Economic Comparison of Torrefaction-Based and Conventional Pellet Production-to-End-Use Chains

Rita Ehrig
Helmut Gugler, Christa Kristöfel, Christian Pointner, Irene Schmutzer-Roseneder, Sabine Feldmeier, Matthias Kolck, Peter Rauch, Christoph Strasser, Fabian Schipfer, Lukas Kranzl, Manfred Wörgetter

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### Objective and reference supply chains

- **Objective**: Comparing processing parameters and costs of wood pellet and torrefied pellet supply chains

- Reference supply chains for wood pellets:

<table>
<thead>
<tr>
<th></th>
<th>Premium pellets</th>
<th>Industrial pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Maderthaner (2012), Obernberger &amp; Thek (2010))</td>
<td>(Ehrig et al. (2013))</td>
</tr>
<tr>
<td><strong>Regional supply</strong></td>
<td>Intracontinental supply</td>
<td>Long-distance intracontinental supply</td>
</tr>
<tr>
<td></td>
<td>(Austria)</td>
<td>(Eastern Europe to Central Europe)</td>
</tr>
<tr>
<td><strong>Long-distance intracontinental supply</strong></td>
<td>Intercontinental supply</td>
<td>(NW Russia to NW Europe)</td>
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<tr>
<td></td>
<td></td>
<td>(Western Canada to NW Europe)</td>
</tr>
<tr>
<td><strong>Raw material</strong></td>
<td>Sawmill residues, 36 – 55 % mc</td>
<td></td>
</tr>
<tr>
<td><strong>(Torrefaction &amp; Pelletisation</strong></td>
<td>40,000 t/a plant capacity</td>
<td>40,000 t/a plant capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120,000 t/a plant capacity</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>50 km by truck</td>
<td>400 km by train + 1,600 km by ship</td>
</tr>
<tr>
<td></td>
<td>800 km by train</td>
<td>500 km by train + 16,500 km by ship</td>
</tr>
<tr>
<td><strong>Distribution</strong></td>
<td>50 km by truck</td>
<td>75 km by train or truck</td>
</tr>
<tr>
<td><strong>End-use</strong></td>
<td>Small-scale pellets boiler</td>
<td>Coal co-firing plant</td>
</tr>
<tr>
<td></td>
<td>(19 kW&lt;sub&gt;th&lt;/sub&gt;, 79 % efficiency)</td>
<td>(800 MW&lt;sub&gt;el&lt;/sub&gt;, 46 % efficiency)</td>
</tr>
</tbody>
</table>

- Torrefaction relevant input data (fuel, processing & costs) generated in TorrChance project
Fuels tested at Bioenergy 2020+

- Sample A
  - Raw material: spruce, torrefied in Europe
  - Pelletised in laboratory pellet press by Bioenergy2020+

- Sample B
  - Raw material: biomass from bark and branches (from landscape maintenance), torrefied
  - Available from European market

- Sample C
  - Raw material: spruce (reference)

Source: BIOENERGY2020+, March 2013
Fuel properties of torrefied biomass

- Torrefied pellets (Schmutzer-Roseneder, 2013; Wojcik, 2013): maximum 10 % increased net calorific value

<table>
<thead>
<tr>
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<th>Reference values for wood pellets</th>
<th>Corresponding values for torrefied pellets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net calorific value</td>
<td>17.7 GJ/t (4.9 MWh/t)</td>
<td>19.6 GJ/t (5.4 MWh/t)</td>
</tr>
<tr>
<td>Moisture content</td>
<td>6 % mc</td>
<td>&lt; 4 % mc</td>
</tr>
<tr>
<td>Bulk density</td>
<td>650 kg/m³</td>
<td>705 kg/m³</td>
</tr>
</tbody>
</table>

- Mechanical durability of torrefied pellets is lower and fines are more compared to wood pellets

- Quality of torrefied biomass depends on quality of originary raw material
Pelletising tests with torrefied biomass in laboratory pelletising press (BIOENERGY2020+)

- Lower energy demand for grinding
- Pelletising process is much more difficult (water input, high temperatures, bonding mechanisms, retention time, dust)
- Pelletising requires more energy input
- Results comply with published papers: Stelte et.al. 2012; Larsson et al. 2012

Amandus Kahl pellet press, Type 14-175

Source: BIOENERGY2020+
## Costs for torrefaction & pelletising

<table>
<thead>
<tr>
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<th>Combined Torrefaction and Pelletising plant</th>
</tr>
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<tbody>
<tr>
<td>Production capacity</td>
<td>40,000 t/a</td>
</tr>
<tr>
<td>Investment costs</td>
<td>11.4 mio € +/- 20 %</td>
</tr>
<tr>
<td></td>
<td>And upscales with branch typical factors</td>
</tr>
<tr>
<td>Technology</td>
<td>Combined belt dryer, rotating drum reactor, heat generator, hammermill, pellet ring die</td>
</tr>
<tr>
<td>Internal heat recovery from torrefaction gas</td>
<td>2.7 MW depending on torrefaction degree</td>
</tr>
<tr>
<td>Input-output mass ratio</td>
<td>1.2:1</td>
</tr>
</tbody>
</table>

- Cost account based on manufacturing of pyrolysis plant in Austria & other conversion plants & literature
- Cost level confirmed by operator of existing torrefaction demonstration plant
Storage tests
Test design

Storage of 4 t torrefied pellets (B) over a 4 month period (01/2013 – 04/2013) in Austria

Torrefied pellets, Jan. 2013

Picture after 1 month, Feb 2013

Storage pile at test beginning, Jan. 2013

Pile after 3 months storage, April 2013

Source of all pictures: BIOENERGY2020+
Storage tests
Results after 1 month

Sample from pile surface

Sample from inside the pile
Transport & logistics

Conclusions:

■ Suppliers will use the same logistic and transport means as for wood pellets (confirmed by biofuel trader)

■ Supply costs are slightly reduced (9 %) by higher bulk density (for train and ship)

■ Supply costs can be decreased approximately 10 % by higher energy density
Combustion tests in small-scale pellet boiler

- Combustion tests in 15 kW\textsubscript{th} pellet boiler
- Combustion of torrefied pellets in small-scale pellet boiler is possible
- Combustion behaviour depends on raw material origin
- Necessary adaptations in control system
  - No additional costs expected for firing torrefied pellets in domestic appliances
  - In large-scale coal plants no adaptations necessary

Exemplary pellet boiler (Source: KWB – Kraft und Wärme aus Biomasse GmbH)
Results of cost assessment
Production of wood pellets vs. torrefied pellets

Production costs of pellets and torrefied pellets in €/GJ

- Pellets
- Torrefied pellets
- Pellets
- Torrefied pellets
- Pellets
- Torrefied pellets
- Pellets
- Torrefied pellets

- Regional chain Austria
- Eastern Europe
- North-West Russia
- Western Canada

Legend:
- Operation & Maintenance
- Other costs
- Personnel costs
- Other production costs
- Raw material
- Heat costs
- Electricity costs
- Capital costs
Results of cost assessment
Logistics & transport

Transport and logistic costs in €/GJ

- Other trade costs
- Transport 3
- Transshipment import harbour
- Transport 2
- Transshipment
- Storage
- Transport 1

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<td>Pellets</td>
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<tr>
<td>Torrefied pellets</td>
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<td></td>
</tr>
<tr>
<td>Regional chain Austria (50+50 km truck)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern to Western Europe (800 km train, 50 km truck)</td>
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<td>North-West Russia to NW Europe (400 km train, 1600 km ship, 75 km train)</td>
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<td>Western Canada to NW Europe (500 km train, 16500 km ship, 75 km train)</td>
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Results of cost assessment
Pellets and torrefied pellets delivered at end-user

Total supply costs to end-user in €/GJ

- Pellets: Regional chain Austria (50+50 km truck)
- Torrefied pellets: Eastern to Western Europe (800 km train, 50 km truck)
- Pellets: North-West Russia to NW Europe (400 km train, 1600 km ship, 75 km train)
- Torrefied pellets: Western Canada to NW Europe (500 km train, 16500 km ship, 75 km train)

Cost components:
- Total costs of pellets transport & logistics
- Operation & Maintenance
- Other costs
- Personnel costs
- Other production costs
- Raw material
- Heat costs
- Electricity costs
- Capital costs
Results of cost assessment

Heat production in small-scale pellet boiler

Heat production costs in small-scale pellet boiler

€/Cent/kWh

Pellets | Torrefied pellets | Pellets | Torrefied pellets
Regional chain | Eastern European pellets used in Central Europe

- Capital costs
- Other costs
- Operation % maintenance costs
- Other consumption costs
- Fuel costs
Results of cost assessment: Electricity production in coal co-firing plant

Electricity production costs for 10% co-firing in a coal power plant

- Pellets: Origin Northwest Russian for use in NW Europe
- Torrefied pellets: Origin West Canada for use in NW Europe

Cost components:
- CO2 allowances
- Additional O&M costs due to co-firing
- O&M costs
- Fuel costs: (torrefied) pellets
- Fuel costs: coal
- Capital costs
Conclusions

- From the current state-of-the-art, torrefaction can be a certain alternative to conventional wood pellets, but:
  - Pretreatment process is much more expensive
  - Cost benefits may arise in long-distance transportation
  - Still more R&D and investigations required:
    - Increase of net calorific value
    - Durability & hydrophobicity of torrefied biomass
    - Profitability of torrefaction plants in operation
    - Densification (feasability, safety, energy demand)
    - Use & availability of biomass residues
Contact information

Rita Ehrig

BIOENERGY 2020+ GmbH, Location Wieselburg Gewerbepark Haag 3, 3250 Wieselburg-Land
Tel: +43 7416 52238-52
Fax: +43 7416 52238-99
rita.ehrig@bioenergy2020.eu
www.bioenergy2020.eu

More results will be published at Central European Biomass Conference 2014 (t.b.c.)

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