Biomass Pre-treatment by Torrefaction

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Torrefaction
Various definitions

Roasting

Wood cooking

High T drying

Mild Pyrolysis

??????

Pre Pyrolysis

mild thermal treatment

Wood browning
**Torrefaction**

**General process description**

- **Energy densification (E/kg):**
  \[
  \frac{0.9}{0.7} = 1.3
  \]

  - Mass
  - Energy

- **Temperature:** 200-300 °C
- **Pressure:** near atmospheric
- **Absence of oxygen
- **Product:** solid phase (energy)
- **Particle size:** < 4 cm thickness
- **Residence time:** 30 to 90 min
- **Heating rate:** <50 °C/min

**Steps:**
- Biomass
- Torrefaction
- Gas
- Solids
Torrefaction
Product quality of torrefied biomass

Green biomass
- Tough and fibrous
- 10 to 17 MJ/kg (LHV, ar)
- Hygroscopic, Hydrophilic
- Vulnerable to biodegradation
- Contaminated
- Heterogeneous

Waste
- Friable and less fibrous
- 19 to 22 MJ/kg (LHV, ar)
- Hydrophobic
- Preserved
- Reduced contaminations
- Homogeneous

Demolition wood

Torrefaction and pulverisation

TOP fuel powder
- 750-850 kg/m³
- 15-20 GJ/m³

Pelletisation

TOP fuel pellets

Size reduction
Combustion / Gasification
Logistic operations (transport)
Feedstock bandwidth
Biofuel standardisation

(4) ECN Biomass, Harold Boerrigter
Torrefaction, Third ThermalNET Meeting, Lille, France, 3-5 April 2006
www.ecn.nl
## Torrefaction
### Comparison of (torrefied) biomass and (TOP) pellets

<table>
<thead>
<tr>
<th>Properties</th>
<th>unit</th>
<th>Wood</th>
<th>Torrefied biomass</th>
<th>Wood pellets</th>
<th>TOP pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Moisture content</td>
<td>% w.t.</td>
<td>35%</td>
<td>3%</td>
<td>10%</td>
<td>7%</td>
</tr>
<tr>
<td>Calorific value (LHV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dry</td>
<td>MJ/kg</td>
<td>17.7</td>
<td>20.4</td>
<td>17.7</td>
<td>17.7</td>
</tr>
<tr>
<td>as received</td>
<td>MJ/kg</td>
<td>10.5</td>
<td>19.9</td>
<td>15.6</td>
<td>16.2</td>
</tr>
<tr>
<td>mass density (bulk)</td>
<td>kg/m³</td>
<td>550</td>
<td>230</td>
<td>500</td>
<td>650</td>
</tr>
<tr>
<td>energy density (bulk)</td>
<td>GJ/m³</td>
<td>5.8</td>
<td>4.6</td>
<td>7.8</td>
<td>10.5</td>
</tr>
<tr>
<td>Pellet strength</td>
<td></td>
<td>-</td>
<td>-</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>Dust formation</td>
<td></td>
<td>moderate</td>
<td>high</td>
<td>limited</td>
<td>limited</td>
</tr>
<tr>
<td>Hygroscopic nature</td>
<td>water uptake</td>
<td></td>
<td>hydrophobic</td>
<td>swelling / water uptake</td>
<td>poor swelling / hydrophobic</td>
</tr>
<tr>
<td>Biological degradation</td>
<td></td>
<td>Possible</td>
<td>Impossible</td>
<td>Possible</td>
<td>Impossible</td>
</tr>
<tr>
<td>Seasonal influences</td>
<td></td>
<td>High</td>
<td>Poor</td>
<td>Moderate</td>
<td>Poor</td>
</tr>
<tr>
<td>(noticable for end-user)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling properties</td>
<td></td>
<td>normal</td>
<td>normal</td>
<td>good</td>
<td></td>
</tr>
</tbody>
</table>
Torrefaction
Van Krevelen Diagram

Biomass becomes like peat!
Torrefaction
Grindability improvement (experimental results)

![Graph showing grindability improvement post torrefaction](image)
Torrefaction Technology
ECN directly heated torrefaction process

Moving bed based reactor technology
- Compact reactor
- Accurate T-control
- Feedstock flexibility
- Low capital investment
- Small footprint
- High capacity

Biomass → Drying → Torrefaction → Cooling

Flue gas recycle

Gas

Combustion

ΔP

Heat exchange

Flue gas

Air

Flue gas

Torrefaction gases
Torrefaction Economics
Change study: TOP pellets vs. conventional pellets

Torrefaction aids ... Economics!

Sawdust
0.7 EUR/GJ

TOP process
(South Africa)
2.0 EUR/GJ

Logistics
2.0 EUR/GJ

Co-firing of TOP pellets in existing coal fired power stations North-West Europe

Savings
30-70%

0.7 EUR/GJ

Sawdust

Conventional Pelletisation
(South Africa)
2.2 EUR/GJ

Logistics
2.9 EUR/GJ

2.0 EUR/GJ

4.7 EUR/GJ

5.8 EUR/GJ

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