Overview of global experience with biomass co-firing and coal to biomass conversions

Technology, fuel supply, byproducts and regulation, economics

Jan Middelkamp, Marcel Cremers

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Biomass (co-)firing in power generation
Sustainability targets and CO$_2$ reduction – the role of biomass

**POLICY MAKERS AND REGULATORS**

(National) targets, incentives

**MARKETS**

Power market, alternative sustainable technologies, dispatchable power > BIOMASS

**UTILITIES**

Business case, implementation
Biomass co-firing and full conversion

What is considered high percentage co-firing

▪ Is it >10% ...
▪ or is it >30% ...
▪ or is it >50% ...
▪ or is it >80%

Fuel coal to biomass conversion

Full conversion is the limit

Bio-CCS as a CO₂ sink
Technology and experiences
Each co-firing route has its own (unique) operational requirements and constraints and specific demands on the fuel quality.
## Experiences with biomass co-firing and repowering

<table>
<thead>
<tr>
<th>Country</th>
<th>Locations</th>
<th>Fuel Types</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNITED KINGDOM</strong></td>
<td>Drax, Ferrybridge, Fiddler’s Ferry, Tilbury, Ironbridge, Lynemouth</td>
<td>Various fuels: wood, crops, residues</td>
</tr>
<tr>
<td><strong>DENMARK</strong></td>
<td>Avedore, Amager, Ensted, Studstrup</td>
<td>Wood chips, wood pellets, straw(pellets)</td>
</tr>
<tr>
<td><strong>BELGIUM</strong></td>
<td>Rodenhuize, Les Awirs, Ruien</td>
<td>Mainly wood-based fuels</td>
</tr>
<tr>
<td><strong>THE NETHERLANDS</strong></td>
<td>Geertruidenberg, Rotterdam, Nijmegen, Borssele</td>
<td>Wood pellets, agro- and industrial residues, meat and bone meal</td>
</tr>
<tr>
<td><strong>CANADA</strong></td>
<td>Atikokan, Thunder Bay</td>
<td>Wood pellets, steam explosion pellets</td>
</tr>
</tbody>
</table>
## Power plant components affected by biomass (co-)firing

| STORAGE       | ▪ Piles  
<table>
<thead>
<tr>
<th></th>
<th>▪ Bunkers</th>
</tr>
</thead>
</table>
| LOGISTICS     | ▪ Conveyors  
|               | ▪ Feeders  
|               | ▪ Mills |
| STEAM PLANT   | ▪ Burners  
|               | ▪ Furnace section  
|               | ▪ Convection section |
| FLUE GAS      | ▪ Flue gas cleaning system  
|               | ▪ Stack |
# Power plant components affected by biomass (co-)firing

## Storage
- Dedicated storage or storage on coal yard?
- Dust emissions and explosion risks!
- Odor...

## Logistics and Milling
- Coal conveyors suitable?
- Low co-firing: pre-mixing and co-milling
- High co-firing: modified or dedicated mills/classifiers
- Dust explosion risks
- Primary air temperature

## Steam Plant (Pulverized Fuel Boiler)
- Particle size > combustion
- Deposition on burners; slagging and fouling
- Soot blowers, water jets, sonic horns, explosive cleaning
- Corrosion risks

## Flue Gas Cleaning
- SO₂ and dust (no major issues)
- NOₓ
  - dependent on fuel
  - SCR deactivation
Fuel selection
# Fuel selection criteria

<table>
<thead>
<tr>
<th>Low co-firing rate or EFLH</th>
<th>High co-firing rate or EFLH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low investments</td>
<td>Higher investments</td>
</tr>
<tr>
<td>More expensive fuel</td>
<td>Cheaper fuel</td>
</tr>
</tbody>
</table>

## ELIGIBILITY OF BIOMASS FUEL
- Meeting subsidy requirements
  - Sustainability criteria
  - Additional requirements

## REGULATORY AND PERMIT ASPECTS
- Biomass waste?
  - Emission requirements
Biomass pre-treatment and upgrading

Steam explosion pellets
(courtesy Arbaflame)

Torrefied pellet production
(courtesy Torrcoal)

Wood pellet production
(courtesy Enviva)
# Choose your co-firing fuel

<table>
<thead>
<tr>
<th></th>
<th>Wood chips</th>
<th>Wood pellets</th>
<th>Torrefaction pellets</th>
<th>Steam explosion pellets</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture content (% wt)</strong></td>
<td>30 – 45</td>
<td>7 – 10</td>
<td>1 – 5</td>
<td>? - 11</td>
<td>10 – 15</td>
</tr>
<tr>
<td><strong>Calorific value (MJ/kg)</strong></td>
<td>9 – 12</td>
<td>15 – 16</td>
<td>20 – 24</td>
<td>17 – 19</td>
<td>23 – 28</td>
</tr>
<tr>
<td><strong>Volatiles (% db)</strong></td>
<td>70 – 75</td>
<td>70 – 75</td>
<td>55 – 65</td>
<td>70 – 80</td>
<td>15 – 30</td>
</tr>
<tr>
<td><strong>Bulk density (kg/l)</strong></td>
<td>0.2 – 0.25</td>
<td>0.55 – 0.75</td>
<td>0.75 – 0.85</td>
<td>0.65 – 0.78</td>
<td>0.8 – 0.85</td>
</tr>
<tr>
<td><strong>Energy density (GJ/m³)</strong></td>
<td>2.0 – 3.0</td>
<td>7.5 – 10.4</td>
<td>15.0 – 16.7</td>
<td>11.0 – 15.0</td>
<td>18.4 – 23.8</td>
</tr>
<tr>
<td><strong>Dust</strong></td>
<td>Limited</td>
<td>Average</td>
<td>Average/high</td>
<td>Average/high</td>
<td>Limited/average</td>
</tr>
<tr>
<td><strong>Hydroscopic properties</strong></td>
<td>Hydrophilic</td>
<td>Hydrophilic</td>
<td>Hydrophobic</td>
<td>Hydrophobic</td>
<td>Hydrophobic</td>
</tr>
<tr>
<td><strong>Biological degradation</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Potentially</td>
<td>No</td>
</tr>
<tr>
<td><strong>Milling requirements</strong></td>
<td>Special</td>
<td>Classic/special</td>
<td>Classic</td>
<td>Classic</td>
<td>Classic</td>
</tr>
<tr>
<td><strong>Handling properties</strong></td>
<td>Special</td>
<td>Special/easy</td>
<td>Easy</td>
<td>Easy</td>
<td>Easy</td>
</tr>
<tr>
<td><strong>Transport cost</strong></td>
<td>High</td>
<td>Average</td>
<td>Low</td>
<td>Low/Average</td>
<td>Low</td>
</tr>
</tbody>
</table>
Regulatory and by-products
Meeting emission limits

- **Dependent on local regulations and emission standard**
- **ESP/baghouse filter**
  - ash content
  - resistivity
- **SCR**
  - deactivation
  - use of coal fly-ash
- **Co-firing of**
  - clean wood: limited impact on emissions
  - specific types of biomass: potential impact on emissions
- **FGD**
  - low SO₂, high HCl load

Dependent on local regulations and emission standard

ESP/baghouse filter
- ash content
- resistivity

SCR
- deactivation
- use of coal fly-ash

Co-firing of
- clean wood: limited impact on emissions
- specific types of biomass: potential impact on emissions

FGD
- low SO₂, high HCl load
What about the ashes (IEA Task 32 study)

<table>
<thead>
<tr>
<th>Application</th>
<th>Requirements/challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposal/landfill</td>
<td>Minimum standard (Directive 2008/98/EC) and preferred solution in many cases</td>
</tr>
<tr>
<td>Use in forestry</td>
<td>Leaching of heavy metals</td>
</tr>
<tr>
<td>Fertilizer/soil amendment</td>
<td>Leaching of heavy metals, strict legislation</td>
</tr>
<tr>
<td>Addition to compost</td>
<td>Up to 3-5%, REACH registration in EU</td>
</tr>
<tr>
<td>Cement, raw meal constituent</td>
<td>Requirements in bi-lateral contracts</td>
</tr>
<tr>
<td>Cement and concrete fillers</td>
<td>EN 450 standard applicable in EU</td>
</tr>
<tr>
<td>Asphalt concrete filler</td>
<td>Dependent on technical product regulation</td>
</tr>
<tr>
<td>Underground mining</td>
<td>Particularly for bottom ashes</td>
</tr>
<tr>
<td>Civil engineering, road construction</td>
<td>Particularly for bottom ashes</td>
</tr>
</tbody>
</table>
Economics and carbon footprint
Costs of co-firing and repowering (for illustration only)

Imaginary case:
100 MW_{e,\text{r}}
40% efficiency,
5,000 equivalent full load hours

Additional costs from co-firing:
- Fuel costs
- Capital costs
- O&M costs

Revenues from co-firing:
- CO₂ credits
- Subsidies
Case: 100 MWe, 40% efficiency, 5,000 equivalent full load hours

**GENERAL DATA**

Annual power production: 500,000 MWh/a

Annual fuel consumption: 4.5 PJ/a

**INCREASED FUEL COSTS**

(co-firing)

<table>
<thead>
<tr>
<th>Coal</th>
<th>Wood pellets:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 EUR/GJ</td>
<td>9 EUR/GJ</td>
</tr>
</tbody>
</table>

Δ Fuel costs: 6 EUR/GJ

Annual Δ fuel cost: 27 MEUR/a

Δ Specific fuel costs: 54 EUR/MWh
Case: 100 Mwₑ, 40% efficiency, 5,000 equivalent full load hours

**CAPITAL EXPENSES**

200 kEUR/MWth

installed > 50 MEUR

Capital expenses:

5 MEUR/a

(linear depreciation, 10 years)

**O&M COSTS**

6% of investment costs:

3 MEUR/a

**TOTAL CAPITAL AND O&M**

8 MEUR/a

Δ Specific capital and O&M costs:

16 EUR/MWh
Case: 100 Mw\textsubscript{e}, 40% efficiency, 5,000 equivalent full load hours

Revenues

- CO\textsubscript{2} emission reduction: 0.5 Mt/a
- CO\textsubscript{2} @ 10 EUR/t: 5 MEUR/a (current)
- Δ specific costs = -10 EUR/MWh

Δ overall costs = 54 + 16 - 10 = 60 EUR/MWh (8,000 JPY/MWh)

Typical range in detailed business cases: 50 - 80 EUR/MWh \(\rightarrow\) minimum subsidy level required

Co-firing of waste streams:

- Low or negative price
- Limited co-firing rate; additional emission standards
Supply chain (CO₂ per MWh of electricity generation)

Specific case generated with DNV GL BioCase®
Coal: 800 – 1200 kg/MWh

- Forest
- Felling, F’warding
- R’side chipping
- Trucking
- Pelletizer, white
- Trucking
- Silo
- Wood pellet carrier
- Inland waterway
- Silo
- Conveyor belt
- Generation

Chain CO2 emissions (kg/MWh)
Conclusion

- Biomass co-firing and full coal to biomass conversion are proven technology
- Biomass fuels
  - white wood pellets commodity fuel
  - strong developments on processed biomass
  - opportunity fuels and biomass waste streams
- Biomass selection based on required co-firing rate and EFLH
- Impact on emissions to be addressed case by case
- Utilization of ashes requires further development
- Economics: prices of biomass, investments, subsidies, CO₂ price
- Carbon footprint: discussions regarding sequestration in forests

Biomass can provide dispatchable capacity to support intermittent solar and wind power
Thank you for your attention

Jan Middelkamp
jan.middelkamp@dnvgl.com
+31 26 356 2483

www.dnvgl.com