successfully for both wall-fired and corner-fired furnaces**
- **The quantities of biomass that can be co-fired into a single burner are quite modest**
- **Modification of the existing coal burners involves additional cost and risk compared to injection into the pulverized coal pipework**
- **This approach may be necessary in some cases, depending on the nature of the biomass, particularly if there is a risk of blockage of the fuel supply pipework at splitters, e.g. with chopped straw at Studstrup in Denmark**

5. Direct Injection of Pre-milled Biomass Through Dedicated Biomass Burners



Ferrybridge Station, UK – 4x500 MW_e Doosan Babcock Boilers



5. Direct Injection of Pre-milled Biomass Through Dedicated Biomass Burners

- If the existing coal-firing capability is to be maintained, additional burners are required for biomass firing
- Appropriate locations for the biomass burners are not easy to find, particularly as a retrofit and additional furnace penetrations and burner support structures are required
- Additional furnace penetrations and burner support structures are required
- Fuel and air supply systems for the biomass burners have to be installed and flame monitoring equipment for the biomass flames is required
- The impact of exposure of the 'out of service' biomass burners to the coal-fired furnace gases needs to be assessed
- The impact of new biomass burners on the coal-firing system has to be assessed
- The biomass burners are normally based on conventional pulverized coal burners or cyclone burners (Ferrybridge)

Overall, the installation of dedicated biomass burners is an expensive and relatively high risk approach to biomass co-firing.



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Logistical and Technical Issues

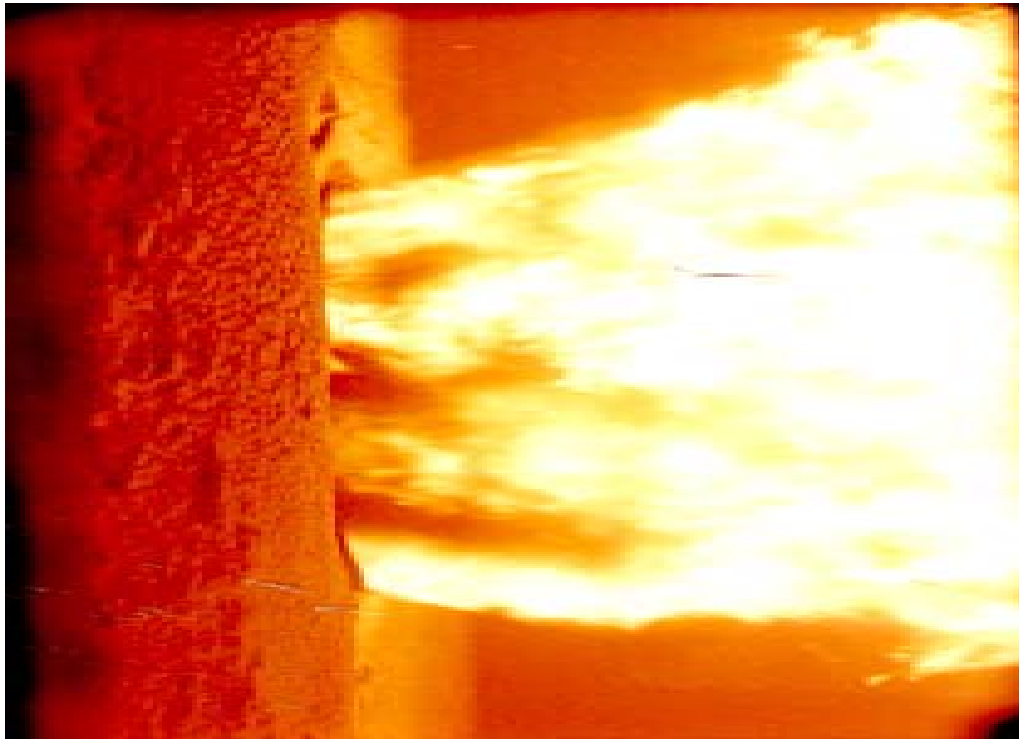
Logistical and Technical Issues



- 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



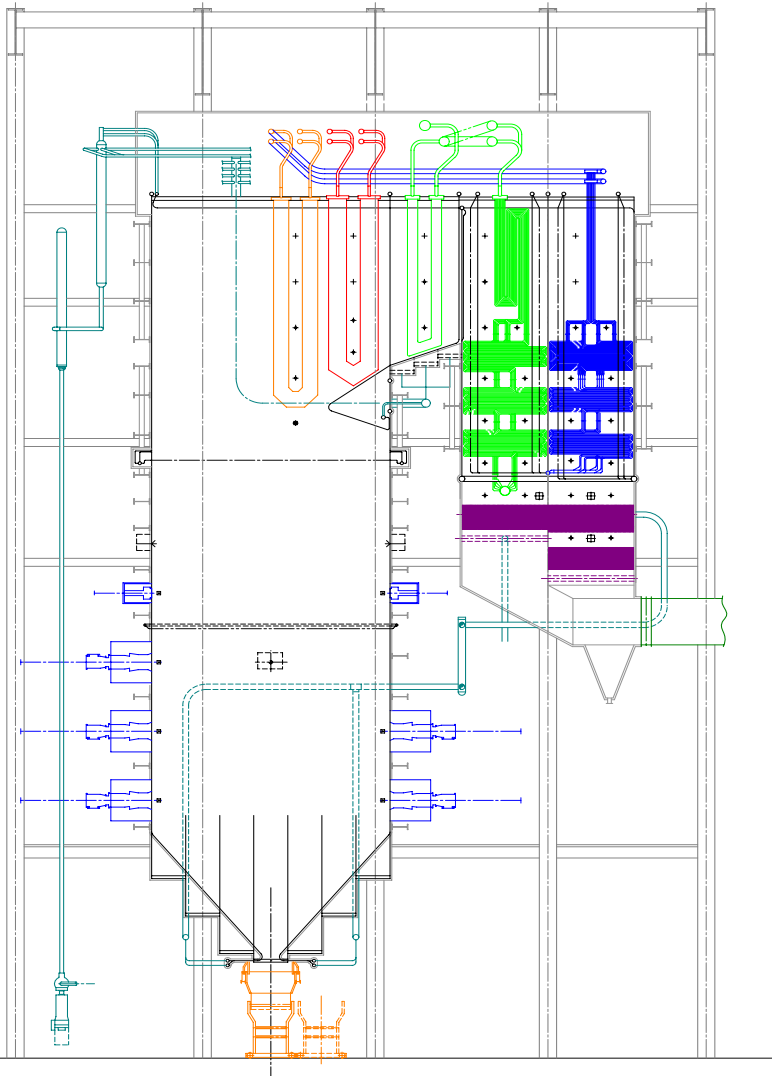
Logistical and Technical Issues



Direct injection of pre-milled biomass at high biomass co-firing ratios and the impact on combustion/NO_x control

- Increased risks of excessive ash deposition and fireside boiler tube corrosion**
- Production of mixed biomass/coal ashes and risks to the normal ash utilization/disposal routes**

Logistical and Technical Issues



- 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 utilization/disposal issues with mixed coal/biomass ashes

Biomass Ash Effects

- **Most biomass materials have low ash contents (<5%), compared to most Power Station coals**
- **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 utilization/disposal issues with mixed coal/biomass ashes**

Drax Power Station Biomass Co-firing System



Station comprises 6x660 MW_e PC Boilers supplied by Doosan Babcock Energy

- **Since 2005 biomass co-firing in 2 units with up to 7% heat input**
- **Current upgrade for all 6 units co-fires biomass up to 12% heat input at MCR**
- **Annual consumption of biomass > 1.6 million tons**

Biomass Storage Building Transfer Conveyor





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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 is being practised successfully as a retrofit to existing plants, by a number of coal plant operators in the UK and continental Europe**
- **Direct injection co-firing projects are being implemented as a means of increasing the co-firing levels**
- **Injection of biomass into the pulverized coal pipework is the preferred direct firing solution for both retrofit and new build projects**
- **To date, the impacts on boiler plant operations have been modest but this will increase with increasing co-firing ratios and with higher ash biomass materials**
- **A number of the ‘new build’ coal power plant projects have a biomass co-firing requirement**