Biomass gasification for the production of SNG: a practical route through available and new technologies

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Agenda

► Introduction and Plant overview

► Technology review
  ► Gasification
  ► Tar removal
  ► Syngas conditioning
  ► Methanation

► Case study

► Conclusions
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Who we are

- Headquartered in London
- Listed on
  - London Stock Exchange (AMFW)
  - New York Stock Exchange (AMFW)

- >40,000 people
- >50 countries
- c$9bn revenues
- >150 years of history
Amec Foster Wheeler
Four business units, operating across four key markets

Markets
- Oil & Gas
  - Upstream
  - Midstream
  - Downstream
- Mining
  - Mining & Minerals
- E&I
  - Water
  - Transport
  - Government
  - Industrial / Pharma
- Clean Energy
  - Renewables / Bioprocess
  - Nuclear
  - Transmission & Distribution
  - Conventional Power

Sectors
- Upstream
- Midstream
- Downstream
- Mining & Minerals
- Water
- Transport
- Government
- Industrial / Pharma
- Renewables / Bioprocess
- Nuclear
- Transmission & Distribution
- Conventional Power

Business units
- Asia, Middle East, Africa & Southern Europe
- Americas
- Northern Europe & CIS
- Global Power Group
Why biomass gasification? Why SNG?

Introduction: why biomass and SNG?

SNG: a practical pathway to final users

Easy connection of production plants to existing NG networks
Plant overview

Main process blocks

BIOMASS

Feedstock preparation → Gasification → Tar Removal

O₂

CO₂

H₂S

Methanation → Treatment & Conditioning → Syngas cooling

Utilities

STEAM/POWER/CW, etc.
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Technology review

Gasification: Amec Foster Wheeler CFB Gasifier

- 11 gasifiers built in 1981-2008
- Readiness to offer plants for over 150 MWth air-blown applications for various wood and waste based fuels
- Readiness to offer pressurized oxygen-steam blown gasifiers up to ~300 MW for biorefinery applications with wood based fuels
- Process conditions according to fuels and applications

Long History
(originally developed end 70's/beginning 80's)

Recent commercial applications

Developments always in progress
Technology review

Gasification: History of Amec Foster Wheeler biomass gasification in brief

Varkaus: Atmospheric clean gas applications Demonstrated

Lahti: raw gas applications commercial

Varnamo: Pressurized air blown gasification Demonstrated
Gasification: Varkaus 12 MWth O2-H2O Demo plant and 5 MWth slip stream
Gasification temp: 870-890 °C
Fluidization gas: O2 40-50 %-m and H2O
Bed material: Mixture of limestone and sand, 70/30 (50/50)
Fuel: Wood based biomass (wood chips, bark, forest residues, etc)

Typical raw gas composition on wet basis:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>17 %</td>
</tr>
<tr>
<td>CO2</td>
<td>22 %</td>
</tr>
<tr>
<td>H2</td>
<td>21 %</td>
</tr>
<tr>
<td>CxHy*</td>
<td>7 %</td>
</tr>
<tr>
<td>H2O</td>
<td>33 %</td>
</tr>
</tbody>
</table>

* Contains components from CH4 to heavy tars.

Gas composition can vary to some extent and is affected by process conditions, fuel type and particle size, bed material, etc.
Gasification: Varkaus 12 MWth O$_2$-H$_2$O Demo plant and 5 MWth slip stream
Gasification: Status of gasification technology development

► Test runs at Varkaus demonstration plant completed
  Complete FT production chain demonstrated successfully
  12 MW_\text{th} O_2-H_2O gasifier (~9000 h)
  5 MW_\text{th} slip stream (~5500 h)
  0.1 MW_\text{th} gas ultra cleaning and FT synthesis
  FT supplier was impressed with regard to the gas quality

► Low pressure (4 bar) design for a commercial size O_2-H_2O gasifier exists, higher pressures under development

► 3D gasification model developed with Lappeenranta University of Technology in use to improve process design

► Commercial size design calculations done (~300 MW)
Technology review

► Tar removal: Syngas quality from biomass gasification

<table>
<thead>
<tr>
<th></th>
<th>Entrained Flow</th>
<th>Circulating Fluidized Bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane content</td>
<td>&lt; 0.5%</td>
<td>5-7%</td>
</tr>
<tr>
<td>Tar content</td>
<td>~ 0</td>
<td>$10^4$ mg/Nm$^3$ max</td>
</tr>
</tbody>
</table>

► Tar: organic compounds with boiling temperature higher than benzene (80°C)

► Heavy tar (boiling temperature > 350°C)

  Potential fouling of heat exchangers, filters, etc.

► Light tar (i.e. phenol, naphthalene)

  Condensate contamination
### Technology review

**Tar removal: Features of TAR removal processes**

<table>
<thead>
<tr>
<th>Process</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aqueous Scrubbing</strong></td>
<td>• Good efficiency</td>
<td>• Tars pass from gas to liquid phase</td>
<td>• Light tars in the clean syngas</td>
</tr>
<tr>
<td></td>
<td>• Smooth and trouble-free operation</td>
<td>• High Capex for WWT</td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Cracking</strong></td>
<td>• Complete removal</td>
<td>• Soot formation</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>• Chemical energy remains in syngas</td>
<td>• High Capex</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Low thermal efficiency (product used to provide heat)</td>
<td>• Low thermal efficiency</td>
<td></td>
</tr>
<tr>
<td><strong>Catalytic Cracking</strong></td>
<td>• Potential complete removal</td>
<td>• Soot formation</td>
<td>• Coke formation and catalyst deactivation</td>
</tr>
<tr>
<td></td>
<td>• Chemical energy remains in syngas</td>
<td>• Catalyst consumption and cost</td>
<td>• Low references</td>
</tr>
<tr>
<td></td>
<td>• Composition of product gas can be adjusted</td>
<td>• Catalyst disposal due to Ni</td>
<td></td>
</tr>
<tr>
<td><strong>Oil Scrubbing</strong></td>
<td>• Stability and availability</td>
<td>• Scrubber/Stripper to remove NH₃, HCl, H₂S</td>
<td>• Naphtalene in the clean syngas: test required</td>
</tr>
<tr>
<td></td>
<td>• Chemical energy remains in syngas (tars recycle)</td>
<td>• High level of filtration at high temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High efficiency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Technology review

► Syngas composition may be adjusted by partial shift to obtain the required H2/CO ratio (depending on Methanation technologies), for example:

- \((H_2-CO_2)/(CO+CO_2)\) (vol. ratio): \(3\) or \(\frac{H_2}{CO}\) (vol. ratio): \(3\) or UNSHIFTED

► Cooling of the shifted gas to enter the absorber of the Acid Gas Removal Unit. Physical/Chemical washing to remove sulphur (and CO\(_2\)), followed by guard reactor: SNG (methanation) catalysts require a very low (a few ppb) sulphur content

► Reference parameters for unit design:

- Sulphur content (before guard bed) \(1-2\) ppm vol max
- B,T,X,N \(5\) ppmv max.
- H\(_2\), CO, CH\(_4\) recovery to be maximized
Methanation: Available Technologies

The recycle of CH$_4$ product to syngas is the standard process. Dilute the CO concentration with CH$_4$.
Technology review

Methanation: VESTA Technology

The Amec Foster Wheeler VESTA SNG process uses CO$_2$ and water to control the heat of reaction.

Gasification
- Full flexibility in gasification technology
- Steam quench versus WHB

Removal of S impurities

Removal of CO$_2$
Technology review

Methanation: VESTA Technology Highlights

► No recycle of CH₄ product to the syngas
► Dilute with CO₂
► Dilute with Water

► Dilution with CO₂ and Water
  - No Recycle Stream
► Temperature cannot exceed 550°C
  - No uncontrolled reaction possible
► Flexibility of syngas composition
  - No need for sour gas shift
Technology review

Methanation: VESTA Pilot Plant

Amec Foster Wheeler has signed a cooperation agreement with Clariant International AG (“Clariant”) and Wison Engineering Ltd (“Wison Engineering”) to build a pilot plant to demonstrate the Amec Foster Wheeler VESTA Substitute Natural Gas (SNG) technology.

The pilot plant:

► Designed for a production capacity of 100 Nm$^3$/h of SNG and includes all reactors and control system in order to completely demonstrate a real plant in addition to the verification of the chemical reactions.

► Erected in Nanjing, China.

► Started up in July 2014; 100% of SNG production, at Chinese natural gas grid specification, reached, and the plant as well as the catalyst performance perfectly in line with expectations.
Methanation: VESTA Pilot Plant
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Case study: Biomass to SNG

Main Input Data

- Feedstock: Woody materials
- Outlet thermal power (SNG): 200 MWth (or 21,000 Nm³/h)

Plant Configuration

- Amec Foster Wheeler CFB Gasifier pressurized and oxygen blown
- Catalytic tar reforming
- Physical solvent washing for H₂S removal
- VESTA SNG Technology
# Case study: Biomass to SNG

<table>
<thead>
<tr>
<th>ITEM</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock type</td>
<td>Woody material</td>
<td></td>
</tr>
<tr>
<td>Feedstock flowrate</td>
<td>130</td>
<td>t/h AR</td>
</tr>
<tr>
<td>Inlet thermal power</td>
<td>315-330</td>
<td>MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Outlet SNG flowrate</td>
<td>21,000</td>
<td>Nm&lt;sup&gt;3&lt;/sup&gt;/h</td>
</tr>
<tr>
<td>Outlet Thermal power</td>
<td>200</td>
<td>MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Biomass to SNG efficiency (Ther. Power bases, including biomass for power production)</td>
<td>60-63…..67</td>
<td>%</td>
</tr>
<tr>
<td>Total Investment Cost (TIC)</td>
<td>340-370</td>
<td>M€</td>
</tr>
<tr>
<td>Specific Total Investment Cost (TIC / Ther. power out)</td>
<td>1,700-1,850</td>
<td>€/kW&lt;sub&gt;th&lt;/sub&gt; SNG</td>
</tr>
</tbody>
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► SNG production via biomass gasification is technically feasible; main technologies are available and sufficiently mature for commercial application

► Recently Amec Foster Wheeler assessments showed that a biomass-to-SNG plant has the potential to be economically attractive

► Amec Foster Wheeler is strongly committed in this field, being technology leader for the biomass gasification process through its proprietary CFB-based gasification technology and, at the same time as owner, together with Clariant, of a patented and novel SNG production process (VESTA)