Handling and storage of torrefied biomass pellets

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June 2016
ECN-L--16-036
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World Biomass Power Markets
Amsterdam, 19th of February 2015
Main biomass R&D areas

- **Upgrading: Biomass to commodity fuel**
  - Torrefaction: ECN technology available on full scale
  - New technology for torrefaction of wet biomass: TORWASH

- **Combustion: Biomass boilers and co-firing**
  - Fuel behavior during combustion & gasification
  - Ashes, slagging, agglomeration behavior

- **Gasification: Production of power or fuels**
  - Gasification technology: MILENA
  - Tar removal and product synthesis
  - Test equipment and expertise to provide services

- **Biorefinery: Technology for a biobased economy**
  - Organosolv fractionation into cellulose, hemicellulose, and lignin
  - Conversion of fractions into marketable products
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 demonstration scale; Andritz ready for market introduction

- Contract R&D for industry to assess the torrefaction potential of specific feedstocks, produce test batches and optimise product quality
Torrefaction – Observations

- Often proven reactor technologies in other applications (e.g. drying, pyrolysis, combustion)
- Good process control is essential for good performance and product quality control (temperature, residence time, mixing, condensables in torrefaction gas)
- High energy efficiency is crucial in view of overall cost and sustainability; strongly depends on heat integration design
- 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 required (e.g. die dimensions)
  - Good control of torrefaction conditions is essential
  - Without binder, window for tuning product quality to logistics and end-use requirements can be small
  - Special attention to safety issues (e.g. self heating, dust explosions)
Technology licensed to Andritz

- **Industrial demo plant in Sønder Stenderup, Denmark**
  - Operational since 2012
  - Capacity 1 ton/hour torrefied pellets

- **Strong combination of industry and R&D**
Torrefaction demo plant

- Demo plant comprises pre-drying, torrefaction and pelletisation
- Blends ECN and Andritz technologies
- Torrefaction pressurized for more effective heat transfer, reduction of equipment sizes
- Torrefaction reactor contains separate zones for final drying and torrefaction
- Torrefaction reactor design suitable to scale up to large single unit capacities
- All individual equipment units built at large-scale
Torrefaction demo plant
Experience and outlook

• Development of dedicated torrefaction and densification recipes:
  – Demo plant: eucalyptus, beech, spruce, pine, poplar, mixed woods, etc.
  – Lab- and pilot plants: many different wood species and mixed woods, bamboo, PKS, EFB, OPF, miscanthus, etc.

• Tailor torrefied products to meet end-user requirements:
  – ECN in-house characterization
  – Logistics, storage and safety
  – Grindability, pneumatic feeding and conversion
Mapping torrefied biomass pellet characteristics
Why torrefaction?

- Annual costs excluding fuel costs white wood pellets vs. torrefied wood pellets in different co-firing scenarios
Purchasing power

- Torrefied wood pellets particularly interesting to establish increased co-firing ratios at power plants w/o co-firing (or at existing low % capabilities)

<table>
<thead>
<tr>
<th></th>
<th>10% co-firing</th>
<th>30% co-firing</th>
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</thead>
<tbody>
<tr>
<td>Annual cost difference: white wood pellets</td>
<td>M€/y</td>
<td>1.86</td>
</tr>
<tr>
<td>minus torrefied wood pellets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pellets used</td>
<td>PJ/y</td>
<td>2.16</td>
</tr>
<tr>
<td>Acceptable price difference for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>torrefied wood pellets</td>
<td>€/GJ</td>
<td>0.86</td>
</tr>
<tr>
<td>Case 1: price difference at higher rate of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>return (12% → 15%)</td>
<td>€/GJ</td>
<td>1.08</td>
</tr>
<tr>
<td>Case 2: price difference at reduction of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>economic lifetime from 10 to 5 years</td>
<td>€/GJ</td>
<td>1.24</td>
</tr>
</tbody>
</table>
Small-scale outdoor storage (1)

- Ongoing experiments simulating pile surface
- Durability determined at set intervals
- Detailed monitoring weather conditions
Small-scale outdoor storage (2)

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

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
Durability and explosivity

• Durability (EN 15210)
  – Andritz/ECN demo pellets typically 96.5-98.0%

• Minimum ignition energy
  – Torrefied pellets were pulverised using disc impaction mill to replicate commercial roller mill
  – Fraction below 63 µm used in accordance with EN 13821
  – Andritz/ECN demo pellets have MIE’s within 30-100 mJ range, both with and without inductance
Minimum Ignition Energy (MIE)

- Pulverised torrefied pellets vs. pulverised raw biomass chips (ind. off)
  - Clear link MIE torrefied pellets with MIE raw material
  - Native dust has high MIE’s
  - Dust from handling low durability pellets (< 93%) is more ignitable → always aim for high pellet durability
  - Same high pellet durability: handling dust from torrefied wood pellets is equally ignitable as white wood pellets
Minimum Explosible Concentration (MEC)

- Pulverised torrefied pellets vs. pulverised raw biomass chips
  - Concentrations corrected using high-speed camera
  - No differences between raw chips and torrefied pellets
• Torrefied pellets vs. raw biomass chips

- Lower average flame front velocity at higher equivalence ratios for pulverised torrefied pellets → reduced severity explosion
Fuel morphology after milling (1)

- Glass beads:

- Coal:
Fuel morphology after milling (2)

- Raw spruce:

- Torrefied spruce chips:
Fuel morphology after milling (3)

- Torrefied spruce pellets
  Andritz/ECN demo:
  - Particle “sphericity” pulverised torrefied wood pellets comparable to pulverised coal

- Coal:
Pneumatic lean-phase transport (1)

- Fluidization tests to assess flowability
- Bulk densities of pulverised torrefied pellets typically between 450-600 kg/m$^3$
- Bulk densities between 550-600 kg/m$^3$ display fluidization behavior similar to coal
- Setup used to determine solids loading/entrainment during dense/lean phase feeding
Pneumatic lean-phase transport (2)

- Mass loading of pulverised torrefied pellets comparable with coal
- Increased gas velocities needed for pulverised white wood pellets → increased risk of saltation
Experience with torrefied biomass at industrial scale
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:
  - 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

* Source: N. Padban, Central European Biomass Conference, Jan ’14, Graz
RWE/Essent AMER-9 experience*

- Consortium of Topell, Essent, NUON, GdF Suez and 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
RWE/Essent AMER-9 experience
DONG Studstrup-3 experience

- Two units with total capacity of 714 MWₑ and 986 MWₜₗₜ
- 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
DONG Studstrup-3 experience
Upgrading of herbaceous biomass
Biomass feedstocks for thermal conversion

- Directly suitable as feedstock
- Requires pre-treatment, e.g. TORWASH

- Waste
- Wood
- (Agricultural) residues
- Energy corps
- Aquatic biomass
Combination of washing and torrefaction

- Torrefaction + Washing = TORWASH
  - upgrades low-grade feedstock into a commodity feedstock

- Combines advantages and eliminates disadvantages
  - Torrefaction
  - Salt removal
  - Dewatering

- Aim: maximum energy content and low mineral content in the solid phase
- Product: high value fuel as powder, pellets or briquettes
- By-product: biogas from fermentation of liquid residue
TORWASH Example: Arundo Donax (1)
TORWASH Example: Arundo Donax (2)

Presence of mass, energy, ash content and elements as function of feedstock, after pre-wash (red) and TORWASH (green)
## TORWASH Example: Arundo Donax (3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>EN plus A1</th>
<th>Wood pellets</th>
<th>Reed raw</th>
<th>Reed torwashed</th>
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<tbody>
<tr>
<td>Additives</td>
<td>wt% ar</td>
<td>0</td>
<td>none</td>
<td>none</td>
<td>none</td>
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<tr>
<td>Water</td>
<td>wt% ar</td>
<td>≤ 10%</td>
<td>8.3%</td>
<td>variable</td>
<td>7%</td>
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<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>≥ 600</td>
<td>636</td>
<td>-</td>
<td>ND</td>
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<tr>
<td>NCV</td>
<td>GJ/ton ar</td>
<td>≥ 16.5</td>
<td>18.6</td>
<td>17.9</td>
<td>20.6</td>
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<tr>
<td>ash</td>
<td>wt% DM</td>
<td>≤ 0.7%</td>
<td>0.3%</td>
<td>2.3%</td>
<td>0.6%</td>
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<tr>
<td>Cl</td>
<td>wt% DM</td>
<td>≤ 0.020%</td>
<td>0.012%</td>
<td>0.227%</td>
<td>0.005%</td>
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<tr>
<td>K</td>
<td>mg/kg DM</td>
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<td>380</td>
<td>4924</td>
<td>116</td>
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Thank you for your attention

Financial support of the European Union through the SECTOR and LogistEC projects is gratefully acknowledged.

Financial support of the Dutch Government through RVO within the framework of the TKI –BBE project Pre-treatment/INVENT is gratefully acknowledged.

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