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The firing and co-firing of difficult biomass fuels

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The principal types of difficult biomass fuels

- **Biomass fuels with difficult physical properties**
  - Wet sludges
  - **Straws and grasses, which are stored and handled in baled form.**

- **Very wet fuels**
  - Wet sludges
  - Wet chips, dusts and small flakes
  - **The co-firing of wet sawdusts with coal**

- **Fuels with difficult ashes**
  - Animal and poultry wastes
  - Distillers grains and similar materials
  - **The co-firing of a range of biomass materials and the impact on ash deposition**

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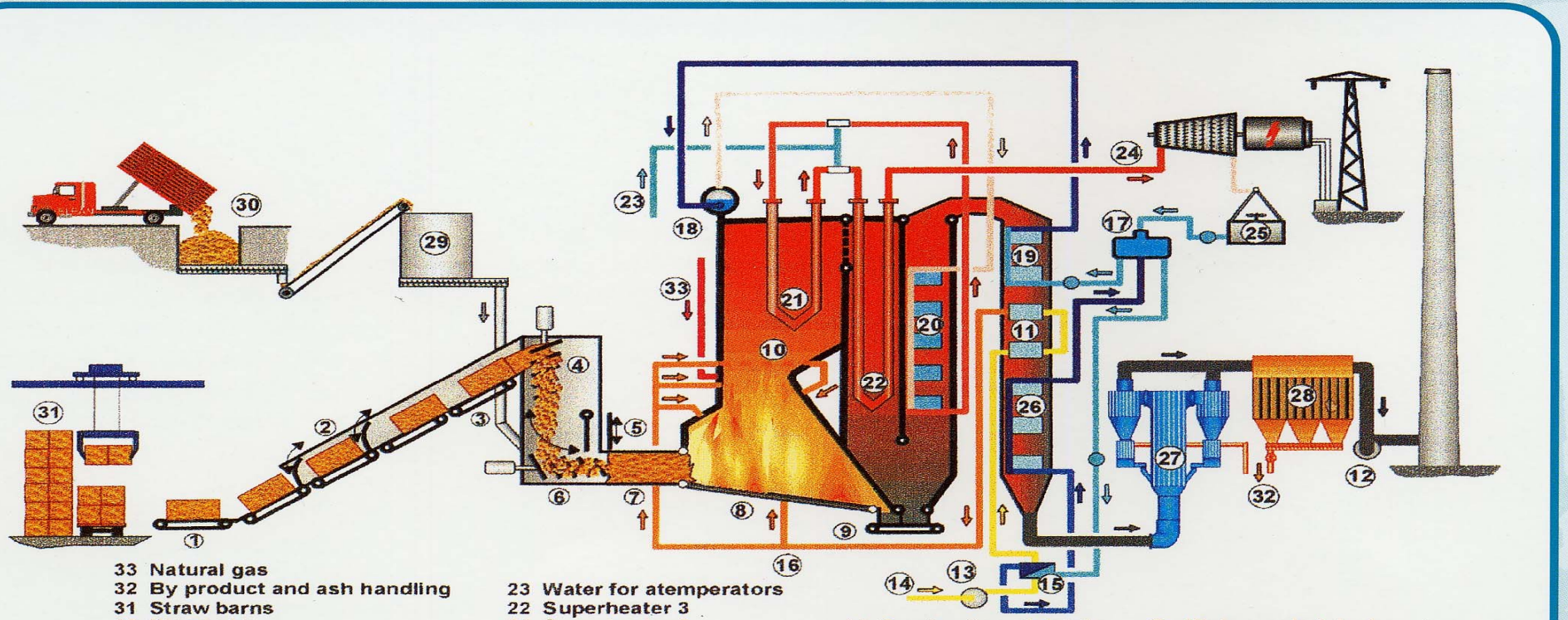
Biomass materials with difficult physical properties

Biomass with difficult physical properties

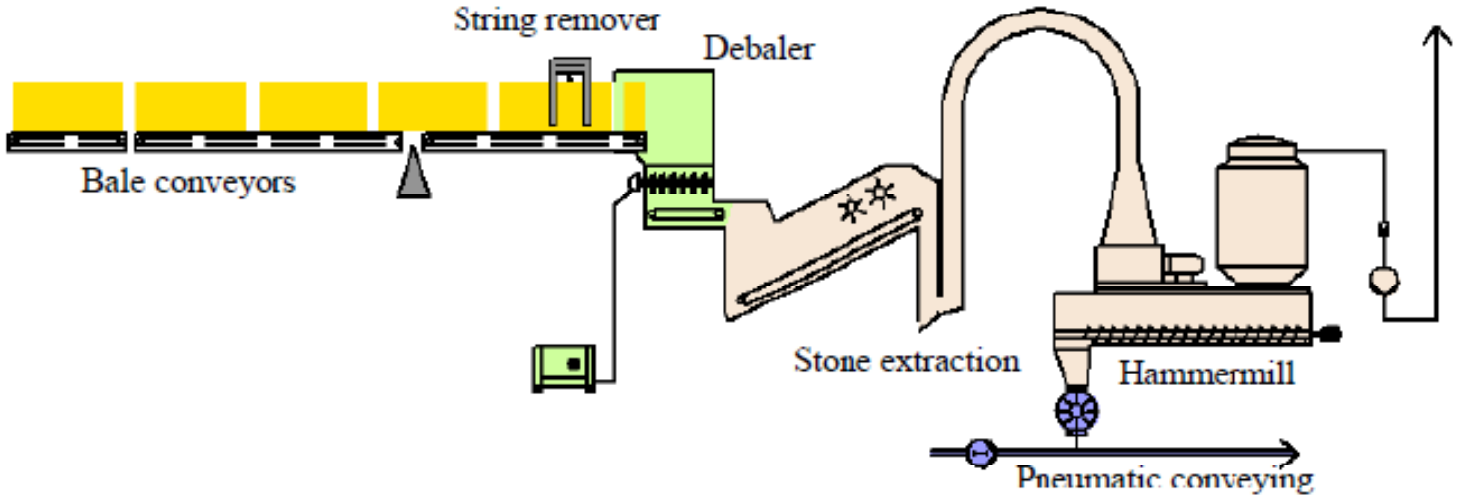
- Cereal straws for biomass are harvested, transported, stored and handled as large Hesston bales.
- The bulk handling of Hesston bales requires relatively expensive specialist equipment.
- The bales need to be broken up prior to feeding to a boiler, and this requires specialist equipment.
- For grate firing, the bales are broken up and a deep fuel bed is formed.
- For pulverised fuel co-firing , the straw is milled and pneumatically injected through modified coal burners.

General process diagram of the straw-fired power plant near Ely, England

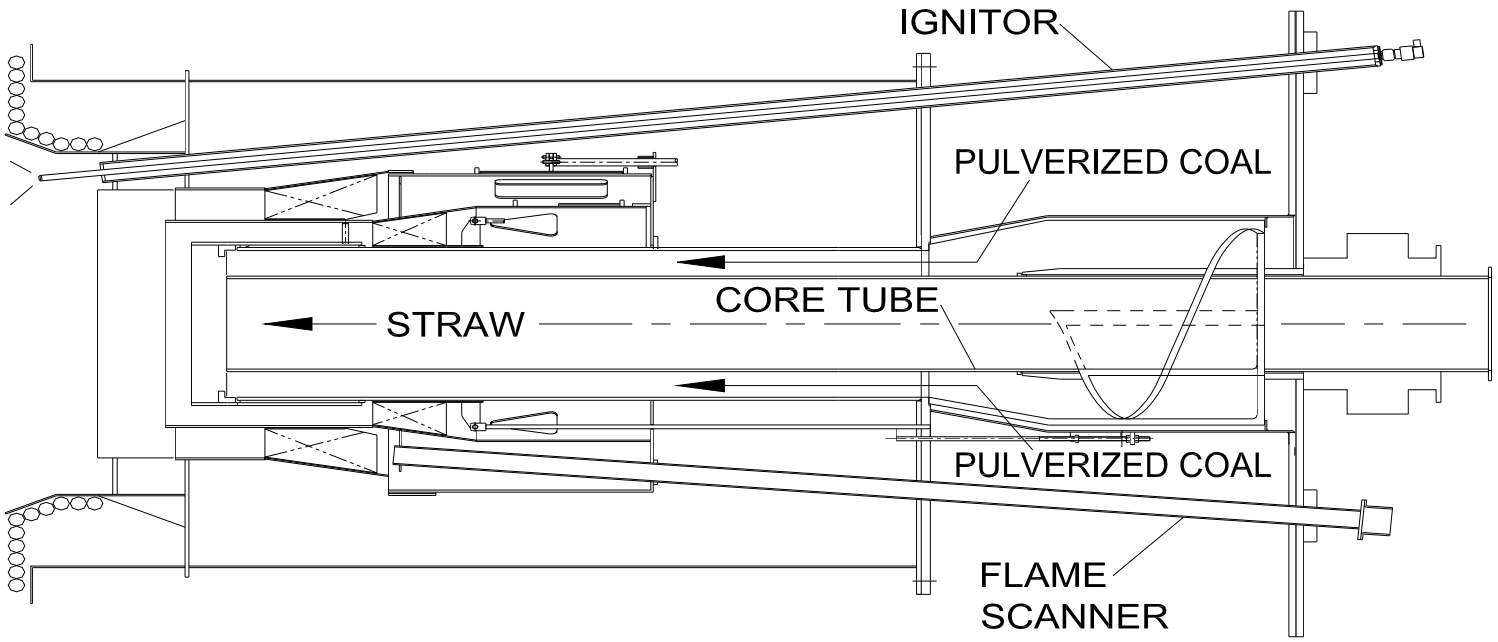


Bale breaking and straw milling equipment at Studstrup (after Overgaard et al., 2006)

Straw processing



Modified Doosan Babcock Mark III Low NOx burners for the combustion of chopped straw at Studstrup in Denmark



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Overview of straw firing and co-firing

- Cereal straws and energy crop grasses are harvested, stored and handled on baled form.
- Specialist equipment is required for handling, processing and feeding the baled material to the boiler.
- The equipment is expensive and not very flexible in nature.
- There has been only limited utilisation of baled cereal straws as fuels outside Denmark, where there are specific government policy instruments encouraging the utilisation of indigenous biomass materials.
- There is now significant quantities of milled and pelletised straw and similar materials available.

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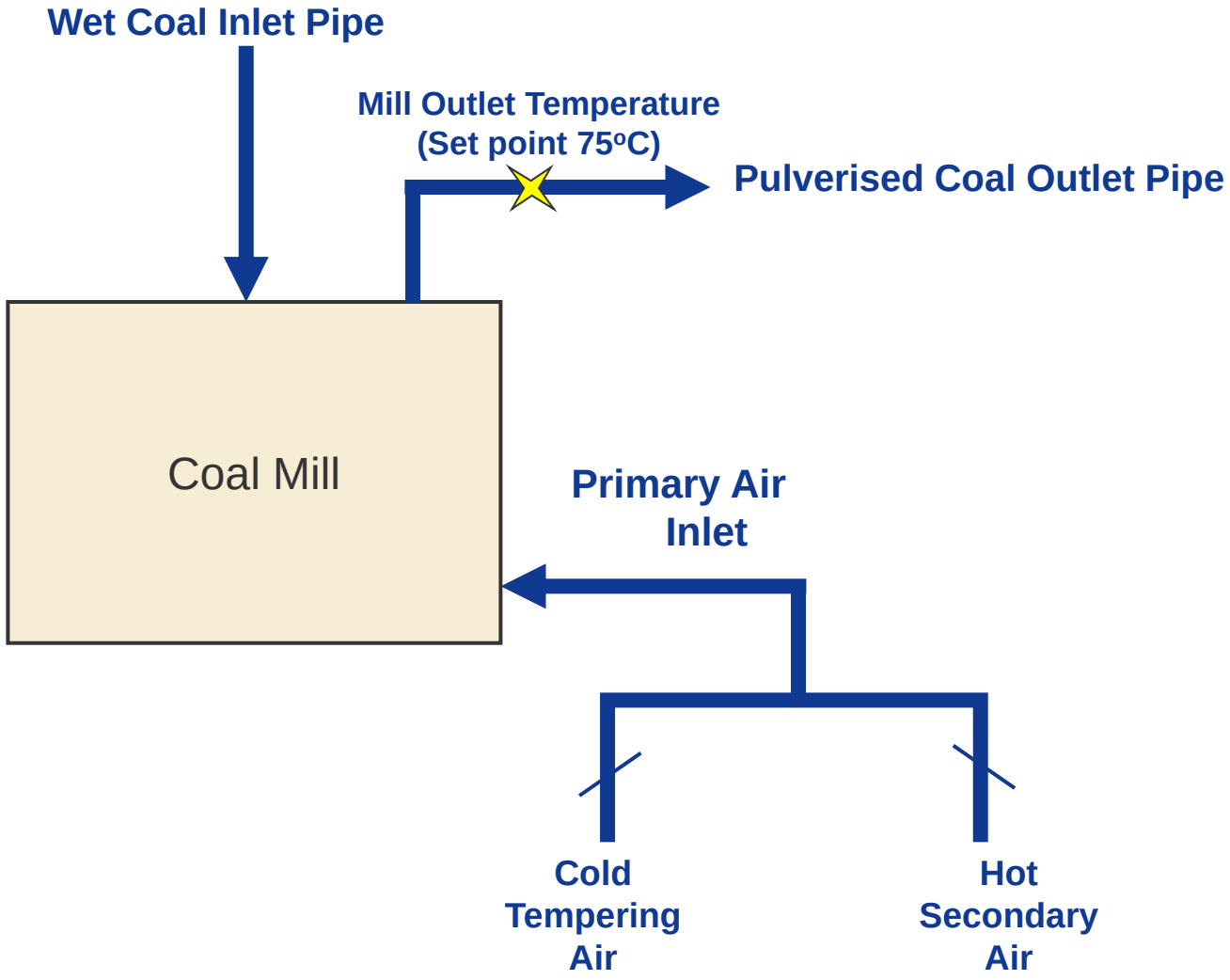
Co-firing wet sawdusts

The co-firing of wet biomass fuels with coal in pulverised coal boilers

- Green wood materials generally have total moisture contents up to around 55-60%.
- A significant quantity of wet sawdust material; has been co-firing in large pulverised coal boilers.
- In the main, the wet sawdust has been co-fired by pre-mixing with the coal at less than 10% by mass in the coal handling system, and processing the mixed fuel in the installed coal milling and firing system.
- The co-firing of the wet biomass has a significant impact on the mill heat balance.

Vertical spindle coal mill schematic



Coal-sawdust blend compositions

	Sample	Total moisture content	Gross calorific value	
		(%)	MJ kg^{-1}, as received)	MJ kg^{-1}, dry ash free)
2% Blend	**Coal**	**14.5**	24.30	33.15
	Sawdust	61.4	7.69	20.30
	Blend	**15.3**	23.99	33.00
6% blend	**Coal**	14.5	25.21	33.40
	Sawdust	53.5	9.14	20.12
	Blend	**16.6**	24.27	32.93
10% blend	**Coal**	14.2	25.51	33.17
	Sawdust	57.1	8.47	21.71
	Blend	**18.6**	23.64	32.48

The impact of wet coal on the mill outlet temperatures.

Biomass level	**2% by mass**		**10% by mass**	
Boiler output	**450-500 MW_e**		**490-500 MW_e**	
Mill	**Coal flow rate (tonnes h^{-1})**	**Minimum mill outlet temp. (°C)**	**Coal flow rate (tonnes h^{-1})**	**Minimum mill outlet temp.**
B	34-37	**60**	37-38	**55**
C	36-37	**74**	35-37	**60**
D	55/60?	**64**	68-76?	**58**
E	30-31	**73**	37-41	**54**
F	30-37	**73**	35-36	**60**
G	20-23?	**60**	18-24?	**66**
H	34-36	**61**	43-46	**53**

- The co-firing of wet biomass materials with can be achieved by mixing the biomass with the coal and processing the mixed fuel through the installed coal mills and firing system
- With very wet solid biomass materials like sawdust, there is a significant impact on the heat balance across the mill and this can be a limiting factor,
- This can limit the co-firing ratio that is achievable in some cases.

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Co-firing biomass materials with coal – ash effects

Biomass ash effects on boilers and associated equipment

- The biomass ashes are very different chemically from coal ashes, i.e. they are not an alumino-silicate systems, but mixtures of simple inorganic compounds, of Si, K, Ca, P and S.
- The levels of Ca, K and P in biomass materials can be significantly higher than in coal ashes.
- This can lead to concerns about increased ash deposition on boiler surfaces, when co-firing biomass with coal.
- There can be 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 on ESP collection efficiency.
- There may be utilisation/disposal issues with mixed coal/biomass ashes.

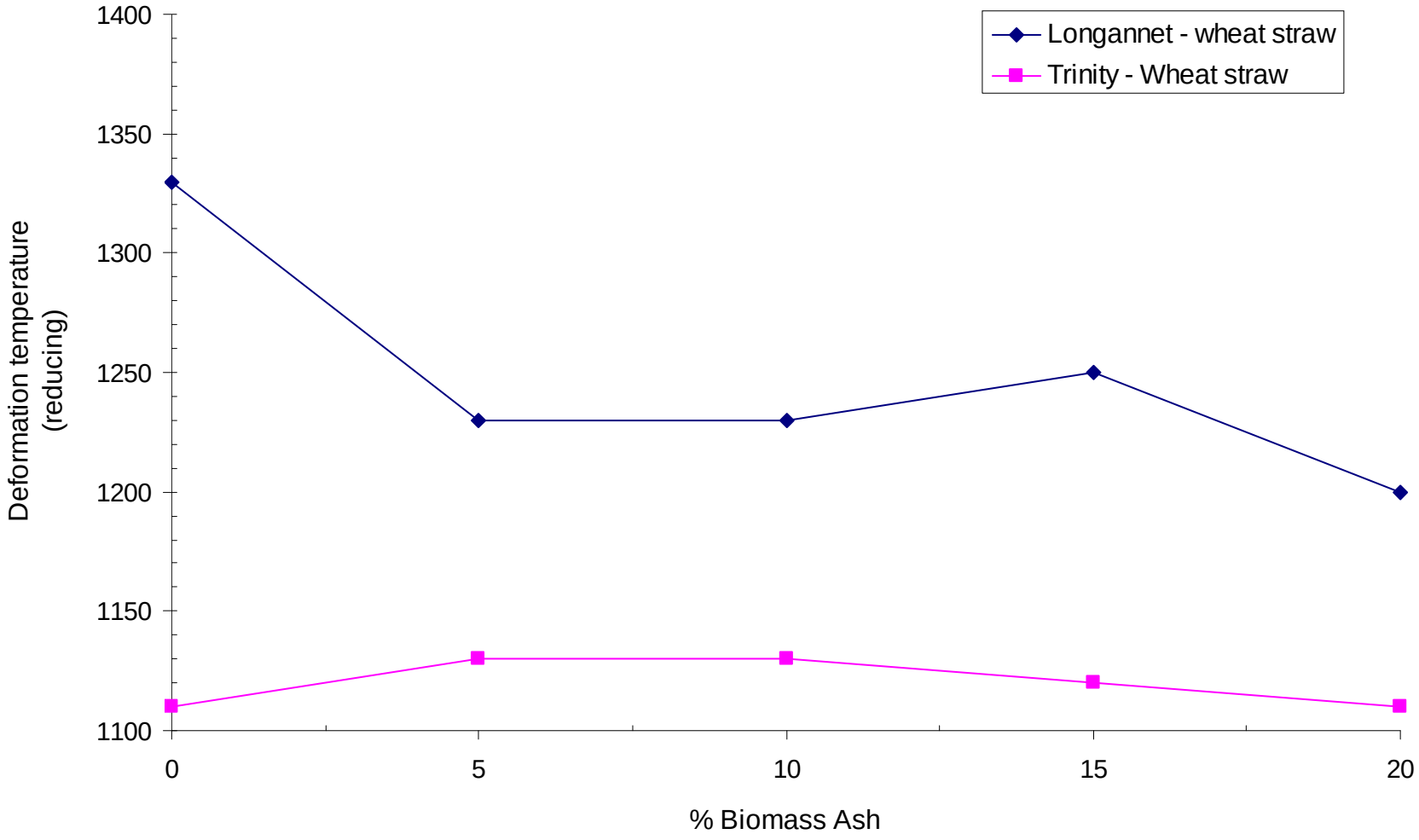
Biomass ash compositions

Biomass	Forestry residue	SRC willow	Cereal straw	Oil seed rape straw	Olive residue	Palm kernel	Distillers grains	Poultry litter
Ash (%)	2	2	5	5	7	4	4	13
Analysis (mg kg^{-1})								
Al	-	-	50	50	1,500	750	-	600
Ca	**5,000**	**5,000**	**4,000**	**15,000**	**6,000**	**3,000**	**1,000**	**20,000**
Fe	-	100	100	100	900	2,500	-	900
K	**2,000**	**3,000**	**10,000**	**10,000**	**23,000**	**3,000**	**8,000**	**5,000**
Mg	800	500	700	700	2,000	3,000	2,000	5,000
Na	200	-	500	500	100	200	1,500	3,000
P	**500**	**800**	**1,000**	**1,000**	**1,500**	**7,000**	**12,000**	**14,000**
Si	3,000	-	10,000	1,000	5,000	3,000	400	9,000

Ash Fusion Temperatures of coal ash-biomass ash mixtures

Parameter	100% Longannet coal ash	95% Longannet ash + 5% Wheat straw ash	Difference	100% Trinity coal ash	95% Trinity coal ash + 5% wheat straw ash	Difference
Deformation Temp. (red.) (°C)	1330	1230	**-100**	1110	1130	**+20**
Hemisphere Temp. (red.) (°C)	1490	1380	**-110**	1120	1130	**+10**
Flow Temp. (red.) (°C)	>1500	1420	**-80**	1150	1140	**-10**

The ash fusion temperatures of mixed ashes



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The slagging and fouling behaviour of mixed ashes at high co-firing ratios

Parameter	SA Export coal	Wood pellets	50% blend	Olive residue	50% blend	DDGS	50% blend
Ash content (%)	**14.6**	**2**	**7.1**	**2.9**	**7.6**	**4.2**	**8.6**
Ash analysis (% in ash)							
SiO_2	51.0	16.1	45.4	22.1	44.4	0.6	37.7
Al_2O_3	31.0	4.1	26.7	2.1	24.4	0.1	22.8
Fe_2O_3	4.4	6.5	4.7	6.0	4.8	1.3	3.6
CaO	**8.0**	**30.9**	**11.6**	**18.7**	**10.5**	**3.6**	**6.0**
MgO	1.6	8.0	2.6	11.1	3.8	12.8	4.7
Na_2O	**0.5**	**0.9**	**0.6**	**14.5**	**3.7**	**7.1**	**2.3**
K_2O	**0.5**	**12.8**	**2.4**	**16.2**	**4.1**	**28.1**	**8.1**
P_2O_5	**1.1**	**15.8**	**3.4**	**6.1**	**2.3**	**44.3**	**12.9**
SO_3	-	4.0	0.6	2.5	0.6	2.0	0.5
Slagging Index	**0.83 (Medium)**	**1.09 (High)**	**1.01 (Medium/high)**	**N/A (Severe)**	**1.43 (High)**	**N/A (Severe)**	**1.63 (High)**
Fouling Index 1	**0.08 (Low)**	**2.3 (Severe)**	**0.5 (Low/medium)**	**5.1 (Severe)**	**1.2 (High/severe)**	**5.9 (Severe)**	**1.6 (Severe)**
Fouling Index 2	**0.028 (Low)**	**0.157 (Medium/high)**	**0.102 (Medium)**	**0.515 (Severe)**	**0.288 (High)**	**0.804 (Severe)**	**0.418 (Severe)**

Conclusions on biomass ash behaviour

- The chemistry and mineralogy of biomass ashes and of the mixed ashes from co-firing biomass with coal are reasonably well understood.
- There are risks of decreased ash fusion temperatures and increased slag formation, depending principally on the co-firing ratio, and the ash content and ash chemistry of the biomass.
- The Slagging and Fouling indexes and other assessment methods devised for coal ashes can be applied successfully to biomass-coal ash mixtures, with appropriate modification.
- In general, the plant experience at co-firing ratios less than 10% on a heat input basis, indicates that the impacts on ash deposition have been modest.
- At higher co-firing ratios the risks of increased deposition and other ash-related impacts are higher, and this will lead to restrictions in the range of biomass materials that can be co-fired.

Summary of the utilisation of difficult biomass materials as fuels

Difficult physical properties

Some biomass materials have physical properties that can require relatively expensive specialist harvesting, storage transport and handling equipment.

Metering and feeding these materials in to the boiler or reactor vessel can be problematic.

High moisture content

The co-firing of wet sawdusts with coal in pulverised coal-fired boilers by pre-mixing the biomass with the coal and co-milling in the installed coal mills is quite widely practised.

The high moisture content has a significant impact on the mill heat balance and this can be a limiting factor.

Difficult ash behaviour

Biomass ashes are very different from coal ashes and a number have high propensities to slagging and fouling of furnace and boiler surfaces.

This can result in significant problems in dedicated biomass combustion plants and boilers

This can limit the allowable co-firing ratio when co-firing with coal.

Thank you for your attention

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