European Biomass Technology Overview

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European Applications

- Heat & Power
  - Gasification
  - Combustion
  - Cofiring – Direct and Indirect
- Biogas production
- Bio-diesel production
- New Applications – Hydrogen, Fuel Cells, Stirling Engines

European Applications

- Sweden, Denmark, Netherlands and Italy have set goals of 5 – 10% of power production utilizing biomass
- Near term goals are being accomplished through cofiring
- Netherlands have been the most aggressive with 5% cofiring of 4100 Mw
- Wood base use of 46 Mtoe/yr

What Is Cofiring?

- Cofiring is the simultaneous combustion of biomass and fossil fuels
- Predominate activity with cofiring has taken place in the U.S. And Europe
- Power stations and industrial facilities have been retrofitted to permit multi-fuel flexibility
- Biomass is a well-suited resource for cofiring with coal as an acid rain and greenhouse reduction control strategy
- Two approaches to cofiring - direct and indirect

Benefits of Cofiring

- Cofiring biomass and coal takes advantage of the high efficiencies obtainable in large coal-fired power plants
- Lower capital cost option for increasing the use of biomass to produce electricity
- Cofiring, at low percentages, in coal plants would dramatically increase biomass use
- Reduces the need for a constant supply of biomass that would be required in a biomass power plant
- Reduces the emissions of greenhouse gases and other pollutants
- Improves combustion due to the biomass higher volatile content

Direct Cofiring

Direct is where the coal and the biomass are burned together in two ways:

Sizing, feeding and combustion of the biomass fuel and coal, takes place in existing equipment

- Biomass feed is less than 2-3%
- Capital cost - 10-25 USD $/kW of biomass capacity

Separate pre-treatment of the biomass

- Larger percentage of biomass feed
- Flexibility of separate control systems and improved plant availability
- Capital cost - 165-200 USD $/kW of biomass capacity

Indirect Cofiring

Combustion or gasification take place separately and the ashes from the coal and biomass are kept separate

Separate gasification of the biomass, after which the low-calorific fuel gas is combusted with separate burners in the coal boiler

- Kymijarvi plant in Finland - foster wheeler Oy

Separate gasification of the biomass followed by a separate gas cleaning system consisting of scrubbers and a bag house

- More variety of fuels without causing serious problems
- Disadvantage is higher capital cost and lower efficiency
- Amerigas plant in the Netherlands – Lurgi

Indirect Cofiring

Separate biomass combustion with steam side integration to the coal fired power plant

- Separate boiler for the biomass combustion
- Costly approach
- Will not impact the coal combustion
- Aabenraa and Avedore plants in Denmark using straw

Separate biomass pyrolysis, after which the pyrolysis products (oil, char, gas) are combusted in the coal boiler

Indirect Cofiring Advantages

- Coal and biomass ash is kept separate, this enables the coal ash to continue to be used in by-products and cement manufacture
- Separate system for biomass overcomes any of the limitations of the existing equipment
- Fossil facility can continue operation should any problems develop with the biomass system
- Suitable for biofuels containing relatively difficult components
- Separate systems is most suitable for use with natural gas systems

Cofiring Combustion Systems

Biomass and coal have been successfully cofired in:

- Stoker fired boilers
- Cyclone boilers
- Pulverized boilers – tangently and wall
- Fluid bed boilers

Technical Issues Related to Cofiring

- Fuel characteristics
- Carbon burnout
- Fuel preparation and handling
- Slagging, fouling, and corrosion
- Ash management
- Pollution emissions
- Trace element emissions

Direct Cofiring Experience

- U.S. DOE estimates biomass generation capacity could reach 20-30 GW by 2020 through the cofiring of existing coal units
- International opportunities could easily double this capacity
- All types of boilers ranging in scale from 15 – 500mwe
- Cyclone boilers can cofire wood up to as high as 15%
- Pulverized boilers can fire wood in the range of 2-10%

Direct Cofiring Experience (Cont)

- Commercial application of cofiring in the U.S. Is dictated by:
  - Price - biomass to be $0.25 –0.35 /GJ less than coal, and
  - Availability of biomass within 80-150 km of the plant
- In the Netherlands cofiring represented 12% of the biomass use and is to increase to 40% by 2006

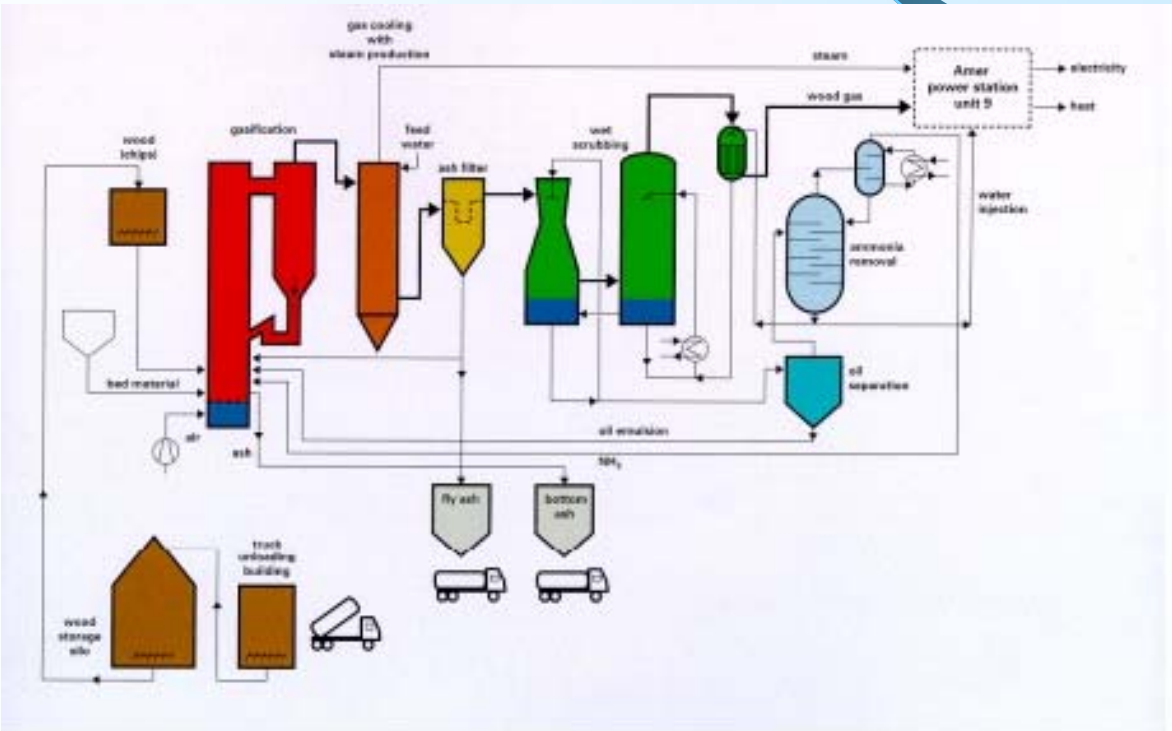
Direct Cofiring Experience (Cont)

- Cofiring is applied in all available Dutch coal-fired plants at about 5% of the energy input level
- There are approximately 150 fluidized bed boilers in Scandinavia using secondary fuels such as sawdust, wood chips, forest residues which are cofired with peat, wood or coal

Indirect Cofiring Experience

- Amer-9 plant is located at the Amer power station in Geertruidenberg and employs the indirect approach utilizing a Lurgi fluid bed gasifier to gasify demolition wood. Already existing at the power station is a coal fired 600 MWe facility
- Gasification was selected rather than combustion since the resulting gas volumes to be cleaned would be much smaller. Wood is more reactive material that is very suitable for fluid bed gasification
- The output of the gasifier is 29 MWe with 34% efficiency

Indirect Cofiring Experience (Cont)



Cofiring of biomass by separate gasification (Lurgi) Amer-9 power plant (EPZ)

Indirect Cofiring Experience (Cont)

- **Enstedvaerket power plant** - Abenraa, Denmark -straw is fed to a separate boiler that is connected to the high-pressure steam line to the turbine. The separate boiler approach was done due to the highly corrosive nature of straw at high temperatures and to prevent the contamination of the coal ash. The biomass boiler is rated at 40 MWe and the coal-fired unit is rated at 660 MWe
- **Vasteras CHP plant** – Vasteras city, Sweden - CHP plant has four units using coal and oil with an overall capacity of 500mwe and 900 MW for district heating. A new unit 5 foster wheeler CFB boiler for biomass has been added to the site of the unit four coal boilers. The steam from the biomass boiler is linked to the steam from the coal boiler prior to the existing steam turbine. The unit 5 boiler produces 200 t/h of steam

Indirect Cofiring Experience (Cont)

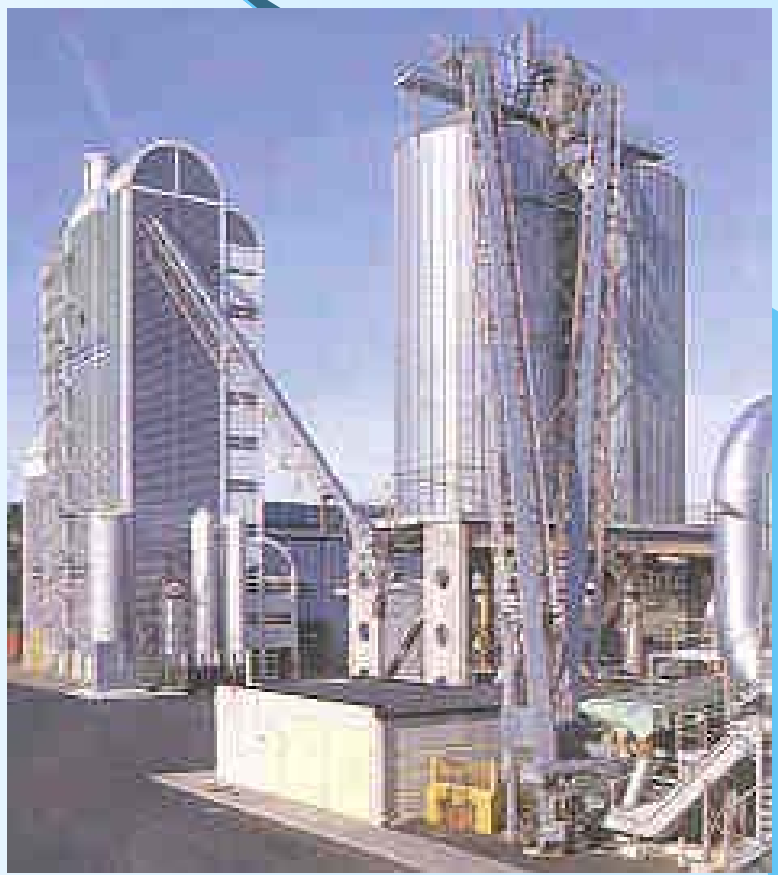
60 MWth Lahti Kymijärvi project in Finland, using foster wheeler's atmospheric CFB gasifier, has now completed 3 years of reliable operation on residues of fuels, paper and textiles, wood and peat

Gasification Experience (Cont)

- The Austrian utility Verbund installed a 10 MWth fluid bed gasifier in a 137 MWe coal fired power plant at Zeltweg. Bark and wood chips are gasified and the gas is combusted in the coal boiler. The project began operation in 1997 and was shut down in 2001. This was due to the fact the coal power plant was shut down for economic reasons. The technical performance of the biomass gasifier was sound
- Due to the success of Zeltweg project the Belgian participate Electrabel is building a CFB gasifier to connect to the Ruien coal-fired power plant. A 100,000 tons of wood will be used to generate 17 MWe
- There are three demonstration IGCC plants in Europe, ARBRE project, Bioelettrica spa energy farm and Varnamo project, which are just using biomass feeds

Gasification Experience (Cont)

The Värnamo IGCC plant produces 6 MWe and 9 MWth, which is channeled into the district heating system of the city during the heating season. The Värnamo plant was developed by Sydkraft AB, and has demonstrated outstanding fuel flexibility - with fuels ranging from wood, RDF and straw - without difficulty at 100% of the input.



Biogas in Europe

- Current production of 2500 Ktoe
- Potential production of 1500 Ktoe
- Distribution of production
  - Industrial Waste Water treatment 25%
  - Commercial Waste Water treatment 33%
  - Biowaste treatment 37%
  - Farm scale plants 5%

Interesting Applications

- Biogas project, Holstebro, Denmark - project scale is1200 ton of biomass/d includes treatment facilities for dead animals

- Planned Biogas plant in Denmark, which combines biogas production with production of bioethanol. The idea is that it is difficult to get good effectiveness in ethanol fermentation on waste materials, but the remaining biomass can be used for biogas production. The advanced process includes separation into liquid and solid fertilizers.
- Italy developing a hydrogen from municipal waste project

New End Use Applications

- Hydrogen
- Methanol
- Synthetic FT fuels
- Stirling engine
- Fuel cells
- Micro-turbine

Economics of Coal/biomass

	Parallel Gasificatio	Parallel Combustio	Direct cofiring	Stand-alone combustio
Electrical efficiencies %	**36**	**40**	**37.5**	**26**
Incremental Capital Euro/kWe	**1270**	**1360**	**680**	**1890**
KWh cost excluding coal plant	**0.011**	**0.012**	**0.003**	**0.039**
KWh cost coal plant	**0.018**	**0.018**	**0.018**	**0.0**
Total kWh cost E/kWh	**0.029**	**0.030**	**0.021**	**0.039**

Conclusion

- Growing interest in the use of biomass residues to reduce carbon dioxide emissions
- Cofiring is a very active application due to improved environmental performance and economic performance
- Europe is the source of many interesting applications for biomass use.