Biomass combustion and co-firing in The Netherlands

by

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KEMA

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Technical description and operational experiences

- Stand-alone biomass combustion projects
- Co-firing in pulverized coal-fired plants
Stand-alone biomass combustion

- Grate-fired wood combustion Schijndel
- Bubbling fluidized bed combustion Cuyk
- Torbed wood combustion Dronten
Timber industry Schijndel B.V.

Combustion plant (1 MWe)
- clean waste wood mostly from their own wood processing, and partly delivered by third parties
- E-production (green electricity)
- internal usage of heat
  (drying processes and residential heating)
- in operation since April 1997
Timber industry Schijndel B.V.

Wood storage in 4 silo’s

Dosing silo

Combustion on a travelling grate (water cooled)

Automatic ash removal

Steam production (28 bar, 420 °C)

Bag house filter
## Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost</td>
<td>3 MEuro</td>
</tr>
<tr>
<td>Operating hours</td>
<td>7000 hours/year</td>
</tr>
<tr>
<td>Payback time</td>
<td>7 - 10 year</td>
</tr>
<tr>
<td>E-power</td>
<td>1 MW&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Internal power consumption</td>
<td>180 kW&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Steam conditions</td>
<td>24 bar, 420 ºC</td>
</tr>
<tr>
<td>Steam production</td>
<td>6.5 ton/hour</td>
</tr>
<tr>
<td>Fuel input</td>
<td>5 MW&lt;sub&gt;th&lt;/sub&gt;, 1400 kg/h</td>
</tr>
<tr>
<td>Permit</td>
<td>Measured</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>CO 250 mg/Nm³</td>
<td>&lt; 100 mg/Nm³</td>
</tr>
<tr>
<td>NOx 400 mg/Nm³</td>
<td>~ 250 mg/Nm³</td>
</tr>
<tr>
<td>CₓHᵧ 50</td>
<td>&lt; 2 mg/Nm³</td>
</tr>
<tr>
<td>Dust 25</td>
<td>&lt; 10 mg/Nm³</td>
</tr>
</tbody>
</table>
Technical evaluation

- Availability reasonable (70%, output increasing)
- Complex operation compared with large-scale
- Various technical problems, solved in part:
  - replacement superheater
  - defect generator
  - leakage/adaptions of the grate
  - major maintenance
  - regular slagging/fouling
  - fluctuating combustion conditions due to variations in fuel composition
Economical feasibility depends strongly on:
- investment cost
- fuel price
- price paid for electricity to the grid and heat
- plant availability
- avoid purchasing wood from third parties
- minimal price 7.5 ct/kWh
- investment subsidies necessary
Bio-energy CHP plant Cuyk
<table>
<thead>
<tr>
<th>Fuel</th>
<th>clean wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>270.000 ton/yr at 50% moisture</td>
</tr>
<tr>
<td></td>
<td>(36 ton/hr)</td>
</tr>
<tr>
<td>Storage capacity</td>
<td>2 x 5000 m³</td>
</tr>
<tr>
<td>type boiler</td>
<td>bubbling fluidized bed</td>
</tr>
<tr>
<td>manufacturer</td>
<td>Kvaerner Finland</td>
</tr>
<tr>
<td>process</td>
<td>steam cycle with air cooled</td>
</tr>
<tr>
<td></td>
<td>condensor (45 °C; 0.1 bar)</td>
</tr>
<tr>
<td>Investment</td>
<td>EUR 50,000,000</td>
</tr>
<tr>
<td>Thermal capacity</td>
<td>84 MW</td>
</tr>
<tr>
<td>gross electric output</td>
<td>27,5 MW</td>
</tr>
<tr>
<td>net electric output</td>
<td>25 MW</td>
</tr>
<tr>
<td>net electric efficiency</td>
<td>29.8 %</td>
</tr>
<tr>
<td>annual production:</td>
<td></td>
</tr>
<tr>
<td>electricity</td>
<td></td>
</tr>
<tr>
<td>heat/steam</td>
<td>190 GWh</td>
</tr>
<tr>
<td>delivery is prepared</td>
<td></td>
</tr>
</tbody>
</table>
### Flue gas cleaning
- DeNOx
- Dust filter

<table>
<thead>
<tr>
<th>Emission-limits (6% O₂,dry)</th>
<th>SCR/SNCR (high dust)</th>
<th>ESP</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg/Nm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dust</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>SO₂</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>NOₓ</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>HCl</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td>1,5</td>
<td></td>
</tr>
<tr>
<td>Sum heavy metals</td>
<td>1,5</td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>0,075</td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>0,075</td>
<td></td>
</tr>
<tr>
<td>PCDD + PCDF</td>
<td>0,15 ng l-TEQ/m³</td>
<td></td>
</tr>
<tr>
<td>CₓHᵧ</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>NH₃</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
Bubbling fluidized bed boiler

Energy Systems BV
Cuijk
The Netherlands

Steam 78 MW<sub>th</sub>
27.4 kg/s
100 bar
525 °C

Fuels  Wood fuel
Start-up  1999

Kvaerner Pulping - Power Division

KEMA POWER GENERATION & SUSTAINABLES
Operational experiences

- Lack of experience with influence of fuel quality on conversion behaviour
- Bed agglomeration / fouling
- Wood fuel handling (bridge formation)
Torbed wood combustion Dronten

- 2 x 4 MW\textsubscript{th} Torbed units
- shredded waste wood as fuel (< 5x1x1 cm)
- hot air for drying manure in a rotary kiln

- emission limits
  - NO\textsubscript{x} 150 mg/Nm\textsuperscript{3}
  - CO 100 mg/Nm\textsuperscript{3}
Torbed vergassingstechnologie
Blade ring detail
Operational experiences

- Operators not trained well with new technology
- Severe mechanical damage by temperature excursions
- Manure drying process more delicate than expected

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- Equipment repaired
- Operator training
# Dutch direct co-firing experiences

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Type of fuel</th>
<th>[kt/yr]</th>
<th>%cofiring (energy)</th>
<th>CO₂-em.red. [kt/yr]</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gelderland-13</td>
<td>demolition wood</td>
<td>60</td>
<td>3</td>
<td>97</td>
<td>operational</td>
</tr>
<tr>
<td>Amer-8</td>
<td>paper sludge</td>
<td>75</td>
<td>0.3</td>
<td>11</td>
<td>operational</td>
</tr>
<tr>
<td>Amer 9</td>
<td>wood pellets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borssele-12</td>
<td>phosphor oven gas</td>
<td>75</td>
<td>3</td>
<td>71</td>
<td>operational</td>
</tr>
<tr>
<td></td>
<td>sewage sludge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>palm kernels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maasvlakte 1/2</td>
<td>Biomass pellets</td>
<td>150</td>
<td>3</td>
<td>77</td>
<td>operational</td>
</tr>
<tr>
<td></td>
<td>animal fat</td>
<td>40</td>
<td>3</td>
<td>82</td>
<td>tested</td>
</tr>
<tr>
<td></td>
<td>meat - and bone meal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buggenum-7</td>
<td>poultry litter</td>
<td>100</td>
<td>10</td>
<td>128</td>
<td>study</td>
</tr>
<tr>
<td>Hemweg-8</td>
<td>sewage sludge</td>
<td>75</td>
<td>3</td>
<td>92</td>
<td>tested</td>
</tr>
</tbody>
</table>

Demolition wood / sewage sludge: negative view from the public (heavy metals)

Biomass pellets: 60 w% paper/cardboard, 24 w% waste wood, 16 w% compost
Gelderland 13 power plant

- 602 MW$_{e}$, pulverised coal wall fired, dry bottom, bituminous coal (import blends)
- Subcritical steam (540 °C, 190 bar; 540 °C reheat)
- Low-NO$_x$ burners, SCR
- ESP + wet FGD
Experiences CG13

- Wood milling circuit capacity not sufficient
- High maintenance cost
- Unburned wood particles in bottom ash

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- Redesign of milling circuit
- Injection wood powder in the coal feed pipes
Co-firing at Maasvlakte

- 2 units 518 MWₑ, pulverised coal tangentially fired, dry bottom, bituminous coal (import blends)
- subcritical steam (540 °C, 180 bar; 540 °C reheat)
- Low-NOₓ burners, overfire air
- ESP + wet FGD
Co-firing experience

- animal fat
- anode cokes
- biomass pellets
- citrus pellets
- meat and bone meal
- meat and bone meal
- petroleum cokes
- poultry litter
Operational experiences

- Pet-cokes: burn-out, fly ash quality
- Biomass pellets: limited by drying capacity of the coal pulverisers
- Animal fat: coal mill pattern essential for steam temperature setpoint
- Meat and bone meal: bottom ash quality
Technical and environmental constraints

- fuel handling
  - storage / spontaneous combustion
- milling / drying
- combustion
  - reactivity ↔ particle size distribution
- fouling and slagging
  - alkali chlorides
- thermal behaviour of the boiler
Technical and environmental constraints

• corrosion / erosion
  – ratio S/Cl

• by-product quality
  – free CaO
  – soluble PO$_4$

• emissions to the atmosphere
  – < CO$_2$, < SO$_2$
  – SCR deactivation

• components capacity
Amer 9 power plant

- 600 MW_e, 350 MW_th, pulverised coal tangentially fired, dry bottom, bituminous coal (import blends)
- Supercritical steam (535 °C, 230 bar; 568 °C reheat)
- Low-NO_x burners, overfire air
- ESP + wet FGD
Upstream gasification 150 kt/a demolition wood (5%) with additional fuel gas clean-up
Upstream gasification 150 kt/a demolition wood (5%) with additional fuel gas clean-up
CONCLUSIONS

• DIRECT CO-COMBUSTION
  - cheapest way
  - high efficiency
  - proven with small percentages (< 10%)
  - strong incentive in the Netherlands to realize Kyoto agreement
  - emerging interest in other countries
CONCLUSIONS

- INDIRECT CO-COMBUSTION
  - more expensive but cheaper than stand-alone
  - increase to higher co-combustion percentage / dirtier fuels
  - most promising concepts:
    - upstream gasification without low-temperature fuel gas clean-up
    - biomass upgrading