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Conversion of forest industry by-products to methanol and DME

Presentation at the *IEA Task 33 Workshop on Liquid Biofuels*, 4 November 2014

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Luleå University of Technology

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Acknowledgements

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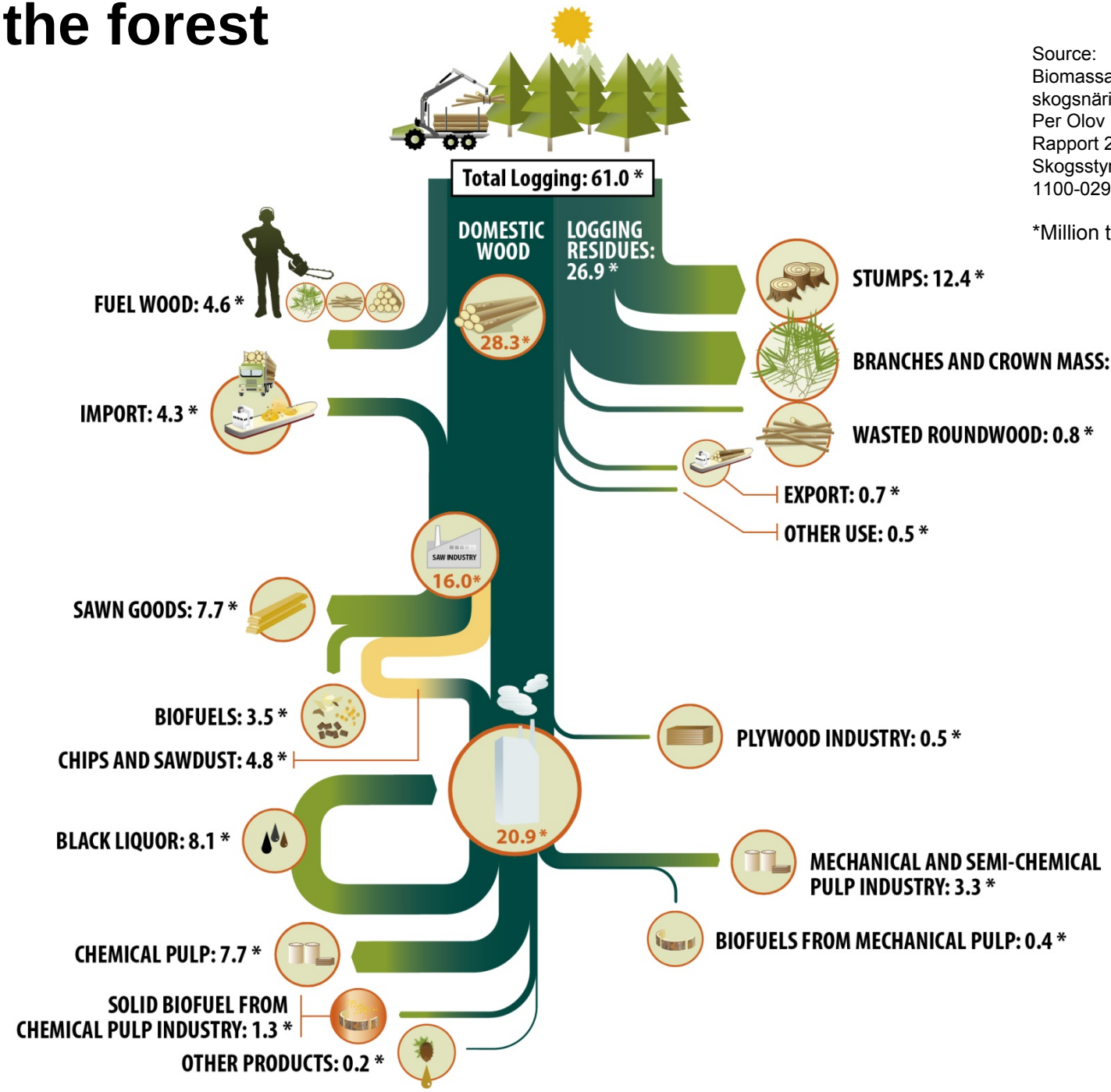
Sweden is a forest country

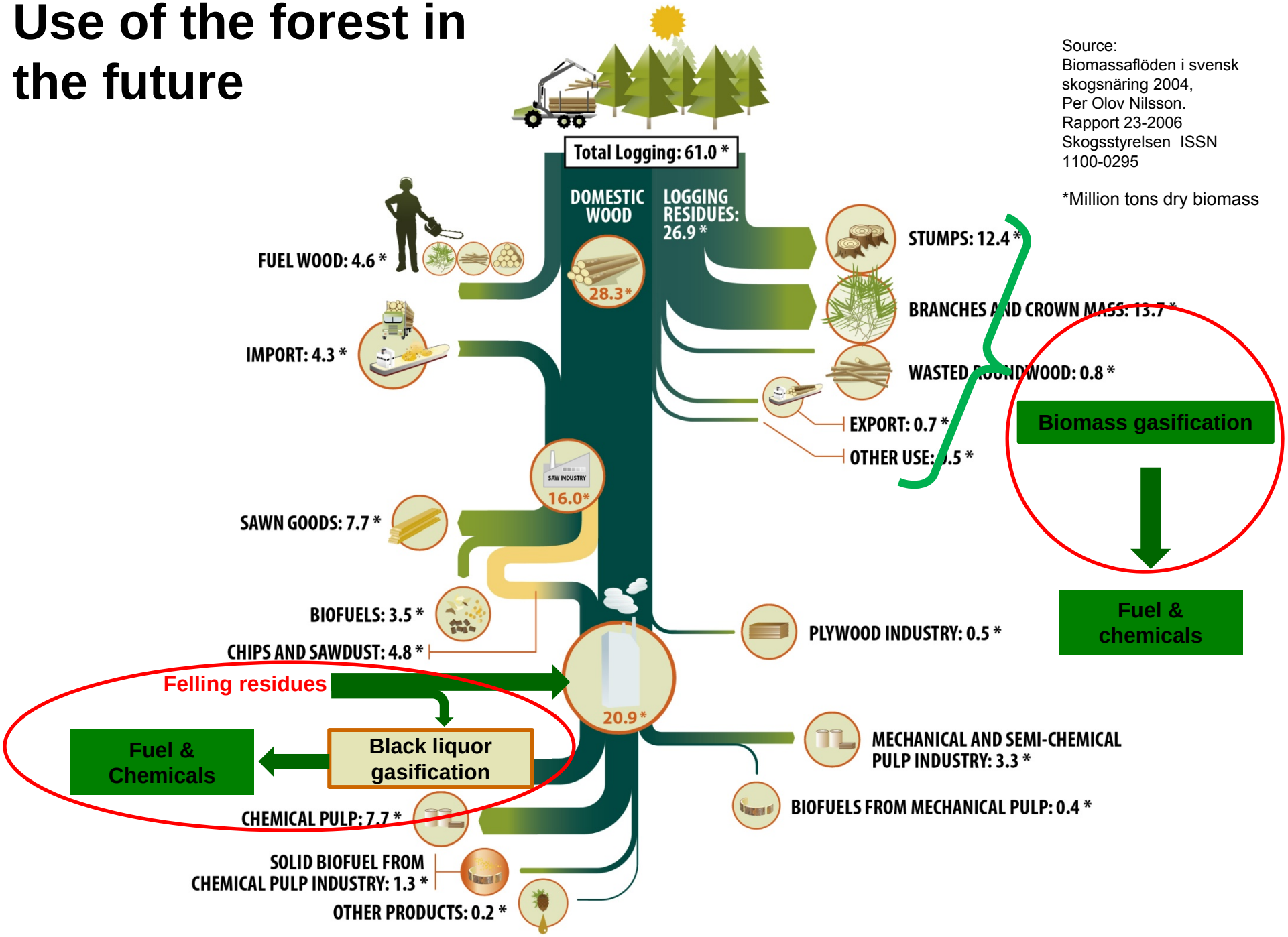
Use of the forest today



Source:
Biomassaflöden i svensk skogsnäring 2004,
Per Olov Nilsson.
Rapport 23-2006
Skogsstyrelsen ISSN 1100-0295

*Million tons dry biomass

Use of the forest in the future



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Potential for motor fuels from the Swedish* forest

Process alternative	Use of black liquor	Use of forest residues	Motor fuels (MeOH/DME)
Direct gasification of residues	-	**70 TWh/y****	**35 TWh/y**
Black liquor gasification + direct gasification	40 TWh/year	30 TWh/y 40 TWh/y **70 TWh/y**	25 TWh/year 20 TWh/year **45 TWh/y*****
Co-gasification of black liquor and pyrolysis oil	40 TWh/year	30 TWh/y 40 TWh/y **70 TWh/y**	25 TWh/year 25 TWh/year **50 TWh/y******

* Finland has about the same potential as Sweden, EU as a whole has about three times this potential for fuels from forest biomass
** Estimated sustainable availability in the near future (no timber or pulp wood)
***High cold gas efficiency from catalytic alkali in the fuel, waste heat recycling to the pulp mill reduces the need for additional fuel
**** Co-gasification with black liquor also benefits from the catalytic effect of cooking chemicals

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Swedish pilot scale research on gasification of forest industry by-products

Pilot plant projects	2000 - 2005	2005 - 2010	2010 - 2015	2015 - 2020	Budget
BLG I					11 M€
BLG II		Black Liquor			11 M€
BioDME					28 M€
LTU Biosyngas		BL + PO + pulverized fuels			20 M€
GoBiGas		Pellets + residues			≈ 25 M€
PEBG		Pulverized fuels			≈ 4 M€

Significant other gasification projects in Sweden	2000 - 2005	2005 - 2010	2010 - 2015	2015 - 2020	Budget
SFC					36 M€
f^3 (system analysis)					≈ 8 M€

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The LTU Green Fuels pilot plant in Piteå

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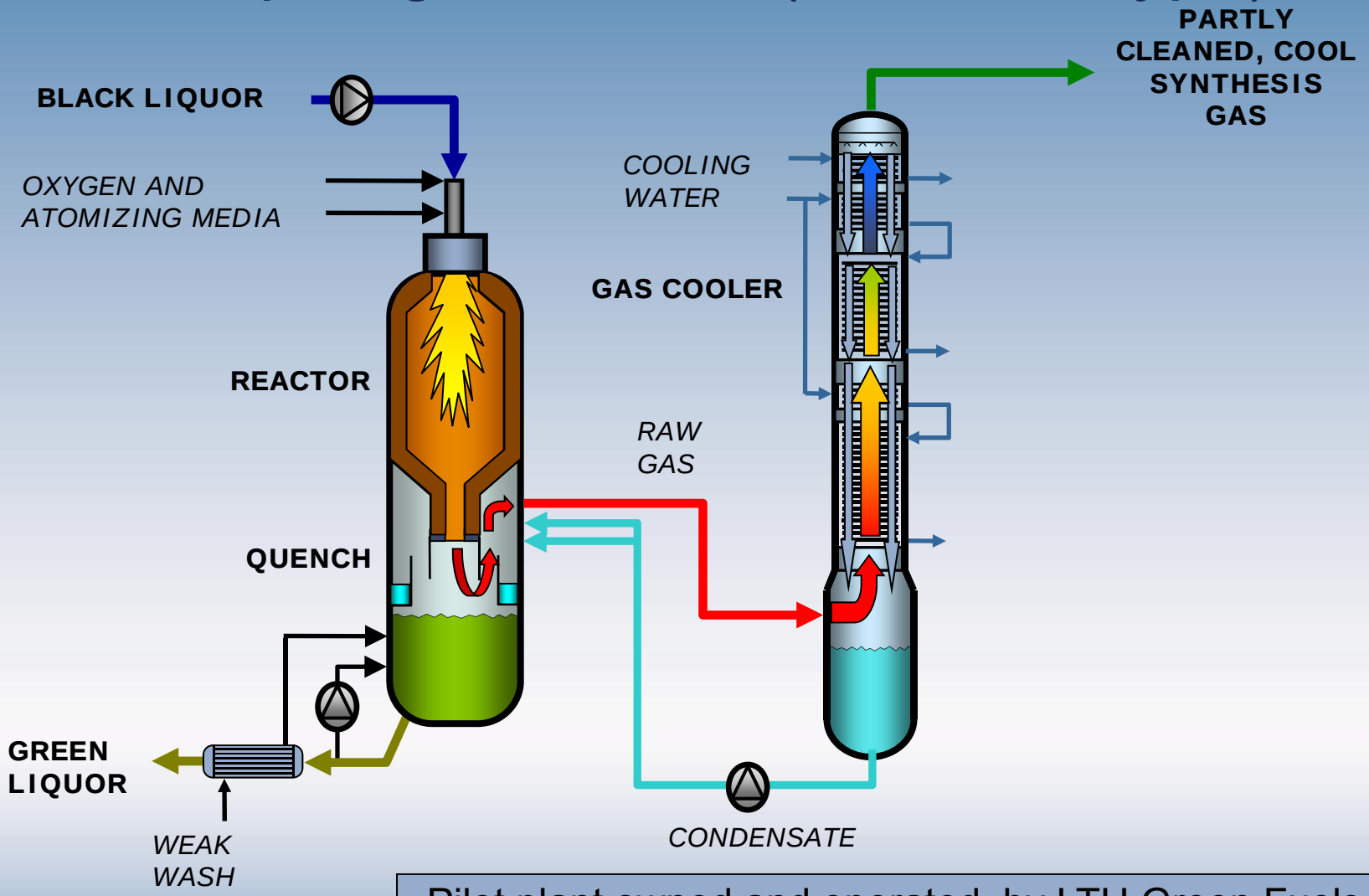
Black liquor gasification (Chemrec-type)



- Pilot plant owned and operated by LTU Green Fuels
- 20 ton BLS/day (3 MW), 30 bar, 1050° C
- Oxygen blown

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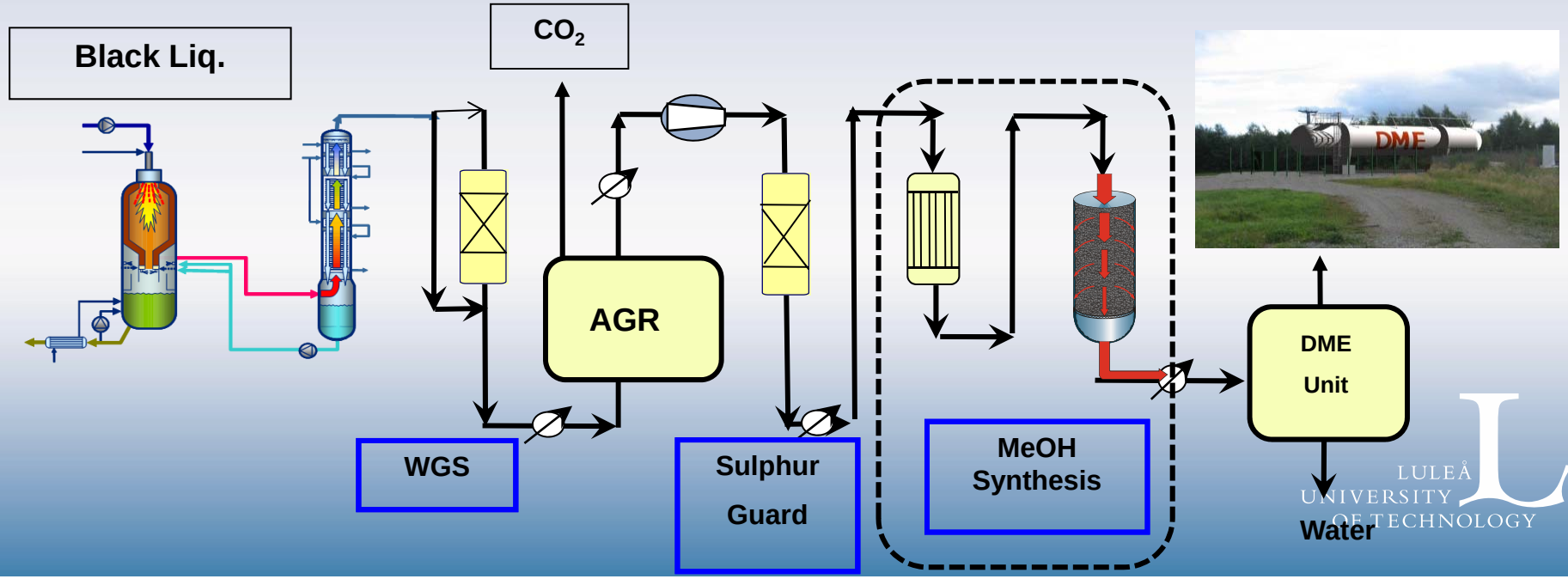
Black Liquor to Green DME Demo

- Gasifier >23 000 h
- DME plant >8 000 h
- New MeOH technology



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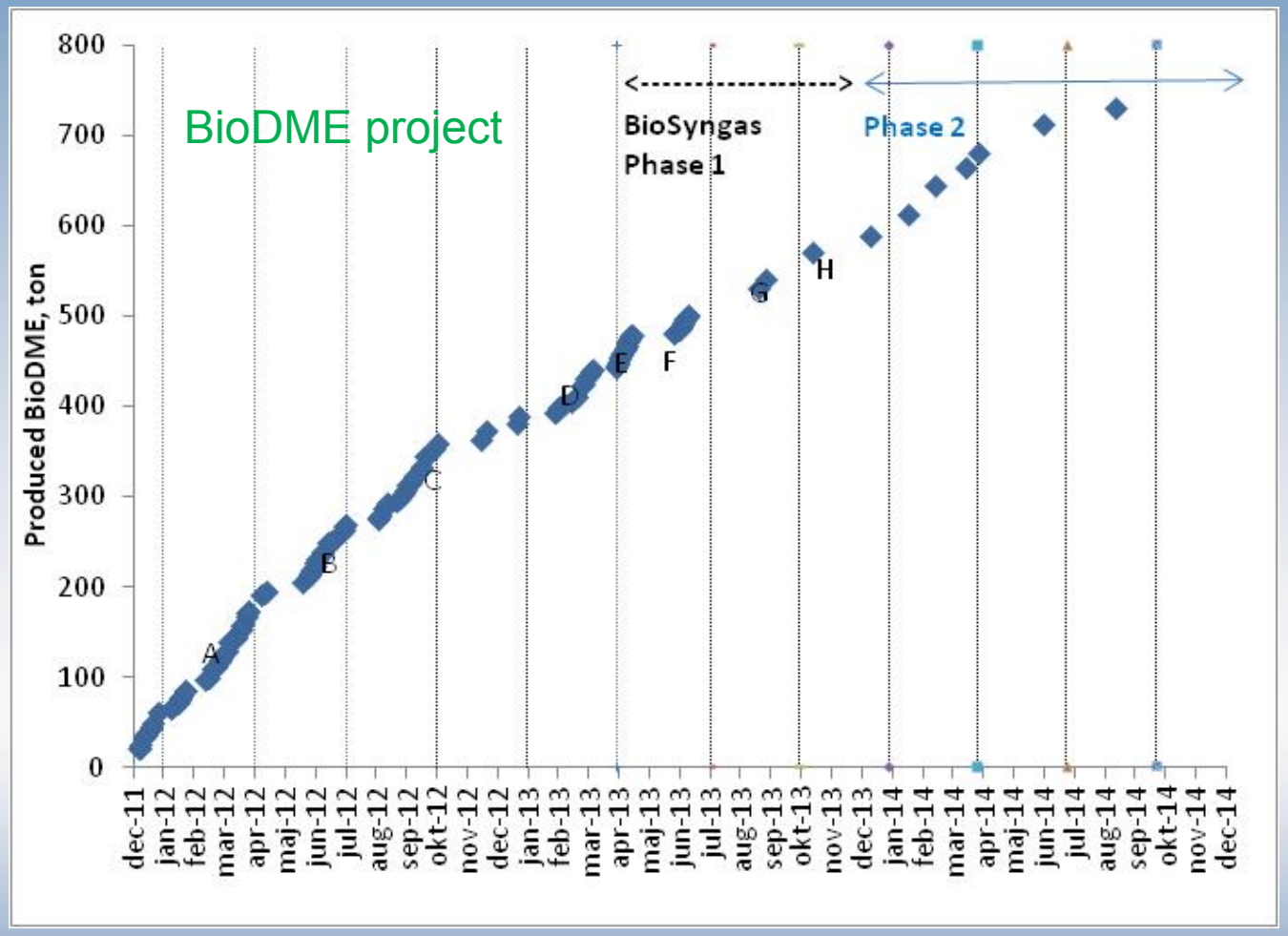
Produced BioDME



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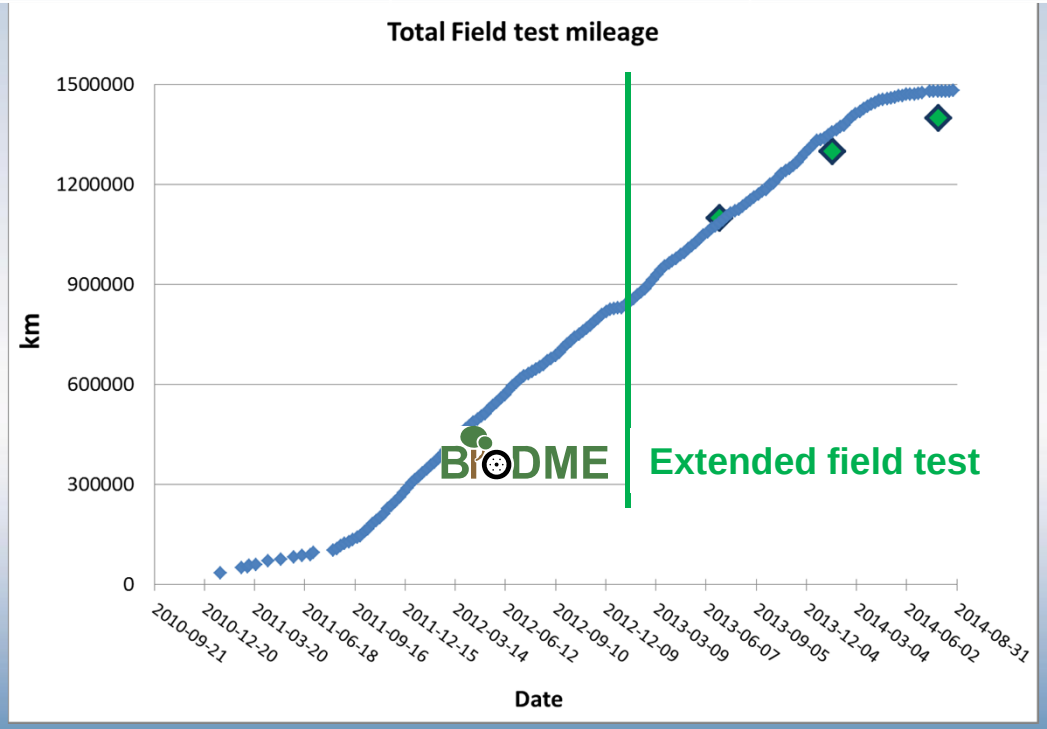
Extended Volvo field test

8 trucks, 2013-01-01 to 2014-06-30

Energimyndigheten

(1000 Km)	Status 2014-08-31	Target June 2014
Total mileage	1 485	1 400
1 truck	296	250



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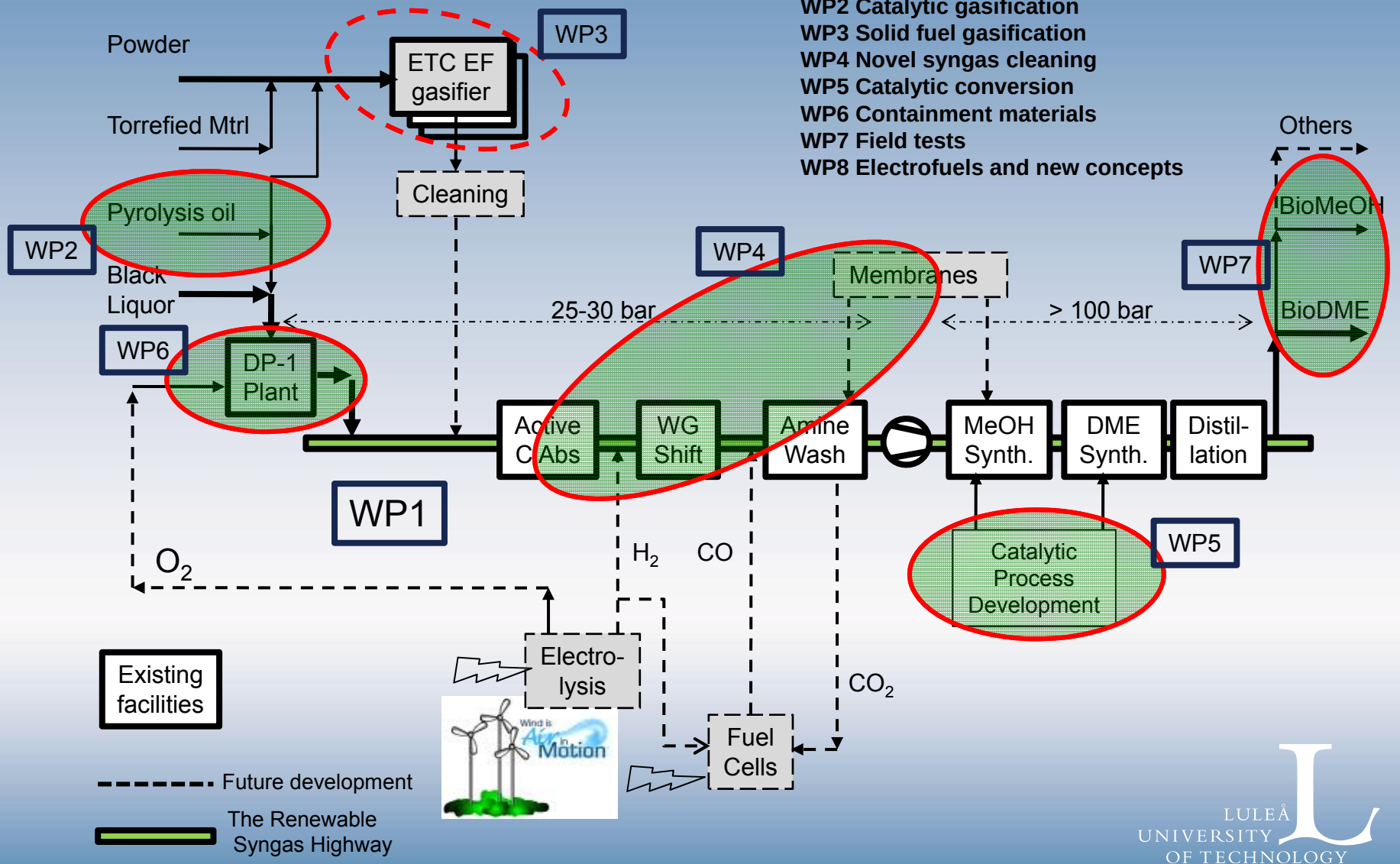
LTU Biosyngas Program Phase 2

WP1 Pilot scale experiments
WP2 Catalytic gasification
WP3 Solid fuel gasification
WP4 Novel syngas cleaning
WP5 Catalytic conversion
WP6 Containment materials
WP7 Field tests
WP8 Electrofuels and new concepts



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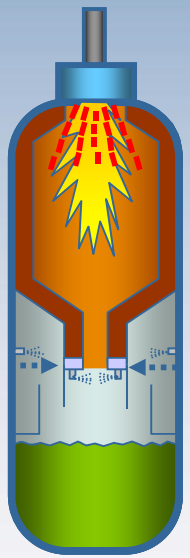
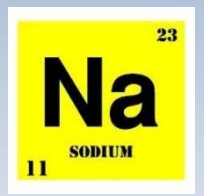
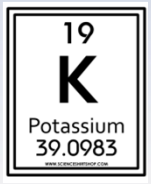
WP2: The catalytic gasification project
- **turning alkali to an advantage**







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Catalytic gasification

- Black liquor contains large amounts of alkali
- Entrained flow gasification at 1050° C results in 100% conversion and extremely low tar content
- For solid biomass the temperature has to be significantly higher (app. 1400° C) for full conversion in an EF gasifier

- Lower gasification temperature means better energy efficiency and less stress on materials

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WP2 Catalytic gasification

2.1 Co-gasification

Mixing processes
- BL/PO ratio
- Lignin precipitation

Pilot plant modifications
- Design
- Implementation

Pilot plant tests
- Proof of concept
- Balances, efficiency
- Long term effects

Techno-econ.

2.2 Fundamental

Lab experim.
- Thermo gravimetry
- Drop tube furnace
- …

Modelling
- Catalytic processes
- Raw material prop.

2.3 Solid biomass

Wood powder
- Alkali impregnation
- Lab gasification

Lignin
- Alkali addition and residue
- Lab gasification

Techno-econ.
- Integration with mill
- Incl alkali addition and recovery

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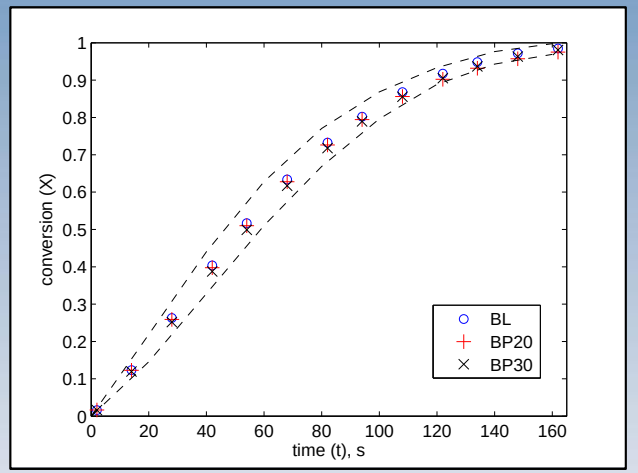
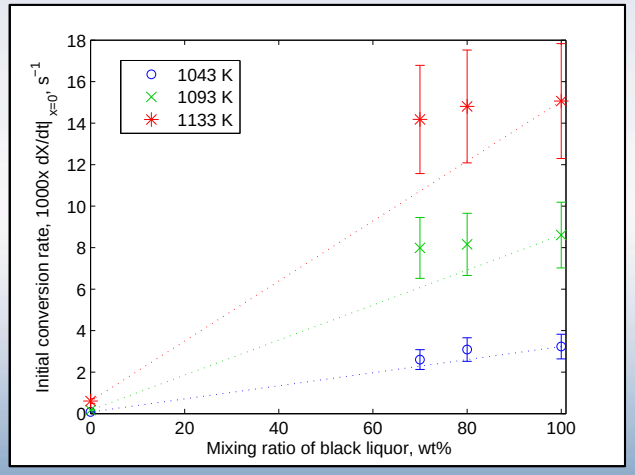
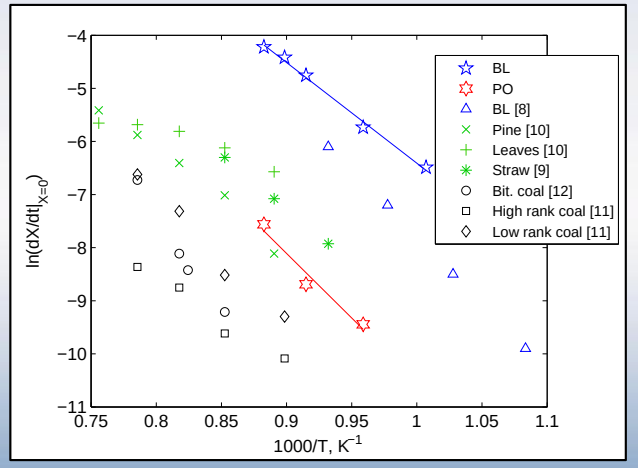
Sub-project 2.2 Fundamental studies

Isothermal TGA measures sample weight loss in controlled atmosphere and temperature







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WP4: Gas cleaning

- Industry standard Rectisol process is complex and has high CAPEX and OPEX
- Alternative method with regenerable solid absorbents and CO_2 selective membranes has the potential to reduce costs significantly

- Challenges:
  - find absorbents with high performance that can be regenerated many times
  - Scale up of zeolite membranes to m^2 scale

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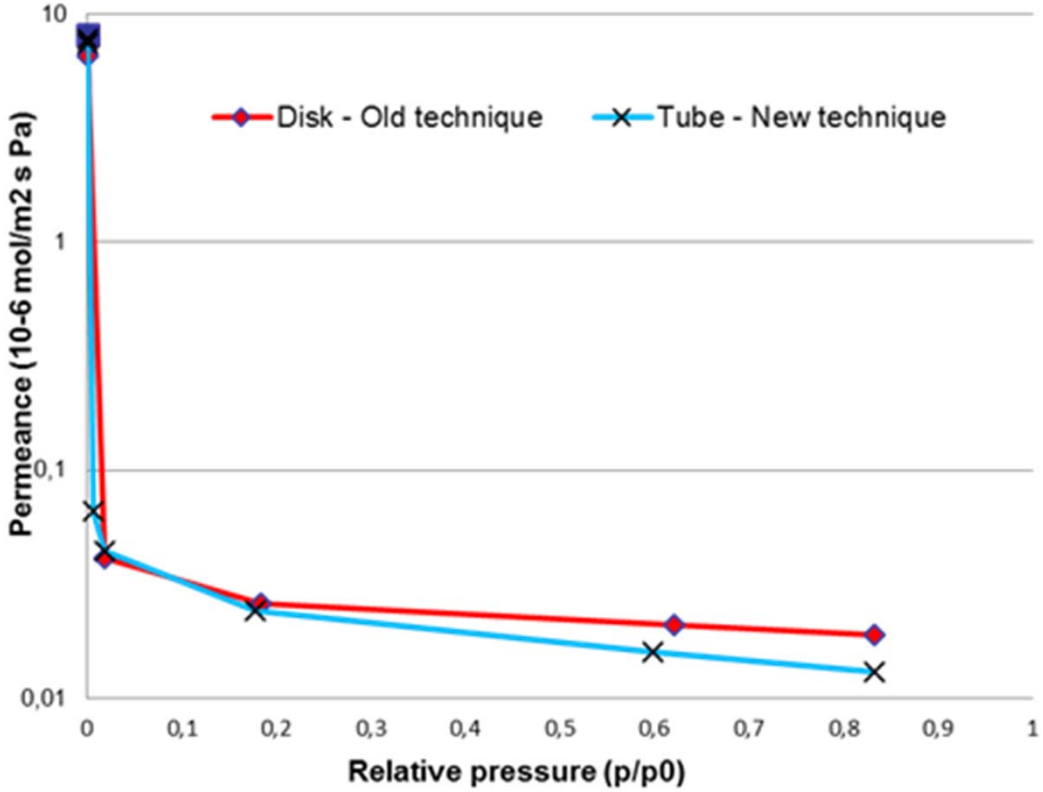
WP4 Gas cleaning: tubular zeolite membranes for CO2 removal



First tubular membrane of comparable quality synthesized.

Awaiting further testing of tubular membranes to check separation performance and reproducibility

Major milestone and goal hereby achieved (ahead of time)

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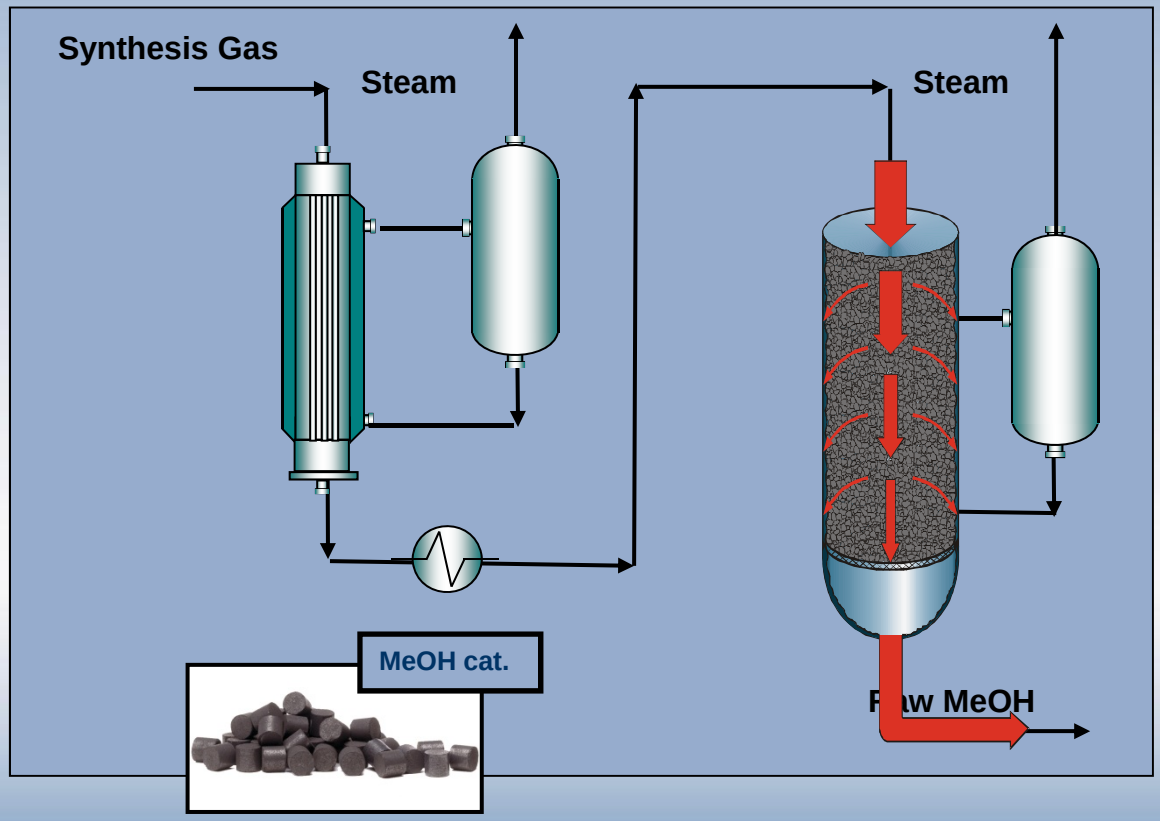
WP5: Once-Through Methanol Synthesis

MeOH reactor

Conrad



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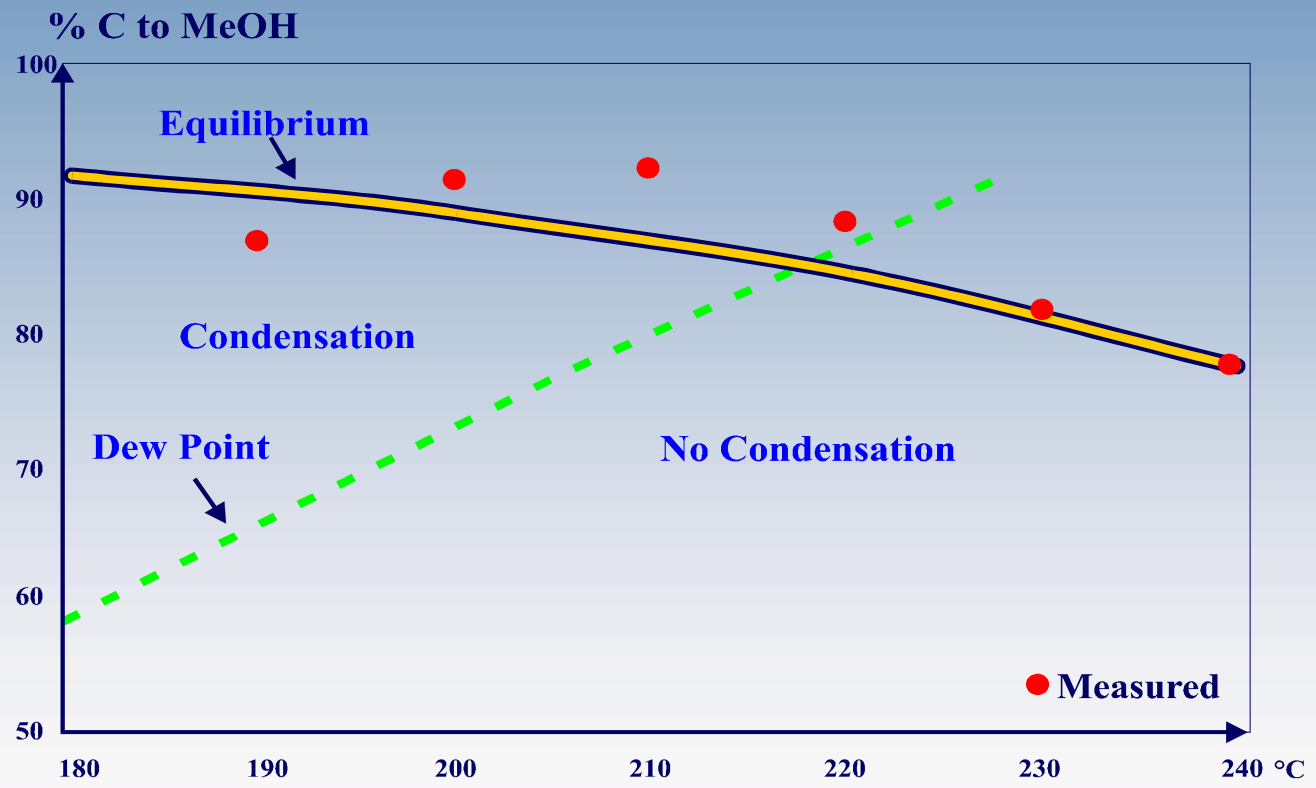
CONRAD – How it all started



- Presented at NGCS in Oslo 1990

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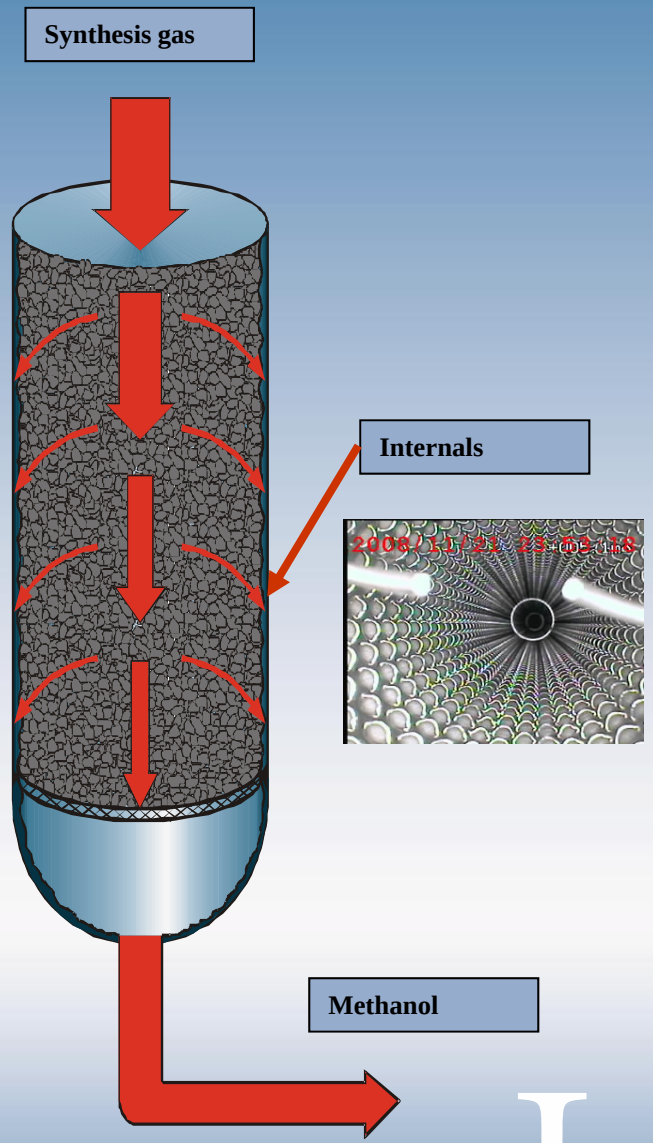
The CONRAD concept

- CONdensing RADial flow converter
- Reactor comprising two-zone tubes
  - High T zone in center of tube
  - Low T zone along tube wall
- Internals for gas-liquid separation
- Operation of CONRAD relies on a carefully designed balance between heat transfer and mass transfer



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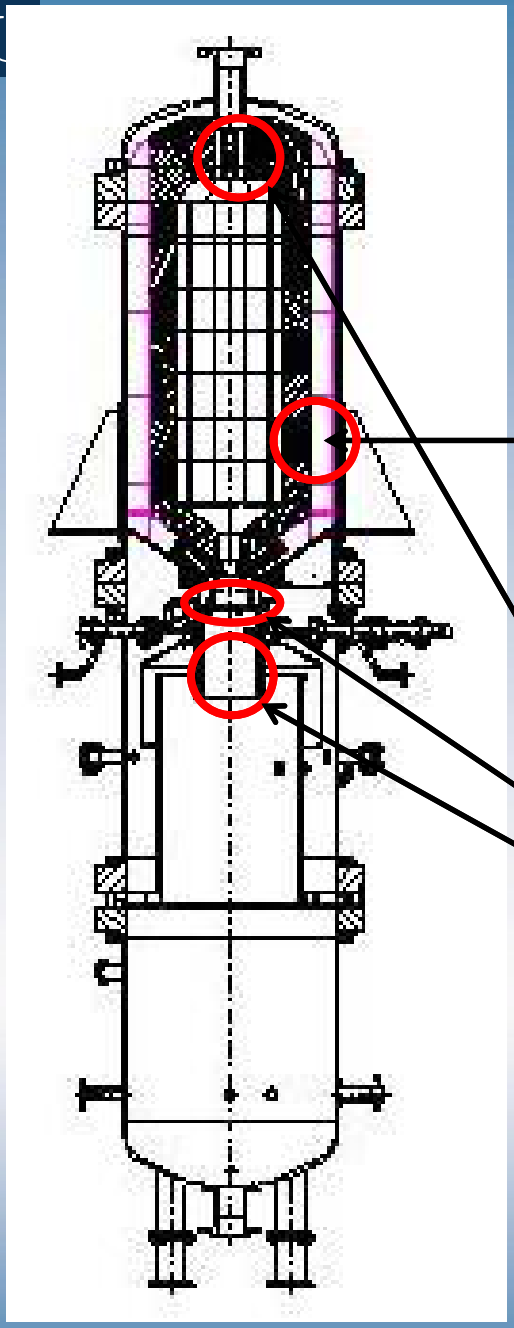
WP6 Construction Material



1.1 Compile report over 1995-today experiences / results for gasifier contain material developments

1.2 Install and operate a low cost ceramic (Lining #1) based on the last 1½ year of experiences*

1.3 Install and operate the most promising lining (Lining #2) based on gained experience*

2.1 Optimize material selection and geometric shape Of the fuel feed nozzle

2.2 Optimize and change out* ceramic support ring

2.3 Optimize and change out* primary quench tube

*)The actual change out is part of normal maintenance

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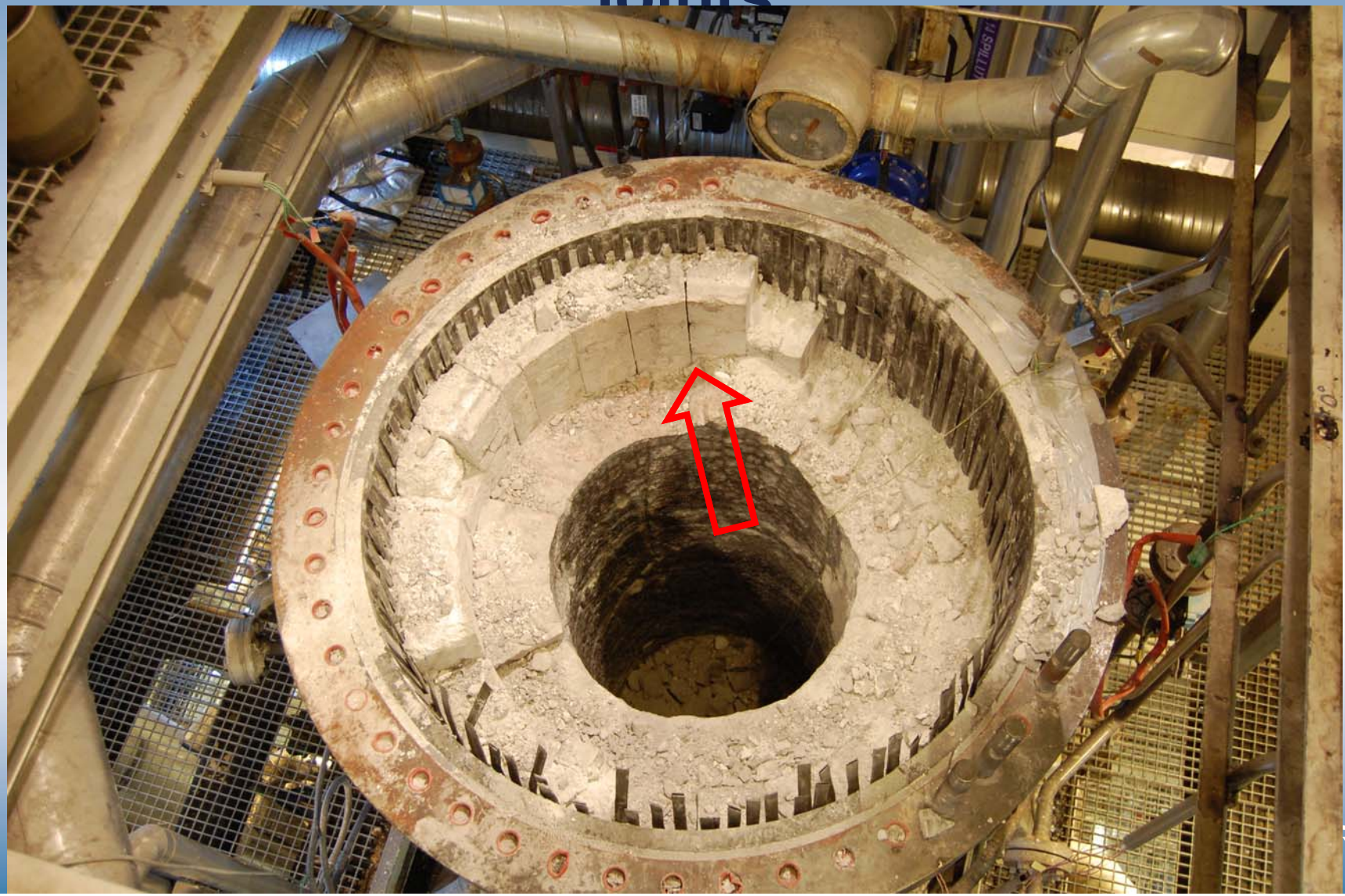
Back-up brick with minimum of smelt in joints



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Conclusions

- Black liquor gasification + MeOH/DME can be considered a proven technology
- Co-gasification looks promising but needs verification in pilot scale tests before it can be commercialised
- Containment solutions are available but cost reductions are possible
- Gas cleaning and solid biomass gasification under development
- New methanol synthesis looks very promising

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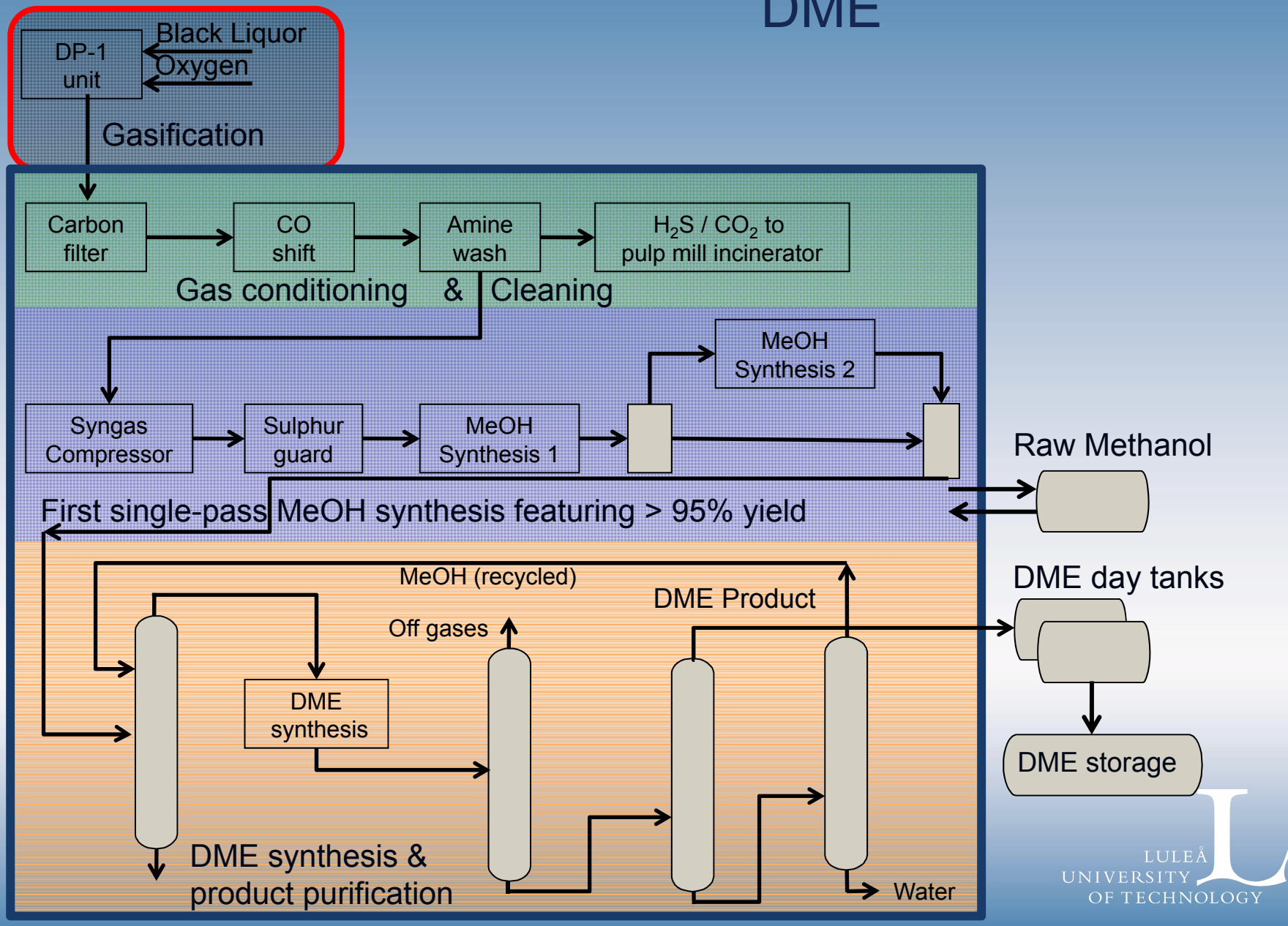
Syngas conversion to methanol and DME



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