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

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L. Mancuso, Process Director
F. Ruggeri, Principal Process Engineer
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)
- c$9bn revenues
- >50 countries
- >150 years of history
- >40,000 people
Amec Foster Wheeler
Four business units, operating across four key markets

<table>
<thead>
<tr>
<th>Markets</th>
<th>Sectors</th>
<th>Business units</th>
</tr>
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<tbody>
<tr>
<td>Oil &amp; Gas</td>
<td>Upstream</td>
<td>Middle East, Africa, Southern E</td>
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<td>Midstream</td>
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<td></td>
<td>Downstream</td>
<td>Americas</td>
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<td></td>
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<td>Northern Europe &amp; CIS</td>
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<td>Mining</td>
<td>Mining &amp; Minerals</td>
<td>Global Power Group</td>
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<td>E&amp;I</td>
<td>Water</td>
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<td>Transport</td>
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<td>Government</td>
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<td>Industrial / Pharma</td>
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<tr>
<td>Clean Energy</td>
<td>Renewables / Bioprocess</td>
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<td>Nuclear</td>
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<td>Transmission &amp; Distribution</td>
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<td>Conventional Power</td>
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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

 Syngas cooling

Methanation

Treatment & Conditioning → Syngas cooling

Utilities: STEAM/POWER/CW, etc.

O2 → ASU

CO2 → Treatment & Conditioning

H2S
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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
Gasification: History of Amec Foster Wheeler biomass gasification in brief

- **Lahti:** raw gas applications commercial
- **Varkaus:** Atmospheric clean gas applications
  Demonstrated
- **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 Component</th>
<th>%</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 O2-H2O 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 MWth O2-H2O gasifier (~9000 h)
    - 5 MWth slip stream (~5500 h)
    - 0.1 MWth 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 O2-H2O 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>Methane content</th>
<th>Tar content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 0.5%</td>
<td>~ 0</td>
</tr>
<tr>
<td></td>
<td>5-7%</td>
<td>104 mg/Nm3 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&lt;br&gt;• Smooth and trouble-free operation</td>
<td>• Tars pass from gas to liquid phase&lt;br&gt;• High Capex for WWT</td>
<td>• Light tars in the clean syngas</td>
</tr>
<tr>
<td><strong>Thermal Cracking</strong></td>
<td>• Complete removal&lt;br&gt;• Chemical energy remains in syngas</td>
<td>• Soot formation&lt;br&gt;• High Capex&lt;br&gt;• Low thermal efficiency (product used to provide heat)</td>
<td>• None</td>
</tr>
<tr>
<td><strong>Catalytic Cracking</strong></td>
<td>• Potential complete removal&lt;br&gt;• Chemical energy remains in syngas&lt;br&gt;• Composition of product gas can be adjusted</td>
<td>• Soot formation&lt;br&gt;• Catalyst consumption and cost&lt;br&gt;• Catalyst disposal due to Ni</td>
<td>• Coke formation and catalyst deactivation&lt;br&gt;• Low references</td>
</tr>
<tr>
<td><strong>Oil Scrubbing</strong></td>
<td>• Stability and availability&lt;br&gt;• Chemical energy remains in syngas (tars recycle)&lt;br&gt;• High efficiency</td>
<td>• Scrubber/Stripper to remove NH3, HCl, H2S&lt;br&gt;• High level of filtration at high temperature</td>
<td>• Naphtalene in the clean syngas: test required</td>
</tr>
</tbody>
</table>
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
- H2/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 CO2), 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.
- H2, CO, CH4 recovery to be maximized
Methanation: Available Technologies

The recycle of CH4 product to syngas is the standard process. Dilute the CO concentration with CH4

Diagram:

Gasification → Sour Gas Shift → Removal of CO2 and S impurities → Methanation
Methanation: VESTA Technology

The Amec Foster Wheeler VESTA SNG process uses CO2 and water to control the heat of reaction.

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

Removal of S impurities

Removal of CO2
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
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 Nm3/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>MWth</td>
</tr>
<tr>
<td>Outlet SNG flowrate</td>
<td>21,000</td>
<td>Nm³/h</td>
</tr>
<tr>
<td>Outlet Thermal power</td>
<td>200</td>
<td>MWth</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>€/kWth SNG</td>
</tr>
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Conclusions

- 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)