Torrefaction – product quality optimisation in view of logistics and end-use

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product quality optimisation in view of logistics and end-use

World Biomass Power Markets

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Amsterdam, the Netherlands
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Biomass – major challenge

• Enable decoupling of biomass production and use
  – Place
  – Time
  – Scale

• By converting biomass into high-quality bioenergy carriers (solid, liquid or gas), that:
  – Better fit in (existing) logistic infrastructures
  – Allow efficient, reliable and cost effective conversion into electricity and heat, transport fuels and chemicals

Solve biomass related problems at the source
Torrefaction for upgrading biomass

- Process parameters
  - Temperature: 240-320 °C
  - Absence of oxygen

Tenacious and fibrous
LHV = 9 - 12 MJ/kg
Hydrophilic
Biodegradable
Heterogeneous

Friable and less fibrous
LHV = 18 - 24 MJ/kg
Hydrophobic
Preserved
Homogeneous

Pelletisation

Bulk density = 650-800 kg/m³
Bulk energy density = 12 - 19 GJ/m³
ECN and torrefaction

- 20 years experience in biomass co-firing R&D, identified the potential of torrefaction and played a pioneering role in adapting torrefaction to bioenergy applications since 2002

- ECN’s torrefaction technology proven on pilot-scale and together with industrial partners now taken to demonstration and commercial market introduction (see Andritz presentation)

- Contract R&D for industry to assess the torrefaction potential of specific feedstocks, produce test batches and optimise product quality
## Torrefied biomass properties in perspective

<table>
<thead>
<tr>
<th></th>
<th>Wood chips</th>
<th>Wood pellets</th>
<th>Torrefied wood pellets</th>
<th>Charcoal</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture content (wt%)</strong></td>
<td>30 – 55</td>
<td>7 – 10</td>
<td>1 – 5</td>
<td>1 – 5</td>
<td>10 – 15</td>
</tr>
<tr>
<td><strong>Calorific value (LHV, MJ/kg)</strong></td>
<td>7 – 12</td>
<td>15 – 17</td>
<td>18 – 24</td>
<td>30 – 32</td>
<td>23 – 28</td>
</tr>
<tr>
<td><strong>Volatile matter (wt% db)</strong></td>
<td>75 – 84</td>
<td>75 – 84</td>
<td>55 – 65</td>
<td>10 – 12</td>
<td>15 – 30</td>
</tr>
<tr>
<td><strong>Bulk density (kg/l)</strong></td>
<td>0.20 – 0.30</td>
<td>0.55 – 0.65</td>
<td>0.65 – 0.80</td>
<td>0.18 – 0.24</td>
<td>0.80 – 0.85</td>
</tr>
<tr>
<td><strong>Vol. energy density (GJ/m³)</strong></td>
<td>1.4 – 3.6</td>
<td>8 – 11</td>
<td>12 – 19</td>
<td>5.4 – 7.7</td>
<td>18 – 24</td>
</tr>
<tr>
<td><strong>Hygroscopic properties</strong></td>
<td>Hydrophilic</td>
<td>Hydrophilic</td>
<td>(Moderately) Hydrophobic</td>
<td>Hydrophobic</td>
<td>Hydrophobic</td>
</tr>
<tr>
<td><strong>Biological degradation</strong></td>
<td>Fast</td>
<td>Moderate</td>
<td>Slow</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Milling requirements</strong></td>
<td>Special</td>
<td>Special</td>
<td>Standard</td>
<td>Standard</td>
<td>Standard</td>
</tr>
<tr>
<td><strong>Product consistency</strong></td>
<td>Limited</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Transport cost</strong></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Abbreviations:**
db = dry basis
LHV = Lower Heating Value

**sources:** ECN (table, fig.1, 3), Pixelio (fig. 2, 5), ofi (fig. 4)
The added value of torrefaction

- Torrefaction (+ densification) enables energy-efficient (>90%) upgrading of biomass into commodity solid biofuels with favourable properties in view of logistics and end-use.

- Favourable properties include high energy density, better water resistance, slower biodegradation, good grindability, good “flowability”, homogenised material properties.

- Therefore, cost savings in handling and transport, advanced trading schemes (futures) possible, capex savings at end-user (e.g. outside storage, direct co-milling and co-feeding), higher co-firing percentages and enabling technology for gasification-based biofuels and biochemicals production.

- Applicable to a wide range of lignocellulosic biomass feedstock, even mixed waste streams.
Densification

- Focus on pelletisation, but briquetting considered as well
- Good quality pellets can be produced without additional binder
- But:
  - Pelletisation performance strongly dependent on biomass feedstock
  - Case-by-case tuning of the pelletisation conditions (e.g., die type) required
  - Good control of torrefaction conditions is essential
  - Without binder, window for tuning product quality to logistics and end-use requirements may be small
  - Special attention to safety issues (e.g., self heating, dust explosions)
Product quality optimisation

- Pilot, demo and first commercial plants produce tonne-scale batches allowing representative logistics and end-use performance testing by industry
- Coal-fired power plants want to be early adopters and show interest in conducting (co-firing) trials
- Product quality optimisation requires a systematic, iterative approach (2 iterative loops)
- For this purpose, European torrefaction developers, combustion and gasification technology providers and end-users have joined forces in the EU-FP7 project SECTOR
Impact of torrefaction degree

- Densification
- Self-heating
- Dust explosion
- Water uptake / leachability
- Grindability
- Heating value
- Reactivity
- Cost / Sustainability
- .......

Indicative trends
SECTOR
Production of Solid Sustainable Energy Carriers from Biomass by means of Torrefaction

- Collaborative project: SECTOR
- Project start: 01.01.2012
- Duration: 42 months
- Total budget: 10 MEuro
- Participants: 21 from 9 EU-countries (+ industrial advisory group)
- Coordinator: DBFZ (supported by ECN, ofi)
Objectives

- **Support the market introduction** of torrefaction-based bioenergy carriers
- **Further development of torrefaction**-based technologies
- **Development of specific production recipes**, validated through extensive lab-to-industrial-scale logistics and end-use performance testing
- Development and standardisation of dedicated **analysis and testing methods** for assessment of transport, storage, handling logistics and end-use performance (+ product standards, MSDS, REACH)
- Assessment of the role of torrefaction-based solid bioenergy carriers in the bioenergy value chains
- Full **sustainability assessment** of the major torrefaction-based biomass-to-end-use value chains
- **Dissemination** of project results to industry and into international forums (e.g. CEN/ISO, IEA and sustainability round tables)
SECTOR
Torrefaction (reactor) technologies

Moving bed (ECN/Andritz) pilot/demo
Rotary drum (Umeå University) pilot
Rotary drum (CENER) pilot
Torbed (Topell) demo

Production with available pilot scale facilities
Typical test runs 50-100 hours
Typical production per test few tons
3-6 different feedstocks

Production with available demo plant
Continuous operation
Production of 100-200 tons
Specific feedstock
SECTOR
Logistics, handling and end-use

- Storage
  - 12,600 GJ (68,150 ft³)
  - Source: Pedersen Group

- Handling

- Grinding & feeding
  - 12,600 GJ (22,300 ft³)
  - Source: Loesche

- Co-firing
  - Source: Vattenfall

- (Co-)gasification

- Pellet boiler
  - Source: BIOS
First results

- Internal project results
  - Biomass feedstock selection
  - Value chains definition
  - Production and distribution of test batches

- Round robin Validation of “standard” test methods

- Requirements for a MSDS for torrefied material

- Product standards for torrefied pellets/briquettes accepted as a New Work Item in ISO 238 – Solid Biofuels

- First technical results (“work in progress”) on logistics and end-use behaviour: e.g., self heating, explosivity, pneumatic transport, milling, combustion and gasification tests

www.sector-project.eu
Exemplary biomass-to-end-use chains
SECTOR
Validation of “standard” test methods (1)

- Round robin, 43 participating labs, 17 countries, 4 continents
- Sample: 1 big bag torrefied wood pellets (6mm), produced from wood chips/forest residues
- 11 “standard” methods included
- Methods for bulk density, mechanical durability, moisture, ash, chlorine, sulphur, volatile matter, CHN and major elements content applicable for torrefied pellets without any adoption
- For net calorific value: repeatability limit is met, but not the reproducibility limit – should be checked again (caused by inhomogeneity?)
- Method for minor elements hard to validate due to low concentrations
- Method for ash melting behaviour should be adopted
Validation of “standard” test methods (2)

Ash content according to EN 14775

<table>
<thead>
<tr>
<th>Ash content</th>
<th>torrefied Pellets (SECTOR)</th>
<th>Orujillo (BIONORM II)¹</th>
<th>Woodchips (BIONORM II)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>General mean = assigned value</td>
<td>m</td>
<td>3.12</td>
<td>11.13</td>
</tr>
<tr>
<td>Repeatability limit</td>
<td>r</td>
<td>0.2</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.37</td>
<td>5.03</td>
</tr>
<tr>
<td>Reproducibility limit</td>
<td>R</td>
<td>0.42</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.4</td>
<td>11.28</td>
</tr>
<tr>
<td>Number of participants</td>
<td>n</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Overall number of individual results</td>
<td>I</td>
<td>161</td>
<td>138</td>
</tr>
</tbody>
</table>

¹BIONORM II project no. 038644 founded by European Commission
SECTOR

Product standards – new work item in ISO 238

<table>
<thead>
<tr>
<th>Property class, Analysis method</th>
<th>Unit</th>
<th>TW1</th>
<th>TW2</th>
<th>TW3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin and source. ISO 17225-1</td>
<td>mm</td>
<td>1.1 Whole trees without roots</td>
<td>1.1 Forest, plantation and other virgin wood</td>
<td>1.1 Forest, plantation and other virgin wood</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.3 Stemwood</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.4 Logging residues</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 Chemically untreated wood residues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter, D and Length L</td>
<td>mm</td>
<td>D06, 6 ± 1; 3,15 ≤ L ≤ 40</td>
<td>D06, 6 ± 1; 3,15 ≤ L ≤ 40</td>
<td>D06, 6 ± 1; 3,15 ≤ L ≤ 40</td>
</tr>
<tr>
<td>ISO 17829</td>
<td></td>
<td>D08, 8 ± 1; 3,15 ≤ L ≤ 40</td>
<td>D08, 8 ± 1; 3,15 ≤ L ≤ 40</td>
<td>D08, 8 ± 1; 3,15 ≤ L ≤ 40</td>
</tr>
<tr>
<td>Moisture, M, EN 14774-1, EN 14774-2</td>
<td>as received, w-% wet basis</td>
<td>M10 ≤ 10</td>
<td>M10 ≤ 10</td>
<td>M10 ≤ 10</td>
</tr>
<tr>
<td>Ash, A, ISO 18122</td>
<td>w-% dry</td>
<td>A2.0 ≤ 2.0</td>
<td>A5.0 ≤ 5.0</td>
<td>A10.0 ≤ 10.0</td>
</tr>
<tr>
<td>Mechanical durability, DU, ISO 17831-1</td>
<td>as received, w-%</td>
<td>DU97.5 ≥ 97.5</td>
<td>DU96.5 ≥ 96.5</td>
<td>DU96.5 ≥ 96.5</td>
</tr>
<tr>
<td>Fines, F, ISOWD XXXXX (hand sieving)</td>
<td>w-% as received</td>
<td>F1.0 ≤ 1.0</td>
<td>F1.0 ≤ 1.0</td>
<td>F1.0 ≤ 1.0</td>
</tr>
<tr>
<td>Additives</td>
<td>w-% dry</td>
<td>Type and amount to be stated</td>
<td>Type and amount to be stated</td>
<td>Type and amount to be stated</td>
</tr>
<tr>
<td>Net calorific value, Q, ISO 18125</td>
<td>dry, MJ/kg or kWh/kg</td>
<td>Q20, Q &gt; 20</td>
<td>Q20, Q &gt; 20</td>
<td>Q19, Q &gt; 19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q5,6; Q ≤ 5,6 Value to be stated</td>
<td>Q5,6; Q ≤ 5,6 Value to be stated</td>
<td>Q5,3; Q ≥ 5,3 Value to be stated</td>
</tr>
<tr>
<td>Bulk density, BD, ISO 17828</td>
<td>kg/m³</td>
<td>BD650 &gt; 650 Value to be stated</td>
<td>BD650 &gt; 650 Value to be stated</td>
<td>BD650 &gt; 650 Value to be stated</td>
</tr>
<tr>
<td>Nitrogen, N, ISO 18049</td>
<td>w-% dry</td>
<td>ND ≤ 0.5</td>
<td>ND ≤ 0.5</td>
<td>ND ≤ 1.0</td>
</tr>
</tbody>
</table>

Initial proposal for specification of torrefied pellets prepared from woody biomass
Particle size 200-350 μm

Pressure drop $P_2 - P_1$ (mbar)

Mass rate (kg/s)

Coal
- Spruce 260°C
- Poplar 265°C
- Spruce 280°C
SECTOR

Particle shape after milling

Spruce 240°C
Spruce 260°C
Spruce 280°C
Coal
Poplar 265°C
Summary

- Torrefaction potentially allows cost-effective production of *commodity solid biofuels* from a wide range of biomass/waste feedstock with a high energy efficiency (>90%) allowing a decoupling of biomass production and use.

- Torrefaction development is in the pilot/demo-phase, with >10 demo initiatives underway in Europe; strong market pull for torrefaction plants and torrefaction pellets.

- Main characteristics of torrefaction are known, but performance testing and iterative optimisation of production recipes for torrefied products still are in an early phase.

- The SECTOR project is focused on this to facilitate commercial market introduction of torrefaction technology and torrefied products ([www.sector-project.eu](http://www.sector-project.eu)).
Thank you for your attention!

Production at ECN of tonne-scale test batches for industrial trials

For more information, please contact:

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