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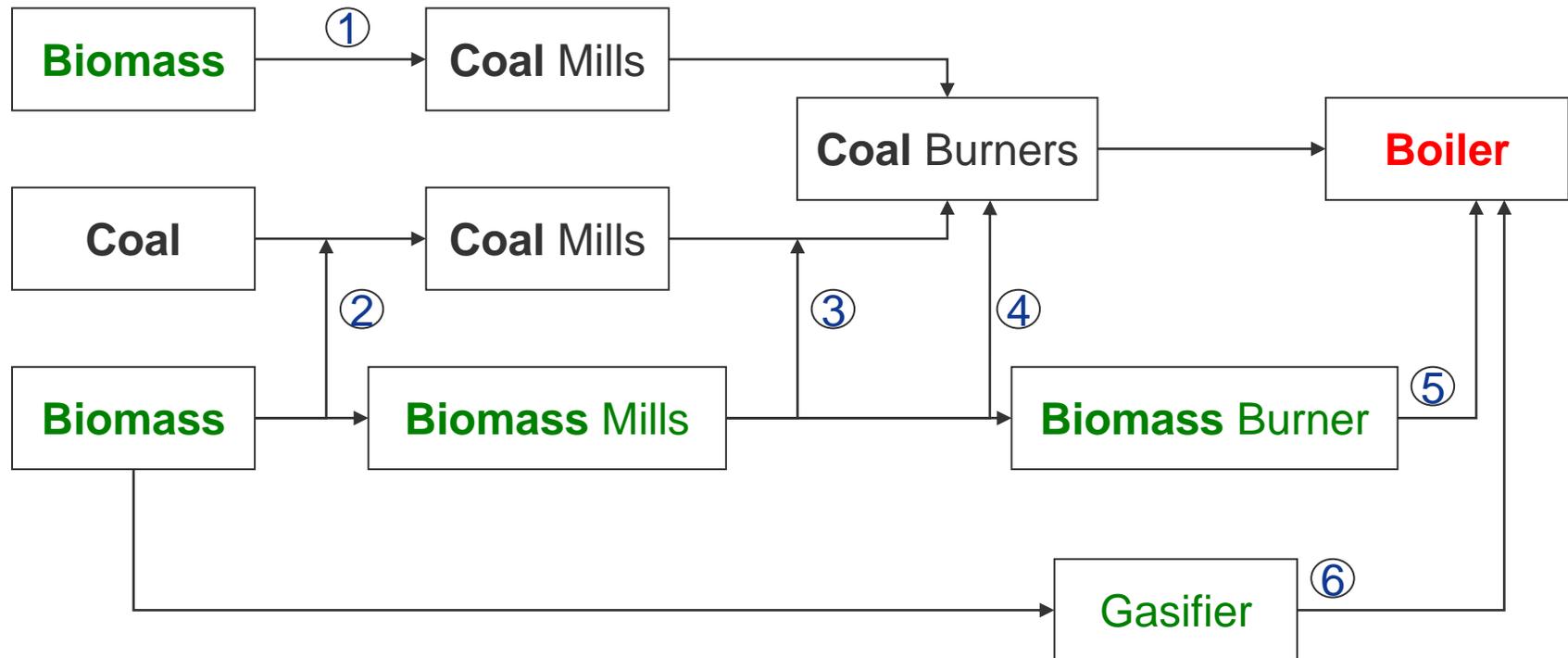
**Recent
developments in
biomass co-firing in
large coal-fired utility
boilers.**

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Copenhagen
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The current status of biomass co-firing and the conversion of existing pulverised coal boilers to 100% biomass firing.

- Initially, in most Northern European countries, the majority of the biomass co-firing was by mixing the biomass, in the form of granules, pellets and dusts, with the coal on the coal conveyor, and the conveying, bunkering, milling and firing of the mixed fuel.
- This permitted the co-firing of a range of biomass materials but at modest co-firing ratios, generally less than 10% on a heat input basis, and the impacts on the boiler were modest.
- For the achievement of higher co-firing ratios, and conversion to 100% biomass firing, two approaches are being adopted
 - Direct injection of pre-milled biomass into the existing coal firing system, and
 - Conversion of the coal mills to biomass pellet firing.

The principal direct and indirect biomass co-firing options



1. The milling of biomass (pellets) through modified coal mills,
2. The pre-mixing of the biomass with the coal, and the milling and firing of the mixed fuel through the existing coal firing system,
3. The direct injection of pre-milled biomass into the pulverised coal pipework,
4. The direct injection of pre-milled biomass into modified coal burners or directly into the furnace,
5. The direct injection of the pre-milled biomass through dedicated biomass burners,
6. The gasification of the biomass, with combustion of the product gas in the boiler.



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Option 1 Milling wood pellets in coal mills

Option 1 The milling of pelletised wood in coal mills

- The milling of wood pellets in coal mills, and the firing of the mill product through the existing pipework and burners, is done at a small number of power stations in Europe.
- The coal mills are very robust, and have high availability/low maintenance requirements.
- The coal mill tends to break the pellets back to the original dust size distribution.
- The mill has to be modified to operate with cold primary air.
- There are generally no requirements for modifications to the grinding elements.
- The maximum heat input from the mill group is significantly derated, commonly to around 70% of that with coal.

Plant Experience

The most successful conversions to date have used the existing equipment, such as mills, pipework and burners, as much as possible.

Vasthamnsverket in Helsingborg, Sweden, originally a 200MW_{th} pulverised fuel boiler, was converted in the late 1990's to firing 100% wood pellets, processing the pellets through the roller mills.

Two roller mills on **Unit 9 at Amer Centrale in the Netherlands**, converted in 2002/3 from coal firing to 100% pelletised wood. The biomass co-firing is still in operation.

Hasselby Heat and power plant, Sweden successfully converted from coal firing to 100% wood pellet firing in 1993, and is still in operation.

Drax Power station, UK, conversion of two large vertical spindle ball and ring coal mills to 100% wood pellets, in 2010. These are still in commercial operation.

Experience from Hasselby, and elsewhere, has indicated that the heat input from the converted mills is significantly derated, to around 50-70% of that with coal, but this can be supplemented with additional hammer mills.

Attempts, to date, to convert large ball and tube coal mills to biomass pellets have been unsuccessful.



The key modifications required to vertical spindle coal mills to permit wood pellet firing

- A rotary valve is installed in the coal feed chute, to form an air-tight seal between the mill and the bunker.
- The mill will be operated with reduced primary air temperatures, i.e. the mill inlet temperatures, and perhaps the mill outlet temperatures, will be reduced.
- The reduction of the mill throat gap to permit operation at the original design primary air velocity at the throat, at the reduced primary air temperatures to be applied when milling biomass pellets, should be considered.
- The addition of a system of baffles in the mill body to maintain suitable primary air velocities within the mill to reduce the tendency of the mill to retain partially ground material;
- The opening up of the classifier vanes to reduce the classifier efficiency, and hence reduce the tendency of material to recirculate within the mill

Safety Issues Related to Milling of Biomass

- Biomass materials have high volatile matter content and combustible volatiles are released in significant quantities at temperatures above about 180°C, i.e. at much lower temperatures than for bituminous coals
- Mill inlet temperatures must be controlled in order to prevent release of volatile materials that can lead to explosions and mill fires
- It is also important to maintain primary air flow rates, at all times, at levels that ensure the clearing of the milled fuel from the top of the mill, as well as air velocities within the pipework leading to the boiler, to prevent settling out of milled fuel.
- This must also be consistent with the maintenance of the correct primary air velocities through the burners.



Biomass combustion characteristics when fired through converted pulverised coal combustion systems

- When the milled biomass is fired through the existing pulverised coal burners, there are a couple of significant technical issues, viz:
 - Because the particle size distribution of the milled biomass is much coarser than that of pulverised coal, the particle drying and heating times tend to be higher,
This can result in delayed combustion, and there may be problems with flame reliable detection.
- There is a requirement, in most cases, to modify the burners, and potentially the flame detectors, to provide a robust solution for both co-firing and 100% biomass firing applications.



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Co-firing by pre-mixing and co-milling

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

- Co-firing by co-milling has been the preferred approach for coal power stations embarking on biomass co-firing for the first time.
- The 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 about the long term security of the subsidy payments for co-firing.



The co-milling of biomass with coal in coal mills

- In Britain, a range of biomass materials are 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.

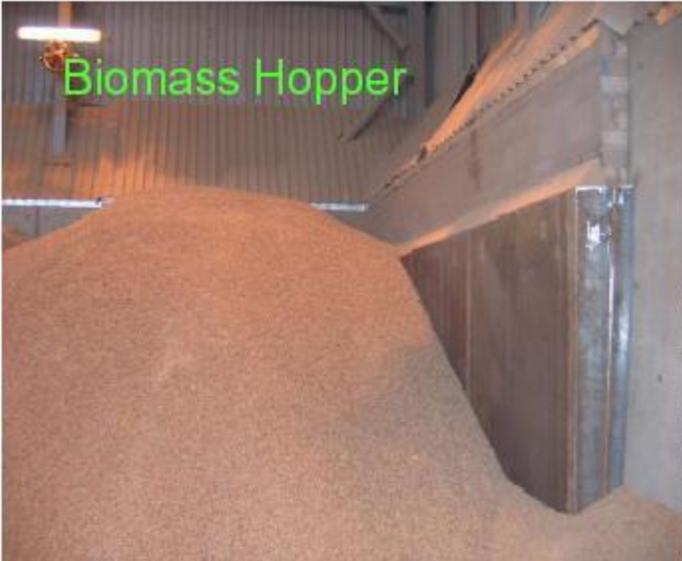
Safety issues when co-milling biomass in large vertical spindle coal mills

- 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 about 180°C, 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.

Biomass storage shed



Biomass pre-mixing system





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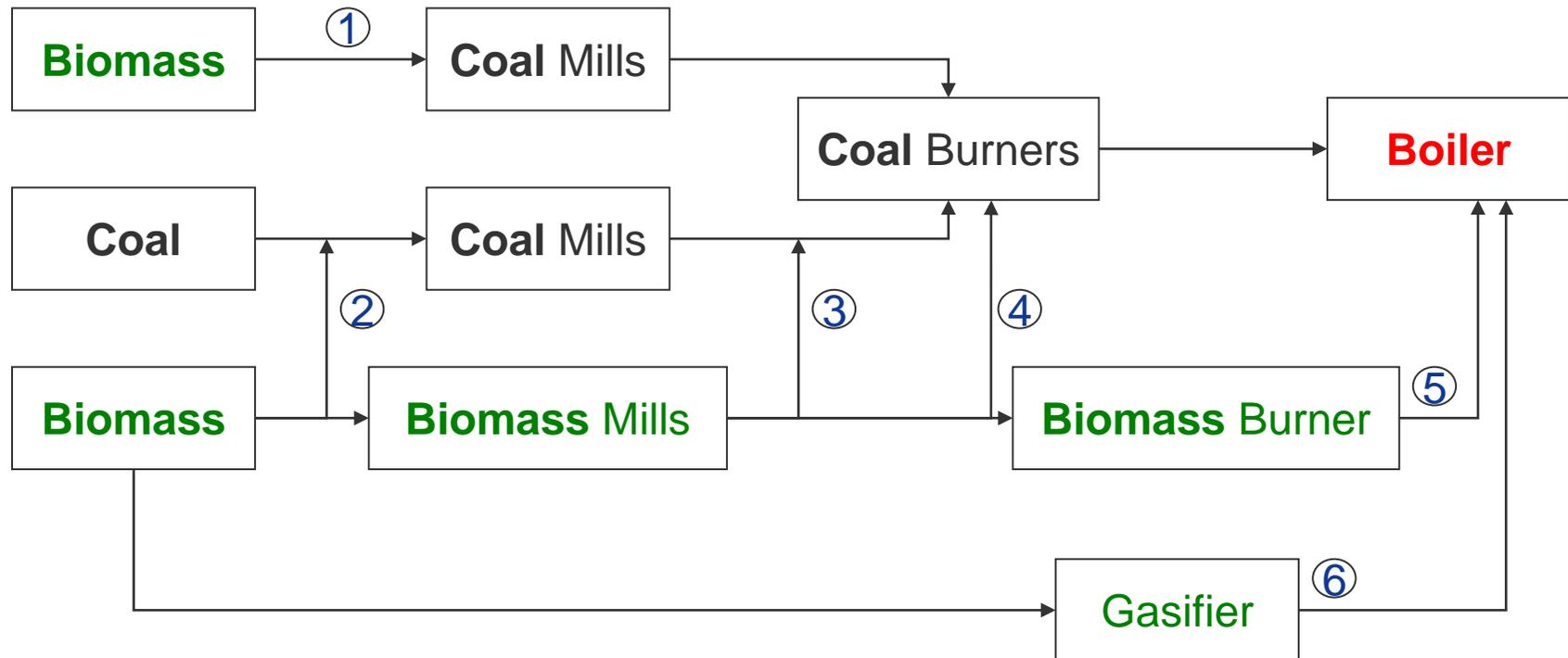
Direct injection of pre-milled biomass

Direct injection co-firing systems for biomass

basic options

- The biomass can be pre-milled either off-site or on-site.
- 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 into the pulverised coal pipework or through modified burners.

The principal direct and indirect biomass co-firing options



1. The milling of biomass (pellets) through modified coal mills,
2. The pre-mixing of the biomass with the coal, and the milling and firing of the mixed fuel through the existing coal firing system,
3. The direct injection of pre-milled biomass into the pulverised coal pipework,
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5. The direct injection of the pre-milled biomass through dedicated biomass burners,
6. The gasification of the biomass, with combustion of the product gas in the boiler.

Direct injection through dedicated 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.
- Fuel and air supply systems for the biomass burners have to be installed, and flame monitoring equipment for the biomass flames are required.
- The impact of exposure of the 'out of service' biomass burners to the coal-fired furnace gases needs assessed.
- The impacts of biomass burners on the coal-firing system have to be assessed.
- The biomass burners are normally based on conventional pulverised coal burners or cyclone burners

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

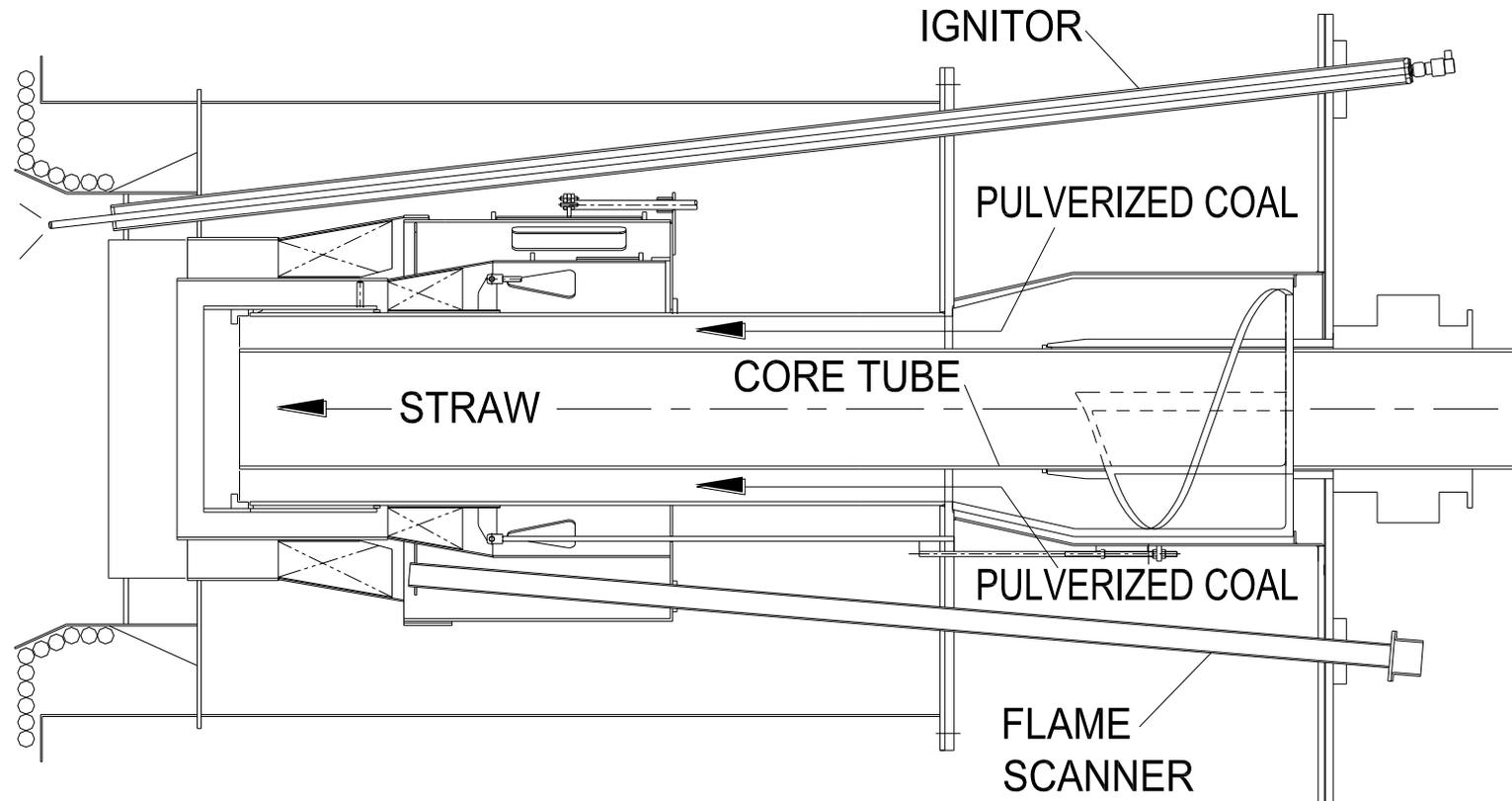
Direct injection into modified burners

- 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 pulverised 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.

Studstrup coal-straw burner

Modified MB Mark III LNB



Direct injection into the pulverised coal pipework

- Direct injection into the existing pulverised coal pipework is relatively simple and cheap to install.
- The mill air and fuel flow rates can 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 can be maintained within their normal operating envelopes for both the heat input and primary air flow rate.
- 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.
- It is possible to fire the burners 100% on biomass by installing two direct injection systems into the same mill group.
- There is a recent demonstration of a direct injection co-firing system at **Drax Power Station** in Britain. The system has been in successful operation since summer 2005, firing a wide variety of pre-milled biomass materials.
- In 2009, this system was replicated at Drax by a factor of 12, i.e. to two mills on each of the six boiler units.
- This system has the capability of co-firing biomass at a rate of 400MW_e , and can fire up to 1.5 million tonnes p.a. of biomass

Drax Direct Co-firing

The biomass metering and feeding system

The prototype direct co-firing system has been in successful operation since summer 2005, firing a range of pre-milled biomass materials.

Drax are now replicating this approach to two mills on all six boilers.



Drax Direct Co-firing

The biomass pipes and the injection point

- The injection point is in the mill outlet pipes, just downstream of the product dampers. The injection point is a simple shallow angle T-in, fitted with an actuated shut-off valve for 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. The maximum heat input from the mill group is not affected.



Conclusions

- **Large scale biomass co-firing is one of the most efficient and cost effective approaches to generating electricity from renewable sources.**
- **The pre-mixing and co-milling of biomass is being practised successfully, as a retrofit to existing plants, by a number of coal plant operators in Britain and continental Europe.**
- **Direct injection co-firing projects are currently being implemented as a means of increasing the co-firing levels.**
- **Injection of the biomass into the pulverised 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.**
- **There is currently an increasing interest in the conversion of pulverised coal boilers to 100% biomass firing, involving the conversion of the existing coals to biomass pellet firing, the installation of new hammer milling capacity, or both.**

Thank you for your attention

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