BIOMASS GASIFICATION FOR THE PRODUCTION OF SNG:
A PRACTICAL ROUTE THROUGH AVAILABLE AND NEW TECHNOLOGIES

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Biomass Gasification for the production of SNG

TOPICS

• Why Biomass Gasification? Why SNG?
• Foster Wheeler CFB Gasification Experience
• Biomass Gasification and Syngas Purification
• Methanation
• Preliminary Economic Evaluation
• Conclusions
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WHY BIOMASS GASIFICATION? WHY SNG?

- **Biomass Gasification: the bridge to a green world**
  - Transport fuels
  - Chemical products
  - Heat and power

- **SNG (Substitute Natural Gas): a practical pathway to final users**
  - Easy connection of production plants to existing natural gas networks
“BLUE Map” scenario: reduction of energy-related CO₂ emissions by 50% in 2050 (vs 2005 level)

Source: IEA 2010
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FOSTER WHEELER CFB GASIFIER

Refractory lined
No heat transfer surfaces

Uniflow cyclone

Air preheater integrated into gas duct below cyclone

Process conditions according to fuels and applications

Cold start up appr. 15-18 hours
Refractory lining heat up rate 50...70 C/h

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

Recent commercial applications

New developments in progress

FOSTER WHEELER CFB GASIFIER

UNIFLOW CYCLONE

GASIFICATION AIR FAN

HOT LOW CALORIFIC GAS (750-650°C)

BIOFUEL FEED

COOLING WATER

BOTTOM ASH COOLING SCREW

BOTTOM ASH
Värnamo IGCC Demonstration Plant
- Airblown Gasification of wood chips
- Gasification pressure temperature: 18 bar g/950°C
- Electrical/Thermal power output: 6 MWe/9MWth
- Efficiency: 32% (el)/83% (overall)
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COMBINATION OF BIOMASS GASIFICATION AND PC BOILER COMBUSTION

- Lahti, Finland (70 MWt) since 1998
- Corenso, Finland (50 MWt) since 2001
- Ruien, Belgium (50 MWt) since 2002
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LAHTI OPERATING EXPERIENCE

Main boiler 360 MWth

Gasifier feed preparation

CFB gasifier 70 MWt
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LAHTI OPERATING EXPERIENCE

- Average gasifier availability during 1998-2002 more than 97.5%
- Boiler emissions decreased
- CO$_2$ reduction 100,000 t/y

- Commercial operation since 1998
- Stable operation gasifier-boiler
- No fouling or corrosion to superheater
- Annual fuel flow ~ 100,000 ton

Main boiler 360 MWth

Gasifier feed preparation

CFB gasifier 70 MWt
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LAHTI GASIFIER FUELS

REF = Recycled Fuel; In-origing classified waste based fuel consisting of paper, plastics, cardboard, wood, etc.
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COMBINATION OF BIOMASS GASIFICATION AND PC BOILER COMBUSTION

• Lower environmental emissions
• Better fuel flexibility
• Possibility to use local fuel (biomass, REF, plastics, etc.) resources in high efficiency steam cycle (say 120 bar, 540°C vs 40 barg, 400°C)
• Low investment and operation costs
• Utilization of existing power plant capacity
• Only small modifications to the main boiler
• High plant availability: gasification unavailability does not cause a power output reduction.
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CLEAN GAS CONCEPT FOR DIFFICULT FUELS (REF / RDF, straw, agrobiofuels, etc.)

Fuels containing harmful components:
- Slagging
- Fouling
- High temp corrosion
- Emissions

Removal of contaminants: particulates, Na, K and HCl

Gas cooling down to 350...400°C

Clean gas

High Steam data: eg. 540°C/120 bar

Pilot plant in operation at Lathi (total operating hours 3300, years 2003/2004)
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FUTURE APPLICATIONS: ULTRA CLEAN GAS DEVELOPMENT FINNISH APPROACH

PHASE 1 - UCG Development Program / 2004 – 2006

• Targeted to optimize the gasification process and gas conditioning&cleaning process to meet the requirements for the Fischer-Tropsch fuels, SNG and other synthesis gas utilization technologies
• Led by VTT; other partners FWE Oy, Neste Oil, Vapo, Andritz, Technical University of Helsinki, StoraEnso, UPM, M-Real, Metsä-Botnia, PVO
• Testing performed by VTT with various test facilities (pressurized and atmospheric)

PHASE 2 - Long term industrial demonstrations

• NSE-FWEOy testing going on in Varkaus, Finland (2009-2011) with VTT as the main R&D partner

ULTRA CLEAN GAS CONCEPT

• Optimised pressurised oxygen-steam fluidised-bed gasification process (FW scope)
• Wide range of feedstocks: woody biomass, agrobiomass, peat, waste derived fuels
• Optimised gas reforming, dirty shift and ultra cleanup
• Liquid biofuel production integrated to pulp and paper industries
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CFB GASIFICATION ISLAND (280 MWt)
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SYNGAS QUALITY FOR 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, adsorbents, etc.

**Light tar** (i.e. phenol, naphthalene)
- Condensate contamination
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SYNGAS PURIFICATION: TAR Removal Options

AQUEOUS SCRUBBING

THERMAL CRACKING

CATALYTIC CRACKING

OIL SCRUBBING

Source: http://www.renewableenergy.nl/

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### SYNGAS PURIFICATION: TAR REMOVAL OPTIONS

<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>▪ Tar condensation at unit outlet</td>
</tr>
<tr>
<td></td>
<td>▪ Smooth and trouble-free operation</td>
<td>▪ High Capex for WWT</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Dew point T remains high</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></td>
<td>▪ Low thermal efficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(product used to provide heat)</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>
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SYNGAS PURIFICATION AND METHANATION

Shift and Acid Gas Removal

Syngas composition adjusted by partial shift to facilitate methanation

Physical washing to remove sulphur, followed by adsorption and guard reactor
Methanation catalysts require a very low (a few ppb) sulphur content
Benzene/Toluene less than 5 ppm

Methanation

\[
\text{CO} + 3\text{H}_2 \quad \Rightarrow \quad \text{CH}_4 + \text{H}_2\text{O}
\]

Highly exothermic reaction: 3 to 4 fixed bed catalytic/adiabatic intercooled reactors
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METHANATION

Recycle Compressor

High Temperature Reactor

Superheater

Feed $\frac{H_2}{CO} = 3$

Cooler

Boiler

Superheater

Boiler

b/w Preheater
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BLOCK FLOW DIAGRAM

ASU

BIOMASS

OXYGEN

FEEDSTOCK PREPARATION & DRYING

NITROGEN

CFB GASIFICATION

LIMESTONE/SAND

FLY ASH

BOTTOM ASH

SYNGAS COOLING & COMPRESSION

TAR REMOVAL

SNG DRYING & COMPRESSION

SNG

FLUE GAS

POWER ISLAND

ACID GAS TO POWER ISLAND

ACID GAS FROM AGR

CO2 REMOVAL

CO2 TO ATM

ACID GAS REMOVAL

BIOMASS

SHIFT & METHANATION

BALANCE OF PLANT

HP STEAM FROM GASIFICATION

ASH
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PRELIMINARY ECONOMICAL EVALUATION

TECHNICAL DATA

Feedstock: Wood chips and forest residues limited amount of back pellets/demolition wood

Flowrate: 94 t/h as received

Inlet thermal power: 280 MWt

Outlet thermal power (SNG): 170 MWt

SNG production efficiency: 60.8%

SNG LHV: 33,900 kJ/Nm³

ECONOMICAL DATA

Total Investment Cost: 280 MM Euro

O&M Cost: 76 MM Euro/year

SNG Production cost: 0.8 €/Nm³

Basis for SNG cost estimate:

- Biomass price: 70 €/t
- Electric power: 50 €/MWh
- IRR: 10%
- Plant life: 25 years
- Location: Central Europe

IEA GHG R&D economic standards applied
CONCLUSIONS

• The economical evaluation shows that investment fundings, tariff incentives and/or Carbon taxation are required to make such projects economically viable.

• CFB biomass gasification in association with syngas purification and SNG production is a promising technology, expected to demonstrate high thermal efficiency, good CAPEX and OPEX in comparison with competing technologies.

• Some applied technologies need to reach a complete technical maturity: numerous R&D&D activities, also supported by National and European funds, are in progress.

• Foster Wheeler is strongly committed to develop and demonstrate both the CFB biomass gasification and the SNG technology.

• Foster Wheeler has developed a SNG production technology together with Süd Chemie (a major catalyst supplier).
THANK YOU