Biomass Torrefaction
Technology Status and Commercialisation, Applications for Torrefied Biomass and its Role in Logistics and Trade

Webinar, 27 Oct 2016

Jaap Koppejan, Managing Director, Procede Biomass BV
Marcel Cremers, Senior Consultant, DNV GL
Michael Wild, President, IBTC
Martin Junginger, Professor Biobased Economy, Utrecht University
Webinar based on two recent reports by tasks 32 and 40
## Presenters today

<table>
<thead>
<tr>
<th>Time</th>
<th>Content</th>
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<tbody>
<tr>
<td>10 min</td>
<td>Introduction to torrefaction, <a href="#">Jaap Koppejan</a>, Managing Director, Procede Biomass BV and Task leader IEA Bioenergy Task 32 (Biomass Combustion and Cofiring)</td>
</tr>
<tr>
<td>15 min</td>
<td>Status of commercialisation, <a href="#">Marcel Cremers</a>, Senior Consultant, DNV-GL</td>
</tr>
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<td>15 min</td>
<td>Possible implications on bioenergy trade, <a href="#">Michael Wild</a>, President, International Biomass Torrefaction Council</td>
</tr>
<tr>
<td>20 min</td>
<td>Q&amp;A, <a href="#">Martin Junginger</a>, Professor Biobased Economy, Utrecht University and Task leader, IEA Bioenergy Task 40 (Biomass Trade)</td>
</tr>
</tbody>
</table>
Torrefaction is like roasting coffee beans….

- Heating biomass to 250-300 °C in absence of oxygen
- Drying + removal of part of the volatiles
Claims made for Torrefaction

1. Volumetric energy densification brings significant cost reductions in transport and handling
2. Broader feedstock basis - geographically + types of raw material
3. Limited or no biodegradation of product when stored
4. Large variety of applications
5. Reduces CAPEX&OPEX at end user – Immediate use in existing coal fired plants – grindability, (water resistance?)....
6. Combustion and gasification behaviour more compatible to coal than raw biomass, high cofiring shares possible
7. Can be made to measure to clients requirements
8. Helps developing the market towards commoditisation
Heat energy balance (LHV basis)

Assumptions: fresh clean wood (0.5% ash content, 50% moisture content) as raw material and a dryer requiring 2.9 MJ per kg of water evaporated
Thermal energy efficiency can easily be over 90% for 30% dry mass loss.

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Energy efficiency from total biomass input to product (% on LHV basis)

Moisture content of used biomass (% wet basis)

80% dry mass loss
Technical challenges remaining

- Water resistance not as good as wanted
- Pelletisation is difficult for material with high torrefaction degree, both high durability and good grindability is difficult to achieve
- Several process owners are unable to produce adequate product at constant quality
- Torrefied wood pellets can generate larger amounts of explosive fine dust than wood dust
- Ash content increases and alkali concentration can go above technical limits for boilers (but Cl may selectively go down)
Flame shape in a PC boiler

100% coal   50% coal/50% TWP   100% TWP

Source: Koppejan et.al., Extrapolation of co-firing results to large scale boilers using CFD calculations, SECTOR D7.8, 2014

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Status of commercialisation

Marcel CREMERS, PhD
Senior Consultant, Green Thermal Power
DNV GL - Energy
Current situation – available production capacity

Available installed capacity 100-250 ktons/y (facilities > 5 ktons/y)

Typical demonstration scale facility is 3-5 t/h (25-40 ktons/year)

Most built in 2010-2014

Few plants currently operational due to market conditions

Interviews (2014): Progress rating 5.7 out of 10
# Status of torrefaction initiatives as of early 2015

<table>
<thead>
<tr>
<th>Developer</th>
<th>Technology</th>
<th>Location(s)</th>
<th>Production capacity (ton/a)</th>
<th>Scale and status</th>
<th>Full integration (pre-treatment, torrefaction, combustion, heat cycle, densification)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Electricity Generation (UK)</td>
<td>Oscillating bed</td>
<td>Derby (UK)</td>
<td>30,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Horizon Bioenergy (NL)</td>
<td>Oscillating belt conveyor</td>
<td>Steenwijk (NL)</td>
<td>45,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Dismantled</td>
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<tr>
<td>Solvay (FR) / New Biomass Energy (USA)</td>
<td>Screw reactor</td>
<td>Quitman (USA/MS)</td>
<td>80,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Topeli Energy (NL)</td>
<td>Fluidised bed</td>
<td>Duiven (NL)</td>
<td>60,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Mothballed</td>
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<tr>
<td>Torr-Coal B.V. (NL)</td>
<td>Rotary drum</td>
<td>Dilsen-Stokkem (BE)</td>
<td>30,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Airex (CAN/QC)</td>
<td>Cyclonic bed</td>
<td>Bécanacour (CAN/QC)</td>
<td>16,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Agri-Tech Producers LLC (USA/SC)</td>
<td>Screw reactor</td>
<td>Allendale (USA/SC)</td>
<td>13,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Scheduled to be built</td>
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<td>Andritz (AT)</td>
<td>Rotary drum</td>
<td>Frohnlleiten (AT)</td>
<td>10,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Out-of-service</td>
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<tr>
<td>Andritz (DK) / ECN (NL)</td>
<td>Moving bed</td>
<td>Stenderup (DK)</td>
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<td>Demonstration scale</td>
<td>Yes</td>
<td>Unknown</td>
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<tr>
<td>BioEndev (SWE)</td>
<td>Dedicated screw reactor</td>
<td>Holmsund, Umea (SWE)</td>
<td>16,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Available (2015)</td>
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<tr>
<td>CMI NESA (BE)</td>
<td>Multiple hearth</td>
<td>Seraing (BE)</td>
<td>Undefined</td>
<td>Demonstration scale</td>
<td>Unknown</td>
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<td>Earth Care Products (USA)</td>
<td>Rotary drum</td>
<td>Independence (USA/KS)</td>
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<td>Demonstration scale</td>
<td>Available/operational</td>
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<tr>
<td>Grupo Lantecc (SP)</td>
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<td>Urnieta (SP)</td>
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<td>Integro Earth Fuels, LLC (USA)</td>
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<td>Mazingarbe (FR)</td>
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<td>Undefined</td>
<td>Laramie (USA/WY)</td>
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<td>Available/operational</td>
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<td>Teal Sales Inc (USA)</td>
<td>Rotary drum</td>
<td>White Castle (USA/LA)</td>
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<td>Available/operational</td>
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<td>Torrec (FI)</td>
<td>Moving bed</td>
<td>Mikkeli (FI)</td>
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<td>Demonstration scale</td>
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<tr>
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<td>Pilot stage</td>
<td>Available/operational</td>
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<td>Undefined</td>
<td>Pilot stage</td>
<td>Available/operational</td>
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<tr>
<td>CENER (SP)</td>
<td>Rotary drum</td>
<td>Aoiz (SP)</td>
<td>Undefined</td>
<td>Pilot scale</td>
<td>Available/operational</td>
<td>Unknown</td>
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<tr>
<td>Terra Green Energy (USA)</td>
<td>Multiple hearth</td>
<td>McKean County (USA/PA)</td>
<td>Undefined</td>
<td>Pilot scale</td>
<td>Available/operational</td>
<td>Unknown</td>
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<td>Wyssmont (USA)</td>
<td>Multiple hearth</td>
<td>Fort Lee (USA/NJ)</td>
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<td>Pilot scale</td>
<td>Unknown</td>
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<td>CEA (FR)</td>
<td>Multiple hearth</td>
<td>Paris (FR)</td>
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<td>Available/operational</td>
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<td>Rotawave, Ltd. (UK)</td>
<td>Microwave</td>
<td>Chester (UK)</td>
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<td>Nova Scotia (CAN/NS)</td>
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</tbody>
</table>

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Current situation - research
Restrictions

Top-3 restrictions (nr of responds, yes, no)

- Lack policy measures
- Standardization
- Neg percept by end-users

[Bar chart showing the distribution of responses for each restriction]
Policy measures

Primary instruments
- Innovation subsidy
- Renewable energy subsidy

Cost recovery gap
- Price parity with coal (fuel, CO\textsubscript{2})
- Competition with wood pellets

Fuel price affects marginal costs significantly
Standardization

- Necessity for trading
- Quality specification
- REACH
- MSDS
- Sustainability (GHG)
### Negative perception by end-users

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Co-firing</td>
<td>New initiatives</td>
<td>IBTC</td>
</tr>
<tr>
<td>commercial</td>
<td>Demo-scale</td>
<td>Product quality</td>
</tr>
<tr>
<td>Lab scale (ECN)</td>
<td>Huge claims</td>
<td>Availability</td>
</tr>
<tr>
<td>Promising results</td>
<td>Financial crisis</td>
<td>Off-take contracts</td>
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<tr>
<td></td>
<td>Focus on torrefaction</td>
<td>Wood pellet market</td>
</tr>
<tr>
<td></td>
<td>Process control</td>
<td>chicken and egg</td>
</tr>
</tbody>
</table>

**IBTC**
- Product quality
- Availability
- Off-take contracts
- Wood pellet market
Enablers

Top-3 enablers (nr of responds, yes, no)

- Production scale up
- Win end-users confidence
- Lower product price
Production scale up

Demand

600 MWe coal plant
10% co-firing
6000 eoh

150 ktons/y
torrefied pellets

Production

Demo plant
25-40 ktons/y
Partly utilized

Global production capacity
< 150 ktons/y

Wood pellets
50-200 ktons/y per facility

Picture of balance: openclipart, designer Enhy
Win end-users confidence

- Identify (niche) markets: developing the chain
- Realistic promises
- Quality assurance
- Health and safety (pros and cons)
- Tradability & standardization
Bring down price

Price comparable with wood pellets, what should be feasible?

Commercial (target) price in USD/GJ

<table>
<thead>
<tr>
<th></th>
<th>Wood pellets</th>
<th>Torrefied pellets</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of biomass</td>
<td>4,28</td>
<td>4,28</td>
<td>0,00</td>
</tr>
<tr>
<td>Cost of electricity</td>
<td>0,60</td>
<td>0,74</td>
<td>0,14</td>
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<tr>
<td>Cost of labor</td>
<td>0,47</td>
<td>0,47</td>
<td>0,00</td>
</tr>
<tr>
<td>Financial costs</td>
<td>1,01</td>
<td>1,49</td>
<td>0,48</td>
</tr>
<tr>
<td>Other costs</td>
<td>0,40</td>
<td>0,43</td>
<td>0,03</td>
</tr>
<tr>
<td>Cost price at production site</td>
<td>6,76</td>
<td>7,41</td>
<td>0,65</td>
</tr>
<tr>
<td>Inland logistics from the plant to the port</td>
<td>1,12</td>
<td>0,57</td>
<td>-0,55</td>
</tr>
<tr>
<td>Deep sea shipment</td>
<td>2,04</td>
<td>1,28</td>
<td>-0,76</td>
</tr>
<tr>
<td>Cost price delivery harbor</td>
<td>9,92</td>
<td>9,26</td>
<td>-0,66</td>
</tr>
</tbody>
</table>

Breaking chicken-egg problem

- Specific offset markets (e.g. energy, (steel)industry, bio-economy)
- Develop the chain
- Alternative feedstock types

Example (in development):
Arsari bio-based economy project REBUILD
Kalimantan, Indonesia
JV of
- Arsari Enviro Industri, and
- A.Hak Renewable Energy
Torrefaction technology supplier
- Torr-Coal International

Figure: The Torr-Coal plant in Dilsen-Stokkem (Belgium). Courtesy Torr-Coal

https://www.youtube.com/watch?v=srq6ox2wk
Implications on international trade

Michael Wild
President, International Biomass Torrefaction Council
Products available today

Source: Andritz AG
## Torrefaction Implementation Indicator

<table>
<thead>
<tr>
<th>Torr-gas Handling and Utilisation</th>
<th>done</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous torrefaction</td>
<td>done</td>
</tr>
<tr>
<td>Predictability and consistency of product</td>
<td>for many raw materials</td>
</tr>
<tr>
<td>Densification</td>
<td>mostly done</td>
</tr>
<tr>
<td>Feedstock flexibility</td>
<td>mostly 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 close</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>mostly open</td>
</tr>
<tr>
<td>Heat application trials</td>
<td>in progress</td>
</tr>
<tr>
<td>Further industrial applications trials</td>
<td>open</td>
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</tbody>
</table>
Conditions for trade

- Will character of torrefied fuel permit using existing logistical infrastructure?
- Is there proof of non hazardousness or are special safety measures to be advised?
- How about standardization and trading documents?
- Is there demand?
  - Where is torrefied biomass a proven fuel
  - Where are reasonable potentials seen
Water uptake

ACB - Weather test prelim. results briquettes

Method:
Briquettes (D=70mm, spruce, production 10.04)
filled in a box of 1,4 m height
and been stored outside

After 43 days of storage box
has been dismantled and
briquette quality evaluated

21 rainfalls have been documented during storage time,
3 rainfalls with > 20 mm/m²

<table>
<thead>
<tr>
<th>Sample</th>
<th>Diameter [mm]</th>
<th>TG [%]</th>
<th>DS [%]</th>
<th>Water uptake [%]</th>
<th>Durability [%]</th>
<th>Density [kg/dm³]</th>
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</thead>
<tbody>
<tr>
<td>Original Sample</td>
<td>71</td>
<td>25</td>
<td>97</td>
<td>2</td>
<td>96</td>
<td>1,14</td>
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<tr>
<td>Sample 1</td>
<td>71</td>
<td>25</td>
<td>92</td>
<td>1</td>
<td>84</td>
<td>1,14</td>
</tr>
<tr>
<td>Sample 2</td>
<td>71</td>
<td>25</td>
<td>93</td>
<td>1</td>
<td>91</td>
<td>1,16</td>
</tr>
</tbody>
</table>
Small-scale outdoor storage

• High pellet durability essential for improved weather resistance in time
• Slight degradation outer surface; inner content pile intact

Source: SECTOR, ECN
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

Minimum Ignition Energy (MIE)

Pulverised torrefied pellets vs. pulverised raw biomass chips (ind. off)

- 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

Leaching/Eluation, Ecotoxicity

BET Surface is reduced

Daphnientests >1/8 dilution of Eluate below the analytical limit of determination

Proof of non toxic character of leaching water against fish
DIN 38412-31
Quality - Standardisation

- **ISO 17225:** Solid biofuels – Fuel specifications and classes Part 8: Graded thermally treated and densified biomass fuels

**Technical Specification release expected in Q4 2016**

**Different Classes** (NCV, Durability, Bulk Density, Volatile Matter etc.)

**Parameters yet to be defined:**
- Grindability
- Water resistance
- Energy balance
Broadening Feedstock Basis

- ISO 17225 TS does define product classes derived from **wood** and product classes from **non woody** biomass

- Torrefaction is clearly seen as **door opener** to the use of by-products from a wide range of agro food industries or/and feedstock from energy plantation such as grasses, fast growing

- By this torrefaction is **addressing the key cost component** in a bioenergy value chain, the feedstock costs and can bring this down substantially.

- This can also be the starting point for **new value chains** into Chemical Industry, torrefaction forming first part of raw material processing into high value product lines
MSDS with SECTOR

REACH

Substance Information
Exchange Forum “SIEF”

IMO 4.1&4.2 testing negativ
(no need to be classified as flammable solid material or as a self heating substance)

All testing to date results in: equal or superior to wood pellets
GHG Comparison

Source: D. Thrän, DBFZ
Successfull large scale co-firing test proves benefits of Topell Energy’s torrefied pellets

**Background on co-firing test**
- Successful large scale co-firing test in Q4 2013
- Partners included ECN and utility companies RWE/Essent, Vattenfall/Nuon and GDF SUEZ
- Total of 2,300 tons were co-fired at a 5% - 25% co-firing rate(1) at the Amer power plant of RWE/Essent in the Netherlands

**Test results**
- Confirmation of superior characteristics of torrefied pellets
- No adverse effect on milling and combustion detected
- Low dust formation
- Torrefied biomass can replace coal in power plants

**NUON/Vattenfall Buggenum experience**
- Maximum 70% co-gasification on energy basis achieved at 90% nominal load without major modifications
- 1200 tons of torrefied pellets during 24 hours trial
- Observations:
  - Relatively low durability led to significant dust formation
  - Low durability disadvantageous during outdoor storage
  - Low Minimum Ignition Energy (MIE)
- ECN conducted lab-scale test programme to characterise pellets and provided consultancy to mitigate risks during commercial operation

**RWE/Essent AMLR-9 experience**
- Consortium: Topell, Essent, NUON, GDF Suez, ECN as part of Dutch TKI Pre-treatment Project
- Maximum 25 wt% co-milling on weight basis; 5 wt% co-firing
- 2300 tons of Topell torrefied pellets during November & December ‘13
- Observations: No significant issues
- ECN conducted lab-scale characterisation of pellets and provided consultancy to mitigate risks during commercial operation

**Source:** Press release Topell/Essent, Feb ‘14

**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

**Source:** ECN
## Non Power Applications

### Steel Industry
- Replacement of coking coal
- Pulverized coal
- Fossil fuels

### Chemical/Petro-chemical
- Gasification
- Chemicals from Biomass

### Pulp&Paper
- Use in lime sludge kilns
- Coal substitute for Energy

### Non Metallic Minerals
- Substitution of conventional fuels in kilns

### Heating
- District heating
- Commercial heating & process heat
## Non Power Applications by Sector

<table>
<thead>
<tr>
<th>Industries</th>
<th>Biomass use as of 2012 and percentage of total consumption</th>
<th>Prediction for 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biomass</td>
<td>Torrefied biomass</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>0.15 EJ (1%)</td>
<td>2.0 %</td>
</tr>
<tr>
<td>Chemical and petrochemical</td>
<td>0.06 EJ (1%)</td>
<td>1.5 %</td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>2.20 EJ (36%)</td>
<td>38–40 %</td>
</tr>
<tr>
<td>Non-metallic minerals (glass, ceramic, cement)</td>
<td>0.40 EJ (2%)</td>
<td>3.0–3.5 %</td>
</tr>
<tr>
<td>Transport equipment and fabricated metal products, machinery and equipment</td>
<td>0 PJ (0%)</td>
<td>0.1 %</td>
</tr>
<tr>
<td>Total</td>
<td>2.80 EJ (0.7 %)</td>
<td>30 %</td>
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## Non Power Applications by Region

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<tr>
<th>Region</th>
<th>Current industrial biomass use and proportion of the total biomass consumption for energy (IEA)</th>
<th>Prediction of consumption by industry in 2025</th>
<th>Most attractive industries for torrefied-biomass use</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU-28</td>
<td>1 EJ (9%)</td>
<td>13%</td>
<td>5−10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pulp and paper, non-metallic minerals</td>
</tr>
<tr>
<td>Africa</td>
<td>0.8 EJ (32%)</td>
<td>35%</td>
<td>Low</td>
</tr>
<tr>
<td>Asia</td>
<td>2 EJ (5%)</td>
<td>7%</td>
<td>0.5−1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iron and steel, pulp and paper</td>
</tr>
<tr>
<td>Canada</td>
<td>0.3 EJ (10%)</td>
<td>13%</td>
<td>2−3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pulp and paper, non-metallic minerals</td>
</tr>
<tr>
<td>US</td>
<td>1 EJ (11%)</td>
<td>14%</td>
<td>2−3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-metallic minerals, pulp and paper</td>
</tr>
<tr>
<td>Australia</td>
<td>0.1 EJ (11%)</td>
<td>15%</td>
<td>1−2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pulp and paper</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.5 EJ (42%)</td>
<td>43%</td>
<td>1−1.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Iron and steel, pulp and paper, non-metallic minerals</td>
</tr>
<tr>
<td>Japan</td>
<td>0.1 EJ (3%)</td>
<td>3.5%</td>
<td>0.5−1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-metallic minerals, pulp and paper</td>
</tr>
</tbody>
</table>
Where we are today

- Quality defined ISO TS
- Handling & Storage advantage in logistics verified
- Cost reductions shown
- Acceptability and advantages in co-firing verified by utilities
- Other industrial applications in testing
- Non Woody Biomass successfully tested
- Tradable product is available
- Several technologies, More than 1 producer
- Final prices to be calculated on basis of offtake, but surely competitive
Download the Reports

Download from:
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www.ieabioenergytask32.com

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IEA Bioenergy

Low Cost, Long Distance Supply Chains
Questions?
Thank you for your attention

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