Vattenfall strategy and experiences on co-firing of biomass and coal

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Main objective: Profitably increase the level of co-firing in the hard coal plants

→ Reduce fossil CO₂-emissions by 8-10 Mt/a through biomass co-firing (4-5 Mt biomass)

Biomass Utilization will involve three main biomass processing qualities:

- **Refined Wood Pellets**: preferred fuel for biomass use in pulverized fuel plants
- **White Pellets**: near-term fuel for first steps before ramp-up of refined wood pellets
- **Wood chips**: co-firing in fluidized bed boilers and in monocombustion plants
Uncertainties and challenges refined wood pellets/briquettes

- Uncertainties
  - Availability and price
  - Quality of refined pellets

- Technical impact on existing installations at heat and power plants

- Incentives
Biomass Strategy: Refined Pellets as Preferred Fuel

- Wood chips (residues)
- Wood chips (logs)
- White pellets/briquettes
- Refined pellets/briquettes
  - Steam explosion
  - Torrefaction

Vattenfall support development of pre-treatment methods for biomass with goal to:

- minimize the carbon footprint
- optimise the overall cost of production, transport and storage
- optimize critical fuel properties such as heat value, density, grindability, water resistance
**Biomass Strategy: Refined Pellets as Preferred Fuel**

**Assumed Advantages of Refined Wood Pellets**
- Utilization of existing coal logistics and downstream handling systems
  - Lower downstream CAPEX + OPEX
  - Optimized co-firing business case
  - High flexibility and fallback option
- Faster ramp-up and higher co-firing rates attainable

**Vattenfall has the goal to verify the assumptions above.**
*For this purpose, the whole power plant process from ship unloader to chimney is subject to thorough investigations.*

**Large-scale tests of refined and densified woody biomass at coal combustion and gasification plants**
# Fuel Property Overview

<table>
<thead>
<tr>
<th>Property</th>
<th>Hard Coal</th>
<th>Wood Chips</th>
<th>Wood Pellets</th>
<th>Refined wood pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture Content</strong></td>
<td>&lt;10%</td>
<td>35-45%</td>
<td>8-10%</td>
<td>1-7%</td>
</tr>
<tr>
<td><strong>Lower Heating Value (LHV)</strong></td>
<td>25 MJ/kg</td>
<td>9-10 MJ/kg</td>
<td>17 MJ/kg</td>
<td>19 - 22 MJ/kg</td>
</tr>
<tr>
<td><strong>Bulk Density</strong></td>
<td>850 kg/m³</td>
<td>300 kg/m³</td>
<td>650 kg/m³</td>
<td>690-740 kg/m³</td>
</tr>
<tr>
<td><strong>Energy Density</strong></td>
<td>~ 21 GJ/m³</td>
<td>~ 3 GJ/m³</td>
<td>11 GJ/m³</td>
<td>13-15 GJ/m³</td>
</tr>
<tr>
<td><strong>Other properties / comments</strong></td>
<td>Design fuel of existing plants</td>
<td>Low energy density</td>
<td>Water Soluble</td>
<td>Water Resistant (Steam Treated Pellets)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not grindable in coal mills at co-milling &gt;3-5% cofiring rate</td>
<td>Grindability at co-milling (5-8%)</td>
<td>Grindable in coal mills at high rates</td>
</tr>
</tbody>
</table>
**Fuel properties of refined wood pellets tested at Vattenfall**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>700 – 750 kg /m³</td>
</tr>
<tr>
<td>Moisture content, 6-8 %</td>
<td></td>
</tr>
<tr>
<td>Ash content 550 °C as received, 0.4-0.5 %</td>
<td></td>
</tr>
<tr>
<td>Volatile matter as received, 74-78 %</td>
<td></td>
</tr>
<tr>
<td>Net calorific value, 17.9-18.8 [MJ/ kg]</td>
<td></td>
</tr>
</tbody>
</table>
Refined wood Pellets Verification Program (2011)

Steering Group

Project Management

Permitting and Communication

Subprojects

BP Quality Definition and Testing
- Interface to suppliers
- Lab analysis
- Fuel Specifications

Logistics and Storage
- ATEX
- HSE
- Long term storage tests

Milling
- Milling tests
- Contact to suppliers
- Milling strategy

Boiler and combustion
- Boiler modelling
- Validation measurements

Fluegas treatment and by-products
- SCR
- ESP
- FGD
- Fly Ash
- Gypsum

Large Scale Tests
- Planning
- Execution
- Evaluation and Reporting

Scope

Lab Scale Tests
- < 50 kg

Small Scale Tests
- < 25 t

Large Scale Tests
- 4.300 t

Timeframe
### Basic Plant Data CHP Reuter West

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical Gross Power Capacity</strong></td>
<td>2 x 300 [MW&lt;sub&gt;el&lt;/sub&gt; (Cond.) (rated)]</td>
</tr>
<tr>
<td></td>
<td>2 x 255 [MW&lt;sub&gt;el&lt;/sub&gt; (Full district heating)]</td>
</tr>
<tr>
<td><strong>Thermal Power Capacity</strong></td>
<td>2 x 293 [MW&lt;sub&gt;th&lt;/sub&gt; (district heating) (rated)]</td>
</tr>
<tr>
<td><strong>Coal consumption</strong></td>
<td>1.1 Million tonnes/a</td>
</tr>
<tr>
<td><strong>CO₂ emissions with 100% coal</strong></td>
<td>2.8 Million tonnes/a</td>
</tr>
<tr>
<td><strong>Coal yard storage capacity</strong></td>
<td>220,000 tonnes hard coal</td>
</tr>
</tbody>
</table>
Relevant plant subsystems for biomass co-firing

1 Delivery and Unloading
2 Storage: Dust, smell, leaching
3 Mills (and drying): capacity decrease, mill operation
4 Dosing and Burners
5 Furnace walls: Corrosion, Slagging
6 Superheaters: Corrosion, Slagging
7 SCR: Catalyst Deactivation
8 ESP: Resistivity Increase
9 Fly Ash: Offtake
10 FGD: Capacity and gypsum quality
11 Exhaust gases: Emissions
Large Scale Unloading Tests (2,400 t):
Unloading and transfer to conveyor

Dusting seems to be an issue
The dust suppression system resulted in minimal/irrelevant dust formation.

→ Conclusion:
   Unloading of tested Black Pellets is possible with existing system, given adaptations in dust suppression systems and in the unloader grabs
Conveying

Airborne dust measurements within a.) conveyor belt and b) transfer point at tower

- No critical/explosive airborne dust concentrations
- Total dustfall was at some points higher than in coal operation
- Some pellets slipped through the rubber fittings at the transfer points

→ Conclusion:
  Conveying is possible with coal conveyors
Storage at Reuter West hard coal yard

- Laboratory analysis resulted in high COD values of the leaching water, so that a ground insulation was installed.

- From May – July, 4.318 t were stored and tested at Reuter West hard coal yard.
Measurement points inside refined pellets piles

Distribution of the temperature and gas measurement points in the large test piles

- Thermocouple with 50 m compensating cable
- Gas sampling PTFE hose with ceramic filters
Fine dust measurement device

PM 10 and PM 2.5 fine dust measurement device at Reuter West coal yard
Boiler Operation during 20% (m/m) Test (16%th)

Steam output (t/h) • Highest boiler output during the last 6 months was achieved (987 t/h, 270 MWel net
O2-concentration (%) • 5 days production of ~33-36 MWe green power
Unburnt carbon (%) CO-Concentration (mg/m³)
Conclusions

• During the test campaign, Reuter West CHP operated at following co-firing rates *without any modifications*:
  - 5 days at 20 ma-% (16%th) → 33-36 MWel green power
  - 2 days at 35 ma% (29%th) → > 53 MWel green power
  - 2 days at 50 ma% (43%th) → > 80 MWel green power

→ Such co-firing rates are unattainable with conventional biomass, unless significant investments are undertaken

• First test results indicate low cost feasibility of co-firing refined wood pellets
Willem-Alexander Power Plant (WAC)

- Integrated Gasification Combined Cycle (240 MWe)
- Biomass Scale Up Project (50-70% e/e)
- CO₂ emission reduction: 550 kton/yr
Process Scheme WAC

Process Willem-Alexander Power Plant
Technical modifications

Coal mills: Flue gas cleaning system

Sluicing system: Increase of volumetric capacity

Logistics: Storage and blending facility

Modifications desulphurization unit

Modifications water treatment installation

Re-commissioning syngas compressor

Modifications fly-ash sluicing system

Modifications slag bath

Sand injection system: Cleaning of fouling in syngascooler
Willem-Alexander Power Plant

- Testing so far has been according to expectations
- Issues can partly be solved by hardware modifications and partly by increasing the quality of the refined pellets (upstream treatment)

Evaluating the solutions is an important part of upcoming phases of development work on biomass co-combustion at Buggenum