Torrefaction of Biomass—Status & Market Requirements, Supply Chain Efficiency Comparison

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Principle and Simplified Mass Balance

**INPUT:**

- Predried biomass:
  - Mass: 1200 kg/h
  - Bulk density: 200 kg/m³
  - Dry mass: 95%
  - NCV: 15-19MJ/kg

**Processing**

- Reactor and process:
  - Temperature: ~ 300°C
  - Residence time: ~ 30 min

**OUTPUT:**

- Torrified biomass:
  - Mass: 903 kg/h
  - Bulk density: >650 kg/m³
  - Dry mass: 100%
  - NCV: 21-23MJ/kg

- Syngas to Combustion:
  - Mass: 297 kg/h
  - GCV $H_\circ$: 461 kJ/Nm³

While processed, about 30% of its mass is extracted from the biomass paralleled by 15% energy content loss. This energy (the volatiles) is used to heat the ACB process.
Carbonisation Reaction under Heat

84% (82 – 85) dry wood

0 – 20% charcoal (EN 1860-3)

0% volatiles (all carbon and minerals)

The torrefaction process (example ACB)

**ENERGY SUPPLY**
Biomass + lean gas incineration

**DRYING**
- Fresh biomass
- Dryer offgas, T=80°C
- Dried biomass, 95% DS

**TORREFACTION**
- Syn gas, T=280°C
- Flue gas, T=4-600°C
- Torrefied biomass
- Torrefied Fuel

**PREPARATION (milling)**
- Torrefied material

**DENSIFICATION**
- Torrefied material

**Fresh biomass**

Source: ANDRITZ AG, Design W&P
Product Form Factors
## Torrefaction Implementation Indicator

<table>
<thead>
<tr>
<th>Area</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torr-gas Handling and Utilisation</td>
<td>done</td>
</tr>
<tr>
<td>Continuous torrefaction</td>
<td>done</td>
</tr>
<tr>
<td>Predictability and consistency of product</td>
<td>for most feedstock</td>
</tr>
<tr>
<td>Densification</td>
<td>done</td>
</tr>
<tr>
<td>Feedstock flexibility</td>
<td>done</td>
</tr>
<tr>
<td>Plant Safety</td>
<td>done</td>
</tr>
<tr>
<td>Indoor storage</td>
<td>done</td>
</tr>
<tr>
<td>Outdoor storage</td>
<td>in optimisation</td>
</tr>
<tr>
<td>Standardisation of product</td>
<td>ISO TS 17225-8</td>
</tr>
<tr>
<td>Safety along supply chain</td>
<td>in progress</td>
</tr>
<tr>
<td>Trade Registrations and Permissions</td>
<td>in progress</td>
</tr>
<tr>
<td>Co-firing trials</td>
<td>done in EU</td>
</tr>
<tr>
<td>Co-firing burn tests</td>
<td>several done</td>
</tr>
<tr>
<td>Co-firing full scale</td>
<td>several done</td>
</tr>
<tr>
<td>Heat application trials</td>
<td>in progress</td>
</tr>
<tr>
<td>Further industrial applications trials</td>
<td>in progress</td>
</tr>
</tbody>
</table>

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Understanding the Product

- Torrefaction pre-processes and upgrades the biomass feedstock
- Number of technology Suppliers - FUNGIBLE PRODUCT
- Shapes of pellets or briquettes for storage and transport
- Well defined within ISO Technical Specification ISO 17225-8
- Immediate biomass blending into coal stream in existing coal fired plants – grindability, water resistance, storability, morphology....
- Almost 0 biodegradation of product when stored
- Combusts cleaner, gasifies easier and cleaner
- NCV highest of all solid biofuels and best adjustable
- Reduces carbon footprint of supply chain substantially
### ISO 17225

Solid biofuels - Fuel specifications and classes

### ISO TS 17225 - 8:

Part 8: Graded thermally treated and densified biomass fuels

#### Different Classes

Wood-Non Woody; NCV, Durability, Bulk Density, Volatile Matter etc.

#### Parameters in standard development:

- Grindability
- Water resistance

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#### Table 1 - Specification of graded pellets produced by thermal processing of woody biomass

<table>
<thead>
<tr>
<th>Property class, Analysis method</th>
<th>Unit</th>
<th>T1WHE</th>
<th>T1WHL</th>
<th>T2WHE</th>
<th>T2WHL</th>
<th>T3WHE</th>
<th>T3WHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross heating value / Lower heating value</td>
<td>MJ/kg</td>
<td>18.5-19.0</td>
<td>18.5-19.0</td>
<td>18.5-19.0</td>
<td>18.5-19.0</td>
<td>18.5-19.0</td>
<td>18.5-19.0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>% w/w</td>
<td>0.1-0.3</td>
<td>0.1-0.3</td>
<td>0.1-0.3</td>
<td>0.1-0.3</td>
<td>0.1-0.3</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Ash</td>
<td>% w/w</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>% w/w</td>
<td>70.0-75.0</td>
<td>70.0-75.0</td>
<td>70.0-75.0</td>
<td>70.0-75.0</td>
<td>70.0-75.0</td>
<td>70.0-75.0</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>% w/w</td>
<td>25.0-30.0</td>
<td>25.0-30.0</td>
<td>25.0-30.0</td>
<td>25.0-30.0</td>
<td>25.0-30.0</td>
<td>25.0-30.0</td>
</tr>
</tbody>
</table>

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#### Table 2 - Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>8.0-10.0% w/w</td>
</tr>
<tr>
<td>Ash content</td>
<td>0.5-1.0% w/w</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>60.0-70.0% w/w</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>30.0-40.0% w/w</td>
</tr>
</tbody>
</table>

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Products and supply chains compared (LLC)
Technically in all parameters superior to Wood Pellets

Minimum Ignition Energy Pulverised torrefied pellets vs. pulverised raw biomass chips

- Clear link between MIE torrefied pellets with MIE raw material
- Native dust has high MIE’s
- Dust from handling low durability pellets (< 93%) is more ignitable → aim for pellet durability ≥ 95%
- Handling dust from torrefied wood pellets is equally ignitable as handling dusts from white wood pellets

Pellets stored 20 days at 20°C at 95% relative humidity

- Dry matter losses significantly higher for white wood pellets, compared with torrefied wood pellets
- Also after uncovered outdoor exposure for 3 months

Fuel Morphology, pneumatic transport

Water Resistance

Full water resistance achieved by several producers with or without binders resp. coating

Energy Balance Comparison
Study carried out by ECN, UMEA university and CENER

**Torrefaction Pellets** (from aggregated averages survey entries)

- **Feedstock**: 1.089 GJ
- **Production Process**:
  - Elec. (GJ/GJ prod): 0.034
  - Heat (GJ/GJ prod): 0.015
- **Torrefied wood pellets**: 1.000 GJ
- **Overall thermal efficiency** (on LHV ar): 90.6%
- **Total electricity consumption**: 188 kWh/tonne
- **Total electricity consumption**: 9.4 kWh/tonne

**White Pellets** (from average data compilation)

- **Feedstock**: 0.952 GJ
- **Production Process**:
  - Elec. (GJ/GJ prod): 0.032
  - Heat (GJ/GJ prod): 0.145
- **White wood pellets**: 1.000 GJ
- **Overall thermal efficiency** (on LHV ar): 91.1%
- **Total electricity consumption**: 152 kWh/tonne
- **Total electricity consumption**: 8.8 kWh/tonne

## Advantages in Logistics

### WWP versus TP: Energy consumed in shipping in MJ/GJ shipped

<table>
<thead>
<tr>
<th></th>
<th>WWP</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handysize</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Handymax</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Panmax</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>

### Energy Consumption from vessel to plant stockyard in MJ/GJ

<table>
<thead>
<tr>
<th></th>
<th>WWP</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>WWP</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>TP</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Source and Copyright: W&P
WWP versus ca. 21/30 GJ TP - Energy consumed in MJ per GJ energy delivered to Consumer stockpile

Source and Copyright: W&P
GHG Comparison

Source: D. Thrän, DBFZ
Positive Experience in co-firing

Many positive examples in co-firing 5-100%:

Vattenfall
Essent - RWE
GDF Suez - ENGIE
Dong
Portland General Electric

DONG Studstrup-3 experience

- Two units with total capacity of 714 MW_e and 986 MW_th
- Dedicated milling on MPS roller mill adapted for either coal or white pellets
- 200 tons of Andritz/ECN torrefied spruce pellets during 8 hours trial
- Co-firing share: 33 wt%
- Observations:
  - No dust formation during unloading
  - Sufficiently high durability; no issues with dust formation in chain conveyors
  - Normal Minimum Ignition Energy (MIE)
- ECN conducted lab-scale characterisation of pellets

Feedstock Flexibility

The thermal treatment of the biomass during the torrefaction process can reduce the organically bound chlorine up to 90%

By this Torrefaction is the processing that does open up the energy market for Agricultural by products, grassy crops and other unused biomasses with unacceptable high Chlorine content

The effect is a significant: reduction in the feedstock costs
Side effect: no sustainability concerns

Diversity of Products

Volume Product: Fuel for Pulverized Coal Power Plants

Value Products: Fuel for Heating
Fuel for Process Energy Needs
Feedstock for Gasification
Soil enhancer
Carbon provider for Plastics industry
Activated Carbon
Products for new (niche) markets

Messages to take home

- Integrated Torrefaction Process Technology mature, available, happening
- Feedstock Flexibility
- Fungible Standard (ISO) Product with adjustment possibilities
- Superior behaviour to all other solid biomasses
- Lowest CO2 footprint
- Ships like coal, stores like coal, mills like coal and combust like coals
- Reduced sensitivity to changes in cost factors along the supply chain
- Torrefaction is happening in industrial plants
- Product supply available: Project pipelines in Asia and Globally

Not many reasons using the intermediate products from wood, go for the final products and capitalize on the advantages

Thank you for paying attention

Contact

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