Gasification for Advanced Biofuels
-
Status of the Chemrec route towards large-scale production

Presentation at
BioPro IBBC 2011

Atlanta
March 16, 2011
Outline

- This is Chemrec
- Core technology
- Key technology drivers
- Project execution model
- BioDME project
- Domsjö project
THIS IS CHEMREC
Core technology: Black liquor gasification
Core competence: Plant integration
Project development
Our owner provide more than capital

- Broad-based US venture capital company with strong management skills and early commitment to Cleantech

- The venture capital arm of AB Volvo, the world's largest heavy diesel engine manufacturer

- European venture capital fund dedicated to Cleantech investments

- Privately held Swedish company with strong tradition in gasification technology and project development
CORE TECHNOLOGY
Black liquor - Liquid biomass with properties uniquely suitable for gasification

- It's available in existing industrial facilities in large quantities
  - About 600 TWh/year globally equal to
    - 30 million tons/year diesel equivalent or
    - 16 billion gal/year of ethanol equivalents

- It is a liquid
  - Easy to feed to a pressurized gasifier
  - Can be atomized to fine droplets for rapid gasification rates

- Uniquely high reactivity due to high Na/K content
Black liquor - Liquid biomass with properties uniquely suitable for gasification

These properties allows gasification in a single step without tar or methane reforming to high-quality syngas and green liquor

Gasification in an entrained flow high-temperature mode gives

- Full carbon conversion
- No tar formation
- Low methane formation
- Small reactor volume (~25 m³/1000 t BLS/d)
- Simple gas clean-up
The New Bern Booster gasifier, > 47,000 h of full-scale operation

- Commercial atmospheric, air-blown gasifier to boost recovery capacity
- Capacity 300 t BLS/d, about 15% of total mill recovery capacity
- Installed in 1996, operated >47,000 h until October 2008
- Reached 95% annual availability and 2 years refractory life
- Of great importance for development of refractory system and other components
Oxygen-blown high pressure gasifier

• Located at the Smurfit Kappa mill in Piteå, Sweden
• Used for development and technical demonstration
• Oxygen-blown and operated at 30 bar(g)
• Capacity 20 t BLS/d (3 MWth), >12 000 operating hours
• Now provides BioDME plant with syngas
A CHEMREC Biorefinery is a New Paradigm

Existing mills:
- Half of inputs end up as power, steam, low value heat and waste

**CHEMREC Biorefinery**
- Gasifies black liquor to produce high value fuel, chemicals or power

100% → 50% → 25% → Syngas

**Black Liquor**

**Power, steam, heat, waste**
Simplified scheme

- Multiple Alternative Feedstocks
  - Wood waste
  - Agricultural waste
  - Municipal waste

- Power Boiler w. turbogenerator

- Gasification
  - Green liquor & steam
  - Black liquor
  - Pulp
  - Syngas

- Pulp Mill
  - Pulp wood

- Pulp mill block
  - Steam and power

- Gas Conditioning

- Synthesis of Renewable Motor Fuels
  - Methanol
  - Ethanol
  - DME
  - Synthetic gasoline
  - Synthetic diesel
Several alternative motor fuel products are feasible from a techno-economic point-of-view:

- **In Europe:**
  - Methanol as low blend component in gasoline (up to 3% as per EN 228) provides highest profitability
  - DME, an excellent diesel fuel, produced from methanol - a dual product plant is possible

- **In the US policy and regulatory constraints favor other fuels:**
  - Ethanol (mixed alcohols, biochemical or acetic acid routes)
  - Synthetic gasoline (MTG or TIGAS)
  - FT products
Approx. relative net yield on energy basis for different processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Main Product</th>
<th>By-product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw syngas</td>
<td>100</td>
<td></td>
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<tr>
<td>Methanol</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>DME</td>
<td>80.5</td>
<td></td>
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<tr>
<td>Synthetic gasoline</td>
<td>11.6</td>
<td></td>
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<tr>
<td>MTG</td>
<td>61.9</td>
<td></td>
</tr>
<tr>
<td>FT Waxes w. ATR</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>FT Waxes wo. ATR</td>
<td>51.5</td>
<td></td>
</tr>
</tbody>
</table>

Yield as gal EtOH eqv. per ST dry biomass, net

122
120
109
104
77
KEY TECHNOLOGY DRIVERS
Drivers for Advanced Biofuels over the black liquor gasification route

• General
  – Security of supply
  – Climate impact and
  – Cost of fossil fuels

  ⇒ Gov’t incentives for renewable motor fuels - EU RED / FQD and US EISA / RFS2

• Forest industry specific
  – Already today provides an excellent logistics structure and a heat sink for excess heat
  – Need to leverage existing assets and commercial positions
  – Need to reinvest to improve competitive position
  – But, insufficient profitability of conventional reinvestment
Benefits of the Chemrec technology

- Very favorable key performance parameters
  - Uses low-cost, low-quality, non-food energy feedstock
  - High feedstock conversion efficiency, up to 69% on energy basis (~122 gallons ethanol eqv. / dry ST biomass)
  - Very high GHG reduction, >90%

- Flexible product selection

- Dual service and integration with existing industrial plants reduces capital cost

- Taps into and enhances an existing forestry-based value chain

- Provides opportunity for profitable reinvestment in the forest industry
Best-in-class Well-to-Wheel GHG and energy efficiency

Source: WtW study Eucar/Concawe/JRC 2005, 2010 Vehicles (basis for EU RED/FQD default values)
FINANCING STRUCTURE AND PROJECT EXECUTION MODEL
Financing structure and project model

Background

• Integration with pulp & paper plants
  – Large investment outside forest industry core business
  – Often weak balance sheets, low ability to absorb risk

• Primary interest from fuels industry
  – Must ensure alignment of interest with host industry

  ⇒ Requires separate entity for fuels production with split ownership between forest industry and external owners
  ⇒ Limited recourse project financing rather than corporate

• This determines the project execution model
A project can be structured to suit risk appetite and capital base

- **Pulp Mill Owner**
  - Equity

- **Industrial Investor**
  - Equity

- **Offtaker**
  - Equity

- **Limited Recourse Finance**
  - Debt

- **Government Funding**

**Biofuels plant**
Project development model ensures a financeable project

- Address risk allocation and contracts early

- Complete plant built under EPC lump-sum contract with full project and process performance guarantees

- Disciplined process: Concept ⇔ Feasibility ⇔ Front-end engineering

- Chemrec: License, Critical components & Project development
CURRENT CHEMREC PROJECT ACTIVITY
BioDME – an environmentally-friendly automotive fuel

Simplest ether, properties similar to LPG

Excellent environmental properties

Excellent diesel fuel

- High cetane number (>55)
- Near-zero formation of particulates
- Zero sulfur content
- Less complicated exhaust clean-up – no urea injection, no particle filter, no three-way catalyst

Efficient to produce

- Very high conversion efficiency
- Moderate production plant cost

Commercially available synthesis technology
The BioDME Project
Demonstration of DME production and use in heavy trucks
On stream September 2010 – www.biodme.eu

Grant funding:
Swedish Energy Agency
SEVENTH FRAMEWORK PROGRAMME

BioPro / IBBC 2011 26 March 16, 2011
The BioDME plant

- Syngas from the existing DP-1 gasifier
- Simplified design compared to full-scale plant
  - Amine wash for CO₂ and H₂S removal w. zinc oxide guard bed
  - H₂S incineration in pulp mill NCG system
  - Once-through MeOH /DME synthesis system
  - Product distillation for fuel grade DME only
- Modularized plant with near-complete modules build indoors, transported to site
The BioDME production plant project – Pipe bridge with pipes, insulation and tracing
The BioDME production plant project – Erecting a process module  May 23
The BioDME production plant project –
Process modules directly after erection
Plant dedication September 9
Synthesis and distillation units completed
DME filling station
Filling up with DME
BioDME project truck
BioDME project test fleet

- **Modified Volvo MD 13 engine**
  - New common-rail DME injection system
  - Euro 5 / EEV compliant
  - Very low PM emissions
  - Higher low RPM torque and lower noise than on diesel oil

- **New DME tank and feed system**

- **Planned yearly distance 100 000 km per truck (avg)**
Preparations for industrial scale plants

Key activities:

- Gasifier and gas cooler scale-up
- Full-scale gasifier plant detail design
- Project development
  - Feasibility studies
  - Front-end engineering
  - Financing and product take-off agreements
Domsjö Project

Location:
Örnsköldsvik, Sweden

Products:
DME and methanol

Capacity:
Dual product plant –
100 000 t DME or
140 000 t MeOH/year

Full recovery boiler replacement

Project cost: Approx. € 300 million / $ 400 million
Utility integration in the Domsjö project

Domsjö Fiber → Biomass → Pulpwood → Local Utility → District heat → Örnsköldsvik Community

- Cellulose fiber
- Lignosulfonate
- Ethanol
- DME/Methanol

Biomass to local utility with integration of cellulose fiber, lignosulfonate, ethanol, and DME/methanol production.
Domsjö project – Current status

- Feasibility study completed
- $75 million investment grant awarded and has now passed EU DG Comp state support review
- Key technology suppliers selected
- Front-end Engineering Design contractor selected, FEED to start shortly
- Likely plant start-up H2 2014
Thank you!
Back-up slides
The Gasifier and Gas Cooler

Reactor

Quench

Black Liquor

Oxygen

Green Liquor

Weak Wash

Condensate

Raw syngas

GAS COOLER STEAM GENERATOR

Cooling water

BFW

Cooled raw syngas

LP-steam

MP-steam

Concentrated Syngas
Char gasification reactivity of different feedstocks

Source: Bürkle et al
Black liquor gasification - MeOH / DME Process
Block Flow Diagram

Steam

Air

Separation

Gasification

CO Shift

CO2

H2S to recovery

DME Synthesis

Product Distillation

Products: DME or MeOH


Black liquor gasification - FT Wax Process
Block Flow Diagram

Air Separation → Gasification → Gas Cooling → CO Shift → FT Reactor

- Steam
- Raw Syngas
- Clean Syngas
- CO
- Acid Gas Removal → CO₂
- H₂S to recovery

- C₁–C₄

- O₂
- Steam

Product: Bio-Syncrude
Liquids / Waxes to Refinery

Required to get acceptable product yield –
High cost and complexity

Not a ready fuel or fuel component – requires upgrading

Dual service:
a) Black liquor recovery
b) Syngas generation

Transforming Pulp Mills to Bioenergies
Black liquor gasification - FT Diesel Process

Block Flow Diagram

Air Separation → Gasification → Gas Cooling → CO Shift → FT Reactor

Steam → Raw Syngas → Acid Gas Removal → CO₂ → CO₂ Separation

H₂S to recovery → H₂ → Hydrogen Plant

Green Liquor to Pulp Mill → Smelt Dissolver

Black Liquor → Weak Wash

Steam → O₂ → Auto-Thermal reforming → C₁ – C₄ → Product Distillation

C₅ + → Wax → Hydro-Cracking

SteamO₂ → C₁ – C₄

Products: Naphtha Diesel

Dual service:
- a) Black liquor recovery
- b) Syngas generation

Added investment to get marketable fuel and chemical feedstock components
Methanol – production and use

• Produced mostly from natural gas and coal gasification

• Global production ~45 million tons per year

• Major uses:
  – Feedstock for production of
    • Formaldehyde
    • Acetic acid
    • Esters
    • Dimethyl ether (DME)
  – Fuel applications
    • FAME biodiesel
    • MTBE octane booster
    • Direct blending in gasoline (European spec allows 3%)