Conversion of Biomass Over Steam Gasification to Biofuels and Chemicals - Actual Status of Work

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Team of R&D

- Scientific partners

- Engineering (as example)

- Operators (as example)
The basic concept – “Green Chemistry”

Biomass

Producer Gas
(gas engine, gas turbine, fuel cell)

Synthetic Natural Gas (SNG)

FT-Fuels
(FT-Diesel)

Synthesis gas
$\text{H}_2 + \text{CO}$

Biomass Gasification

Hydrogen

Mixed alkohols

Oxosynthesis for aldehydes

Isosynthesis for Isobutane

Methanol / DME

Ammonia

Over 50,000 hours
Biomass CHP Güssing

Gasifier
BioSNG PDU
Technikum
Fuelling Station
# Commercial FICFB gasifiers

<table>
<thead>
<tr>
<th>Location</th>
<th>Product</th>
<th>Fuel / Product MW, MW</th>
<th>Start up</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Güssing, AT</td>
<td>Gas engine</td>
<td>$8.0_{\text{fuel}} / 2.0_{\text{el}}$</td>
<td>2002</td>
<td>Operational</td>
</tr>
<tr>
<td>Oberwart, AT</td>
<td>Gas engine / ORC</td>
<td>$8.5_{\text{fuel}} / 2.8_{\text{el}}$</td>
<td>2008</td>
<td>Operational</td>
</tr>
<tr>
<td>Villach, AT</td>
<td>Gas engine</td>
<td>$15_{\text{fuel}} / 3.7_{\text{el}}$</td>
<td>2010</td>
<td>Commissioning</td>
</tr>
<tr>
<td>Klagenfurt, AT</td>
<td>Gas engine</td>
<td>$25_{\text{fuel}} / 5.5_{\text{el}}$</td>
<td>2011</td>
<td>planing</td>
</tr>
<tr>
<td>Ulm, DE</td>
<td>Gas engine / ORC</td>
<td>$14_{\text{fuel}} / 5_{\text{el}}$</td>
<td>2011</td>
<td>Under construction</td>
</tr>
<tr>
<td>Göteborg, Sweden</td>
<td>BioSNG</td>
<td>$32_{\text{fuel}} / 20_{\text{BioSNG}}$</td>
<td>2012</td>
<td>planing</td>
</tr>
<tr>
<td>Vienna, OMV</td>
<td>Hydrogen</td>
<td>$50_{\text{fuel}} / 30_{\text{hydrogen}}$</td>
<td>2015</td>
<td>planing</td>
</tr>
</tbody>
</table>
Gas Composition (after gas cleaning)

<table>
<thead>
<tr>
<th>Main Components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>CO</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>CH₄</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>CO₂</strong></td>
<td>%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Possible poisons</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂S</strong></td>
<td>mgS/Nm³</td>
</tr>
<tr>
<td><strong>COS</strong></td>
<td>mgS/Nm³</td>
</tr>
<tr>
<td><strong>Mercaptans</strong></td>
<td>mgS/Nm³</td>
</tr>
<tr>
<td><strong>Thiophens</strong></td>
<td>mgS/Nm³</td>
</tr>
<tr>
<td><strong>HCl</strong></td>
<td>ppm</td>
</tr>
<tr>
<td><strong>NH₃</strong></td>
<td>ppm</td>
</tr>
<tr>
<td><strong>HCN</strong></td>
<td>ppm</td>
</tr>
<tr>
<td><strong>Dust</strong></td>
<td>mg/Nm³</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minor Components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C₂H₄</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>C₂H₆</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>C₃H₄</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>O₂</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>N₂</strong></td>
<td>%</td>
</tr>
<tr>
<td><strong>C₆H₆</strong></td>
<td>g/m³</td>
</tr>
<tr>
<td><strong>C₇H₈</strong></td>
<td>g/m³</td>
</tr>
<tr>
<td><strong>C₁₀H₈</strong></td>
<td>g/m³</td>
</tr>
<tr>
<td><strong>TARS</strong></td>
<td>mg/m³</td>
</tr>
</tbody>
</table>

**H₂:CO = from 1.7:1 to 2:1**
BioSNG Demonstration Project

A 1 MW SNG Process Development Unit (PDU) is erected within the EU project BioSNG and allows the demonstration of the complete process chain from wood to SNG in half-commercial scale (2006-2009).

A consortium consisting of four partners is responsible for the PDU:
- CTU – Conzepte Technik Umwelt AG
- Repotec GmbH
- Paul Scherrer Institute
- Technical University Vienna

The project BioSNG is co-funded by
- the European Commission
- 6th Framework Programme
- PrNo TREN/05/FP6EN/
  S07.56632/019895
- Swiss electric research
- Bundesförderung Österreich
- WIBAG
Results

- December 2008: First conversion of product gas into rawSNG
- June 2009: BioSNG at H-Gas quality produced

- June 24th: inauguration – CNG cars were fuelled using BioSNG from wood
- June 2009 CNG-car was successfully used for 1000km with BioSNG
- No more activities since end of 2009
# Quality BioSNG

<table>
<thead>
<tr>
<th></th>
<th>unit</th>
<th>Germany DVGW regulation G260</th>
<th>Austria ÖVGW regulation G31</th>
<th>BioSNG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wobbe Index</strong></td>
<td>[kWh/m³]</td>
<td>12,8-15,7</td>
<td>13,3-15,7</td>
<td>14,15</td>
</tr>
<tr>
<td><strong>Relative density</strong></td>
<td>[-]</td>
<td>0,55-0,75</td>
<td>0,55-0,65</td>
<td>0,56</td>
</tr>
<tr>
<td><strong>Higher heating value</strong></td>
<td>[kWh/m³]</td>
<td>8,4-13,1</td>
<td>10,7-12,8</td>
<td>10,7</td>
</tr>
</tbody>
</table>
Synthetic biofuels (FT-Route)

- Cellulose, Polyose (Hemicellulose)
- Lignin

1. **Gasification**
   - Wood chips
   - Raw Syngas H2/CO = 1.5
   - Steam

2. **Cleaning/Conditioning**
   - Pure Syngas H2/CO = 2

3. **FT-Synthesis**
   - FT-wax
   - FT-fuels

4. **Hydro-(Co)-Processing**
   - Fossil products (e.g. LGO, HGO, VGO)
   - Purge Gas
   - Hydrogen (pure/recycled)
   - HPFT-Fuels

- i/n-paraffins (hydrocarbons)
- i/n-paraffins (hydrocarbons)
FT synthesis at biomass CHP Güssing
A Slurry-Reactor is used. A slurry reactor is a 3-phase reactor, where the solid catalyst is suspended in the liquid product and the gas goes from the bottom to the top and keeps the catalyst in suspension.

The main advantages are:
- Simple and cheap construction
- Excellent heat transfer
- No hot spots and no temperature gradient along the reactor
- Easy to scale up

The following catalysts were used till now:
- Haber Bosch catalyst (mainly for start up)
- Research catalyst (based on cobalt ruthenium, produced from University of Strasbourg)
- Commercial cobalt catalyst
- Commercial iron catalyst

Actual 1300 hours of operation, without any change in activity
FT dependency on temperature

FT (Fischer-Tropsch) reaction shows a decrease in CO conversion and an increase in alpha with increasing temperature. The blue bars represent CO conversion in percentage, while the red line indicates the alpha value. At 230°C, CO conversion is higher, but alpha is lower compared to 240°C, where the CO conversion is lower, but alpha is higher.
FT dependency on pressure

CO Conv. Prod.%  alpha

pressure [bar]

16 20 24
FT dependency on space velocity
Comparison of produced FT Fuels

<table>
<thead>
<tr>
<th></th>
<th>FT- Diesel</th>
<th>HPFT- Diesel</th>
<th>CEC- Prüf.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACN:</td>
<td>&gt;72</td>
<td>68.5</td>
<td>&gt;51.8</td>
</tr>
<tr>
<td>CFPP/CP/FP:</td>
<td>-12/-9/-9°C</td>
<td>-62/-60/-98°C</td>
<td>-18/-5°C</td>
</tr>
</tbody>
</table>

Carbon-number fraction [%wt]

- i-paraff/res. (FT)
- n-paraff. (FT)
- i-paraff/res. (HPFT)
- n-paraff. (HPFT)
- i-paraff. /res. CEC- Prüf DK
- n-paraff. CEC- Prüf- DK
Results on engine tests with 20% blends

- Verbr. gr.
- CO2
- HC
- CO
- NOx
- FSN
- PA

Vergleichsbasis B0 Diesel

Normalized values [%]

FT
HPFT
Mixed alcohols

- Funded by „Klima und Energiefonds“ and Bioenergy 2020+
- Aim is to get fundamental know how in the synthesis of mixed alcohols from biomass
- Main advantage is very simple gas cleaning, due to sulphur resistant catalyst
Actual status: first experiments are done

- **Reformer**
- **Drying** (glycol-scrubber)
- **Compressor** (5-7 Nm³/h; 90-300 bar)
- **Reactor**
- **Alcohols separation**
- **Gas expansion**
Expected results
(from literature and lab scale)

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>composition without methanol recycle</th>
<th>composition with methanol recycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>28 %</td>
<td>-</td>
</tr>
<tr>
<td>Ethanol</td>
<td>50 %</td>
<td>75%</td>
</tr>
<tr>
<td>Propanol</td>
<td>16 %</td>
<td>11%</td>
</tr>
<tr>
<td>Butanol</td>
<td>4 %</td>
<td>8%</td>
</tr>
<tr>
<td>Pentanol</td>
<td>2%</td>
<td>6%</td>
</tr>
</tbody>
</table>

CO conversion should be about 20-30%
BioH2-4Refineries

Economic evaluation of production of hydrogen for a refinery

- Coordination by OMV
- 50 MW fuel plant to replace fossil hydrogen
- Evaluation of the biomass resources available for such a plant
- Basic - engineering of the gasifier as well as of all other sub units, including pipelines, utility systems, logistic needs
- Optimal use of by-products
- Economic evaluation
Simplified flow chart
Summary

- Biomass CHP Güssing has excellent frame conditions for R&D on synthesis gas applications
- Focus of R&D is on small CHP and on synthesis gas applications (BioSNG, Fischer Tropsch, Mixed Alcohols, Hydrogen)
- Gasification enables the conversion of biomass to many useful products

More info at
http://www.ficfb.at
http://www.vt.tuwien.ac.at
http://www.bioenergy2020.eu