



# **Chemrec pilot DP-1 and BioDME project & Chemrec industrial developments**

**Ragnar Stare  
Project Manager**

# Overview

- **This is Chemrec & Black Liquor**
- **Chemrec pilot DP-1 and BioDME project**
  - DP-1
  - BioDME
- ***Coffee break***
- ***Industrial development***
  - *Scale-up*
  - *Domsjö*

Transforming Pulp Mills to Biorefineries



**Core technology:**  
Black liquor gasification

**Core competence:**  
Process and equipment design  
Plant integration  
Project development



# Black liquor - Liquid biomass with properties uniquely suitable for gasification

- Its 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
    - Approx
- 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



# Typical Black Liquor Data

		Example Kraft liquor composition mass/mass
HHV	MJ/kg DS	13.3
C	kg/kg DS	33.0%
H	kg/kg DS	3.3%
S	kg/kg DS	5.5%
O	kg/kg DS	35.7%
Na	kg/kg DS	19.9%
K	kg/kg DS	2.4%
Cl	kg/kg DS	0.1%
N	kg/kg DS	0.1%
DS	kg/kg wet	71.9%

**Density:** ~ 1.4 kg/dm<sup>3</sup>  
**Viscosity:** ~100 cp @ 125 °C  
**pH** ~13

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**Note: A liquid biomass feedstock with a consistent and higher dry solids content than most woods when harvested ! Note also that it correspond to 18.6 MJ/dm<sup>3</sup> HHV !**

October 18-20, 2011

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## Folie 5

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RS1

Den här kommer jag inte prata om, enbart säga "for the the hand-out version I enclude a coarse spec of our feedstock"

Ragnar Stare; 25.08.2011

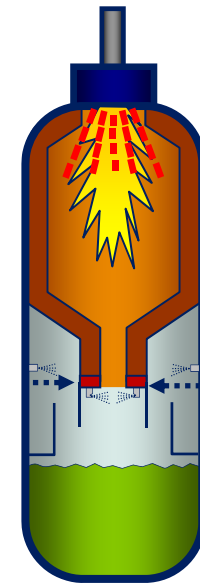
# Black liquor - Liquid biomass with properties uniquely suitable for gasification

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 m<sup>3</sup>/1000 t BLS/d)*
- *Simple gas clean-up*





# KEY TECHNOLOGY DRIVERS

*-WHY GO AHEAD WITH A CHEMREC PROJECT?*



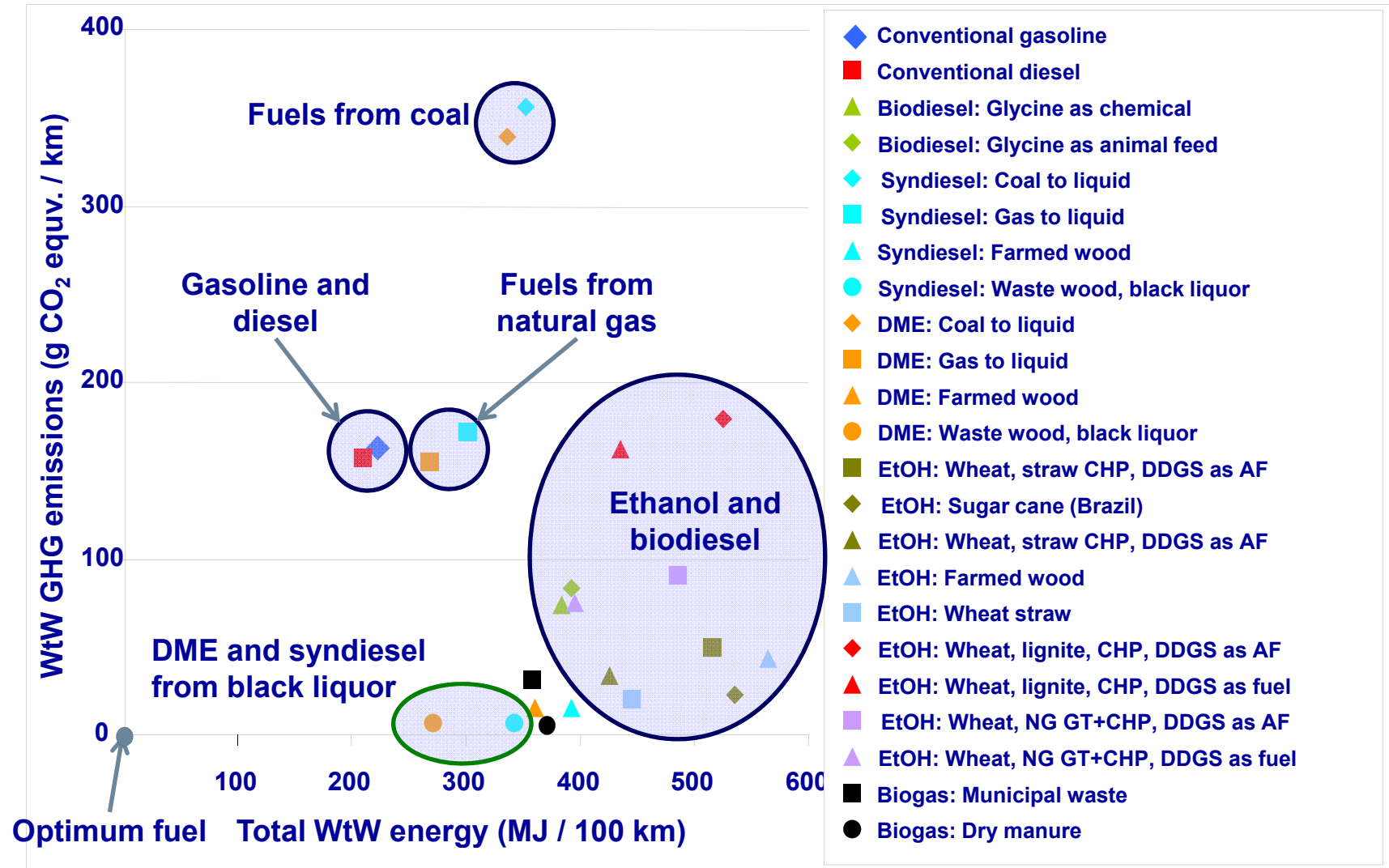
# Inherently more efficient, lower cost syngas production

- Ready-to-gasify liquid biomass feedstock available in existing industrial plants
  - Dual service – syngas production and black liquor recovery
  - Full heat integration with host plant significantly increases overall energy efficiency
  - Single-stage gasification without need for secondary tar or methane reduction
  - Location at industrial sites with existing efficient biomass logistics & existing utilities system
  - Low quality requirements on supplemental biomass for steam and power generation
- ⇒ **Reduced investment cost**
- ⇒ **Low variable cost**



Transforming Pulp Mills to Biorefineries

# Highest efficiency, lowest emissions



Source: WtW study Eucar/Concawe/JRC 2005, 2010 Vehicles





Transforming Pulp Mills to Biorefineries

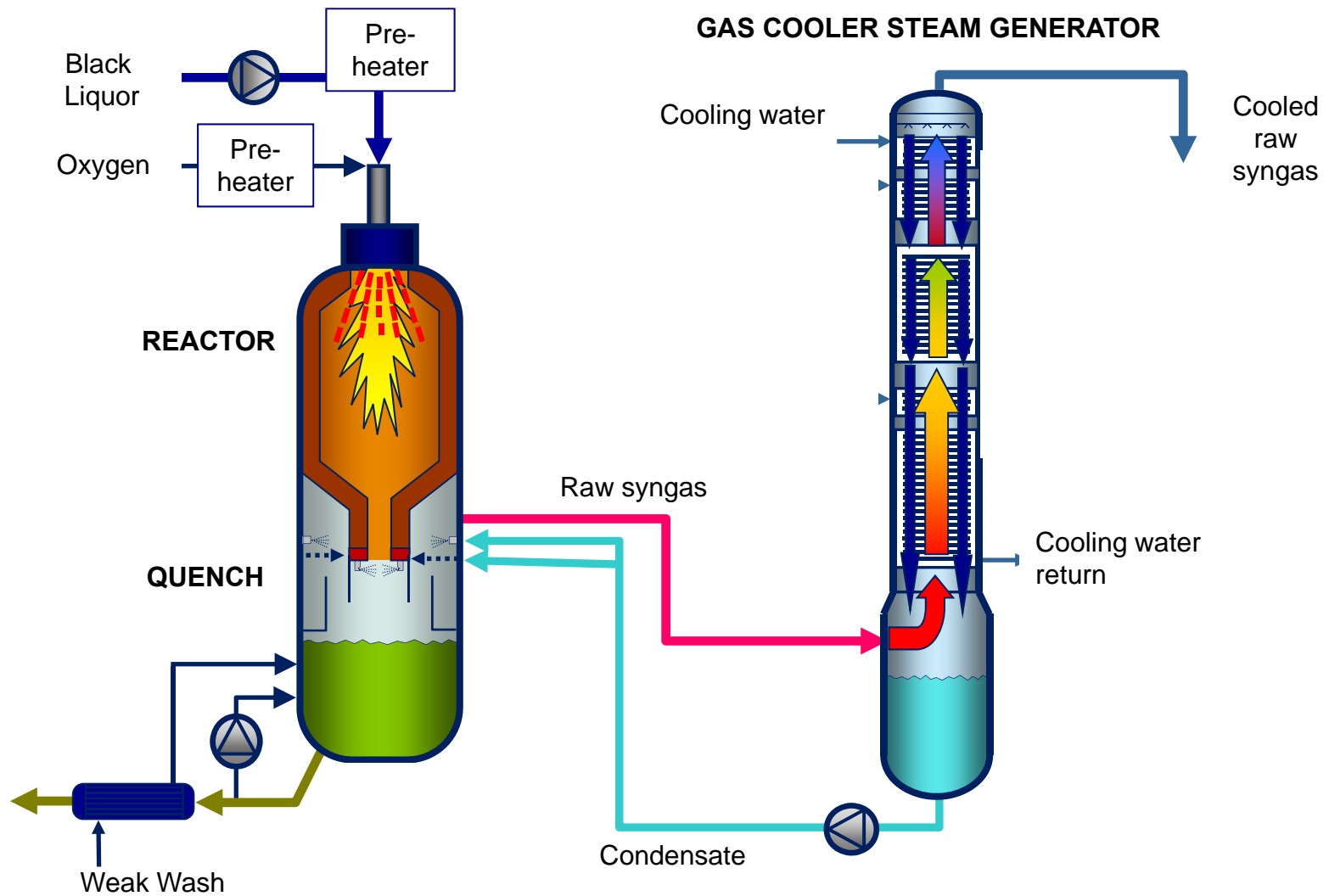
# DP-1

# 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 MW<sub>th</sub>), ~13 000 operating hours
- Provides BioDME plant with syngas



# DP-1 - The Gasifier and Gas Cooler



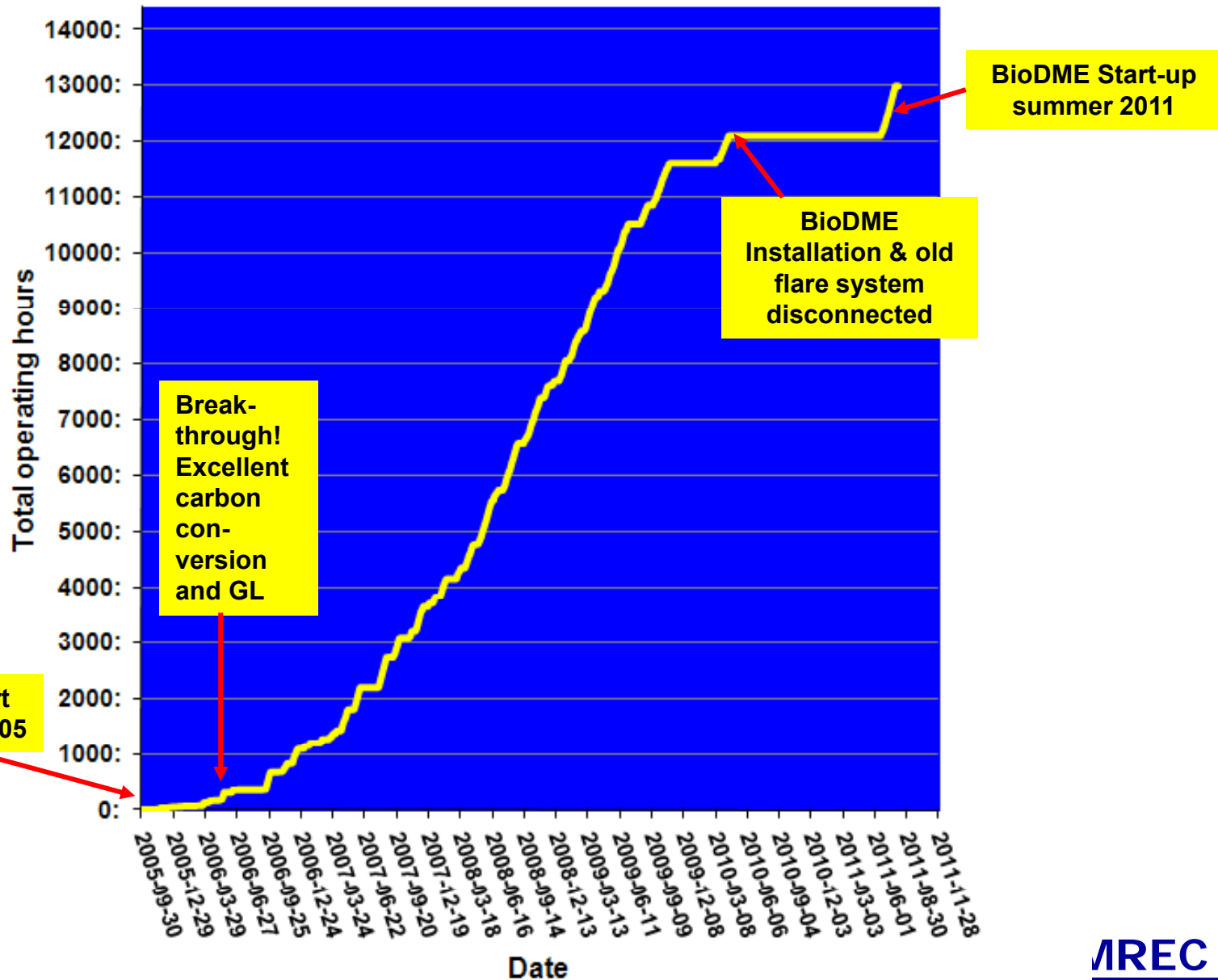
# DP-1 Key systems

- Black Liquor day tank
- Black liquor two stages pumping and preheating
- Oxygen Storage & supply ,incl. Preheating
- Burner system
- Gasification reactor with quench and dissolver sections
- Counter Current Gascooling (no heat recovery)
- Green Liquor system
- Supporting media systems (N<sub>2</sub>, various water systems)

**Cool Raw Syngas transferred to BioDME inlet**

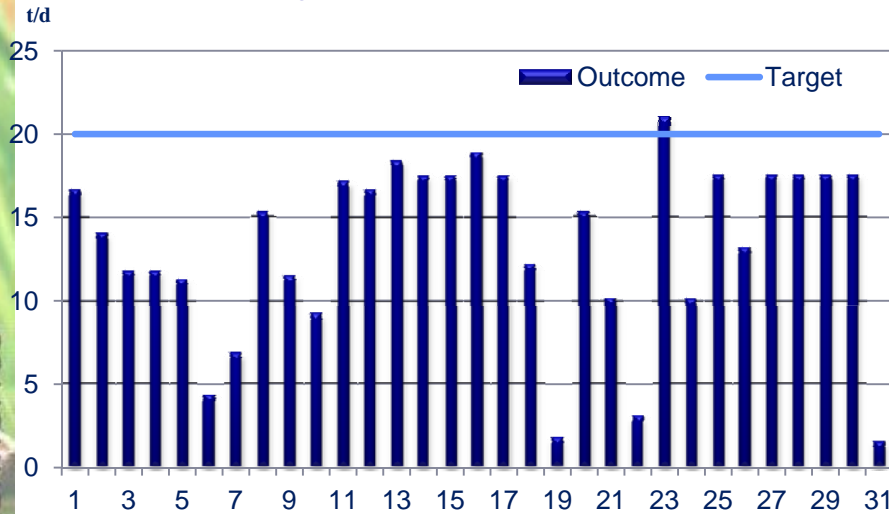


# DP-1 Accumulated Operating Hours

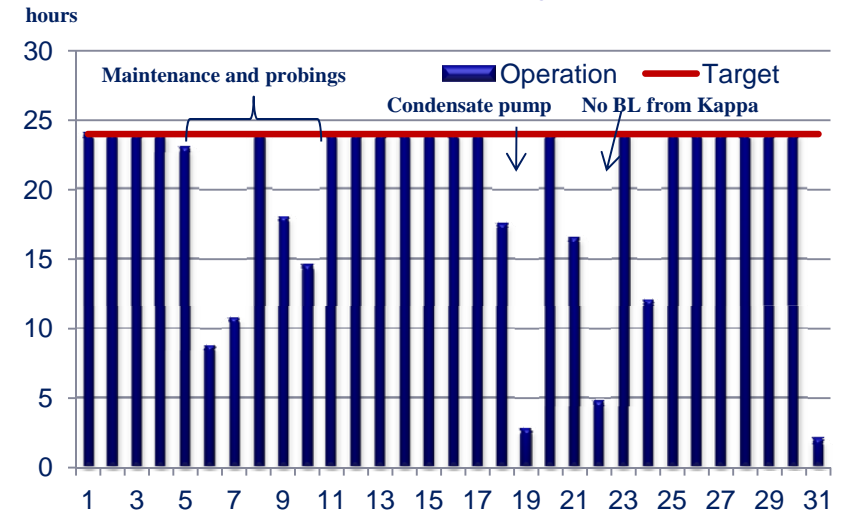


# DP-1 operating data per October 2008

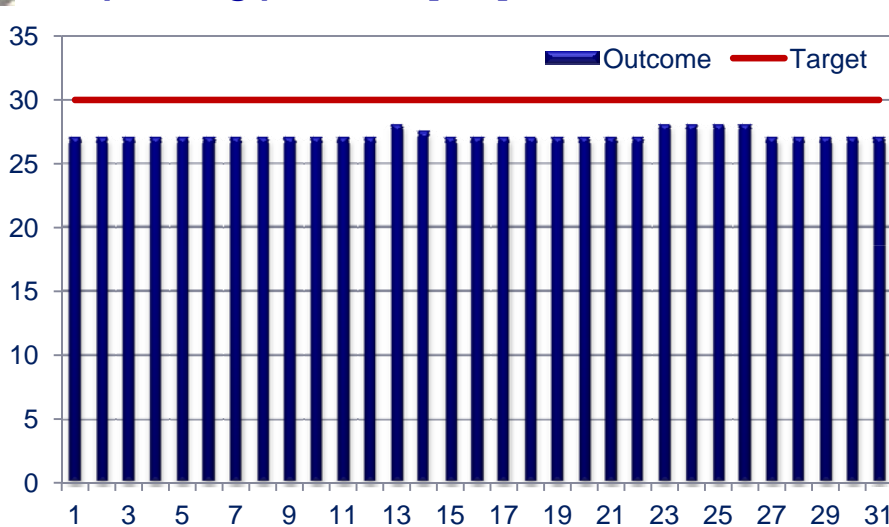
BL load [t/day]



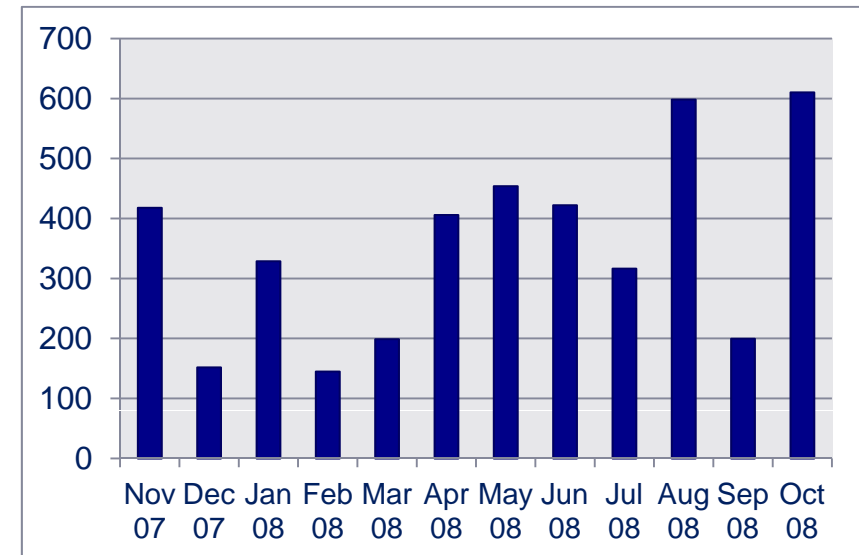
Operation time/day



Operating pressure [bar]

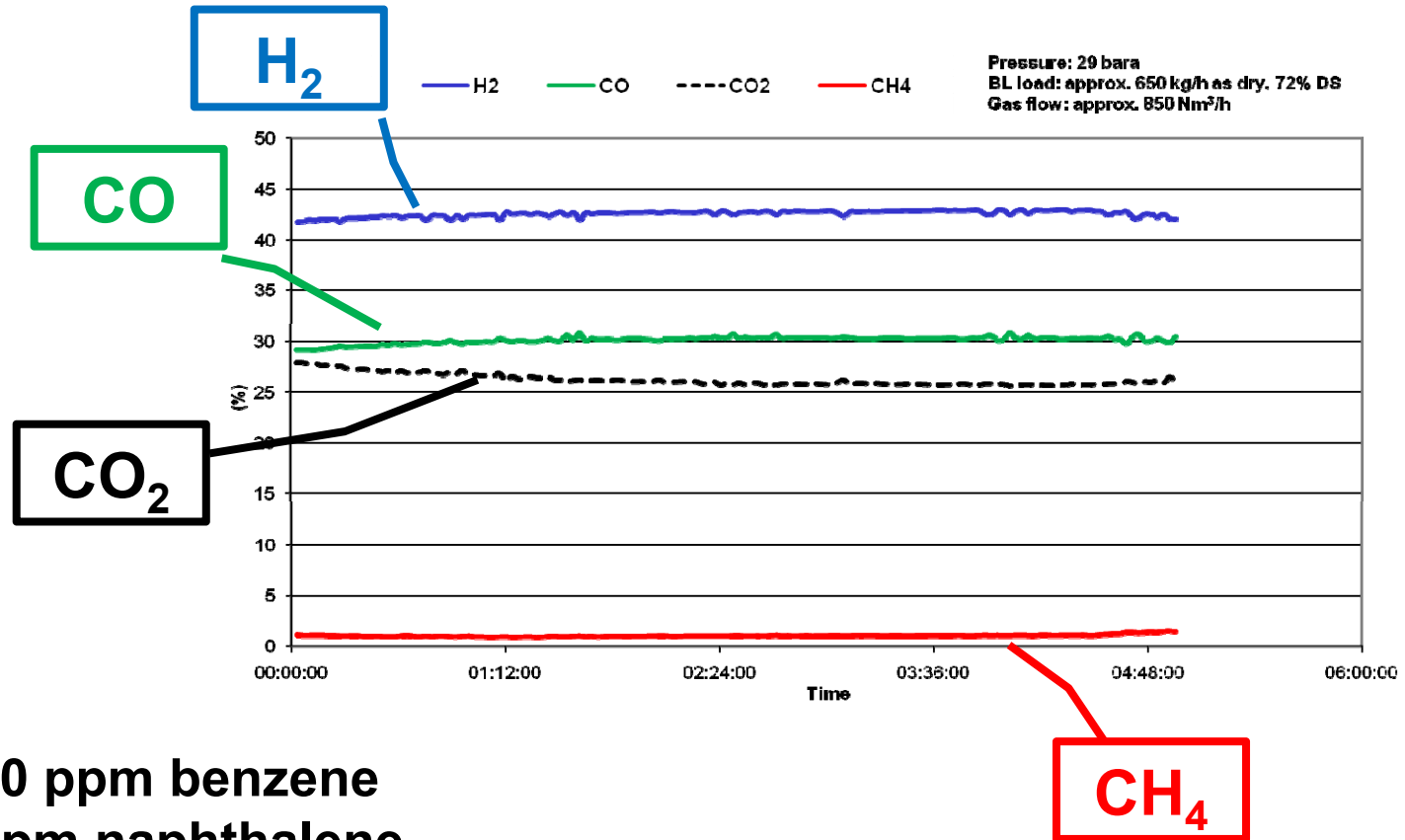


Operation time [last 12 months]





# Raw gas – Pilot Plant Data



- 50-70 ppm benzene
- < 5ppm naphthalene
- Zero or close to zero higher tars
- Very little fouling in heat exchangers
- Particulates "non-detectable"

# Plant activity today

- Syngas provider for BioDME downstream train
  - Development and optimization of process parameters
    - Atomization
    - Further optimize quench operation
  - Component development & testing
    - New designs tested for core components
    - Materials testing
  - Gain experience of operating , to see what is needed to achieve a high availability
  - Marketing, sales and educational purpose
  - Test potential clients spent cooking liquors
- ⇒ The knowledge base needed for scale-up to a larger plant!

# Plant Operation & Maintenance

- Facility budgeted and planned to operate in consecutive campaigns, each campaign with a planned set-up of tasks as indicated
- DP-1 operated with 5 shifts of 2 people in each shift handling all processes in both DP-1 and the BioDME downstream train (from inlet to black liquor day-tank to Biofuel product tanks)
- Engineers and facility management staff working day time/weekdays
- Maintenance either done by operations team with wider range of skills or sub-contracted whenever heavy equipment, licens-welding etc is required.

A vertical banner on the left side of the slide. It features a close-up photograph of green plant leaves and a cluster of small, purple, cone-like structures. The text "Transforming Pulp Mills to Biorefineries" is written vertically in white on a dark green background strip.

# BIODME PROJECT

# BioDME consortium

**CHEMREC**

**DELPHI**

**ETC**

**HALDOR TOPSØE**   
CATALYSING YOUR BUSINESS



**TOTAL**

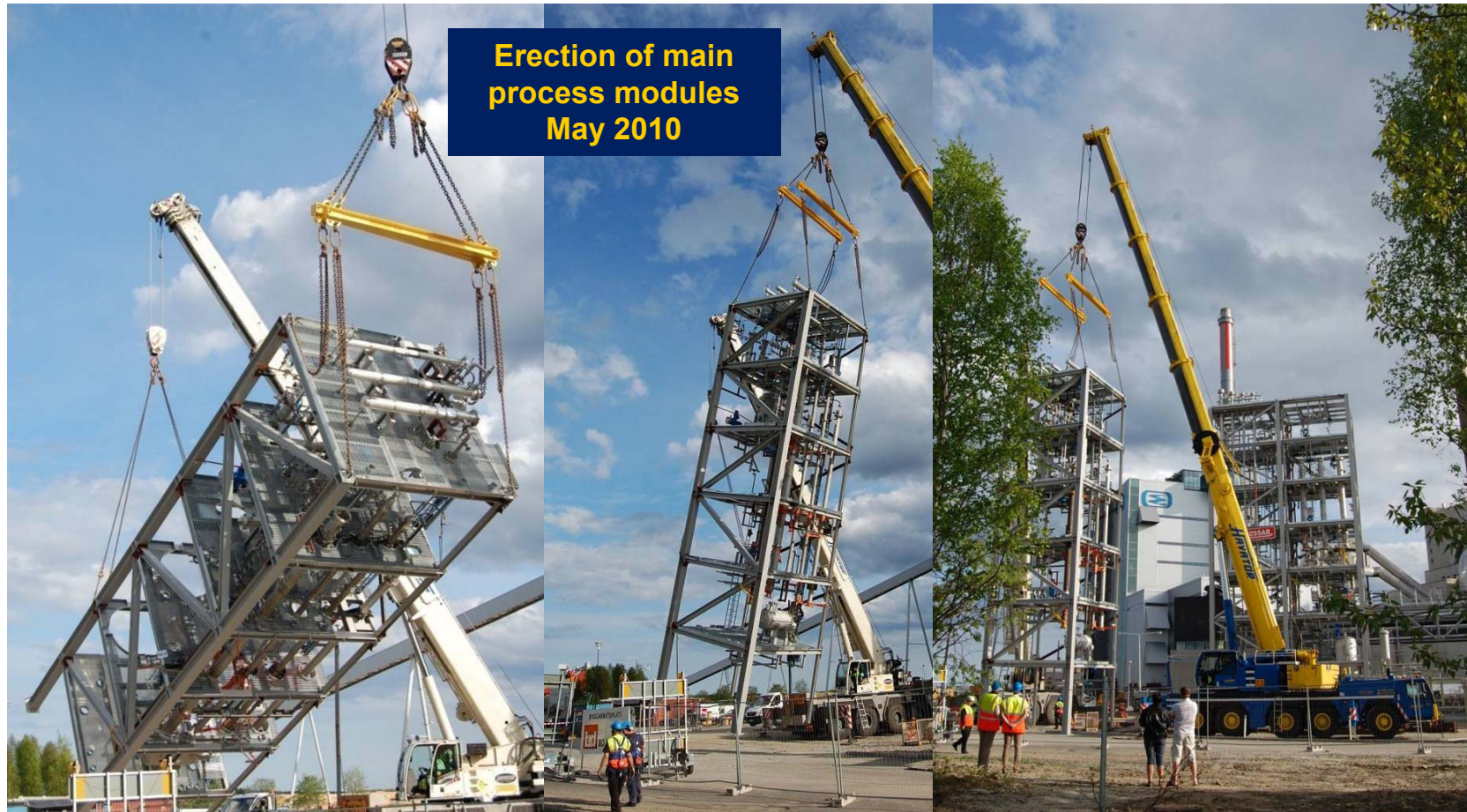
**VOLVO**

- Chemrec builds and operates the BioDME plant based on Haldor Topsøe technology
- Volvo Trucks develops, builds and places DME trucks with Delphi providing fuel injection system technology
- ETC, the Energy Technology Centre in Piteå, contributes its technical expertise
- Preem is responsible for BioDME distribution and builds fuel stations in Sweden
- Total is responsible for fuel and lubricant specifications
- The project is financed by the participants, the EU and the Swedish Energy Agency

Starting date:	1 September 2008
Duration	48 months
Total budget	28.4 M€
EU funding:	8.2 M€
Swedish Energy Agency:	9.6 M€



# Engineering, Procurement and Construction of BioDME Plant



Transforming Pulp Mills to Biorefineries

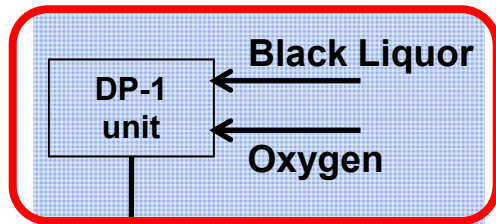
# Engineering, Procurement and Construction of BioDME Plant



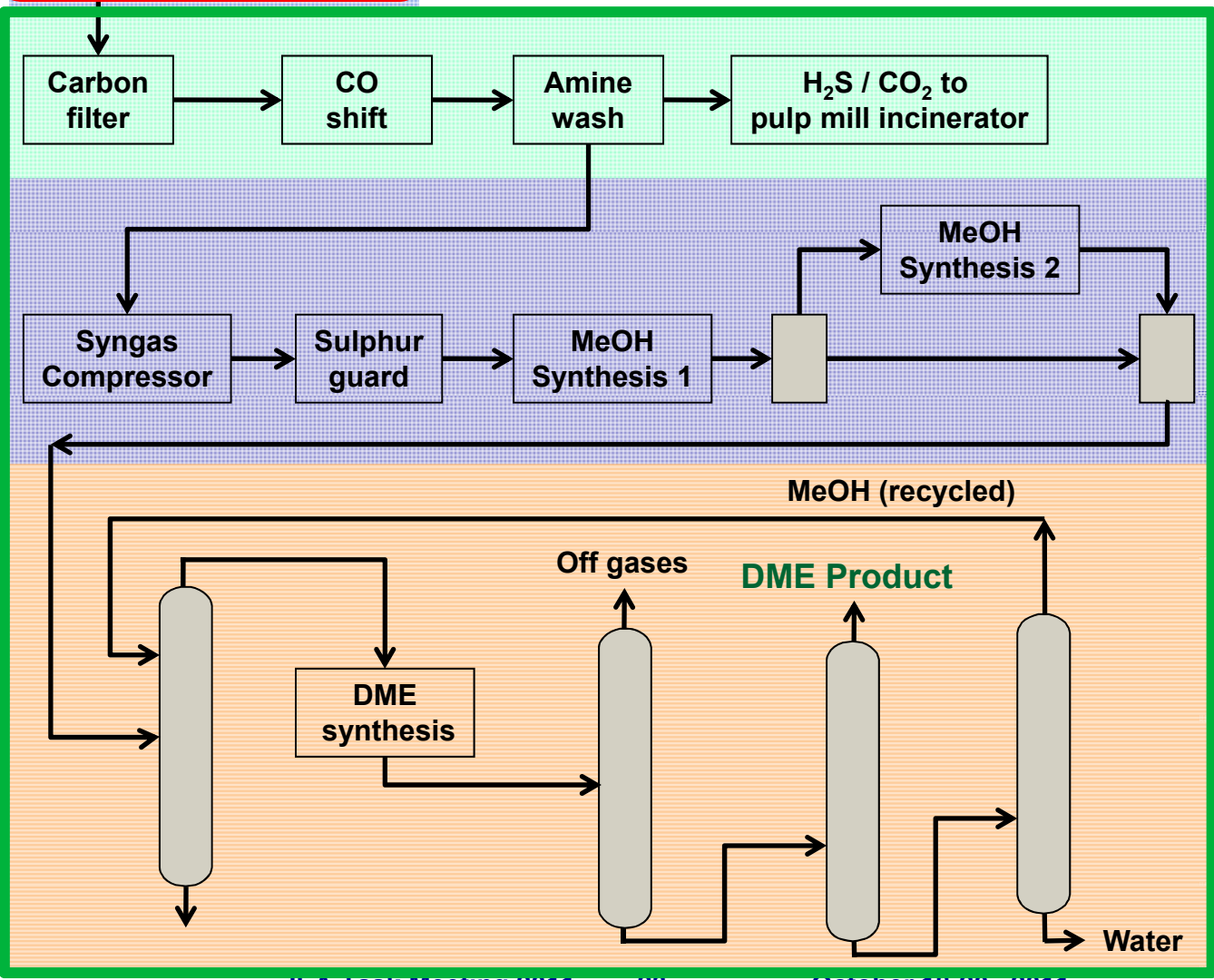
<b>DME Production capacity:</b>	<b>4 tons / day</b>
<b>Pipe installation:</b>	<b>~10 000 m</b>
<b>Hand valves &amp; on off valves:</b>	<b>~1400 pieces</b>
<b>Instruments:</b>	<b>~450 pieces</b>
<b>Vessels:</b>	<b>~30 pieces</b>
<b>Heat exchangers:</b>	<b>~25 pieces</b>
<b>Process Plant Foot Print</b>	<b>20 x 30 m</b>
<b>Construction cost:</b>	<b>~ € 20 million</b>

Transforming Pulp Mills to Biorefineries

Transforming Pulp Mills to Biorefineries



Gasifier unit



Gas conditioning

First single-pass MeOH synthesis featuring > 95% yield

DME synthesis & Product purification





# BioDME Production



**First bio-methanol produced 2011-07-18**

**The plant has produced 7 m<sup>3</sup> of bio-methanol**



- **First BioDME was produced 2011-07-27**

# DP1+BioDME today 19th October

- The BioDME pilot plant successfully produced 7 m<sup>3</sup> of biomethanol in July and start of the DME section was initiated (2011-07-27)
- The turnaround of the mill during August/ September has been used to make some improvements and maintenance work.
- The pilot is expected to be in full operation in November.



# Fuel distribution



- Available LPG technology modified for DME
- Low cost

# Fuel Distribution

- Four filling stations dedicated for the 10 DME trucks in Sweden
- Technology based on LPG and modified for DME
- Safety regulations based on LPG
- Investment about 200.000 Euro per Filling Station



# 10 Field test trucks




Transforming Pulp Mills to Biorefineries



# COFFEE BREAK

# ***INDUSTRIAL DEVELOPMENT***

- SCALE-UP***
- DOMSJÖ***

# Not the first scale-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 (~47 MW<sub>Feedstock HHV</sub>)
- 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





# Chemrec Unit Scale-up strategy employed

- **Break down into defined pieces to scale-up and manage the interfaces**
- **Use analogies with knowledge from proven full-scale equipment whenever possible**
- **Test/verify all that reasonably can be tested in lab or pilot scale**
- **Ensure that multiple solutions and fall-backs are enabled in design**

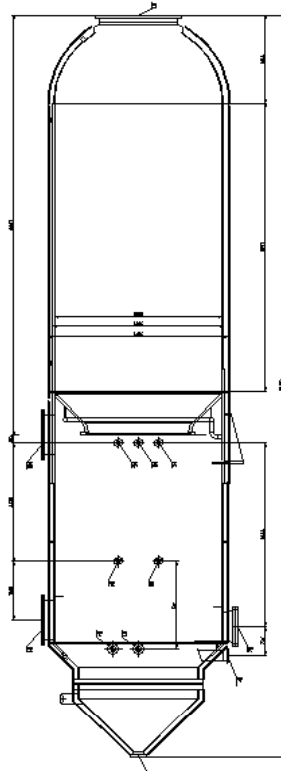
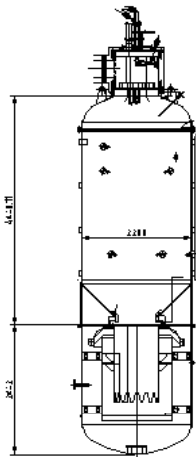
# Scale-Up – Operating experience a foundation

Air-blown , atmospheric



New Bern,  
300 t DS/d,  
47 000 op. h

Frövi  
50-75 t DS/d



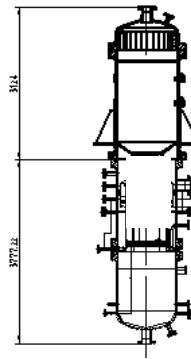
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Pressurised, O<sub>2</sub>-blown

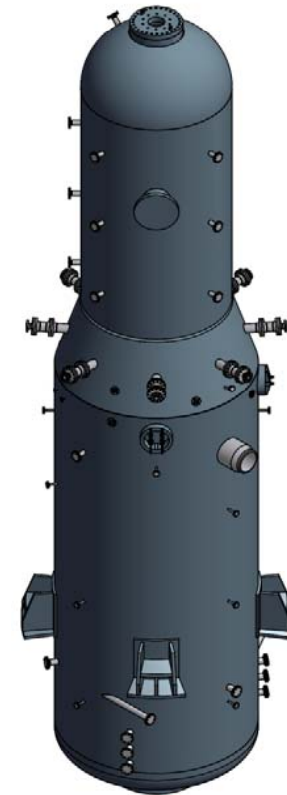


DP-2  
500 t DS/d

DP-1  
20 t DS/d  
13 000 op. h



October 18-20, 2011



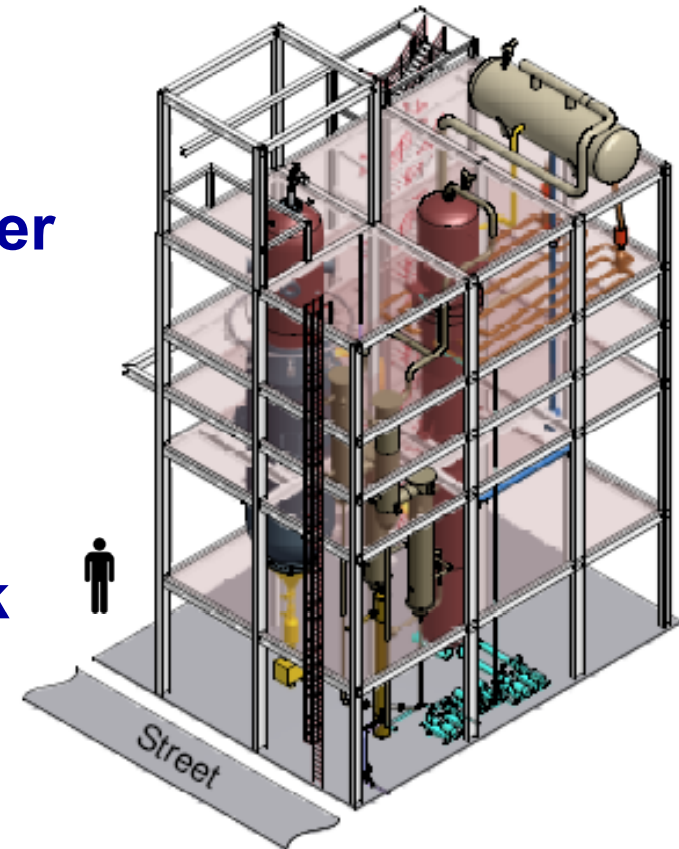
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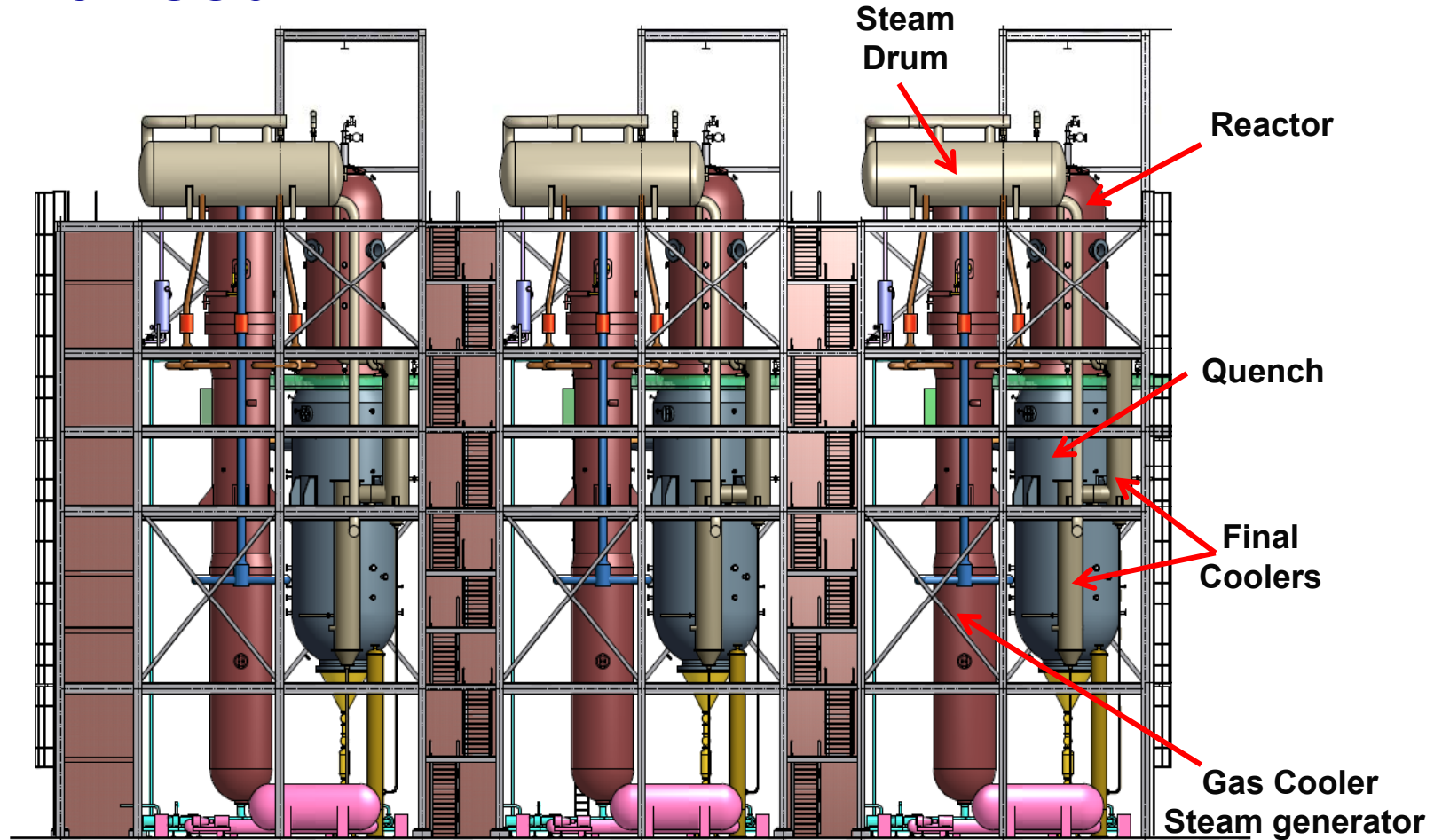
# Preparations for industrial scale plants

## 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 well advanced in cooperation with key suppliers**



# Equipment and plant design well advanced



Train #1

Train #2

Train #3



Transforming Pulp Mills to Biorefineries

# INDUSTRIAL-SCALE PROJECTS

# The Domsjö Project

## Location:

Örnsköldsvik, Sweden

## Products and capacity:

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

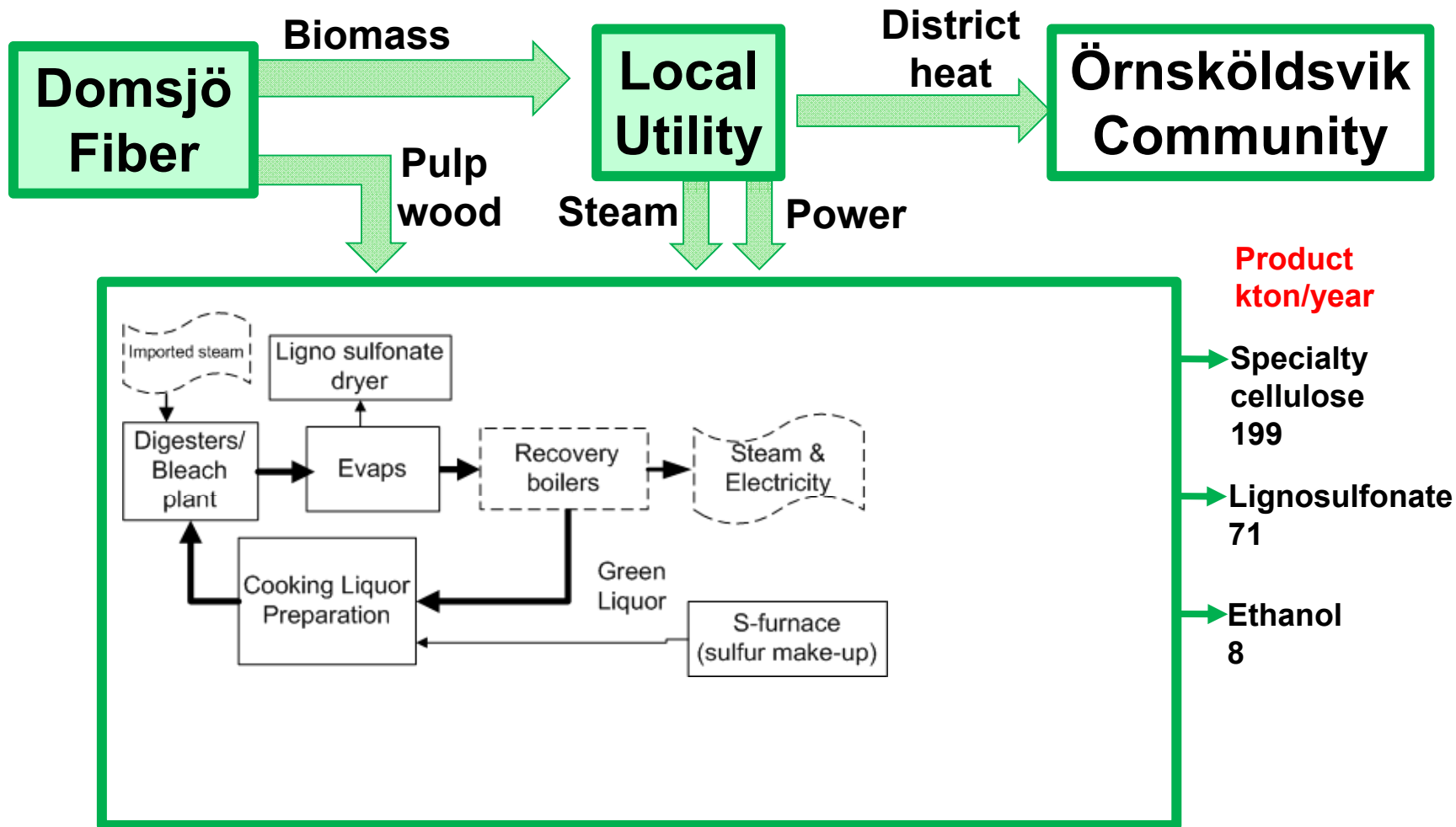
## Full recovery boiler replacement

**Project cost:** Approx. € 300 million / \$ 400 million  
minus €54 million grant

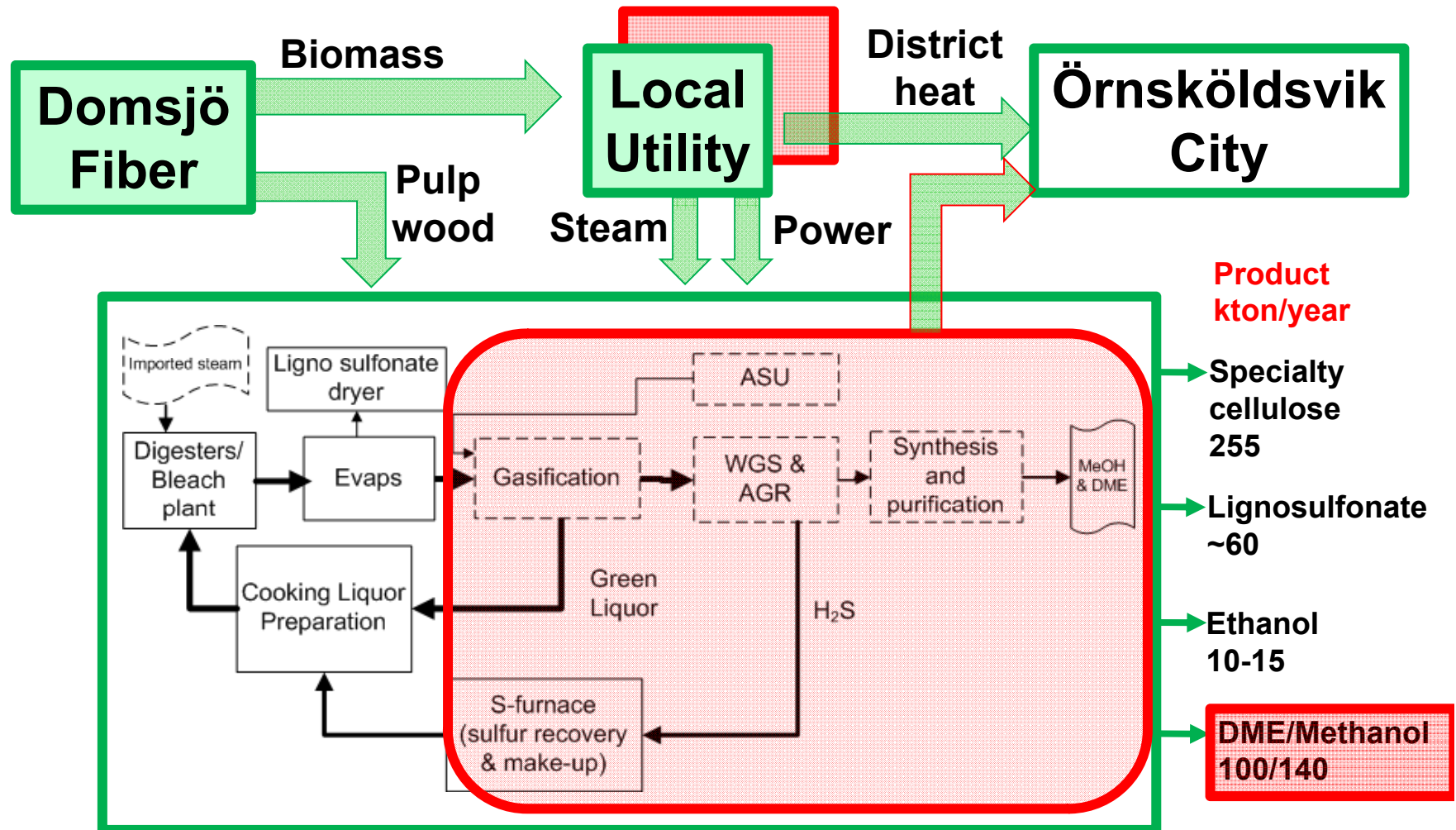
**Scheduled start-up:** 2015



# Domsjö – already a biorefinery today



# ... and more so with BioMethanol and BioDME production



Transforming Pulp Mills to Biorefineries



# Biorefinery Throughput – Before & After

- **A Biorefinery based on the Sulfite Pulping process**

<b>Domsjö Production</b>	<b>2010</b>	<b>With BFP</b>
	kton/y	kton/y
Specialty Cellulose	199	255
Lignin (lignosulfonate)	71	~60
Ethanol	8	10-15
BioMethanol (BioDME)		140 (100)
Mass, sold products	278	470 (425)
Thick liquor combusted	239	0

- **Domsjö with BFP will buy approx ~1.3 MJ of low grade biomass for every MJ sold as high quality biofuel**

# Domsjö Project Time-line

Pre-Studies , (Conceptual & Feasibility) ,  
2008-2011

Technology and Engineering contractor  
Selected 2010-2011

Environmental Permit Application, Prepared  
& handed in, 2011

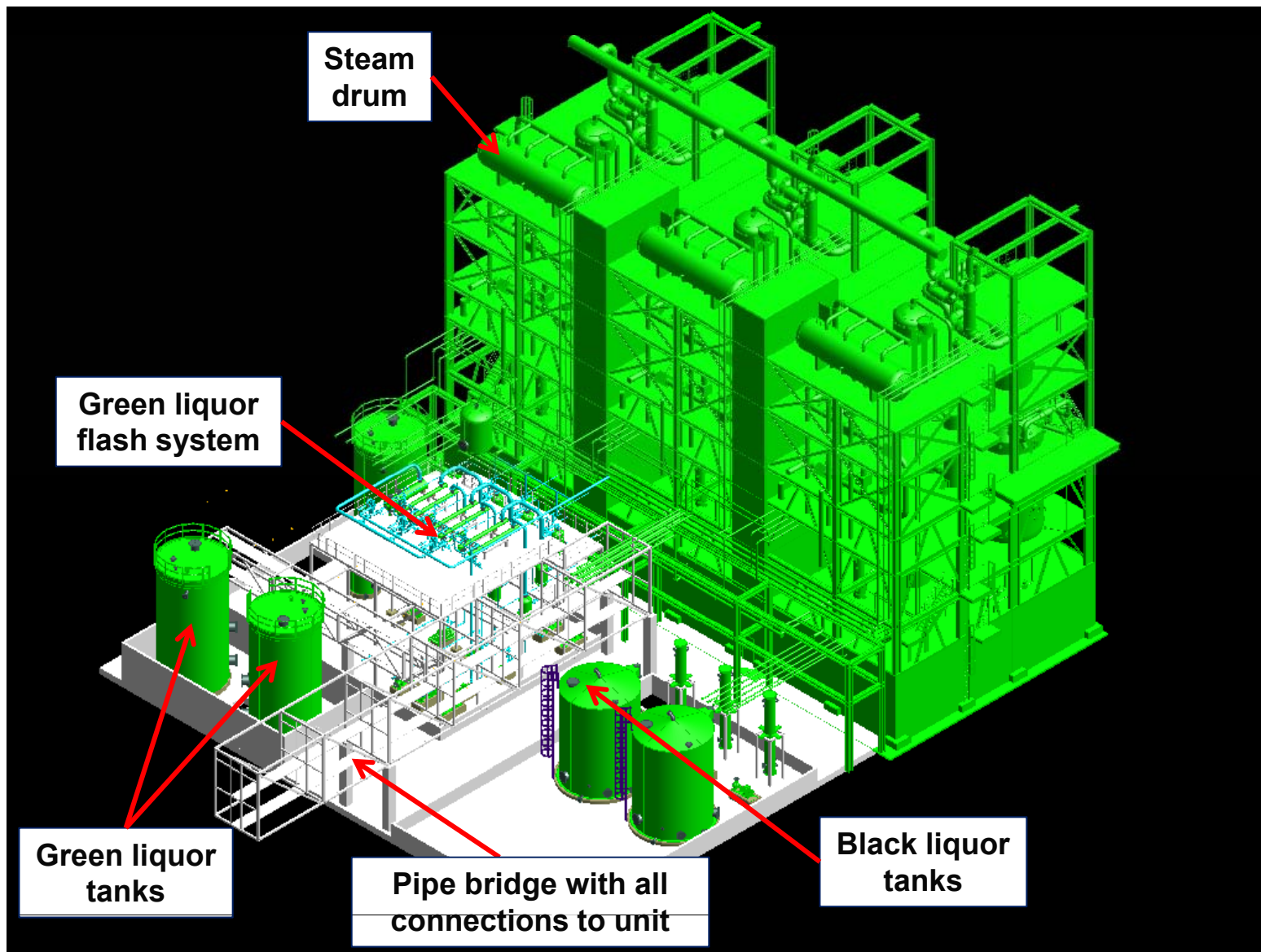
Front End Engineering and Design ,  
FEED, Start early 2012

Project Execution, start 2012/2013

(Conditional on financial close and  
Environmental permit awarded)

Plant Commissioning and Start-up 2014/2015

# Gasification unit for Domsjö project



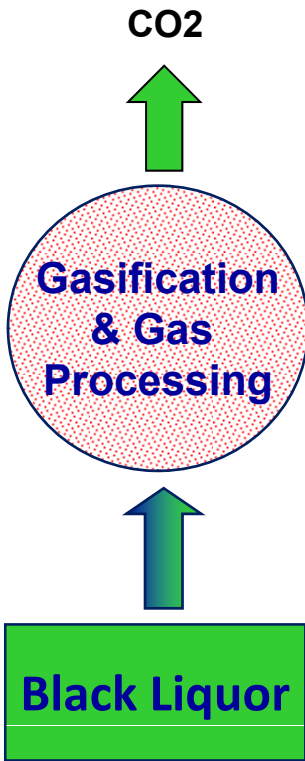
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# Options studied for actual clients with a commercial interest (scientific studies excluded)

Multiple feedstocks to provide make-up steam demand for mill

- Natural gas (✓)
- Coal
- Petcoke
- Residual oil
- Biomass ✓

## CHEMREC Technology



Output Choices

- Transportation Fuels
- or
- Chemicals
- or
- Combined Heat & Power

Existing Processes

Products

- Mixed Alcohols/Ethanol
- Methanol ✓
- DME (DiMethylEther) ✓
- Synthetic Diesel (FTD) ✓
- Synthetic Gasoline ✓
- Hydrogen
- NG/Fuel oil replacement in kiln (✓)

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# Wood-to-Wheel efficiency....?



Source: Wikipedia, *Adler Diplomat 3 GS mit Holzgasgenerator, 1941*

**Thanks for your attention!**

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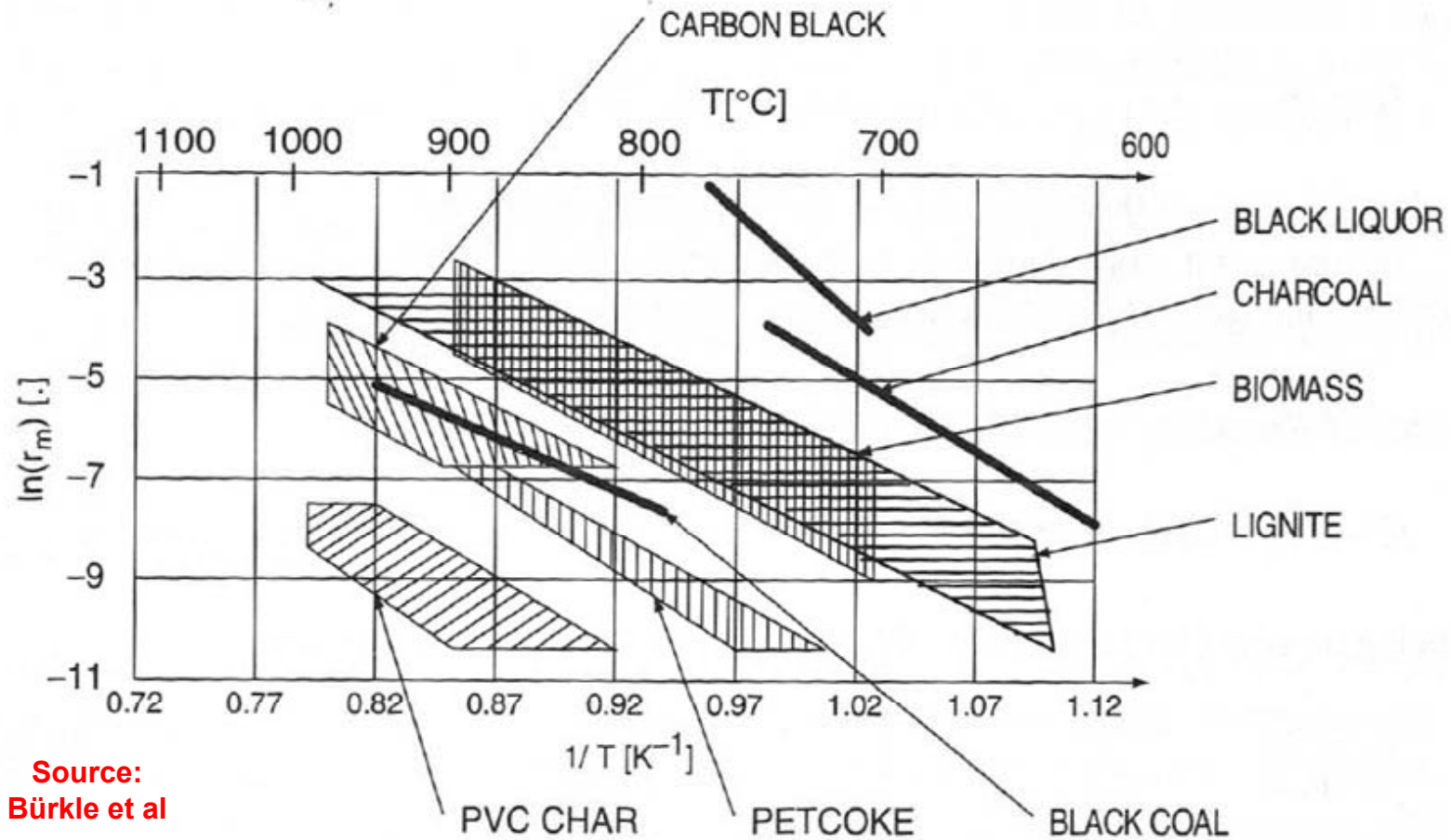




# BACK-UP SLIDES



# Char gasification reactivity of different feedstocks

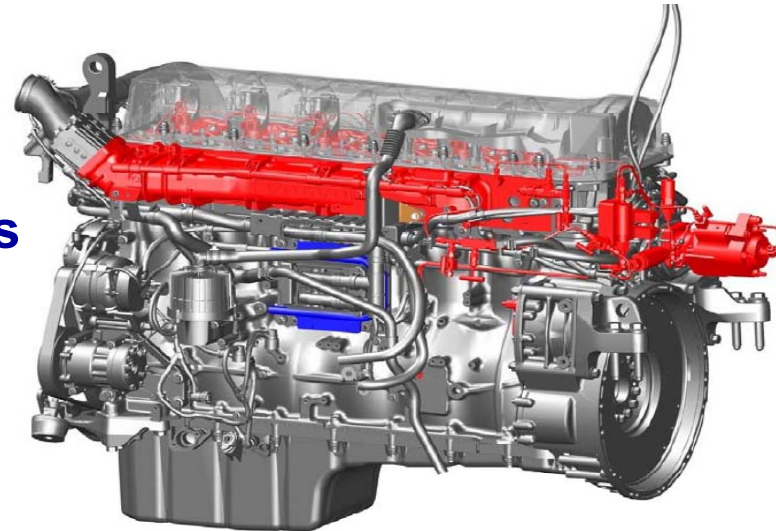


Source:  
Bürkle et al

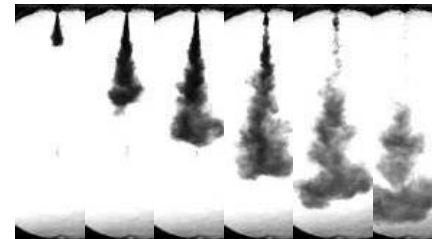


# DME engine

- Ideal fuel for diesel process
- 440 HP, 13 L engine
- Minor technical modifications
- Euro 5 without urea-SCR or Particulate filter

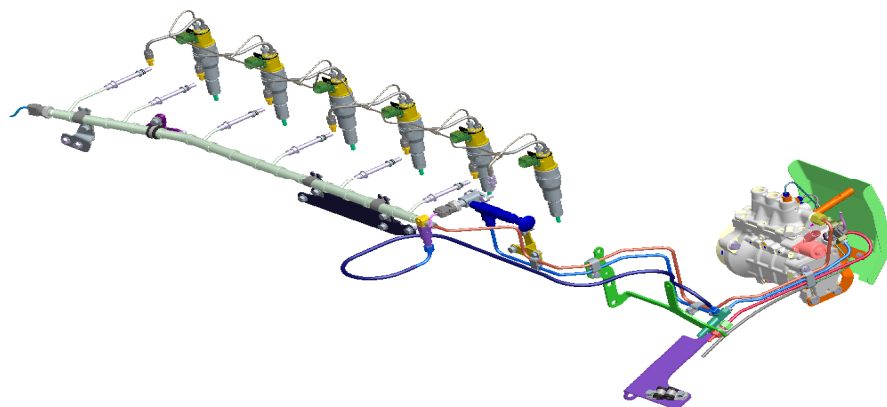


Small modifications in the engine



DME spray - No soot formed

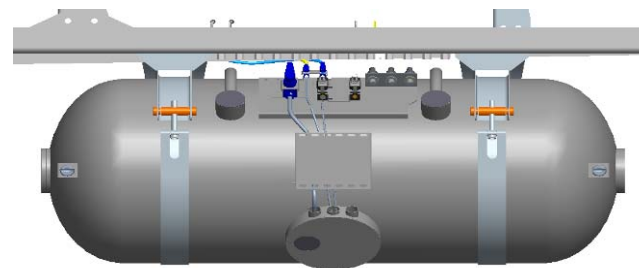
# DME fuel system



200 - 400 bar

13 - 20 bar

1 - 15 bar



# The BioDME trucks are in operation today!



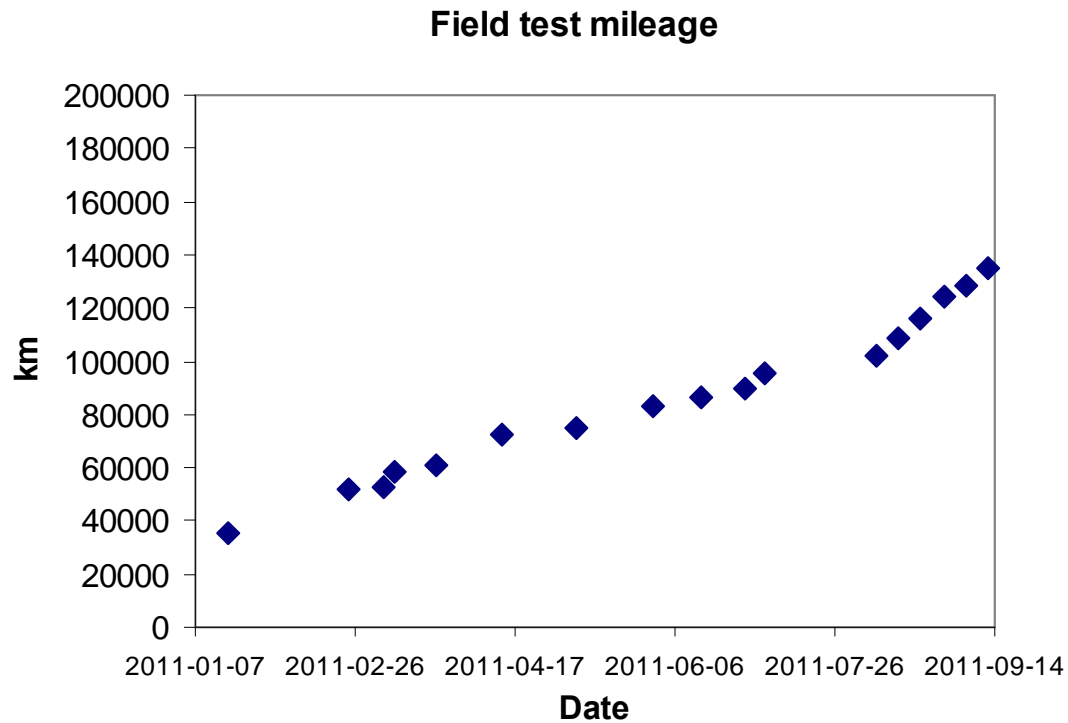
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# Field test status 2011-09-12



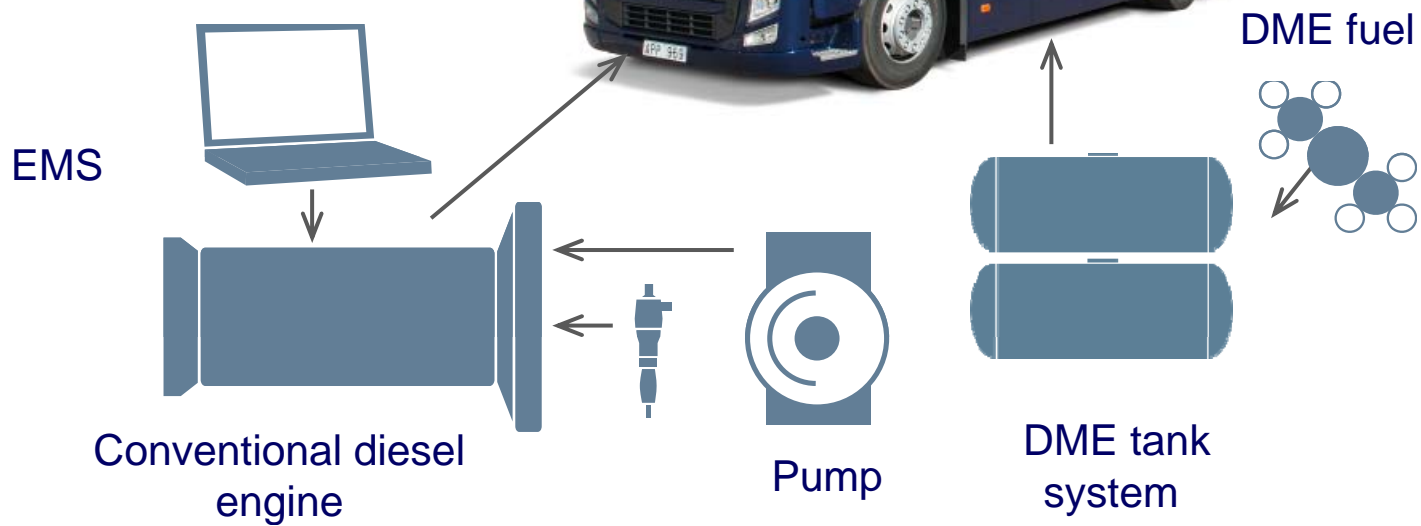
- Trucks at customer: 7
- Mileage last week: 7 177 km
- Accumulated mileage: 135 254 km



# Volvo DME truck



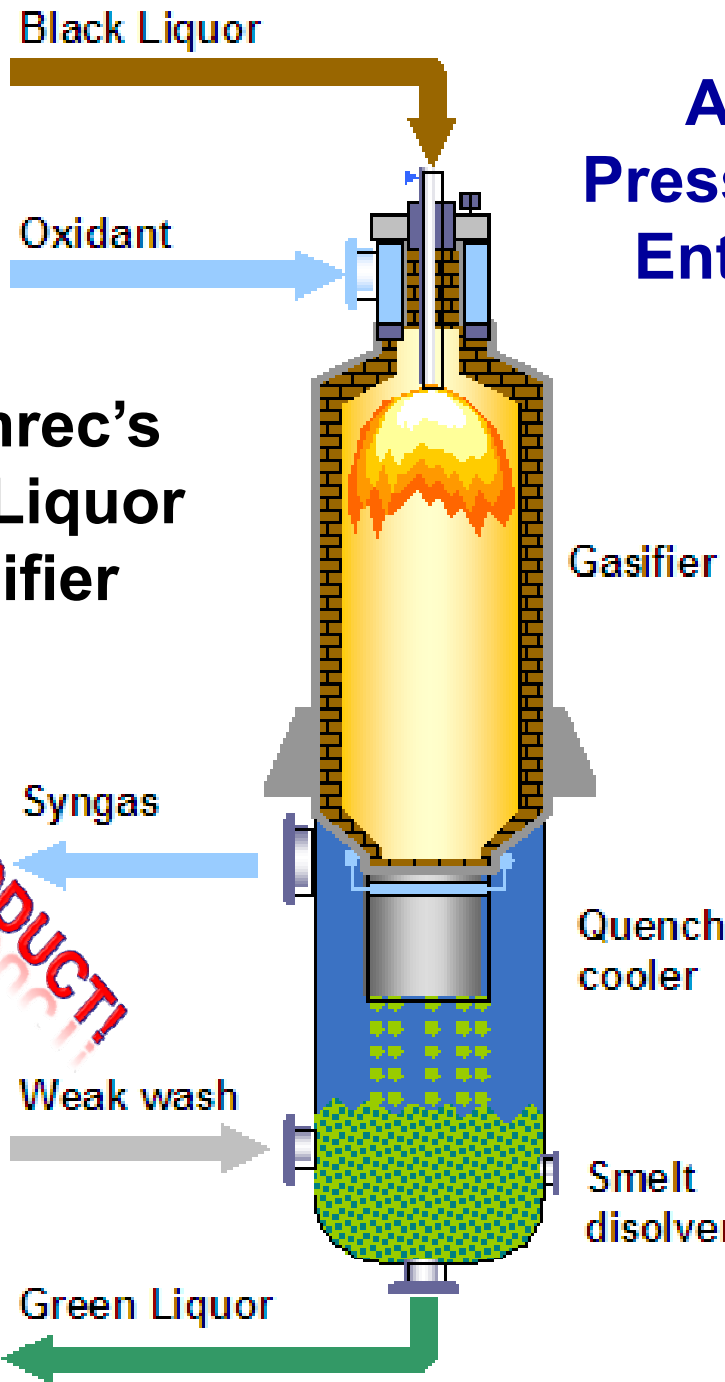
- Standard Volvo truck
- New fuel system
- New engine control
- Diesel engine with diesel efficiency
- 440 HP, 13 L engine
- Euro 5 without urea-SCR or Particulate filter





Transforming Pulp Mills to Biorefineries

## Chemrec's Black Liquor Gasifier



## A High Temperature Pressurized Oxygen blown Entrained Flow Gasifier

### Examples of suspension gasifier technologies:

- \*GE (ex-Texaco) (oil & coal-slurry)
- \*Shell (oil & coal-slurry)
- \*Chemrec (Black Liquor)
- \*MPG/Lurgi (Bioliq)

· 18-20, 2011

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