Biomass co-firing
Technology, barriers and experiences in EU

TNO Science and Industry

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Presentation overview

- Biomass co-firing: concepts and technology
- Drivers and Barriers
- Experiences (Europe and NL)
- Research issues
- Concluding remarks
TNO

• was founded by law in 1930

• assists companies that have no in-house R&D

• is independent of public and private interests

• Market turnover: 400 millions euro

• 5000 employees
TNO is active in five core areas

- TNO Quality of Life
- TNO Defence, Security and Safety
- TNO Science and Industry
- TNO Environment and Geosciences
- TNO Information and Communication Technology
TNO in practice
Department of High Temperature Processes

- Biomass combustion and co-firing
- Waste-to-energy
- High temperature production processes (cement ovens, glass melting,..)
- Gasification and pyrolysis processes
- Liquefaction (HTU)
- Supercritical water gasification (H₂)
Biomass co-firing (concepts)

- Direct co-combustion in coal fired power plants
- Indirect co-combustion with pre-gasification
- Indirect co-combustion in gas-fired power plants
- Parallel co-combustion (steam side coupling)
Direct co-firing of biomass

Two methods were developed:

- Blending the biomass and coal in the fuel handling system and feeding blend to the boiler (20 euro/kW)
- Separate fuel handling and separate special burners for the biomass, and thus no impact to the conventional coal delivery system (200 euro/kW)
Biomass co-firing via pre-gasification

- Option for waste-derived fuels
- Amer (NL), Lahti (Finland)
- Investment costs: 300-1100 euro/kWₑ
Amer-9 wood gasifier

CFB gasifier
- waste wood
- 83 MWth input
- 170 kton CO$_2$ red
(sourced KEMA)
Indirect co-firing for gas fired boilers

Biomass → Pyrolysis → Liquefaction → Bio oil

Gas/coal → Bio oil → Boiler
Parallel co-combustion (steam-side coupling)

Enstedvaerket power plant – Abenraa, Denmark
- Straw
- Highly corrosive nature of straw at high temperatures
- Contamination of the coal ash.
- Biomass boiler: 40 MWₑ and coal-fired unit: 660 MWₑ

Vasteras CHP plant – Vasteras city, Sweden
- CHP plant has four units using coal and oil with an overall capacity of 500 MWe and 900 MW for district heating.
- CFB boiler for biomass 200 t/steam)
Drivers of co-firing biomass

• Reduces the emissions of greenhouse gases and other pollutants

• Co-firing in coal plants would strongly increase biomass use

• Lowest capital cost option for increasing the use of biomass to produce electricity

• Co-firing biomass and coal takes advantage of the high efficiencies obtainable in large coal-fired power plants

• Improves combustion due to the biomass higher volatile content

• Jobs creation
Technical barriers

- Fuel flexibility (quality, quantity)
- Complete combustion and well mixing in boiler
- Fouling and corrosion of the boiler (alkalis, chlorine)
- Ash utilization (unburnt carbon, contamination)
- Negative impact on flue gas cleaning (SCR DeNO$_x$)
Non-technical barriers

• Economic aspects (lack of financial incentives, uncertain fuel prices, open market)

• Legislative aspects (utilization of fly ash in cement, determining green share, emission legislation)

• Public perception of co-firing of biomass/waste

• Mountain of Death
European activities on biomass co-firing - directives -

• Reduce Greenhouse gas emissions by 8% by 2010 compared to 1990 (Kyoto Protocol)

• Doubling the share of Renewable Energy sources from 6 to 12% by 2010 (White Paper)

• National countries need to support initiatives (e.g. 12% co-firing in NL in 2008-2012)

• EU Directive on Transport Biofuels may increase the amount of residues generated via the production of biofuels
European activities on biomass co-firing
- activities -

- EU-countries have set goals of 5 – 12% of power production utilizing biomass

- Near term goals are being accomplished through co-firing

- In The Netherlands co-firing is applied in all available Dutch coal-fired plants at about 5% of the energy input level

- 150 fluidized bed boilers in Scandinavia use secondary fuels such as sawdust, wood chips, forest residues which are co-fired with peat, wood or coal

- PC plants (Lignite and coal) in Germany:
  - sewage sludge commercially,
  - trials with straw and wood
Overview of biomass co-firing initiatives

- Recently done by IEA Bioenergy Task 32
- Internet database produced at www.ieabcc.nl
- 135 plants identified that co-fire biomass in plants that originally fire coal as main fuel
- 105 direct, 1 parallel, 5 indirect, 24 yet unknown
## IEA Bioenergy Task 32 database (1/2)

Results of the above selection:

<table>
<thead>
<tr>
<th>Continent</th>
<th>Country</th>
<th>Plant name</th>
<th>Location</th>
<th>Cofiring type</th>
<th>Boiler type</th>
<th>Burner config</th>
<th>Output (MWth)</th>
<th>Output (MWe)</th>
<th>Primary fuel</th>
<th>Cofired fuel(s)</th>
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<td>Ocean Sky Co</td>
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<td>BFB</td>
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<td>BFB</td>
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<td>Coal, peat, wood chips, bark, oil</td>
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<td>Pakang</td>
<td>direct</td>
<td>CFB</td>
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<td>20</td>
<td>Coal, sludge</td>
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<td>wood waste</td>
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<td>PF T-fired</td>
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<td>4 x 500</td>
<td>pulverised real</td>
<td>wood waste (sawdust, shavings)</td>
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<td>Coal, lignite, oil, wood</td>
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IEA Bioenergy Task 32 database (2/2)

Allen (T.H) Fossil Plant, Memphis, Tennessee

<table>
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<tr>
<th>Station</th>
<th>Allen (T.H) Fossil Plant #1, #2, and #3</th>
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<tbody>
<tr>
<td>Nominal Size</td>
<td>272 MW e</td>
</tr>
<tr>
<td>Boiler Type</td>
<td>Cyclone</td>
</tr>
<tr>
<td>Fuel</td>
<td>Sawdust, bit and subbit coal</td>
</tr>
<tr>
<td>Max cofiring %</td>
<td>20% wt</td>
</tr>
<tr>
<td>Duration</td>
<td>10-24 tests, 3-6 hours each</td>
</tr>
<tr>
<td>Fuel Preparation</td>
<td>Fuel screened (most &lt; 3/4&quot;, but up to 1&quot;) and introduced beforeusher</td>
</tr>
</tbody>
</table>

Power Plant Description:

Allen Station is located five miles southwest of Memphis, Tennessee. The plant is owned and operated by the Tennessee Valley Authority (TVA) and consists of three coal-fired boilers with cyclone-fired furnaces. Each boiler is rated at 272 Gross MW e and was manufactured by Babcock & Wilcox in 1959.

Boilers #1, #2, and #3 each have the capacity to generate 1,520,000 lb steam/hour at 1000°F and 2400 psig with a single reheater. There are three cyclone barrels on one wall of each boiler and four barrels on the opposite wall.

The boilers are typically fired with bituminous coal at a rate of about 105 tons/hour. Each boiler has an electronic precipitator for particulate control.

Project Description/Objectives:

A series of biomass cofiring tests have been conducted at Allen Station over the past several years to determine the operational feasibility and performance of cofiring with biomass, to determine what fuel particle sizes for wood fuel allow acceptable operation and performance, and to investigate the role of biomass cofiring in NOx emissions control.

The tests were accomplished by blending various amounts of waste sawdust and wood chips with coal and burning the resultant mixture in the cyclone boilers at the...
Countries where cofiring has been done:

- USA: 41
- Sweden: 15
- Germany: 27
- Finland: 18
- Norway: 1
- Italy: 1
- Indonesia: 2
- Spain: 2
- Switzerland: 5
- Thailand: 1
- Taiwan: 1
- Denmark: 5
- Belgium: 1
- Austria: 5
- Australia: 8
Co-firing biomass in the Netherlands

• Since 1993 more than 40 small and full scale trials co-firing up to 40 wt% of a wide variety of biomass and waste fuels with coal.

• Currently experience up to 10+ wt% co-firing

• Co-firing is daily practice in all Dutch coal-fired power plants

• Coal covenant
Co-firing - Current issues in EU

- Permits
- The quality of biomass
- Fuel flexibility and pre-treatment
- Maximizing co-firing
- Thermal behavior and efficiency
- Environmental constraints - emissions
- Quality and applicability of by-products
- Integration, optimization
- Economics
Identification of research topics

- Corrosion mechanisms
- Ash deposition mechanisms
- Fuel flexibility (characterization)
- Particle burn-out and gas mixing
- Particle size control
- Fuel mixes / use of additives
- Ash reuse in building materials
- Contaminated biomass
- High temperature steam boilers
- Effect on gas cleaning / DeNO$_x$ catalysts
- Pre-treatment of biomass (torrefaction)
Biomass co-firing

IEA Task 32
Biomass Combustion and Co-firing

Country priorities next triennium IEA Combustion and Co-firing

- Fuel storage, handling, and preparation (e.g., size reduction)
- Small scale combustion systems
- Deactivation of SCR
- Advanced process control / sensor development
- Particulates (aerosols)
- Primary measures for NOx reduction
- Flue gas cleaning technologies
- Processing fuel mixes and use of additives to improve combustion behaviour
- Increasing fuel flexibility / waste wood / pellets
- Corrosion and deposit formation mechanisms
- Utilization of contaminated biomass fuels
- Improvement of existing and development of new CHP concepts
- Utilization of ash in building materials

Chart showing priorities for different countries.
Concluding remarks

• Co-firing represents a cost effective, short term option at a large scale

• Although more needs to be done, there is already a wealth of practical experience under different conditions

• For low co-firing ratios are no irresolvable issues but there are poor combinations of fuel, boiler, and operation.

• For higher co-firing ratios additional research needs to be done.
Thank you for your attention