BO$_2$-technology for biomass upgrading into solid fuel – an enabling technology for IGCC and gasification-based BtL

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Presentation overview

- Biomass utilisation in IGCC and gasification-based XtL
- Torrefaction
- BO$_2$-technology
- Development status and market introduction
Biomass utilisation in IGCC and gasification-based XtL

- Biomass (co-)firing in entrained-flow gasifiers
- Biomass-to-liquids (BtL)
  - EU: 10% of the transportation fuels from renewables in 2020
  - Preferably 2\textsuperscript{nd} generation biofuels from lignocellulosic biomass
- And further replacement of oil in the following decades?

"The fuel of the future is going to come from fruit, weeds, sawdust - almost anything. There’s enough alcohol in an acre of potatoes to drive the machinery necessary to cultivate the field for a hundred years."

_Henry Ford, 1906_
Biomass (co-)firing in dry-feed entrained-flow gasifiers

- Entrained-flow gasification is proven technology for coal
- Major bottleneck for biomass: feeding of small particles (< 1 mm) needed
  - Difficult
  - Energy intensive
  - Costly

Wood powder silo and pneumatic feeding lines
NUON IGCC plant, Buggenum, the Netherlands
Biomass – a difficult energy source

- Tenacious and fibrous (grinding difficult)
- Low energy density \( (LHV_{ar} = 10-17 \text{ MJ/kg}) \)
- Hydrophilic
- Vulnerable to biodegradation
- Heterogeneous
Torrefaction for upgrading biomass

Process parameters
- Temperature: 200-300°C
- Residence time: 10-30 minutes
- Particle size: < 4 cm
- Absence of oxygen
- Pressure: near atmospheric
Why torrefaction: from biomass/waste to commodity fuel

Woody biomass
- Friable and less fibrous
- Hydrophobic
- Preserved
- Homogeneous
- 19 - 22 MJ/kg (LHV, ar)

Agricultural residues
- Tenacious and fibrous
- Hydrophilic
- Vulnerable to biodegradation
- Heterogeneous
- 10 - 17 MJ/kg (LHV, ar)

Mixed waste

Torrefaction and pulverisation

Fuel powder

Superior fuel properties:
- Transport, handling, storage
- Milling, feeding
- Gasification, combustion
- Broad feedstock range
- Commodity fuel

Pelletisation

Fuel pellets

Bulk density 700-800 kg/m³
Bulk energy density 13-17 GJ/m³
Bench-scale testing

20 l batch reactor

5 kg/h Auger reactor (screw reactor)

Main product groups (dry basis)

Permanent gases

Organics
Grindability of (torrefied) woody biomass

Torrefaction leads to a dramatic decrease in required milling power and increase in milling capacity.
Bench-scale pelletisation tests

Features:
- 10 kg/h
- No automatic moisture supply

Preliminary findings:
- Easy pelletisation
- Low energy input required
- Pellet quality strongly dependent on torrefaction and pelletisation conditions
## BO₂ pellets in perspective

<table>
<thead>
<tr>
<th>Properties (typical values)</th>
<th>unit</th>
<th>Wood</th>
<th>Torrefied Wood</th>
<th>Wood pellets</th>
<th>BO₂ pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>wt.%</td>
<td>35</td>
<td>0</td>
<td>10</td>
<td>3</td>
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<tr>
<td>Calorific value (LHV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Dry</td>
<td>MJ/kg</td>
<td>17.7</td>
<td>20.4</td>
<td>17.7</td>
<td>20.4</td>
</tr>
<tr>
<td>As received</td>
<td>MJ/kg</td>
<td>10.5</td>
<td>20.4</td>
<td>15.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Mass density (bulk)</td>
<td>kg/m³</td>
<td>475</td>
<td>230</td>
<td>650</td>
<td>750</td>
</tr>
<tr>
<td>Energy density (bulk)</td>
<td>GJ/m³</td>
<td>5.0</td>
<td>4.7</td>
<td>10.1</td>
<td>14.9</td>
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<tr>
<td>Pellet strength</td>
<td></td>
<td>Good</td>
<td>Very good</td>
<td></td>
<td></td>
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<tr>
<td>Hygroscopic nature</td>
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<td>Hydrophilic</td>
<td>Hydrophobic</td>
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<tr>
<td>Biological degradation</td>
<td></td>
<td>Fast</td>
<td>Slow</td>
<td>Fast</td>
<td>Slow</td>
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<tr>
<td>Handling properties</td>
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<td>Normal</td>
<td>Normal</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>
BO₂-technology

Features:
- Conventional drying and pelletisation
- Compact moving bed technology with direct heating
- Heat integration
- High energy efficiency (> 90%)
- Cost effective
Torrefaction pilot-plant testing (50-100 kg/h)
Pilot-scale testing – results (1)

- **Testing history:**
  - Over 300 hours of operation (21 day runs + three 50-hour runs)
  - Biomass feedstock: poplar chips, softwood/hardwood mixture, agricultural residues
  - Conditions: 220-280 °C torgas inlet temp., throughput approx. 60 kg/h (input basis)

- **Modifications after initial tests:**
  - New continuous discharge system
  - Replacement of valves, flow meters, pipework
  - Tuning of afterburner
  - Additional measurement points
Pilot-scale testing – results (2)

• Total production:
  – >10 tonnes of torrefied material

• General findings:
  – Smooth operation, easy start-stop
  – High feedstock flexibility, limited pressure drop and no bridging given proper sizing of the feedstock
  – Torrefaction modestly exothermic, reactor showed good temperature control
  – Emissions of afterburner comparable to natural gas burning (0-50 ppmv CO and 20-70 ppmv NO\textsubscript{x})
Pilot-scale testing – results (3)

- Torrefied material from pilot-plant subjected to initial bench-scale and semi-industrial-scale pelletisation tests at CPM:
  - Good quality pellets can be produced, despite heterogeneous nature of the biomass
  - But specific pelletisation conditions required
  - Large influence of torrefaction conditions

- Next tests:
  - Optimisation torrefaction + pelletisation for woody fuels
  - Long-duration performance and production of larger batches for end-use testing
  - Other feedstocks (agro residues)
BO$_2$-technology – market potential

....... some figures

- EU-27: coal-fired plants with 10% co-firing requires 70 Mtonne/a dry biomass
  $\approx$ 700 BO$_2$-plants with plant-size 100 ktonne/a.

- EU-27: 10% biofuels in 2010, $\approx$ 1300 PJ/a, corresponding to approx. 110
  Mtonne/a dry biomass (@ 60% conversion efficiency). BO$_2$-technology is an
  enabling technology for HT gasification-based BtL.

- EU-15: 43 Mtonne/a dry biomass (agro-residues) available for energy purposes;
  substantial possible role of BO$_2$-technology to increase efficiency and reduce
  cost of overall biomass-to-energy chain.

- Worldwide: @@ pellet plants that can be retrofitted into torrefaction plants
Retrofitting a conventional wood pellets plant
Industrial partnership formed with Econcern aimed at technology demonstration and market introduction.

- Involvement of major equipment supplier and end-users of BO₂ pellets
- World-wide engineering and supply of commercial BO₂ plants
- Preparing market introduction of BO₂ pellets 1st demonstration/commercial plant
BO₂GO demonstration plant

- Location: Delfzijl, the Netherlands
- Capacity:
  - Input: 130,000 tonne – 170,000 tonne/a
  - Output: 70,000 tonne/a
- Start-up: 2010
In conclusion

• BO₂-technology allows cost-effective production of 2nd generation biomass pellets from a wide range of biomass/waste feedstock with a high energy efficiency (>90%)

• BO₂ pellets show:
  – High energy density
  – Water resistant
  – No/Limited biological degradation and heating
  – Excellent grindability
  – Good combustion and gasification properties

• BO₂-technology is an enabling technology for biomass (co-)firing in entrained-flow gasifiers and gasification-based BtL

• Other fields of application:
  – Long distance biomass transport
  – Co-firing in pf boilers
  – Small-scale pellet boilers/stoves

• Pilot-plant testing ongoing, demo-plant in preparation and industrial consortium (nearly) established, strong market pull for BO₂-plants and BO₂ pellets
Thank you for your attention………

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