Scenarios for Development of BioDME Supplies

Stockholm, September 7-8, 2010

Ingvar Landälv, Chief Technology Officer, Chemrec AB
Content

• BioDME from Pulp Mills via Black Liquor Gasification

• BioDME from Biomass through gasification

• Supply and Demand Balance for a DME fuel system
  - Flexibility for BioDME producers
  - Guarantee DME availability in the fuel system
  - Flexibility for fossil DME producers

• Conclusions
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The Route via Gasification and Syngas to Automotive Fuels

Coal
Heavy oils
Natural Gas
Biomass
Black liquor

Syngas (CO+H2)

CO2

Syntetic Diesel (FTD)
Methanol
DME (DiMetylEter)
Hydrogen
Chemicals
SNG

GASIFICATION
Major Biomass Flow from the Forrest Today
Major Biomass Flow from the Forrest
With the BLG* Based Biorefinery Concept

* BLG: Black Liquor Gasification
The BioDME Block Flow Diagram

- H₂S / CO₂ to mill
- Amine wash
- CO shift
- Carbon filter
- Sulphur guard
- MeOH synthesis 1
- First single pass MeOH synthesis featuring > 95% yield
- MeOH Synthesis 2
- Gases
- DME synthesis
- DME Product
- ~ 4 ton DME/day
- Raw MeOH
- Evaporator
- Water
- MeOH (recycled)
- MP steam

Transforming Pulp Mills to Biorefineries

CHEMREC
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New BioDME Pilot - CAD Illustration

- WGS, MeOH/DME, Distillation
- Flare
- Amine Wash
- Carbon filter
- DP-T plant
Current project status of Domsjö project

- Domsjö mill sulphite thick liquor gasified successfully in DP-1
- 500 MMSEK (~ 50 MM€) investment grant approved by Swedish Energy Agency (conditioned EU’s DG Competition approval)
- Feasibility report complete (May 2010)
- Technology for Gas Purification and MeOH/DME Synthesis selected.
- Front-end Engineering Design (FEED) scheduled for Q3/10-Q2/11 for final investment decision in Q3 2011.
The Energy Combine of Örnsköldsvik
Domsjö Mill ⇔ Övik Energy ⇔ Övik Community
- TODAY -

Domsjö
Fiber

Biomass

Övik
Energy

District
heat

Örnsköldsvik
Community

Pulp
wood

Steam

Power

Domsjö
Fabriker

A sodium sulphite based mill

Exist. Recovery boiler to gasboiler

Imported steam

Evaps

Ligno sulfonate dryer

Chemicals recovery / Cooking Liquor prep

S-furnace

Existing. Recovery boiler to gasboiler

E:OH Fermen-
tation

Digester/ Bleach plant

Cellulose fiber

Ligno sulfonate

Ethanol

Recovery boilers
The Energy Combine of Örnsköldsvik Domsjö Mill ⇔ Övik Energy ⇔ Övik Community - TOMORROW -

Domsjöö
Fiber

Biomass

Övik Energy

Pulp wood

District heat

Steam

Power

Örnsköldsvik Community

The sodium sulphite based mill

- Imported steam
- E:OH Fermentation
- Evaps
- Gasification
- WGS & AGR
- ASU
- Synthesis and Purification
- Methanol/DME
- CO₂
- H₂S-furnace
- S-furnace
- Chemicals recovery / Cooking Liquor prep
- Ligno sulfonate dryer
- Digesters / Bleach plant

Waste heat:

Cellulose fiber
Ligno sulfonate
Ethanol

300 t/d DME
or 450 t/d Methanol
Domsjö Fuels Plant Build Up – Parallel Trains

- Air separation
  - Power
  - Oxygen
- Gasification and Quench
  - Rawgas
- Gas cooling
  - Steam
- Gas Conditioning And Purification
  - CO₂
  - H₂S
- Synthesis- and Distillation
  - DME/Methanol
Preparations for industrial scale plants

Chemrec Gasifier Unit Status:

• Gasifier, quench and gas cooler scale-up work complete
• Gasifier black liquor nozzle scale-up work ongoing
• Process Design Package work ongoing together with key suppliers
Preparations for industrial scale plants
Location for Potential Pulp Mill Biorefineries in the US

More than 100 suitable pulp mills in North America with 200-400 MW of Black Liquor per plant

Some 250 suitable pulp mills worldwide
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GASIFICATION

Syngas
(CO+H2)

CO₂

Syntetic Diesel (FTD)
Methanol
DME (DiMetylEter)
Hydrogen
Chemicals
SNG
Major Biomass Flow from the Forrest including Direct Biomass Gasification

TOMORROW (2)

- Forest
- Logs
- Pulp
- Wood Products
- Saw-mill
- Pulp Mill
- Fuel
- Direct Biomass conversion
- Combined Recovery and Fuel Generation

- Forest Residual
- Pulp
- Pulp Mill
- Wood Products
- Fuel
Major Biomass Flow from the Forrest
Enlarged Feedstock Base

TOMORROW (3)

Forest
- Logs
- Pulp Wood
- Forest Residual

Saw-mill
- Wood Products

Pulp Mill
- Combined Recovery and Fuel Generation

Pulp
- Fuel

Energy crops, Agricultural waste, etc

Direct Biomass conversion

Fuel
Synthetic fuels through gasification. Value Chain A as defined by EBTP \(^1\)

\(^1\) European Biofuels Technology Platform

Biomass Production System

- Pre-treatment
  - pyrolysis
  - coarse prep.
  - drying
  - torrefaction
  - grinding

- black liquor *

Co-located

* No pre-treatment necessary before gasification.

** Final Conversion
  - Synthesis
    - reforming
  - Cracking
  - hydrotreating
  - Distillation
  - Etc

** Certain steps of final conversion may be located elsewhere

Initial Conversion

- Feeding sys.
- Gasification
- CH\(_4\) ref’ng
- Tar handling
- Particulate handling
- Shifting
- Gas cleaning
- Etc

Final Conversion

- Hydrotreatment
- Co-treatment

Transport Biofuels

Co-products
Synthetic fuels through gasification
Examples European project developments (1)
Source: EBTP

Choren Projects
a. Beta plant,
~45 MW_t / FT products / Under Start-up
b. Sigma Plan
~640 MW_t / FT products / Start-up 14-15(?)

BioLiq Project
2 MW_t / via DME to
HC:s / 2012
Synthetic fuels through gasification
Examples European project developments (2)

Source: EBTP

Chemrec Projects
a. BioDME
~3 MW_t / DME / Start-Up Sept 2010
b. Domsjö Biofuels
~200 MW_t / DME and Methanol / Start-Up 2013

UPM Project
a. Pilot testing at IGT, Chicago
~5 MW_t / syngas production / Ongoing
b. Commercial Demonstration
~300_t / FT products / Start-Up 2014/15
Synthetic fuels through gasification
Examples European project developments (3)

Source: EBTP

VVBGC Project
(under re-financing & re-organisation)
~15 MW_t / clean syngas / 2012-13

Neste-Stora Enso project
~ 12 MW_t / part stream to FT / Gasification in operation

BioTfueL Project
~ 12 MW_t / FT products / 2012
Production Cost as Function of Price of Biomass

Source: Renew (2008)

- ~ 75-95 € per dry ton biomass
- ~ 0.5 €/lit. diesel eqv. as DME

Total biomass provision costs at BtL plant [€/GJ]

Chemrec
CHOREN
FZK
TU Wien
Abengoa CFB
Abengoa EF
CUTEC

0 10 20 30 40 50 60
0 1 2 3 4 5 6 7 8 9
### Scenario: All Planned Renewable Gasification Capacity in Europe to produce BioDME

<table>
<thead>
<tr>
<th>Project</th>
<th>Feedstock (MW&lt;sub&gt;t&lt;/sub&gt;)</th>
<th>BioDME Prod. (Tonnes / year)</th>
<th>Start-up Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemrec, Domsjö</td>
<td>200</td>
<td>100 000*</td>
<td>2014</td>
</tr>
<tr>
<td>UPM</td>
<td>300</td>
<td>180 000*</td>
<td>2014/15</td>
</tr>
<tr>
<td>Choren</td>
<td>640</td>
<td>380 000*</td>
<td>2014/15</td>
</tr>
<tr>
<td>BioLiq, StoraEnso VVBGC and other minor projects</td>
<td>40</td>
<td>11 000*</td>
<td>2012/13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>~ 670 000</td>
<td><strong>2015</strong></td>
</tr>
</tbody>
</table>

* Different yield from different processes as well as different utilization
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• Conclusions
Concept for development of the BioDME market for heavy duty vehicles (short / medium term)

- **The BioDME Project**
  - Methanol
    - for low blend in gasoline
    - for RME/MTBE
    - for chemical use

- **DME**

Number of heavy duty vehicles running on DME

- **The Domsjö Project**

Transforming Pulp Mills to Bio refineries

Time

3Q 2010

2014

10

1000

2000

3000
Concept for development of the BioDME market for heavy duty vehicles (medium / long term)

Number of heavy duty vehicles running on DME

Time

2010 2014 2018 2022

BioDME Project

The Domsjö Project

MeOH

DME

10 4000 8000 12000 16000
Concept for development of the BioDME market for heavy duty vehicles (medium / long term)

Production: 680 000 t DME/y
30 ton dieseleqv / truck, year
Corresponds to apr. 15 000 HD trucks

Number of heavy duty vehicles running on DME

Time

2010 2014 2018 2022

2010 2014 2018 2022

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Energy to Succeed
How to meet the demand from a growing BioDME Fuel Market?

Alternate usage of renewable MeOH

Alternate usage in the world MeOH market

BioMeOH

BioDME

Dual Fuel Plants

Renewable Feedstock

DME Fuel

Fossil MeOH

Fossil DME

Blend into LPG

Alternate usage in the world MeOH market
The Route via Gasification and Syngas to Automotive Fuels

- Coal
- Heavy oils
- Natural Gas
- Biomass
- Black liquor

Syngas (CO+H₂)

- CO₂

- Syntetic Diesel (FTD)
- Methanol
- DME (DiMethyl Ether)
- Hydrogen
- Chemicals
- SNG
## Price Levels of some Key Commodities

<table>
<thead>
<tr>
<th>Commodity</th>
<th>€ cents / kWh (approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude at 80 USD/bbl</td>
<td>3.5</td>
</tr>
<tr>
<td>Gasoline at refinery gate, NW Europe (0.4€/lit)</td>
<td>4.0</td>
</tr>
<tr>
<td>Diesel at refinery gate, NW Europe (0.4€/lit)</td>
<td>4.0</td>
</tr>
<tr>
<td>Methanol, contract price (average Jan -09 to March -10) Rotterdam, (200€/t ↔ 250 USD/t)</td>
<td>3.6</td>
</tr>
<tr>
<td>DME, estimate based on methanol price</td>
<td>3.7-3.8</td>
</tr>
</tbody>
</table>
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SNG

CO₂ to CCS
PRINCIPLE: Net CO2 emission from GTL and BTL if CCS is applied. **Case DME**

**Source:** EUCAR/CONCAWE/JRC
The chicken / egg problem has been resolved before!

- Produce BioDME
- Develop Market
- Distribute the Fuel
- Produce Fossil DME
Summary and Conclusions 1

• Fuel generation at pulp mills has in various studies shown to have highest efficiency and lowest production cost compared to renewable fuels alternatives

• BioDME will be produced from November 2010. Capacity 4 tons / day

• An industrial demonstration plants planned to be in operation early 2014. Capacity 100 000 tons of DME or corresponding amounts of methanol

• BioDME can be produced efficiently in biomass gasification based plants
Summary and Conclusions 2

- BioDME production needs to be balanced with a second product, preferably BioMethanol
- Fossil DME will play a role to secure DME availability in the DME fuel system
- Fossil DME can be produced at competitive costs compared to fossil diesel in a crude oil price scenario > 50-60 USD/bbl
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