Outlook on Biomass Pellet Market & Biomass Processing Technologies

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Your energy. Our passion.

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Content

• Introduction ECN
• Biomass Demand of Northwest Europe
• ECN’s Biomass Technologies
  – Biomass Upgrading
  – Biomass Gasification (Combustion)
  – Biomass Refinery
Mission

With and for the market, we develop **Knowledge** and **Technology** that enable a transition to a sustainable energy system.
Our Position

- Universities
- Industrial partners

- fundamental research
- applied research
- industrial development

Independent connecting partners
R&D fields

Policy Studies

Biomass

Solar Energy

Wind Energy

Energy Efficiency

Energy Engineering

Environment
Demand for Lignocellulosic Biomass of Northwest Europe
Biomass demand & supply in The Netherlands

- Renewable energy target 2020 is 16%
  - Currently 4%
- Co-firing obligation expected

Demand and supply of lignocellulosic biomass
[Mt wood pellets eq / year]

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>BaU</td>
<td>BaU-BM</td>
<td>SNP</td>
</tr>
<tr>
<td>Demand</td>
<td>3.1</td>
<td>3.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Domestic</td>
<td>1.7</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Import EU</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Import non-EU</td>
<td>1.2</td>
<td>0.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>
## Biomass demand & supply in Northwest EU

### Demand and supply lignocellulosic biomass [Mt wood pellets eq / year]
- Belgium, Denmark, Netherlands, Germany, United Kingdom

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<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand</strong></td>
<td>BaU</td>
<td>BaU-BM</td>
<td>SNP</td>
</tr>
<tr>
<td>Domestic</td>
<td>45</td>
<td>67</td>
<td>78</td>
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<tr>
<td>Import EU</td>
<td>2.2</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Import non-EU</td>
<td>1.9</td>
<td>0.0</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Port of Rotterdam, Ric Hoefnagels et al
Wood pellet consumption per sector in 2010

Based on Chocchi et al
Biomass pellets import / export

Search for cheaper biomass
- High quality
- Fulfilling sustainability criteria
Biomass
Revolutionizing a Global Primary Energy Source
Making bioenergy work

Focus on thermochemical processing

Feedstock
- Characterization
- Property databases

Pre-treatment
- Torrefaction
- Torwash
- Pyrolysis
- Fractionation

Conversion
- Combustion
- Gasification
- Biorefinery

Separation
- Gas cleaning
- Tar removal
- Gas conditioning
- Separation

Product Synthesis
- Biofuels (incl. Synthetic Natural Gas (SNG))
- Biochemicals & materials
- Power & Heat

Higher efficiencies, higher availability, lower environmental impact, higher public acceptance, lower CAPEX/OPEX, new applications

Feasibility studies, techno-economic evaluations, LCA, sustainability assessments
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
  – Ashes, slags, agglomeration behavior

• **Gasification: Production of power or fuels**
  – Development of 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
Biomass Upgrading
Torrefaction

- Converting biomass into commodity fuel

**Torrefaction**

- Tough and fibrous
- LHV = 9 - 12 MJ/kg
- Hydrophilic
- Biodegradable
- Heterogeneous

**Pelletisation**

- Brittle and less fibrous
- LHV = 18 - 24 MJ/kg
- Hydrophobic
- Preserved
- Homogeneous

Bulk density 650-800 kg/m³
Bulk energy density = 12 - 19 GJ/m³
Torrefaction

Facilities & Services

• Torrefaction reactors
  – 5 kg/h screw reactor
  – Testing torrefaction for various biomass types
  – 50 - 100 kg/h pilot unit
  – Production of 1 to 10 tonne torrefied biomass pellets

• Knowledge and test-equipment on pelletisation

• Test quality of torrefied biomass for combustion and gasification

• Pyrolysis
  – Production of biochar
Torrefaction licensed to Andritz

- Industrial demo plant in Sønder Stenderup, Denmark
  - Operational since September 2012
  - Produces 1 tonne/hour black pellets
- Strong combination of industry and R&D
Biomass feedstocks for thermal conversion

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

- waste
- wood
- (agricultural) residues
- energy corps
- aquatic biomass
Sources of biomass fuels for TORWASH

- Difficult materials
  - too high water content
  - seasonal harvesting and bio-degradable
  - too high salt content
  - bulky material with low energy density
  - tenacious, springy materials

- Essentially, the growing parts of plants

- Some attractive but difficult feedstocks
  - grass, reeds, park maintenance
  - palm fronds, leaves of sugar cane
  - wet residues from food and agro industry, e.g. brewer’s grains and digestate
Combination of Washing and Torrefaction

Torrefaction + Washing = TORWASH

• Combines advantages and eliminates disadvantages
  – Torrefaction
  – Salt removal
  – Dewatering
• Aim: maximum energy recovery in the form of solid residues
• Product: torrefied fuel pellets with high added value or briquettes or powder
• By-product: biogas
Biomass Upgrading

ECN helps its customers to:
• Convert their biomass feedstock into an energy carrier
• Develop technology for torrefaction and Torwash

Customers

- Siemens
- Mitsubishi Heavy Industries, Ltd.
- Stora Enso
- UBE/UBE Industries, Ltd.
- Vattenfall
- Braskem
- Dieffenbacher
Biomass Gasification and Tar removal
MILENA Indirect Gasification

- Temperature level 850°C
- Product gas contains methane, ethylene, benzene, and tars
- Complete conversion of the fuel
- Carbon free ash
- High efficiency
- Very little nitrogen in producer gas
- Heat transfer through bed material
- One single vessel: compact design
- Fuel flexible
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>MILENA</th>
<th>CFB/BFB</th>
<th>Downdraft</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conversion</strong></td>
<td>100% / white ash</td>
<td>~90% / black ash</td>
<td>~90% / black ash</td>
</tr>
<tr>
<td><strong>Cold Gas Efficiency</strong></td>
<td>~80%</td>
<td>~70%</td>
<td>~70%</td>
</tr>
<tr>
<td><strong>Temperature control</strong></td>
<td>Good control, no char accumulation</td>
<td>Lower control ability due to char hold-up</td>
<td>Very heterogeneous</td>
</tr>
<tr>
<td><strong>Temperature versus Efficiency</strong></td>
<td>lower temperature = higher efficiency</td>
<td>lower temperature = lower conversion</td>
<td>lower temperature = lower conversion</td>
</tr>
<tr>
<td><strong>Fuel flexibility</strong></td>
<td>waste, agricultural residues any size</td>
<td>less freedom any size</td>
<td>woody only large chunks</td>
</tr>
<tr>
<td><strong>Gas</strong></td>
<td>12-15 MJ/Nm³ essentially N₂-free</td>
<td>5-6 MJ/Nm³ ~50% N₂</td>
<td>5-6 MJ/Nm³ ~50% N₂</td>
</tr>
<tr>
<td><strong>Scale</strong></td>
<td>Scalable (&gt;100 MW)</td>
<td>Scalable (&gt;100 MW)</td>
<td>Max. 1 MW</td>
</tr>
</tbody>
</table>
Tested feedstocks

- Clean Wood
- Demolition Wood
- Straw
- Soya stalk
- High-ash coal
- Lignite
- RDF
- Sunflower husks
Markets for MILENA gasifier

• Co-firing in coal boilers or gas turbines
  – Clean gas feeding to boiler or turbine
  – With Milena lower grade biomass or waste can be used, rather than the clean wood pellets needed for direct co-firing in boilers

• Combined heat and power
  – On-site conversion of waste to energy
  – In combination with gas engine or small gas turbine
  – Milena produces high calorific gas, not diluted with nitrogen

• Substitute Natural Gas production
  – High methane content of producer gas makes Milena very suitable for SNG production

• Production of fuels or chemicals
ECN OLGA gas cleaning

- Tar dew point 10°C
- Tar cleaning above water dew point
  - No mixing of water and oil

All tars recycled back to gasifier, i.e. no energy loss, no waste streams
Tondela, Portugal
Project in Development in Alkmaar, The Netherlands

- 12 MW$_{th}$ MILENA and OLGA producing green power
- Side stream SNG production, i.e. green methane
- Royal Dahlman will build the plant
- Currently detailed engineering
- FID in mid 2013
- Construction 2013/2014
- Start-up 2015
Biomass Gasification and Combustion Service and technology offering

• MILENA indirect gasifier: high efficiency, produces gas with high energy content
• OLGA tar removal technology and other solutions for tar removal
• Consultancy on biomass feeding, milling, gas cleaning, synthesis processes
• Any gasification/combustion process with any fuel can be investigated in one of our lab-scale simulators
• Tar, dust, aerosol, slagging and fouling analysis in the lab but also on-site
Biorefinery
Organosolv process

- Optimal valorization of lignocellulosic biomass
  - Lignin
  - Cellulose -> ethanol
  - Hemi-cellulose
- High-purity streams for direct use in downstream processes

Straw

Pre-organosolv

Post-organosolv
Organosolv process
fractionation into cellulose and lignin

Lignocellulosic biomass
Organic solvent
Water + catalyst

Organosolv

Solvent recycling

Cellulose
Lignin separation
Lignin (sulphur and ash free)

Solvent separation

Hemicellulose
Lignin valorization

- Potential feedstock for wide range of chemicals (aromatics!) and performance products.
- Valorization lignin improves carbon footprint & economics lignocellulose Biorefinery.

- No large-scale commercial market for lignin at the moment
Biorefinery and Processing

ECN helps its customers to

• Develop strategies and business cases to convert biomass into high-value products
• Develop technologies to convert raw biomass into fractions for further processing
• Optimize the value chain for seaweed and especially the synthesis of products from seaweed
Thank you for your attention and looking forward to cooperate with you on profitable biomass projects

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