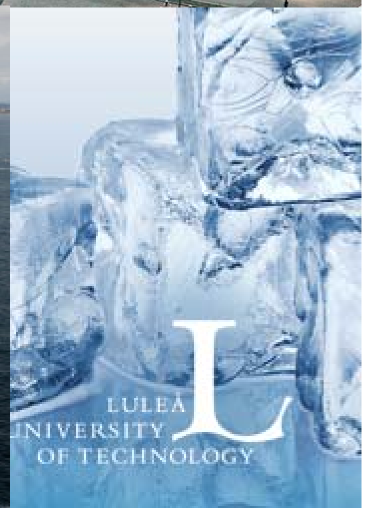
METHANOL, a Multi Source and Multipurpose Energy Carrier Alternative

IEA Bioenergy / IETS:
System and Integration Aspects of Biomass-based Gasification

Gothenburg
November 19, 2013

Ingvar Landälv
Senior Project Manager
LTU



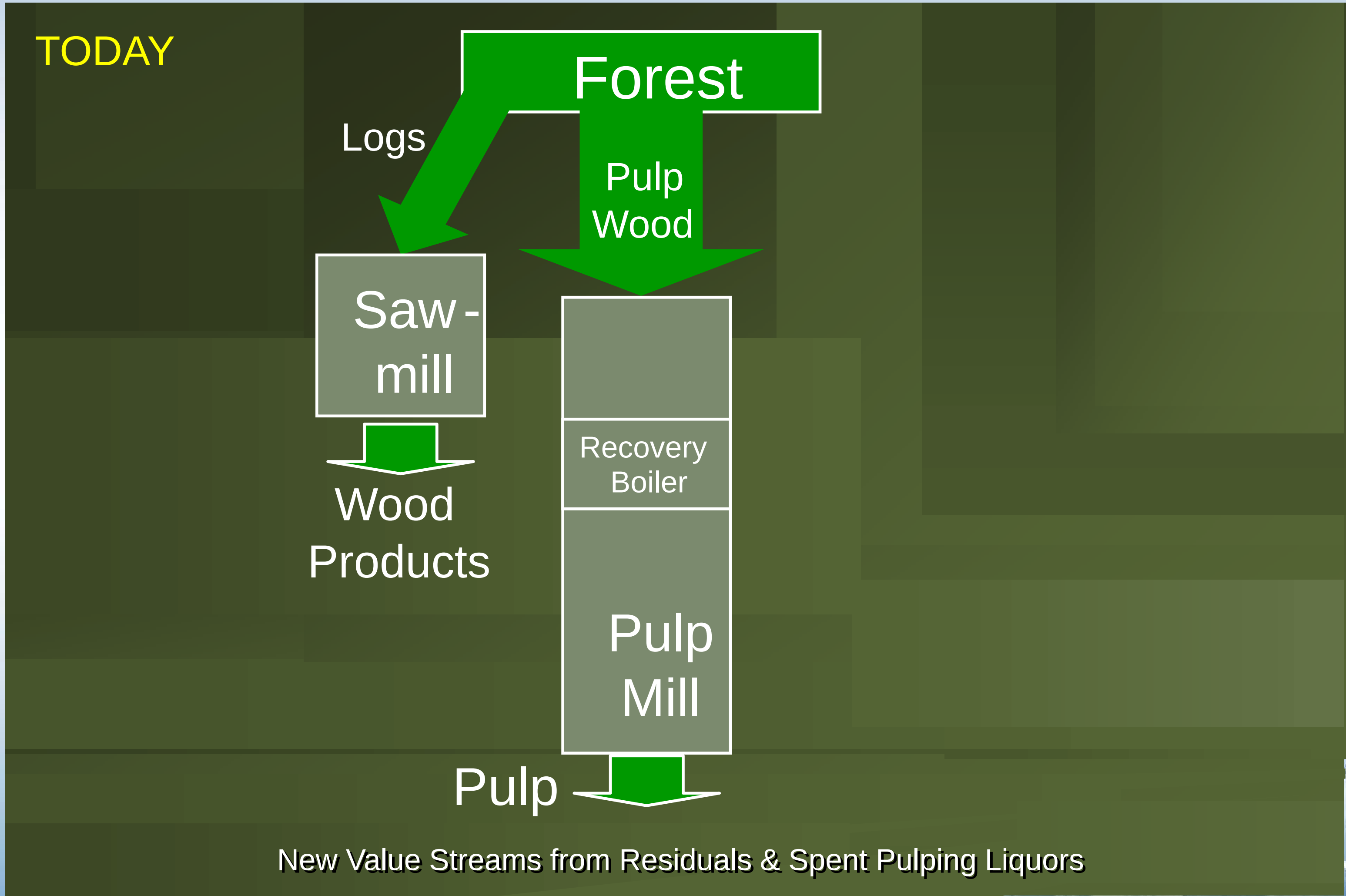
AGENDA

- **Turning alkali in the feedstock to an advantage**
  - Why has Chemrec focused Black Liquor so long?
  - Is technology ready for commercialization?
  - Can the BLG developments be used for other applications?

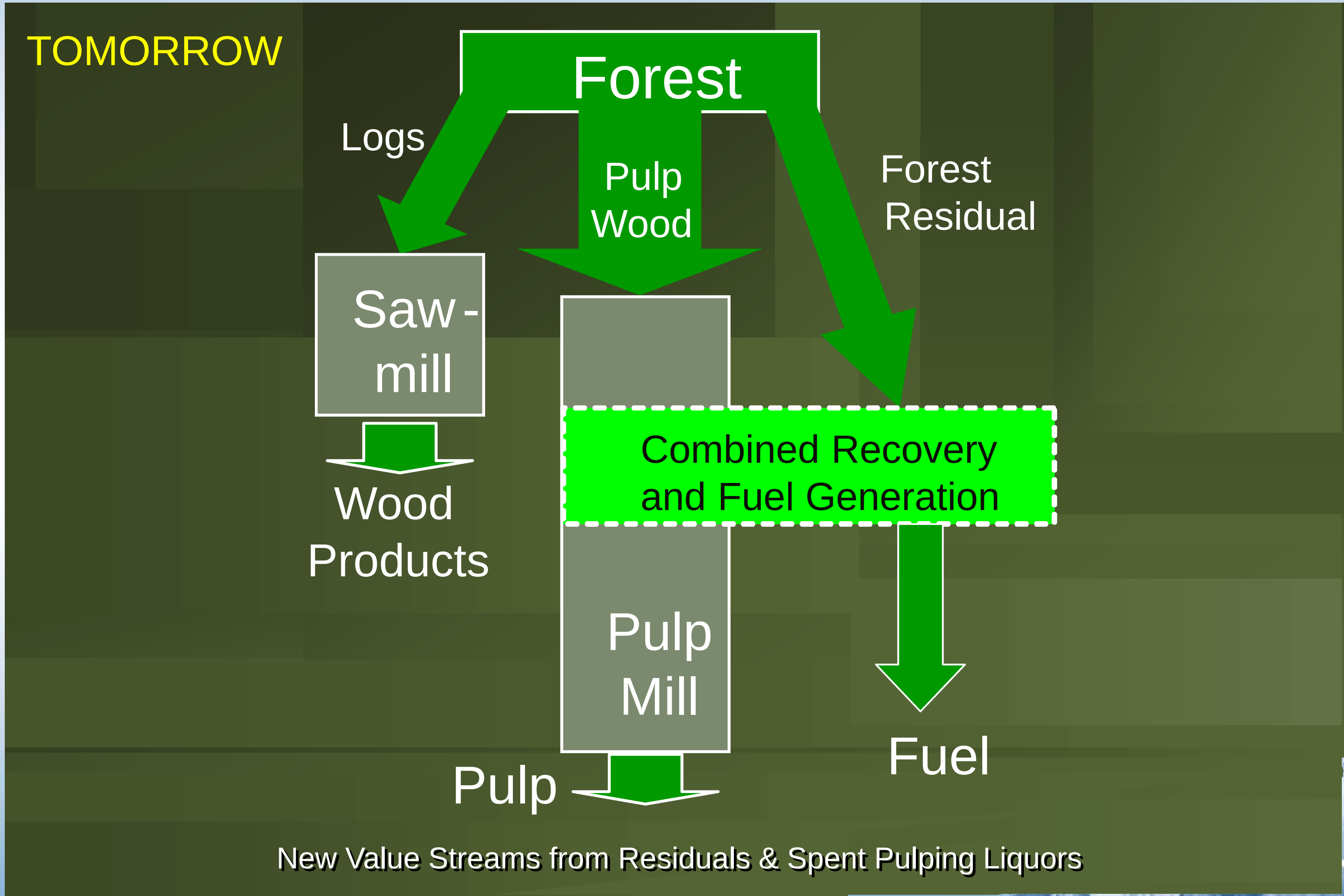
- **Future Energy System Scenarios**
  - The need to look at the total cost of a new energy system
  - An example from the marine sector
  - An example from the HD vehicle sector

- **Summary**

Today's commercial Forrest Industry has two main legs



BLG is a transformative technology converting pulp mills to biorefineries making efficient use of the third fraction from the forest

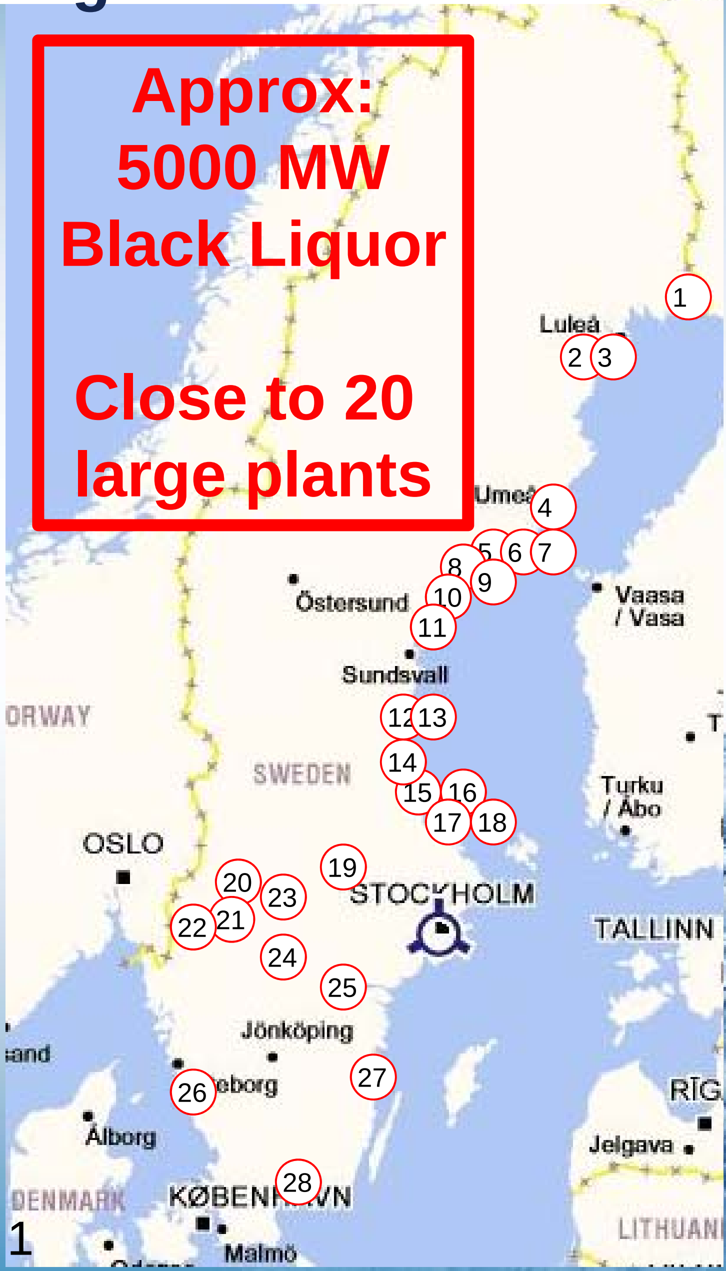


BL Energy is a large renewable energy source in some areas of the World e.g. Sweden

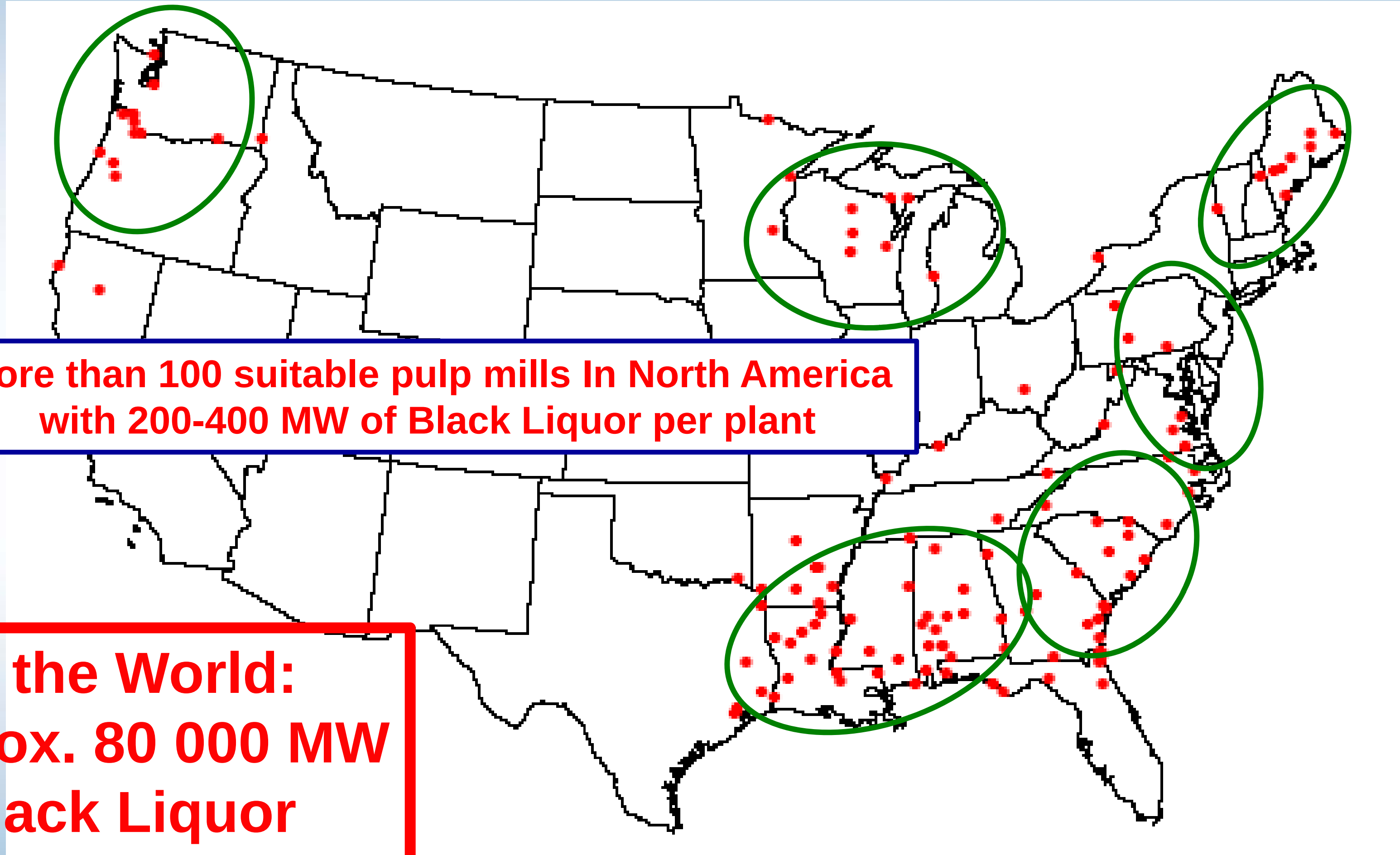
Nr	Mill owner, name	Nominal capacity	Current capacity	Year of start-up
1	Billerud, Karlsborg	1250	1500	1980
2	SCA, Munksund	600		1965
3	Smurfit Kappa, Lövholmen	1450	1950	1972
4	SCA, Obbola	1000		2007
5	Husum, M-Real	750	1100	1965
6	Husum, M-Real	700	2000	1978
7	Husum, M-Real	1100	1300	1988
8	Domsjö, Domsjö	375		1958
9	Domsjö, Domsjö	375		1964
10	Dynäs, Mondi	915		1978
11	Östrand, SCA	3300		2006
12	Iggesund, Holmen	520	900	1966
13	Iggesund, Holmen	520	900	1967
14	Vallvik, Rottneros	760/1000	1200	1974/1999
15	Korsnäs, Korsnäs	865	1330	1968
16	Korsnäs, Korsnäs	1550	1550	1987
17	Skutskär, StoraEnso	585	650	1967
18	Skutskär, StoraEnso	1900	2800	1976
19	Frövi, Korsnäs	520	1260	1970
20	Skoghall, Stora Enso	2200/(3350)		2005
21	Gruvön, Billerud	2500/(3300)		2000
22	Billingsfors, Munksjö	230	330	1976
23	Bäckhammar, Wermland Paper	570	750	1976
24	Aspa, Munksjö	510	1200	1973
25	Skärblacka, Billerud	1250	1850	1976
26	Värö, Södra	2500		2002
27	Mönsterås, Södra	4000		1996
28	Mörrum, Södra	2000	2260	1995

Approx: 5000 MW Black Liquor

Close to 20 large plants



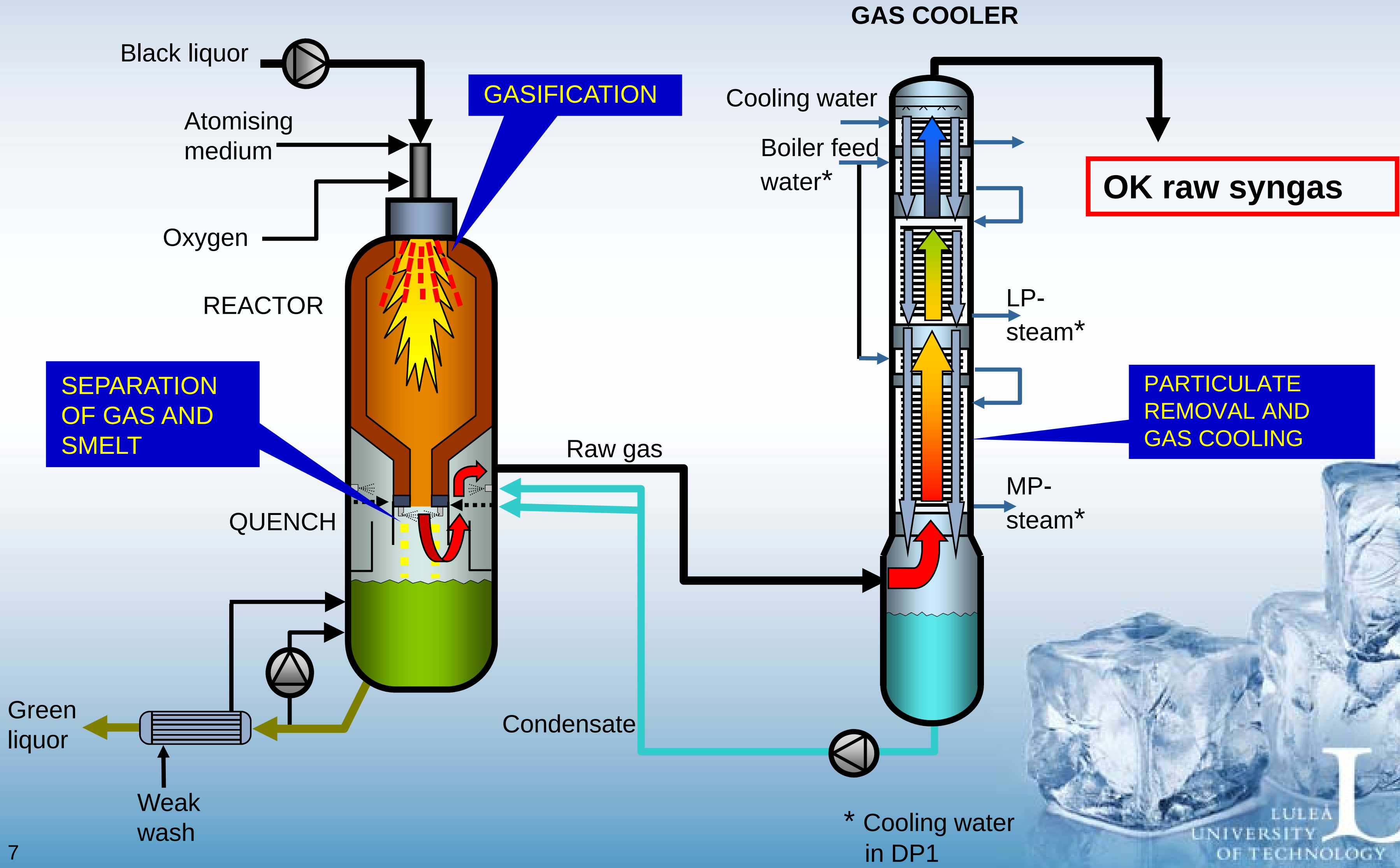
BL Energy is a substantial energy source in some states in the US e.g. Georgia



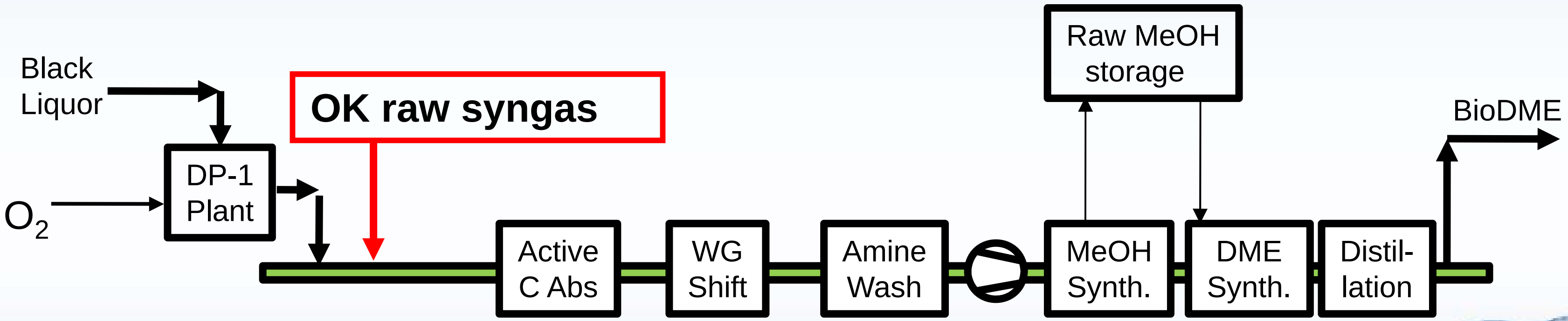
More than 100 suitable pulp mills In North America with 200-400 MW of Black Liquor per plant

In the World:
approx. 80 000 MW Black Liquor
or
250 – 300 large plants

Chemrec technology generates good quality raw syngas with three main process steps: Gasification, Quenching and Cooling



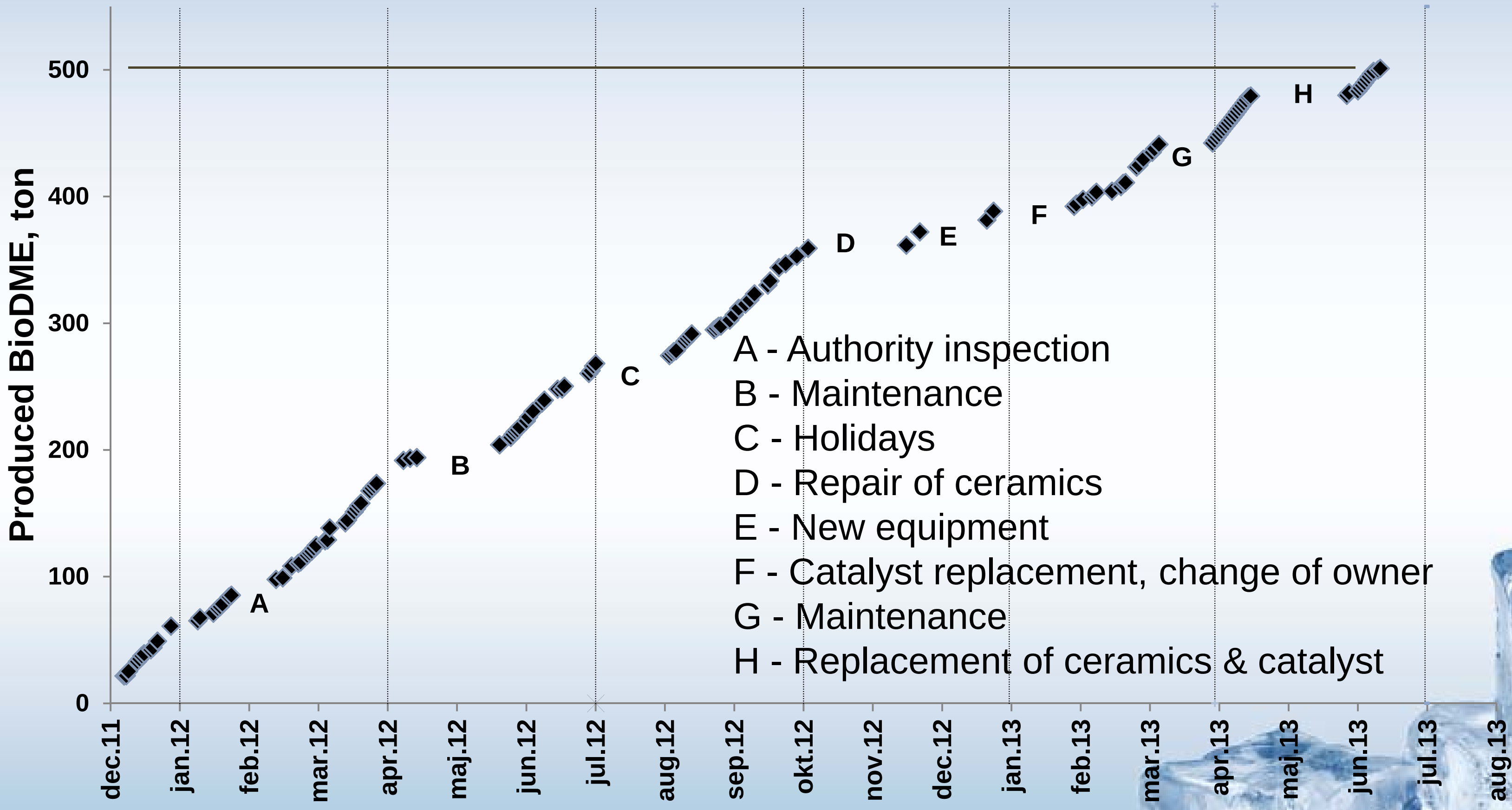
BL to BioDME: Well proven Concept by Chemrec and LTU in the Pilot Plant in Piteå



Development Plant for Oxygen-blown high pressure BL gasification

- Located at the SmurfitKappa mill in Piteå, Sweden
- Oxygen-blown and operated at 30 bar(g)
- Capacity 20 metric tons per day of black liquor solids (3 MW(th))
- Used for technical development and design verification
- Started up 2005 –Now in operation more than 21 000 hours (10/2013).
- Raw syngas converted to BioDME since 2011 (about 6000 h)
- Operations: 10 operators in 5 shifts

Accumulated BioDME Production is close to 600 tons in October 2013



Chemrec technology ready for industrial scale and can be built by world-class EPCs with adequate risk allocation

- **EPC 1: *…one of few mature and feasible technologies*** *for large-scale production … to produce fuels from forest-based biomass ...”*
- **EPC 2:** *“...in principle willing to provide* ***customary EPC wrap around guarantees*** *...”*
- **EPC 3:** *“...LSTK service with customary* ***wrap around guarantees****... ”*
- **Oil major** evaluation (10 experts): **“*No showstoppers for industrial scale-up”.***
- **Piteå demo plant** producing methanol and DME using commercial processes.

New Bern, 1st gen, 47 000 hrs

Piteå, 2nd gen, >21 000 hrs

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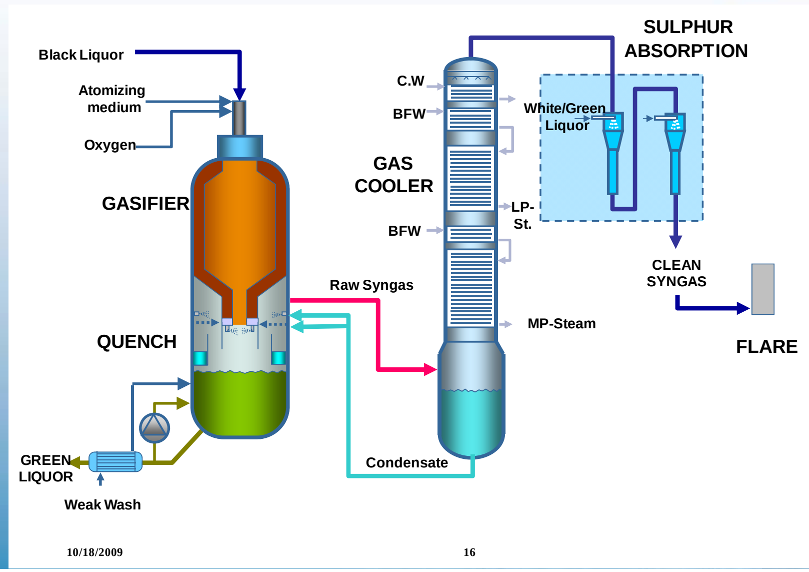
Chemrec Status as per January 2013

- ***Dec 31, 2012*:** Chemrec Piteå companies including pilot plants sold by Chemrec AB to LTU Holding AB,
- ***Jan 1, 2013:*** 17 pilot plant staff employed by LTU.
- ***Dec 31, 2012:*** License agreement between licensors Chemrec AB & HaldorTopsøe with LTU and LTU Holding. Technology rights stay with licensors.
- ***Jan 30, 2013:*** Consortium Agreement between parties involved in continued R&D
- Chemrec has reduced staff awaiting long term stable **regulations for advanced biofuels**. Two Chemrec Stockholm staff temporarily on leave assigned to LTU
- Continued operation of the plants as part of LTU Biosyngas Program

With the FFF Commision and their just releast report there is a very good chanse that legislation will be developed that meets the requirement to start investment in advanced biofuels plant



LTU Biosyngas Centre Program

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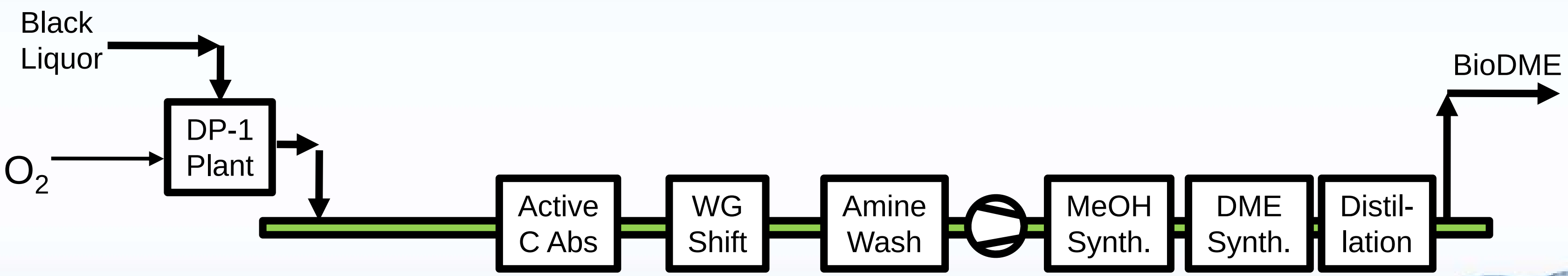
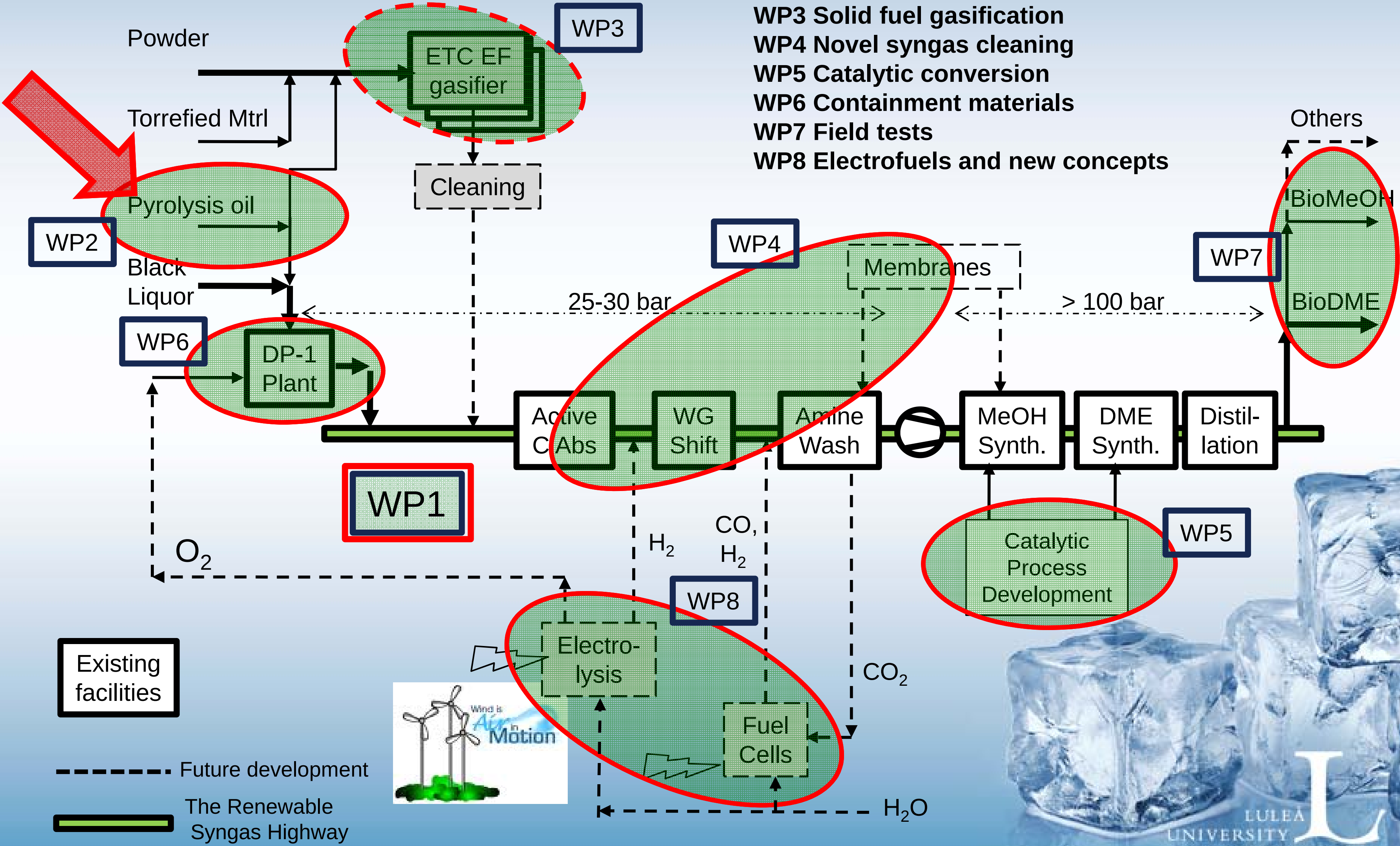
The BL to BioDME facility is the backbone in the LTU Biosyngas Centre Program

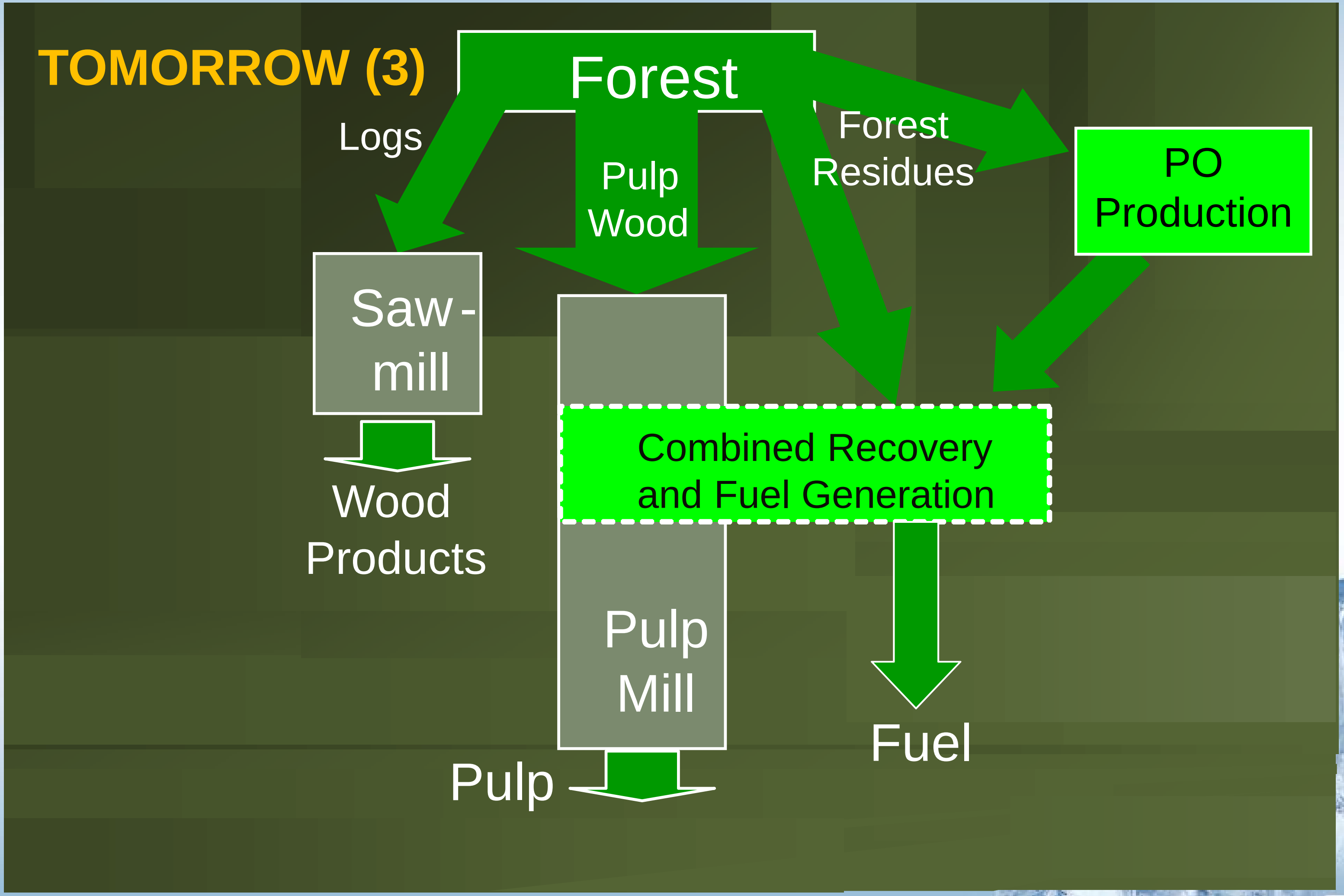


LTU Biosyngas Program planned for 2013-2016

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



Biomass flow from the forest can be increased adding pyrolysis oil to the black liquor flow

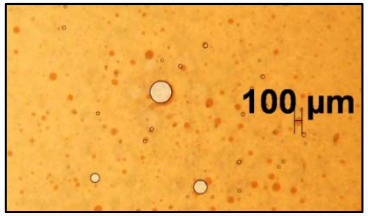


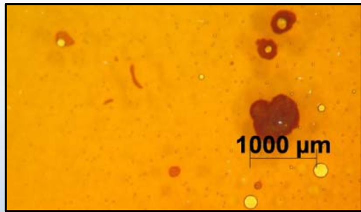
WP2: Co-gasification BL/PO – some impressions from the lab

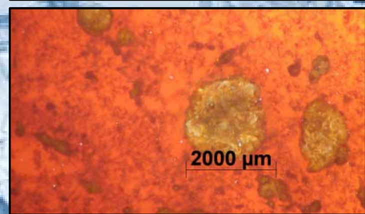
TGA and DTF lab activities during spring 2013

PO/BL mixing study

- Lignin precipitation needs to be considered above 20-25% PO
- No solids up to 20% PO







WP 2: Co-gasification of BL and PO offers many potential advantages

All calculations thus assume that BL/PO can be gasified at same temperature as BL is today.

Syngas Capacity increases about 100% by adding about 25% PO to the BL (by weight)

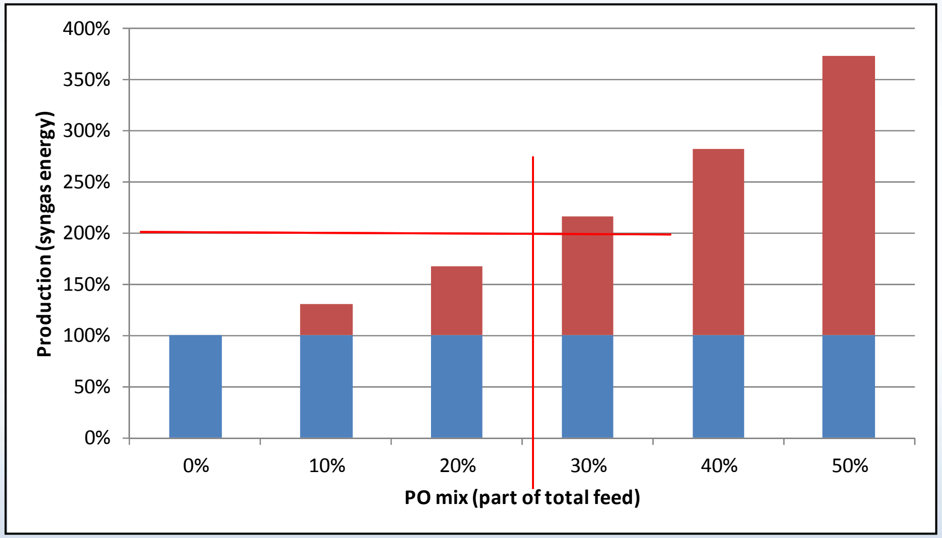


Figure shows simulated increased production of final liquid biofuel product at fixed BL feed (i.e. for specific mill)

Energy efficiency for gasification of added PO is 80-85%

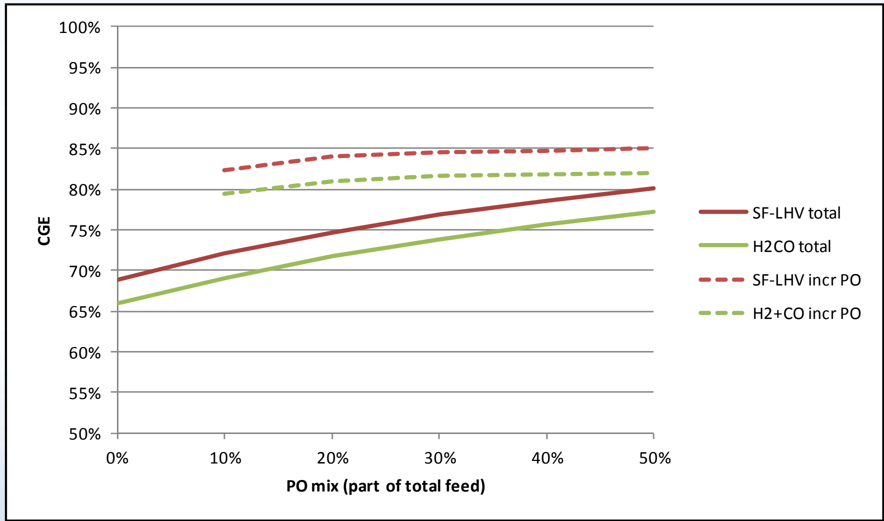
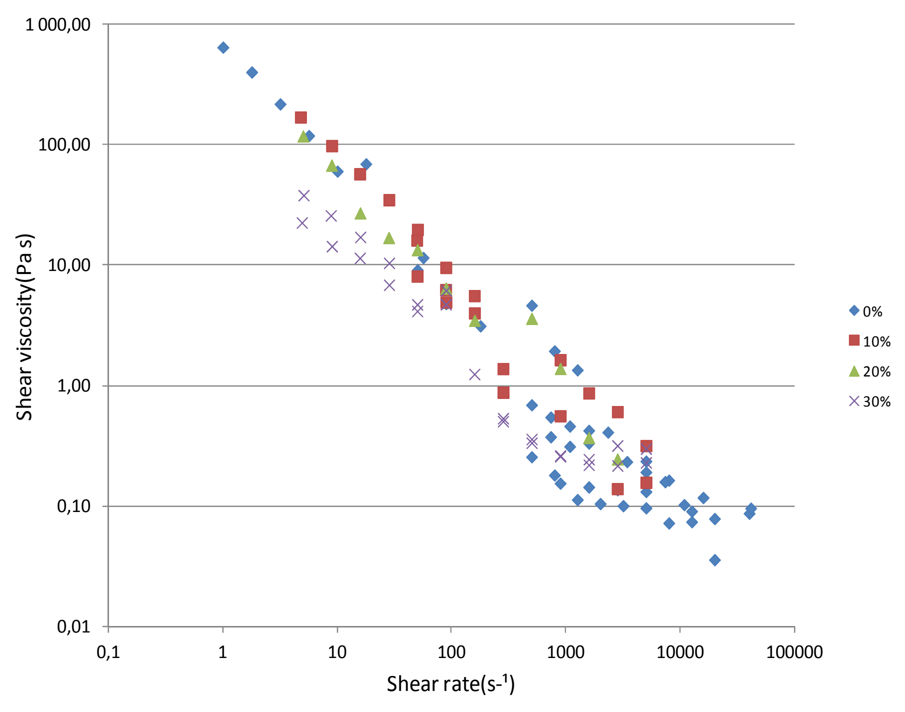


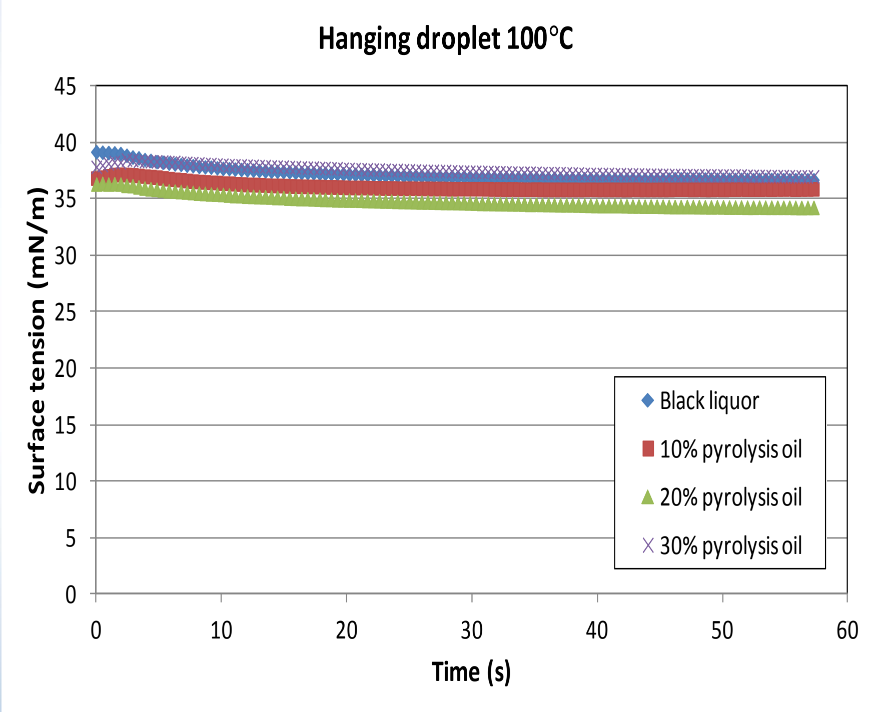
Figure shows simulated gasifier energy efficiency of total mixed feed (solid) and for added PO (dashed)

WP 2: Key physical properties of PO/BL mixtures are promicing based on lab tests

Viscosity



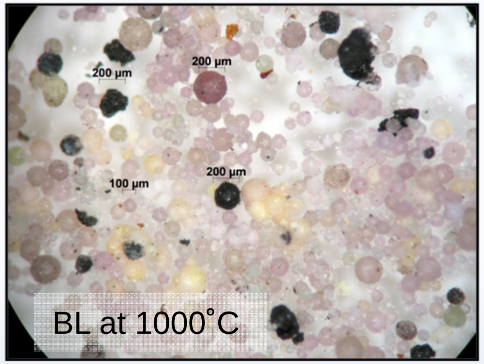
Surface tension



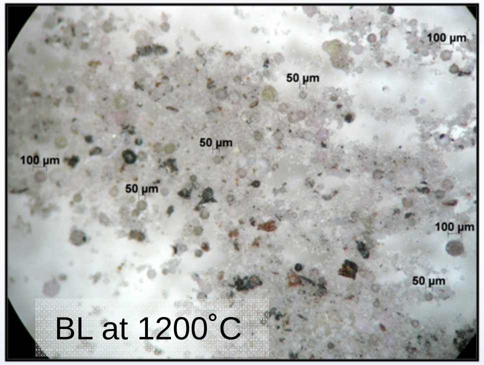
WP2: Drop tube furnace experiments shows carbon conversion of PO/BL mixtures to be at least as good as BL alone

Gasification ash microscopy

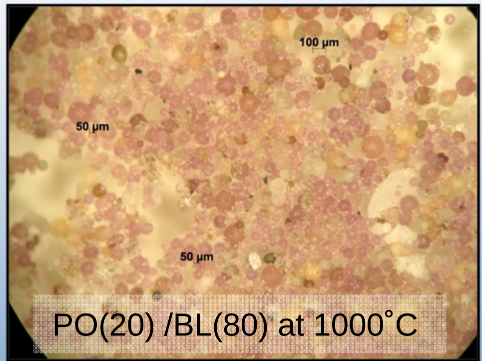
(same magnification)



BL at 1000˚C



BL at 1200˚C



PO(20) /BL(80) at 1000˚C

WP2: Techno-economic study co-gasification - preliminary results indicate good profitability

- **Case study: Rottneros Vallvik**
  - medium sized pulp mill
  - good data from black liquor gasification study available
- **Methanol plant alternatives evaluated**
  - Black liquor gasification ~200 MW BL
  - Two co-gasification alternatives
    - Extend methanol production by adding 25% and 50% pyrolysis oil
- **Preliminary results indicate very favorable production cost for realistic pyrolysis oil price scenarios**
  - Economies of scale and high efficiency contribute

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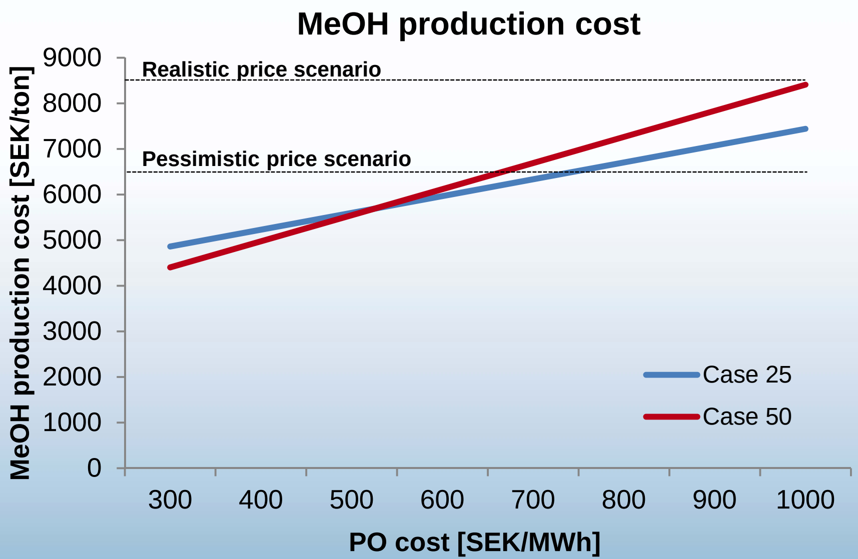
WP2: Techno-economic study co-gasification - preliminary results indicate good profitability

- **Case study**: small/medium sized pulp mill
- **Methanol plant alternatives**
  - Black liquor gasification ~200 MW BL
  - Two co-gasification alternatives – 25% and 50% pyrolysis oil



MeOH production cost

- First plant CAPEX@10% annuity
- Nth plant will give lower CAPEX

MeOH price reference levels for low-blend into gasoline

- **Pessimistic** 6500 SEK/t based on 2011 Rotterdam EtOH price volume equivalence
- **Realistic** 8500 SEK/t projection based on RED and proposed ETD (biofuel mandate)

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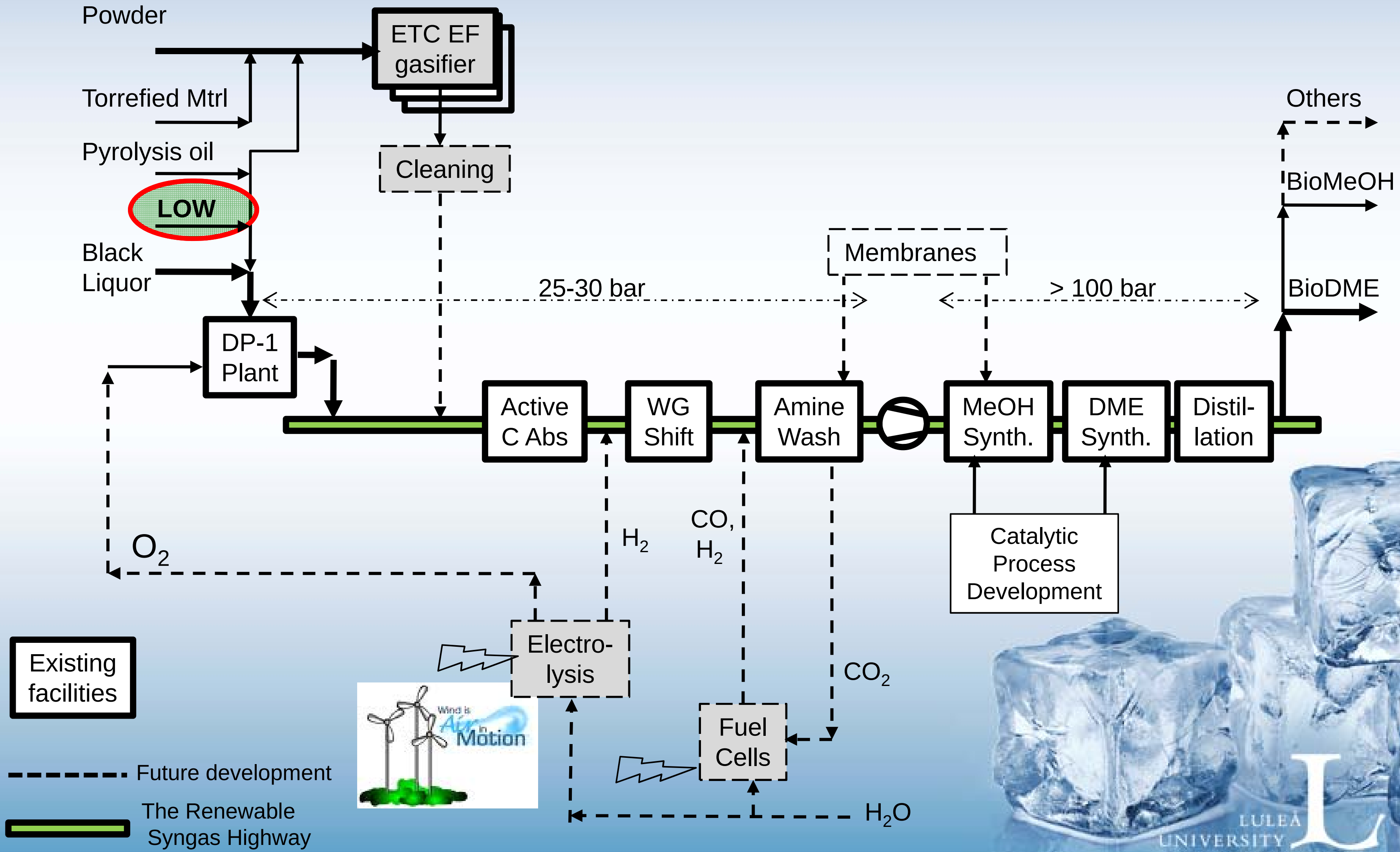
Potential to test Liquid Organic Waste (LOW) in the LTU Green Fuels Plant



Fuels and chemicals from organic waste - liquefaction opens new opportunities

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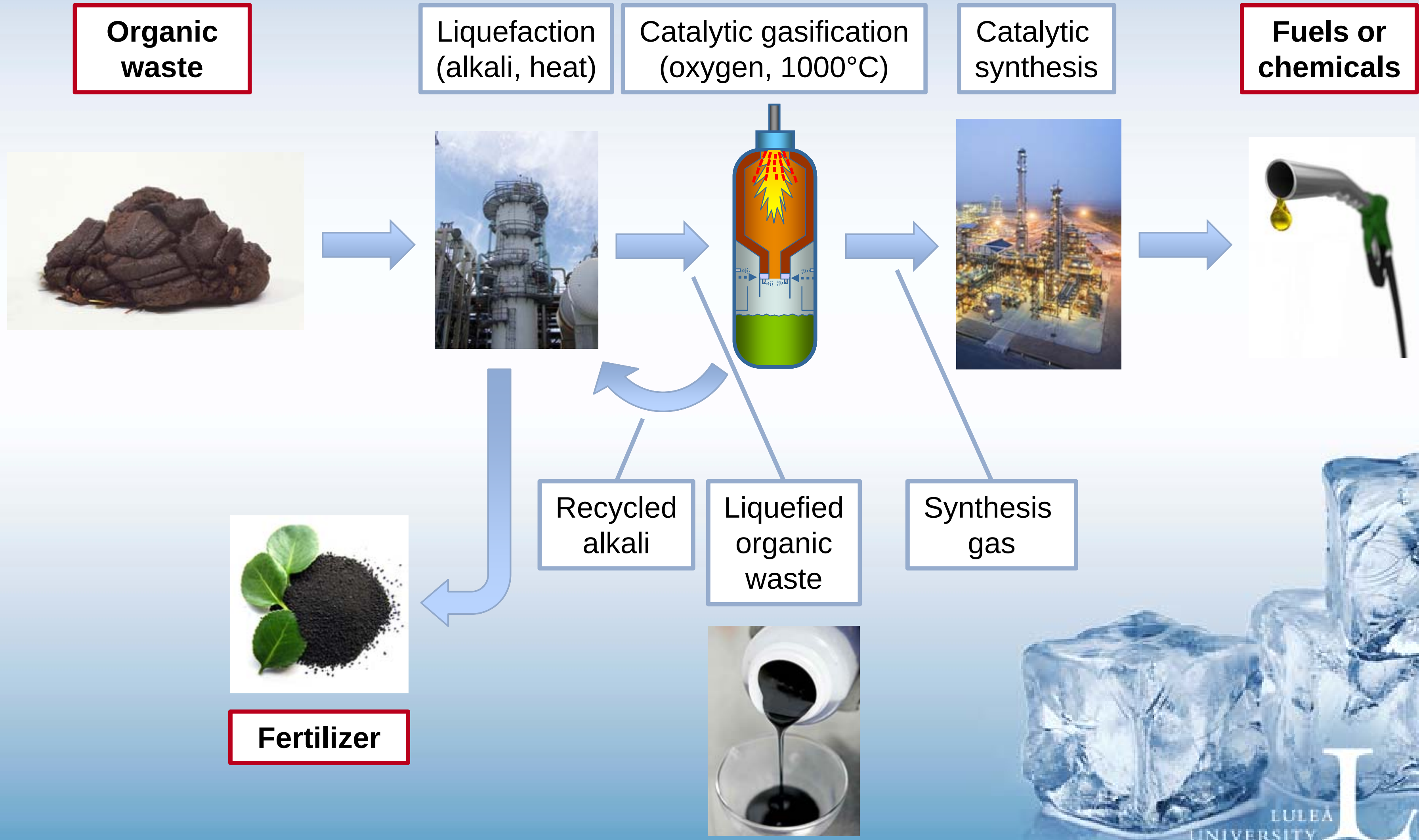
Fuels from organic waste
- via liquefaction, gasification, synthesis



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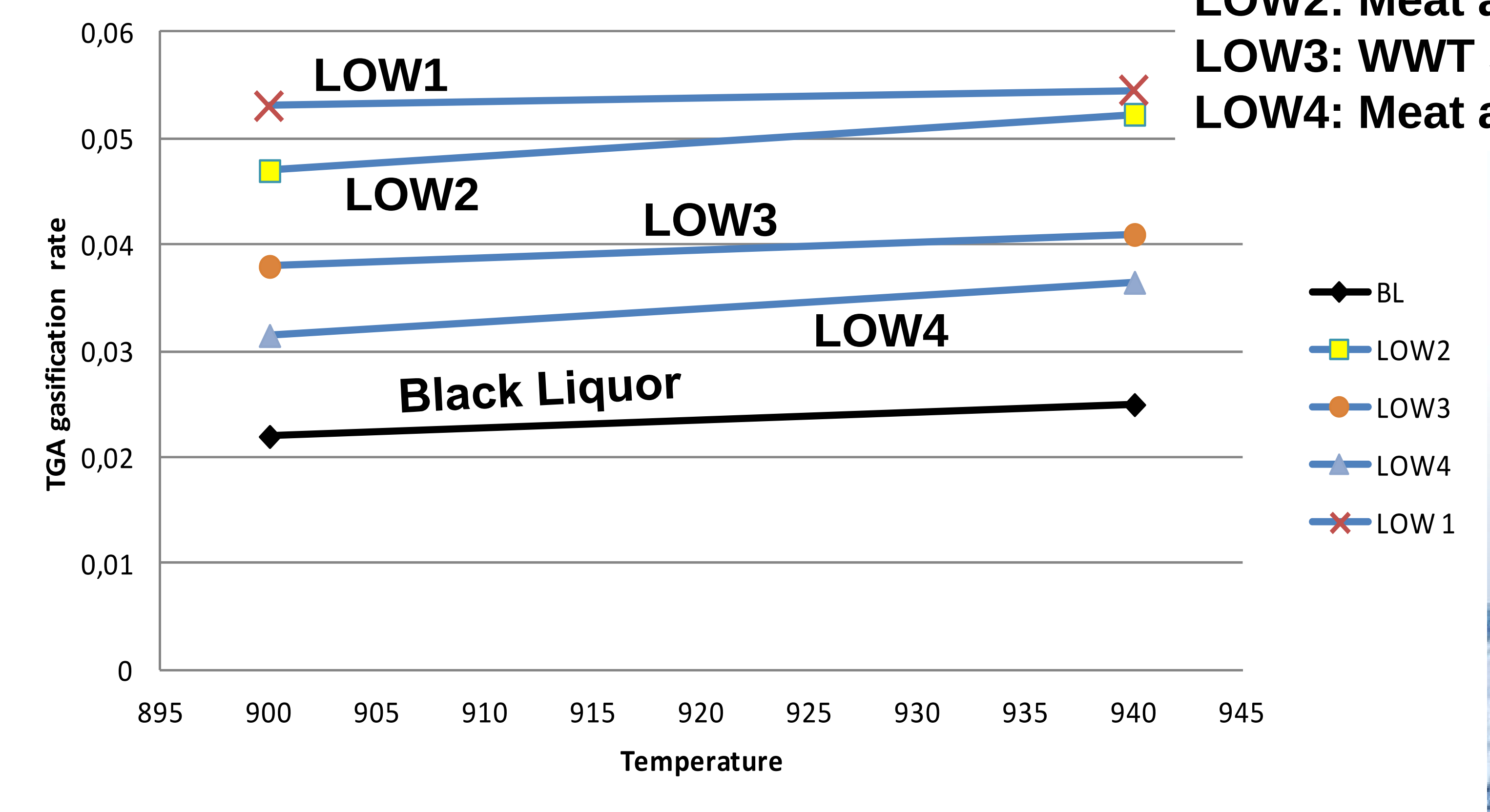
According to lab tests LOW liquids gasifies more easy than black liquor

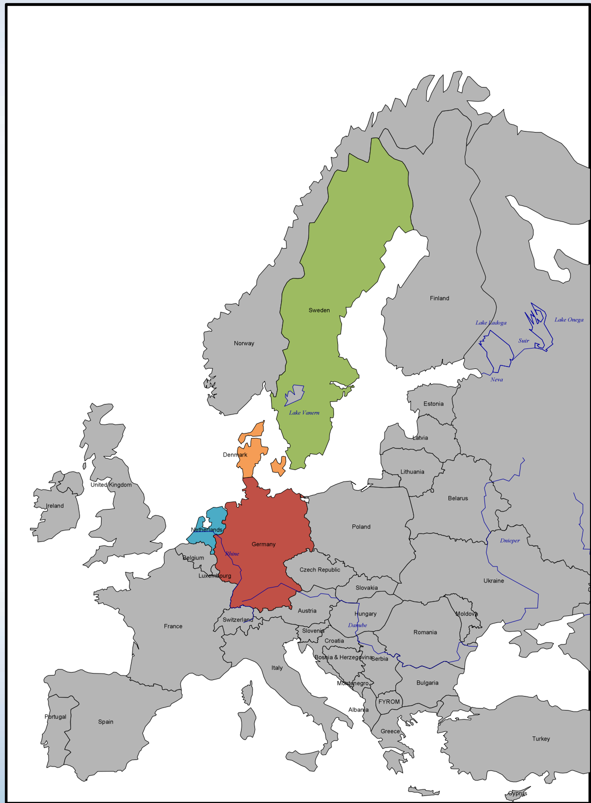
The analysis above is based on a first order model fitted to the gravimetric data

LOW1: Pig manure
LOW2: Meat and bone meal
LOW3: WWT sludge
LOW4: Meat and bone meal



Feedstock study – fuel from organic waste
(IVL Swedish Environmental Research Institute)

- **Selected feedstocks**
  - Liquid manure
  - Chicken manure
  - Slaughterhouse waste
  - Biogas digestate
  - WWT sludge
- **Selected countries**
- **Potential**
- **Price**
- **Alternative use**



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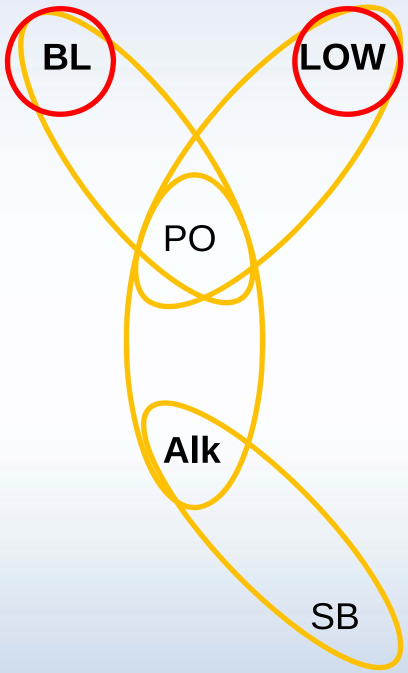
Many potential applications of catalytic gasification – long term research

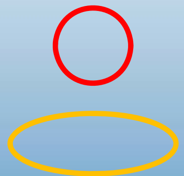


Now:

- Black liquor
- Pyrolysis oil + black liquor (BL)

Potential future developments:

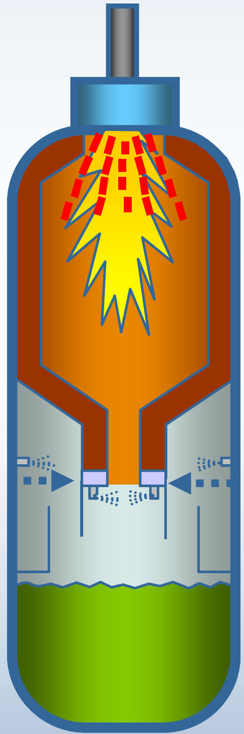
- Liquefied organic waste (LOW)
- Pyrolysis oil + liquefied organic waste
- Pyrolysis oil + Alkali salts (ALK)
- Solid biomass (SB) impregnated with alkali salts

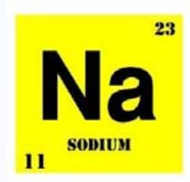


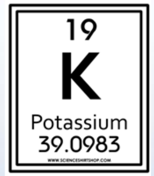
Alkali containing feedstock

Alkali addition or co-gasifiaction

The catalytic gasification project:
Turning alkali to an advantage







Future Energy System Scenarios

- The need to look at the total cost of a new energy system
- An example from the marine sector
- An example from the HD vehicle sector

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on the deployment of alternative fuels infrastructure

(European Commission Proposal dated January 24, 2013)

From Page 2:

The Commission Communication on a European alternative fuels strategy[3] evaluates the main alternative fuel options available to substitute oil whilst contributing to reduce greenhouse gas (GHG) emissions from transport, and suggests a comprehensive list of measures to promote the market development of alternative fuels in Europe, complementing other policies for reducing oil consumption and GHG emissions from transport.

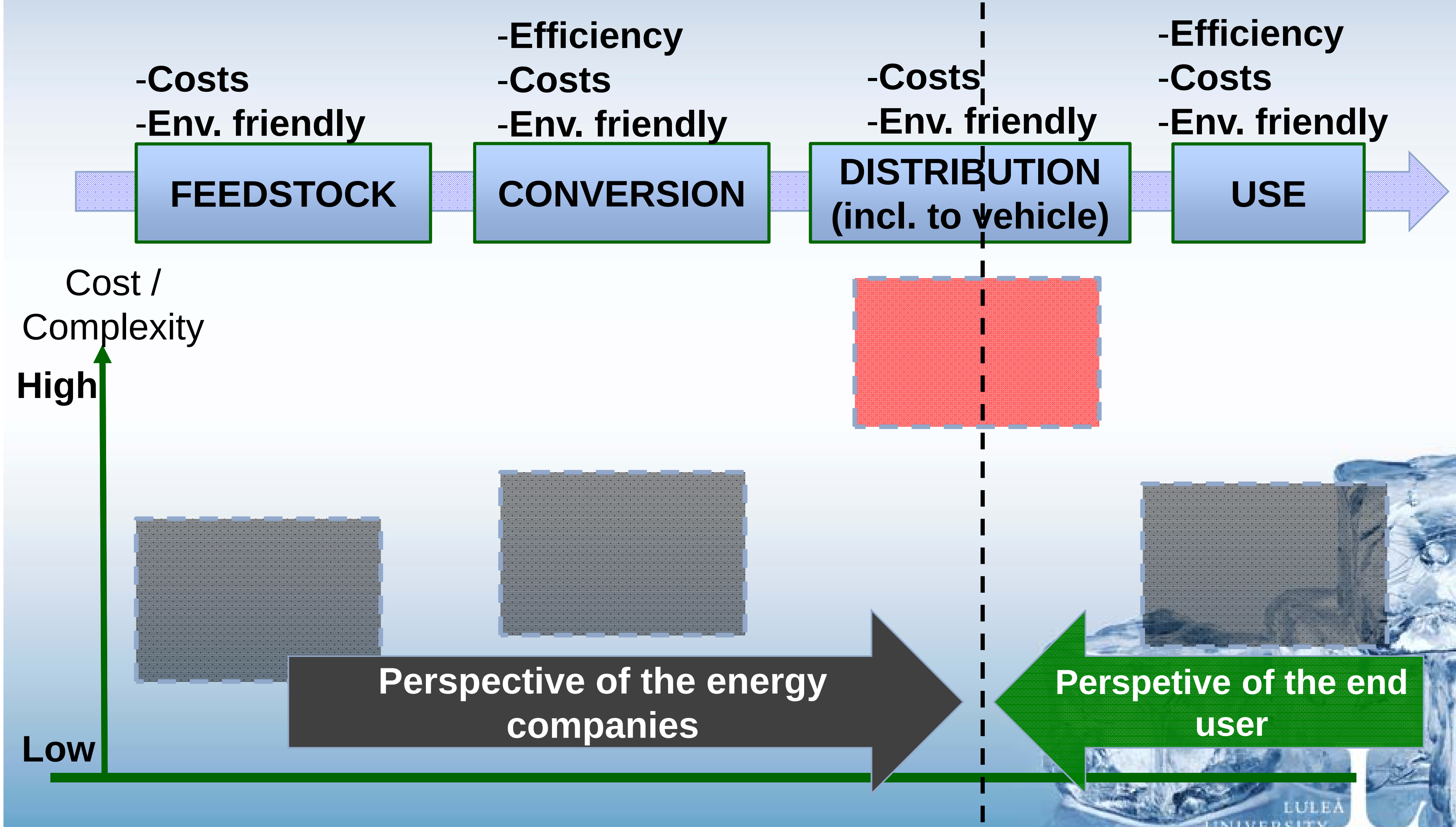
From Page 3, under leagel elements:

Minimum infrastructure coverage is proposed to be mandatory for electricity, hydrogen, and natural gas (CNG and LNG), which is key for acceptance for these alternative fuels by the consumers (market uptake) and further development and deployment of the technology by industry.

"Well to Wheel" Qualitative Cost / Complexity Analysis

Typical comment: *"The fuel must comply with existing infrastructure"*

Implying: **Very complicated/costly with new infrastructure**



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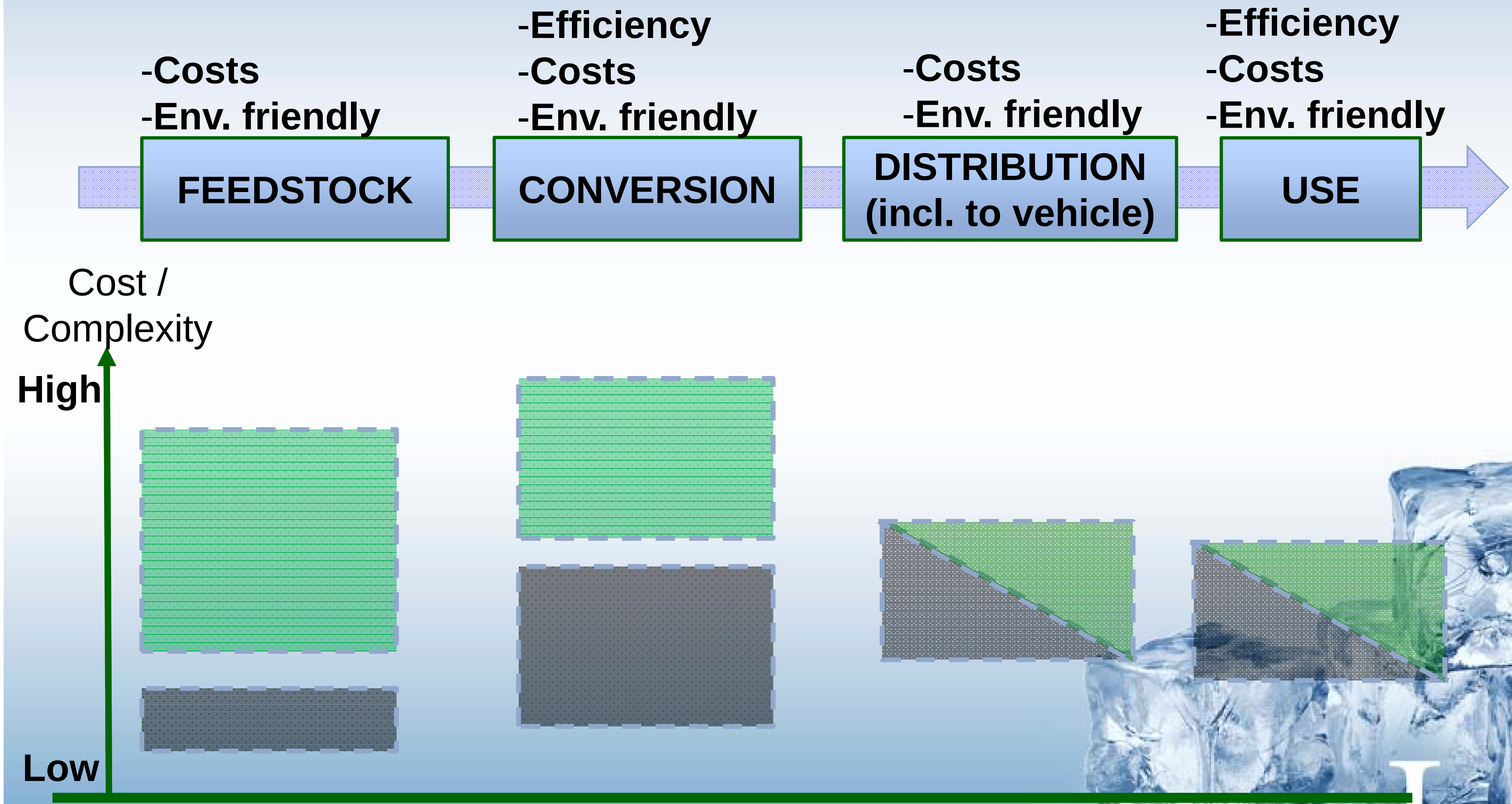
"Well to Wheel" Qualitative Cost / Complexity Analysis

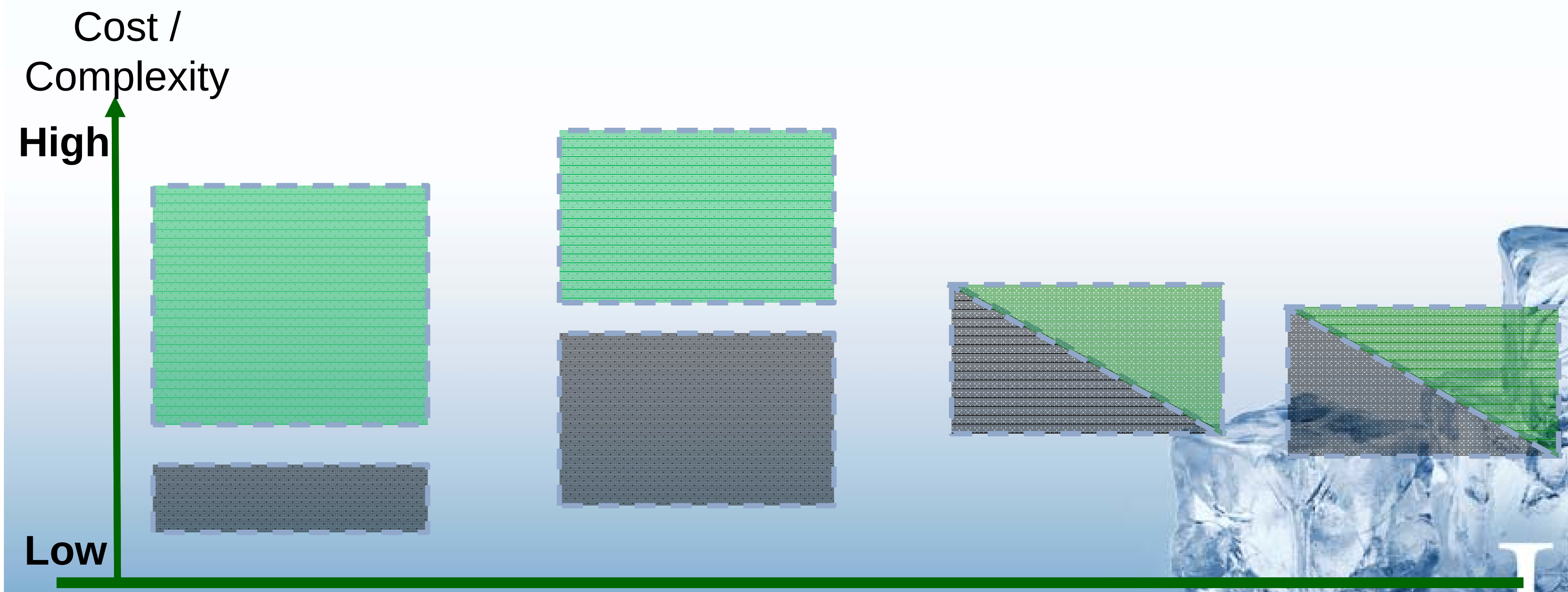
DME: fossil / renewable



“Well to Wheel” Qualitative Cost / Complexity Analysis

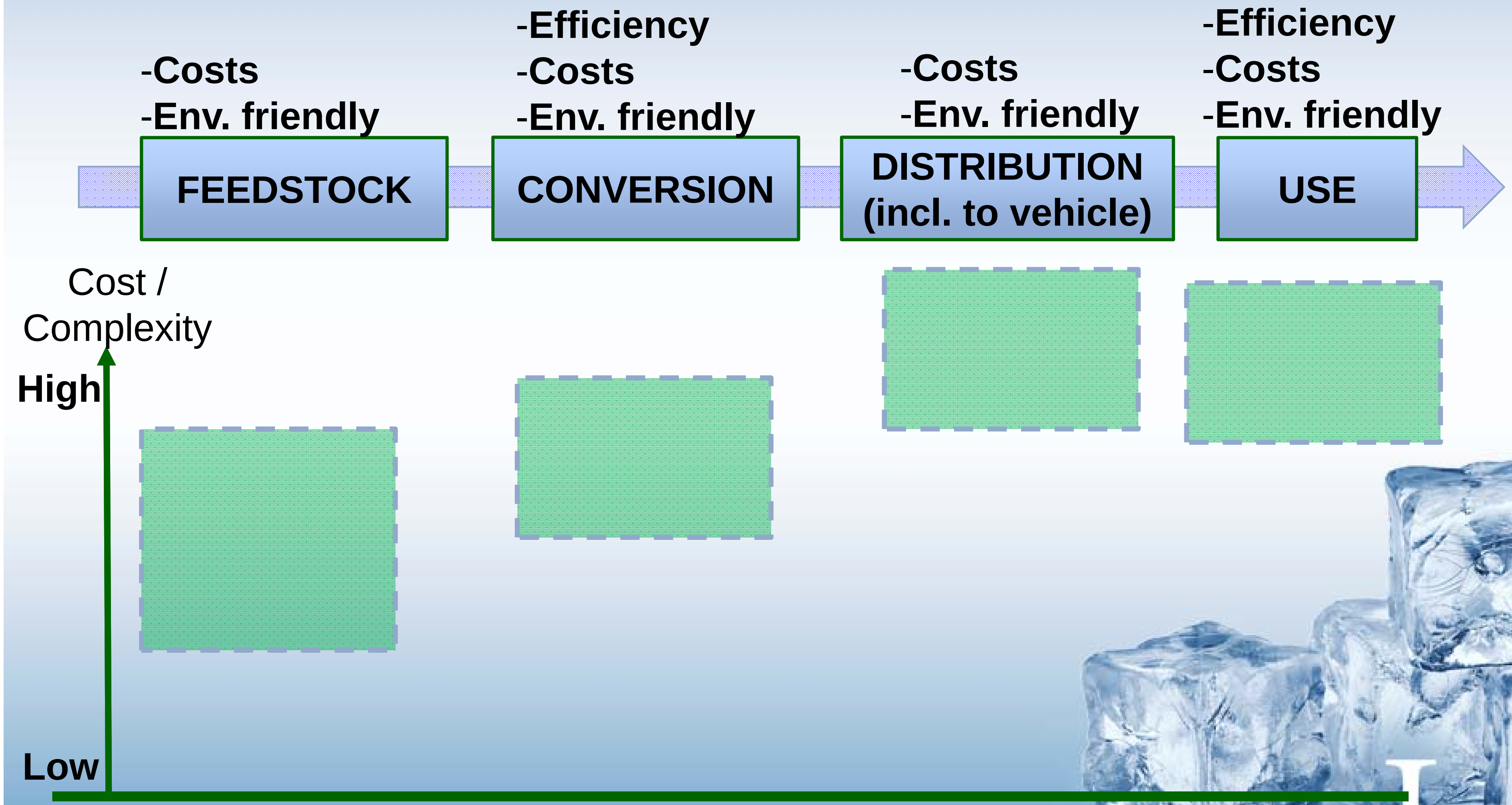
Methanol: fossil / renewable

FEEDSTOCK	CONVERSION	DISTRIBUTION (incl. to vehicle)	USE
-Costs -Env. friendly	-Efficiency -Costs -Env. friendly	-Costs -Env. friendly	-Efficiency -Costs -Env. friendly



“Well to Wheel” Qualitative Cost / Complexity Analysis

Hydrogen



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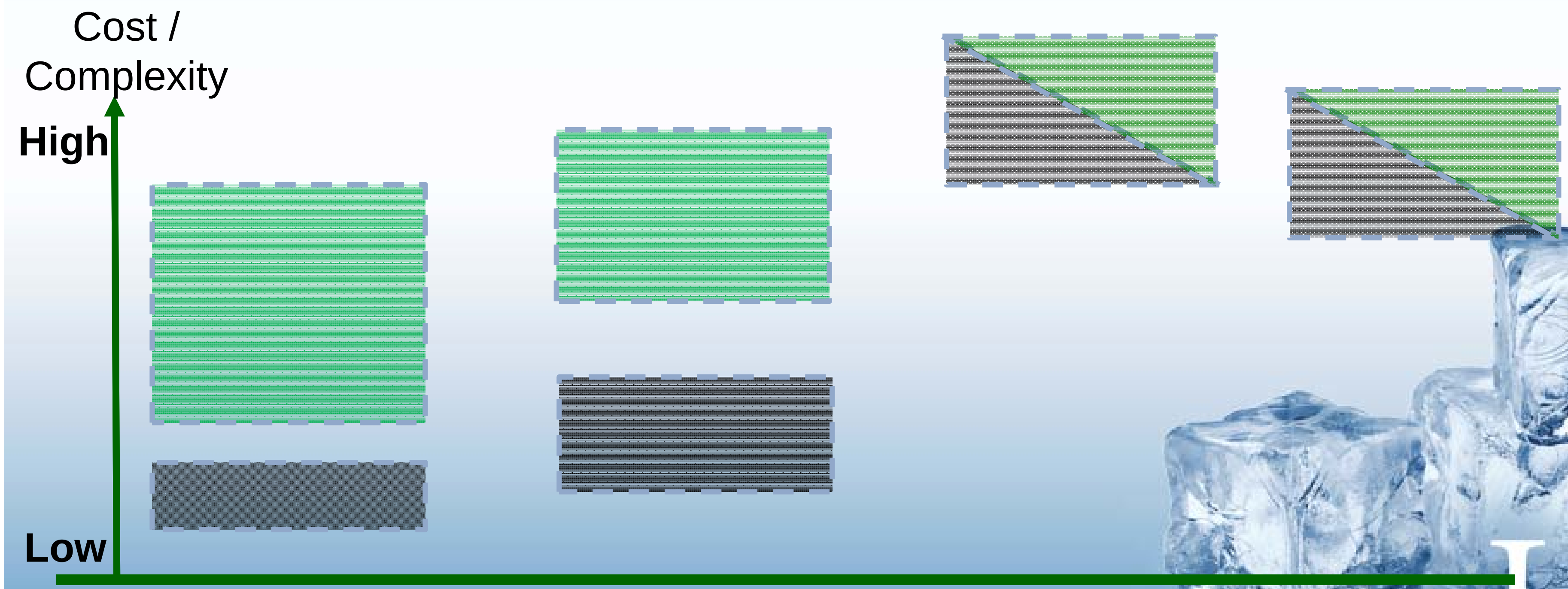
"Well to Wheel" Qualitative Cost / Complexity Analysis

LNG: fossil / renewable

FEEDSTOCK	CONVERSION	DISTRIBUTION (incl. to vehicle)	USE
-Costs -Env. friendly	-Efficiency -Costs -Env. friendly	-Costs -Env. friendly	-Efficiency -Costs -Env. friendly



Vision for a Methanol based Energy System

1. today

Natural gas

Methanol plants

Fossil MeOH

Via Ports

Chemical industry

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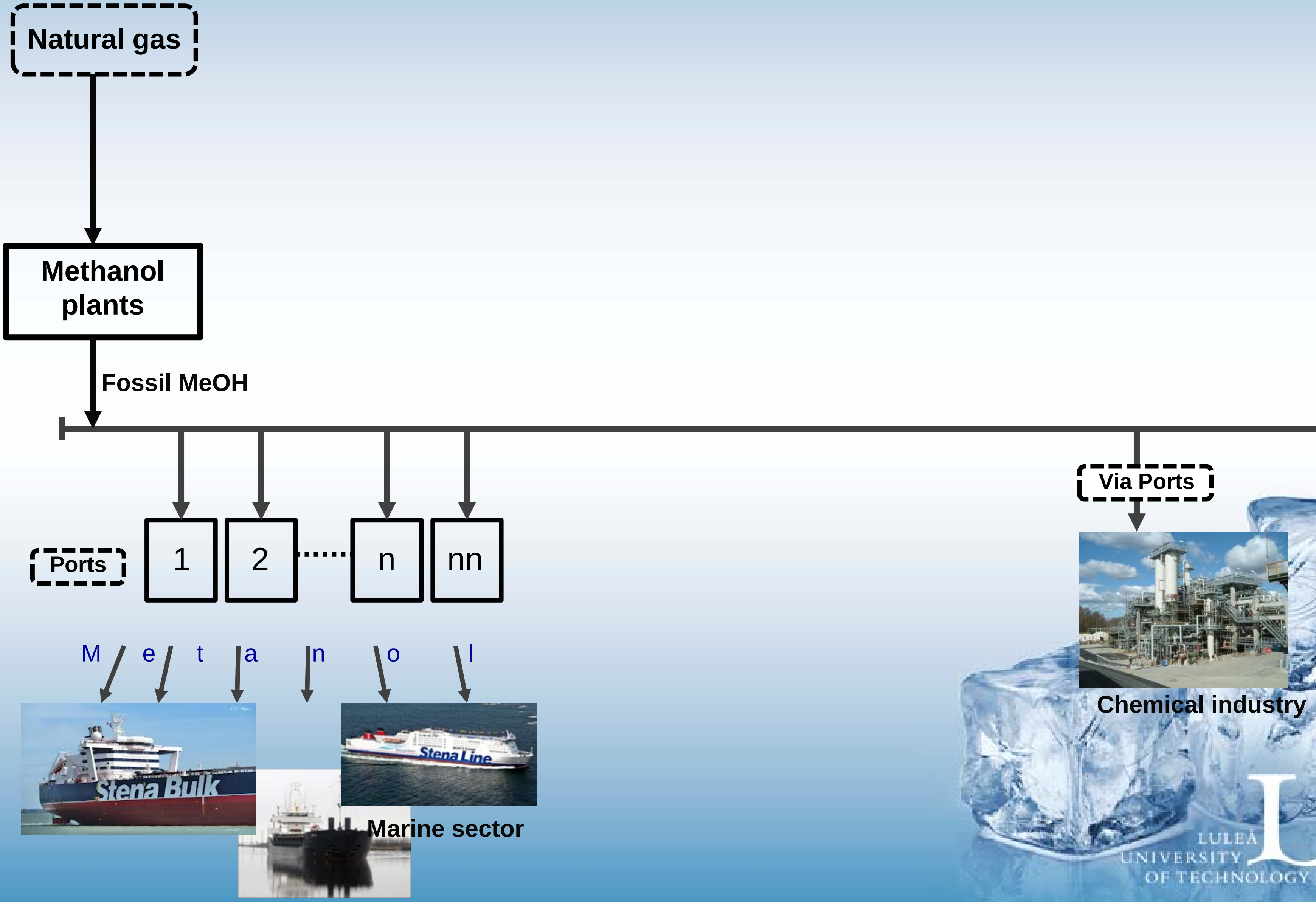
Vision for a Methanol based Energy System

2. + methanol as bunker fuel



An example where an international agreement results in a fundamental rethink:

IMO, International Maritime Organization, on new sulphur levels in bunker fuels coming into force 1 January 2015

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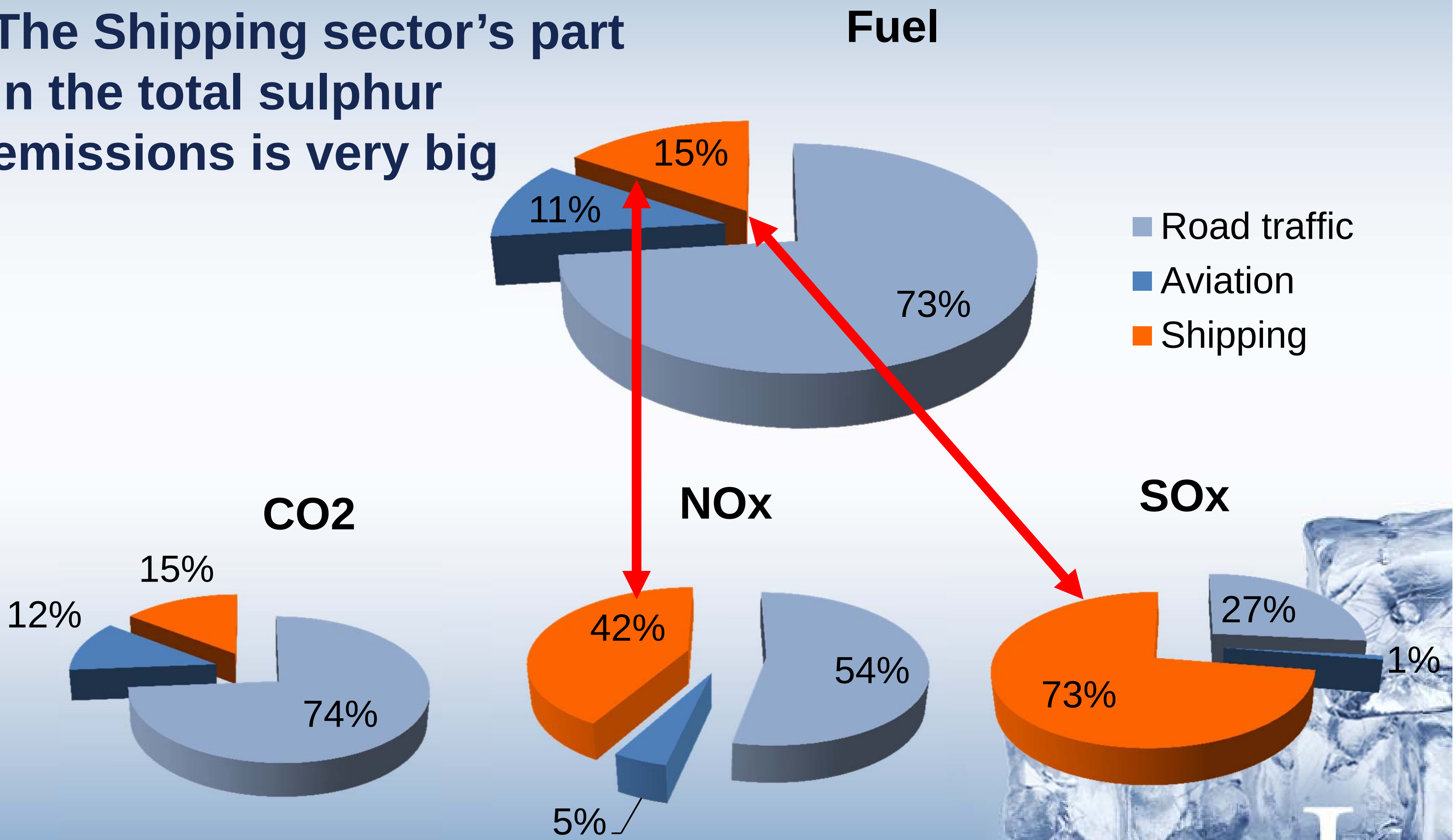
Background to the new sulphur emission legislation:

The Shipping sector's part in the total sulphur emissions is very big



Source: ScandiNAOS AB

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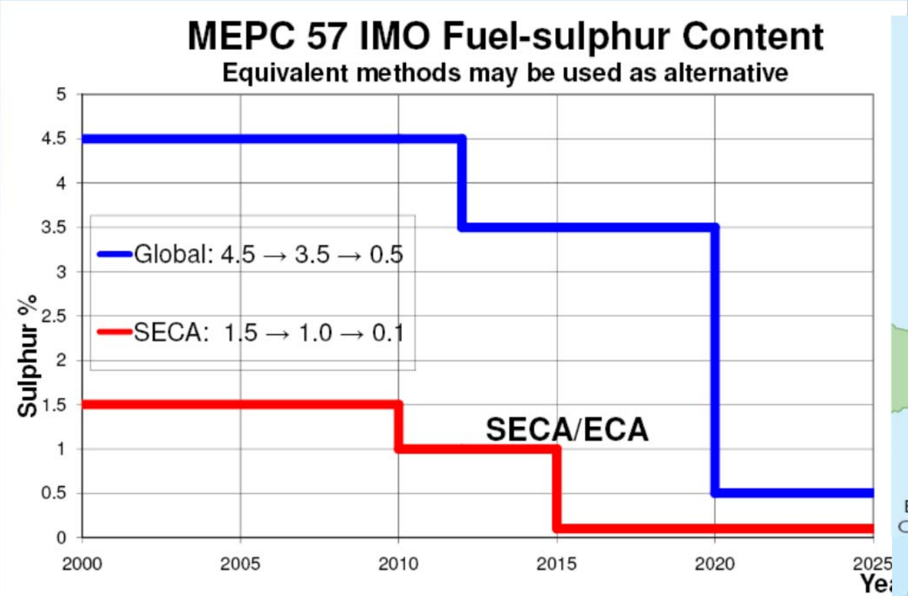
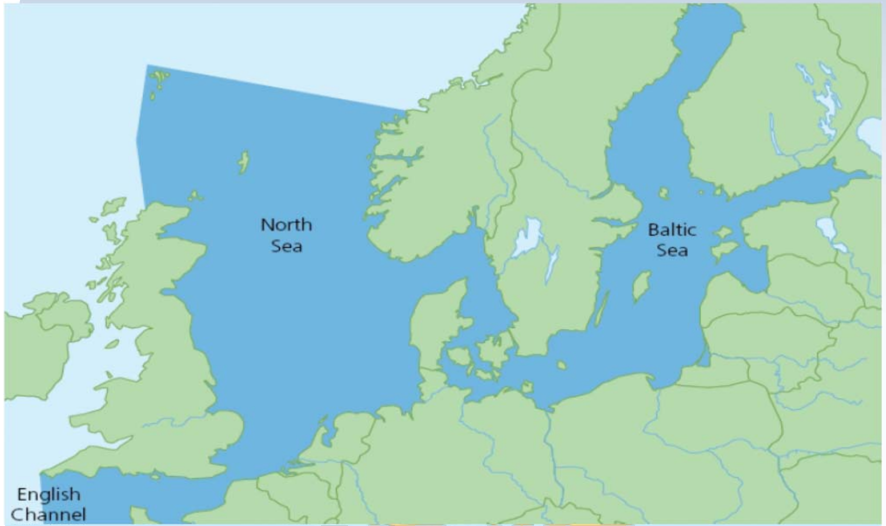
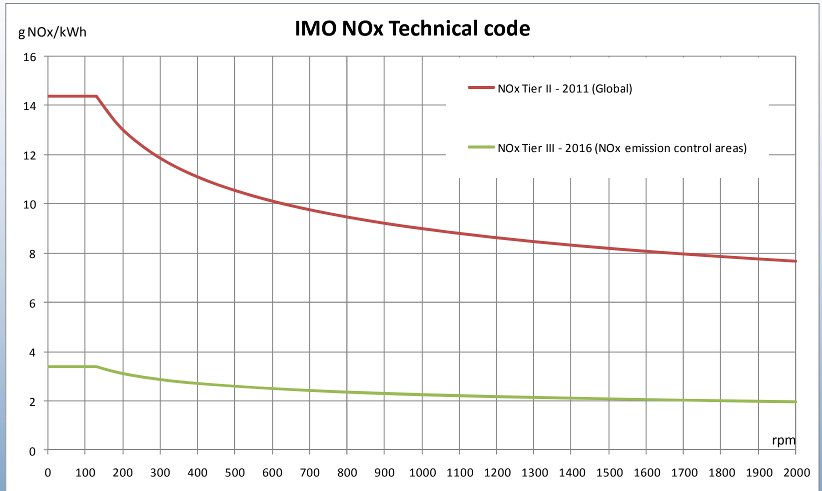
Upcoming regulations for Marine Fuels

Sulphur level in bunker fuels must be < 0.1% by 2015

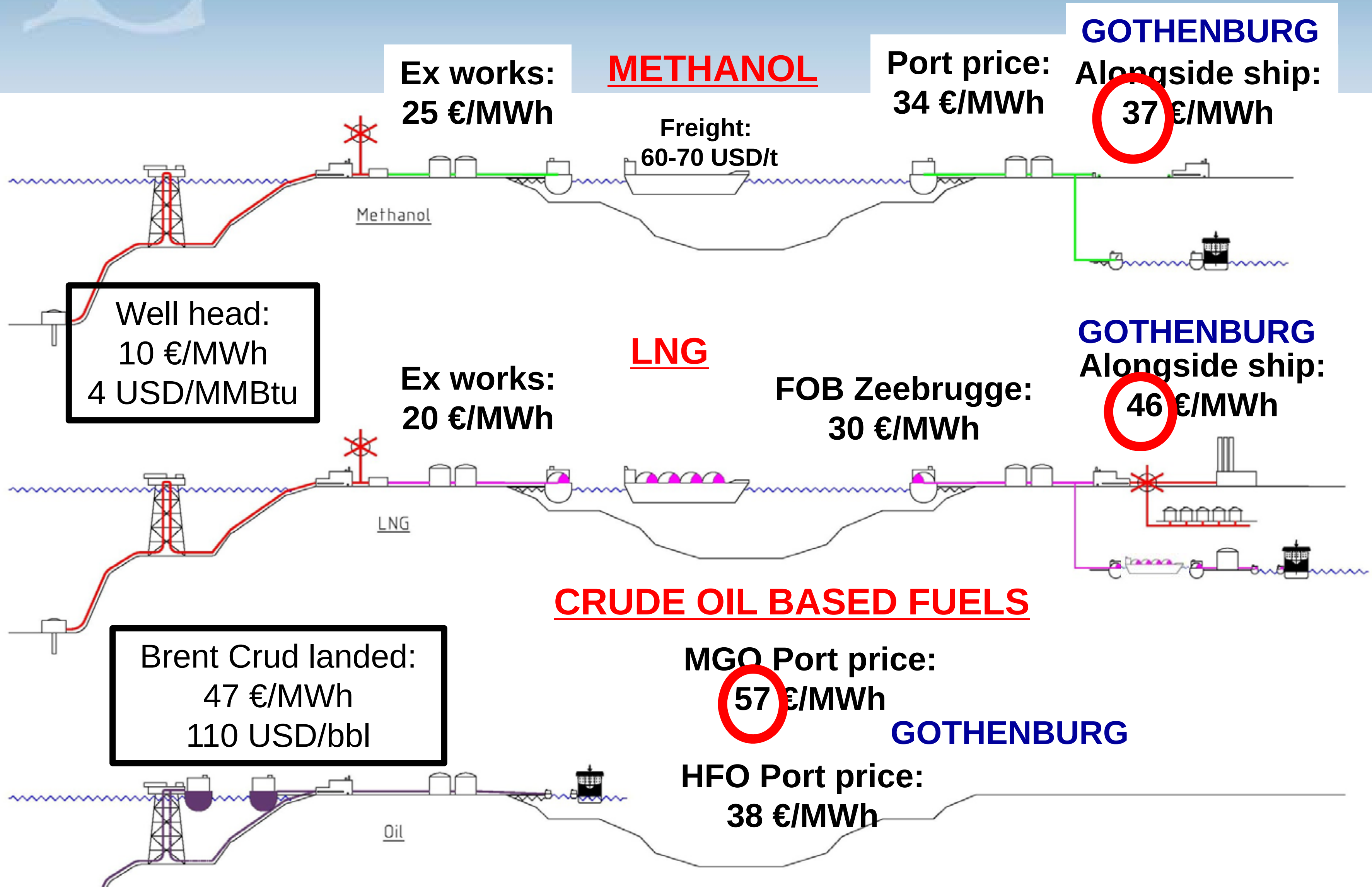






Source: ScandiNAOS AB

Price scenarios for Alternative Bunker Fuels



Source : Stena and Chemrec

Stena Methanol Pilot Project, Gotheburg

Item	LNG	Methanol
Handebility	Liquid at -163˚C, Atmosperic P	Liquid at ambient T and P
Storage	Cryogenic handling; Space demanding	Can be stored as bunker oil
Cost of main storage in port	500 MSEK *)	50MSEK *)
Feedership R'dam - Gbg	500 MSEK *)	0 MSEK; With today's methanol tankers
Bunker vessel	300 MESK *)	15 MSEK *)
Rebuilt of ship, total 25 MW	250 MSEK	100 MSEK
Total cost diff	1550 MSEK / 180 MEUR	165 MSEK / 20 MEUR

Source: Stena

*) First time investment

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Stena Germaica is planned to run on Methanol starting early 2015

2 X

90.000 Cars
90.000 Lorries → Lifted from the road every year

Fuel: 25 000 tons of MeOH / year

Source: Stena

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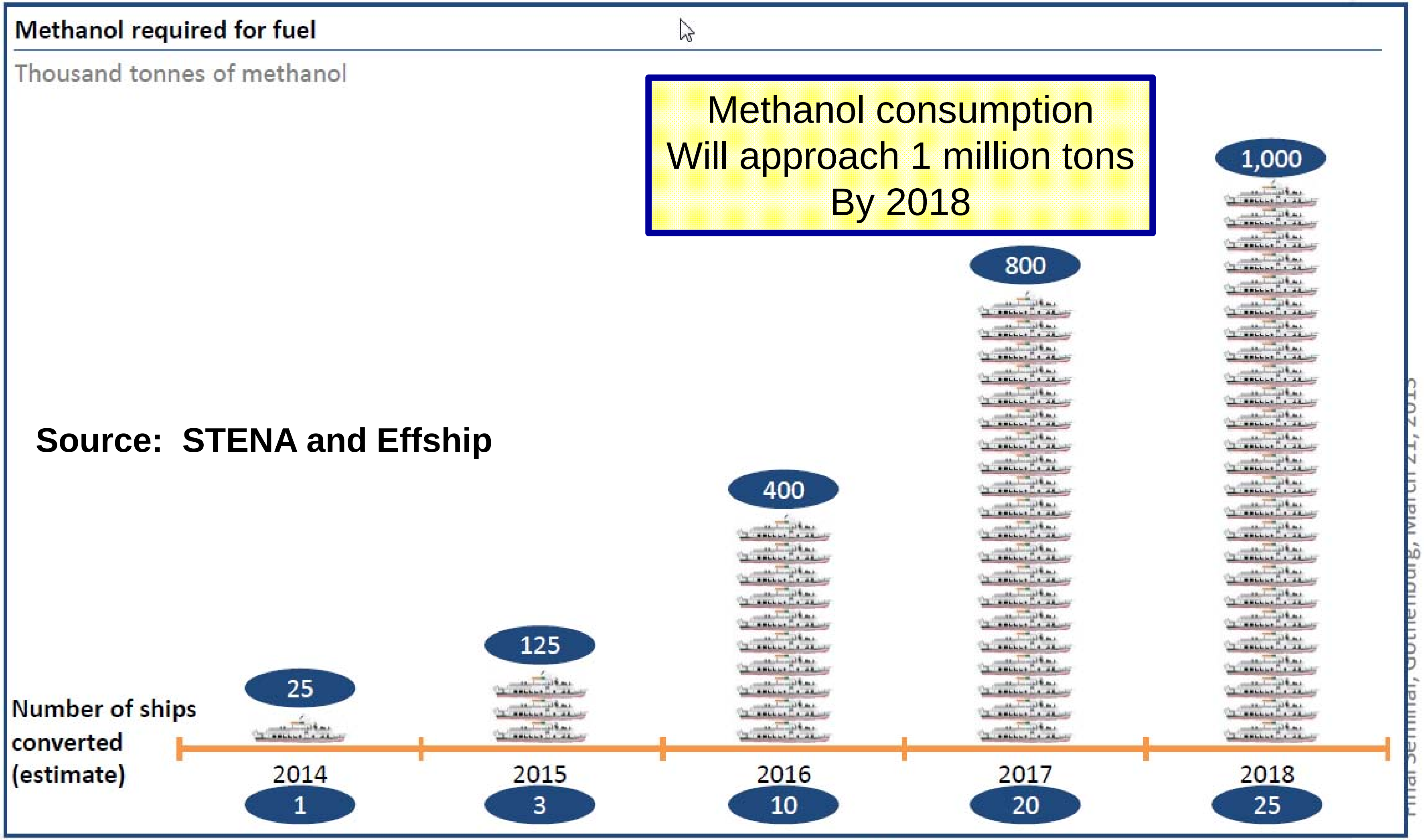
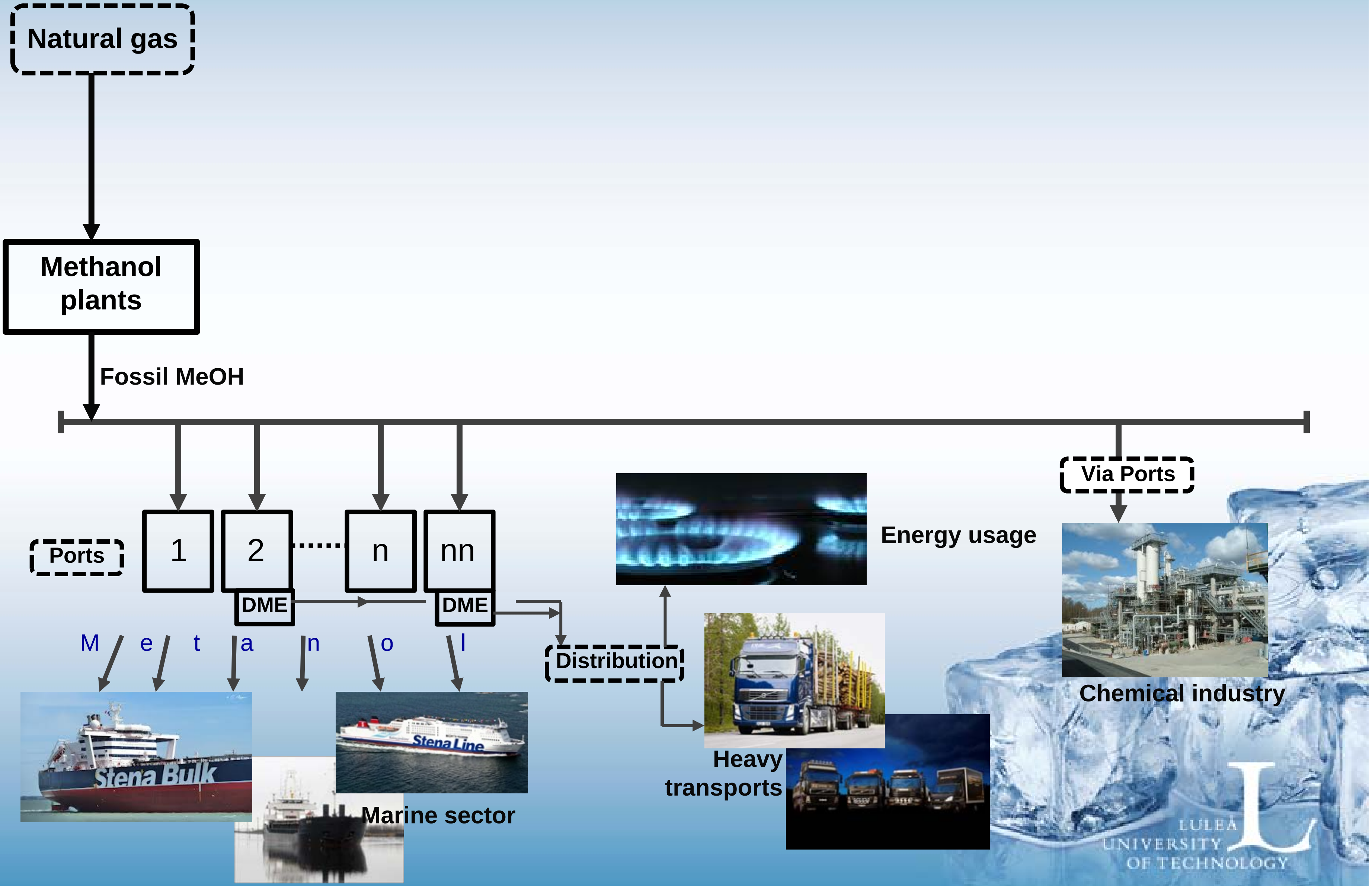
Stena's Global Methanol Project

(Initial timeplan for converting Stena's SECA fleet)



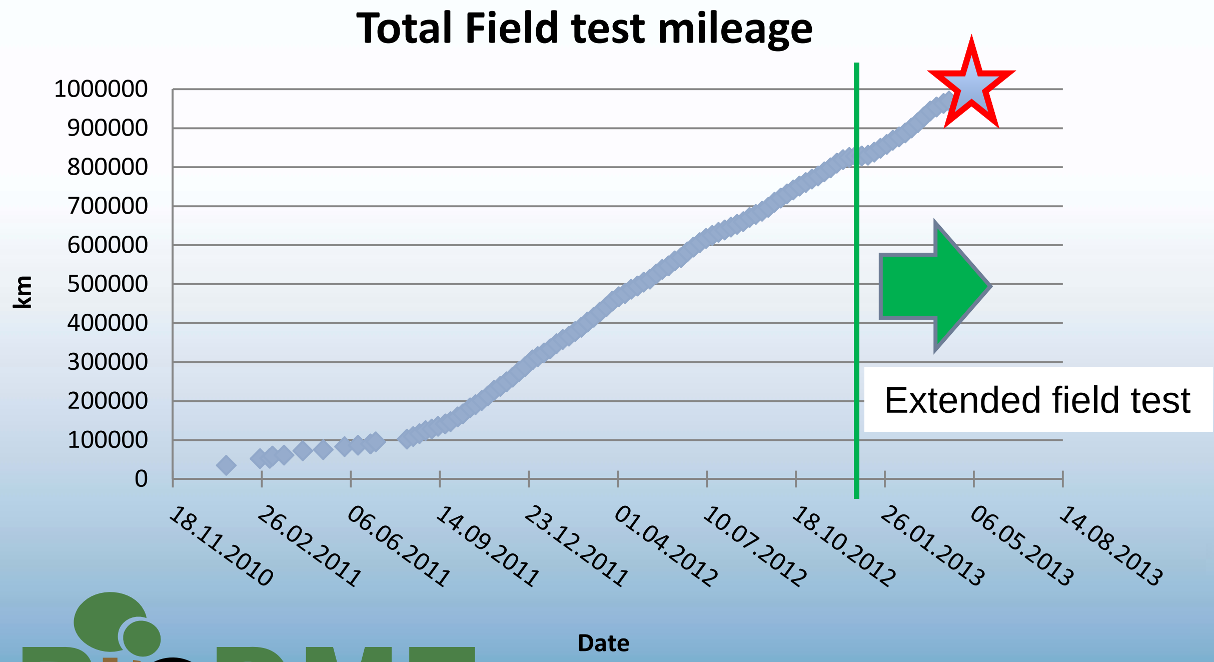
Vision for a Methanol based Energy System

3. + methanol to DME for HD trucks and industry



Extended Volvo field test
8 trucks, 2013-01-01 to 2014-06-30

(1000 Km / 1000 mi)	**Status** 2013-04-08	**Target** June 2014
Total mileage	970 / 603	1 475 / 917
1 truck	200 / 124	300 / 186



BioDME

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Fuel Distribution

- Available technology modified for DME
- Safety regulations based on LPG
- ~200 k€ per filling station (+33% vs diesel)
- Easy to achieve

200 m^3 storage tank in Piteå

34 m^3 trailer

Four filling stations

Volvo through their US branch on June 6, 2013 decided to start commercial production of DME fuelled vehicles in the US in 2015.
See various films at:
http://www.youtube.com/watch?v=L946kk7_NIE
The link includes:
DME – “The future is here”
DME – “It is all around us”
and other material.

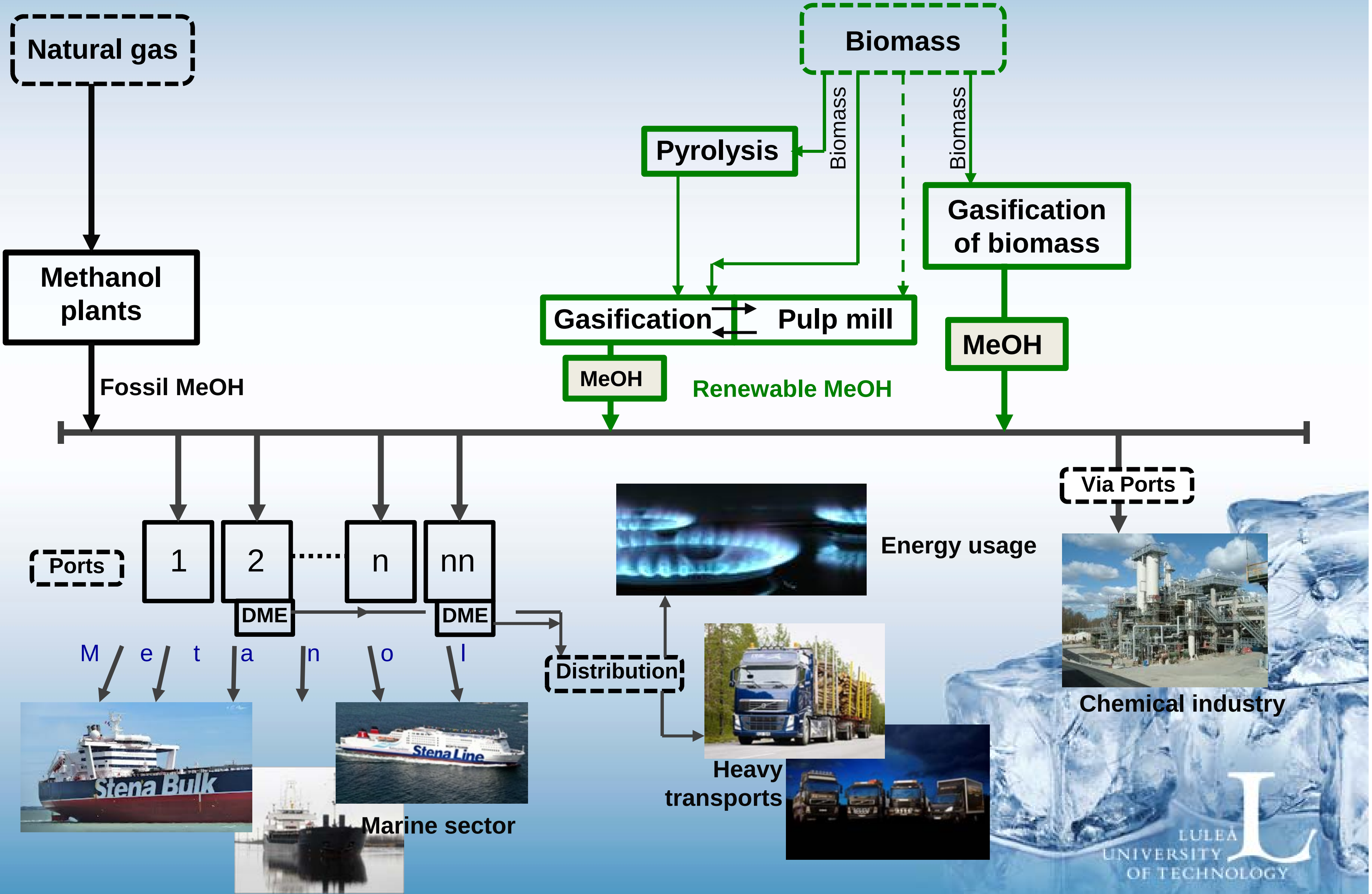
See also:

www.biodme.eu
BioDME Video
http://www.youtube.com/watch?v=cF1F7luFpnc#t=13

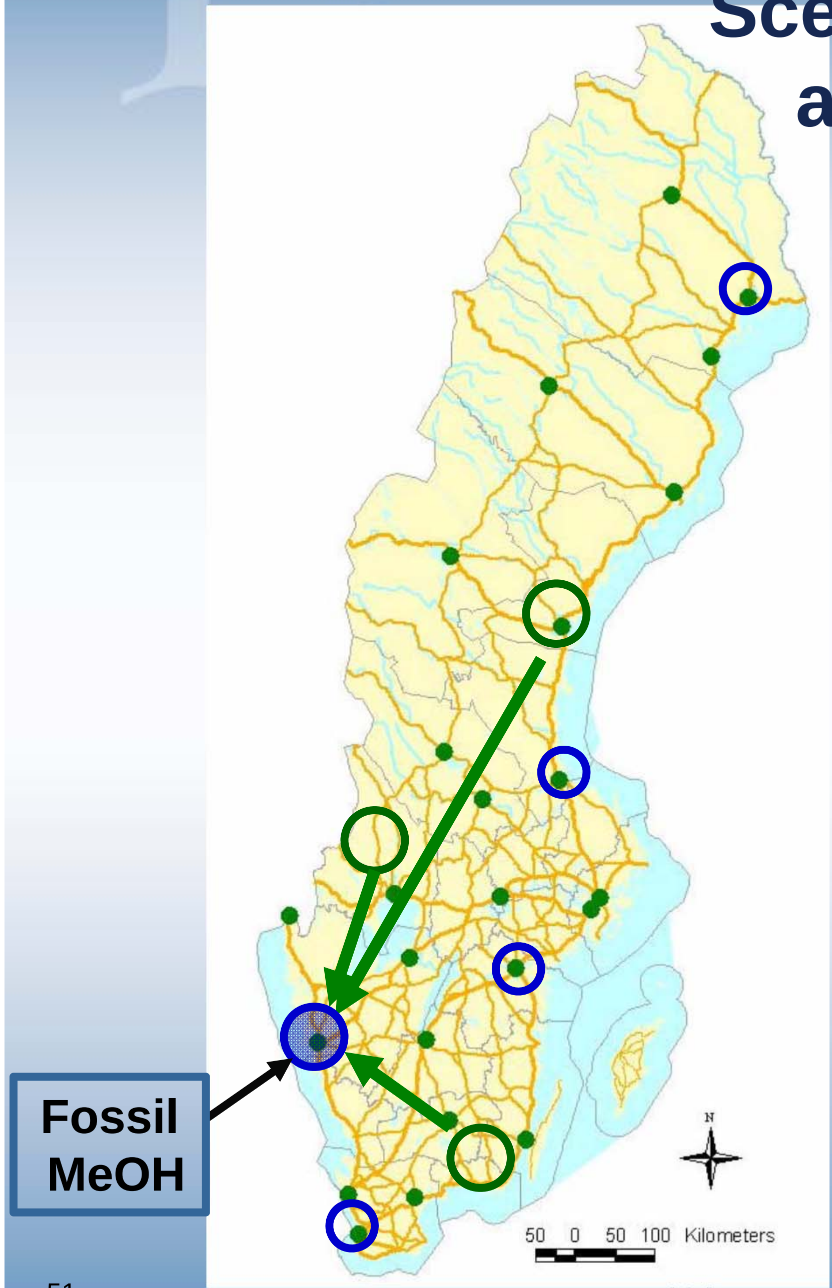
Volvo US DME truck

Vision for a Methanol based Energy System

4. + providing system with renewable methanol from biomass



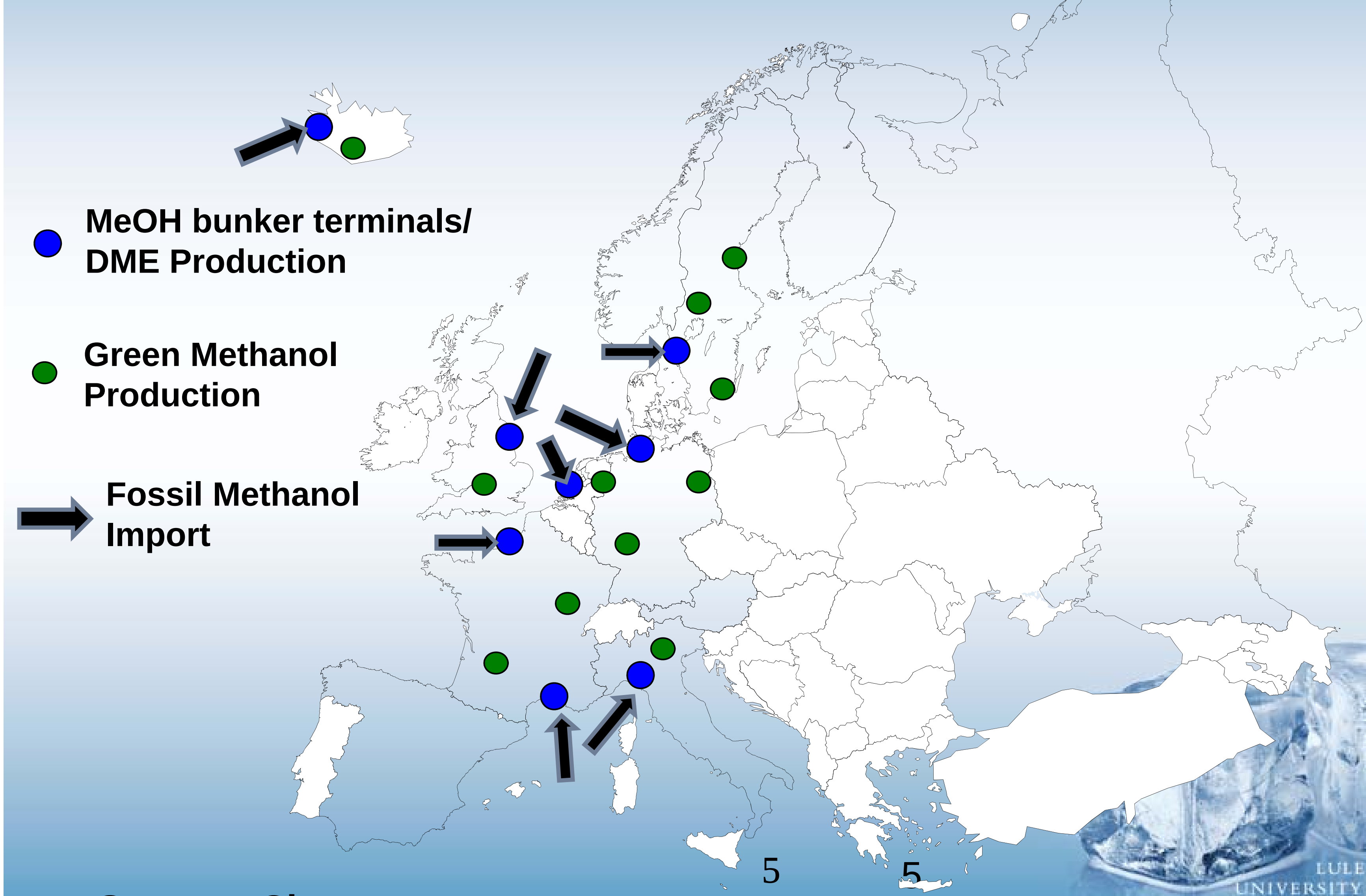
Scenario for Introduction of DME as a Fuel in Sweden combined with fossil / renewable methanol



- DME Fuel Station
- BioMethanol Production
- DME Production
- DME Terminals

Source : Chemrec

Scenario for Introduction of renewable / fossil DME and methanol in Europe



5
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Source : Chemrec

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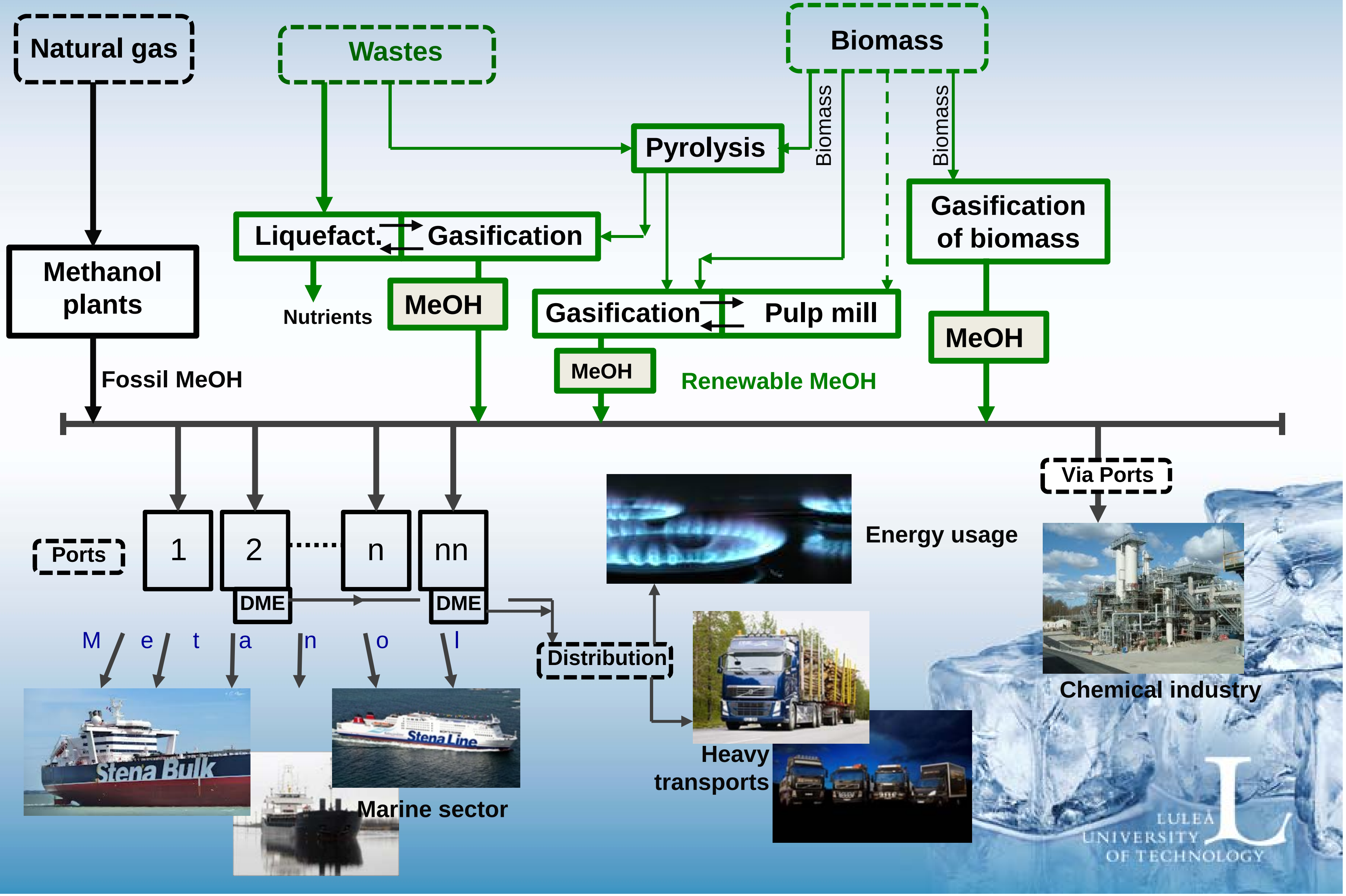
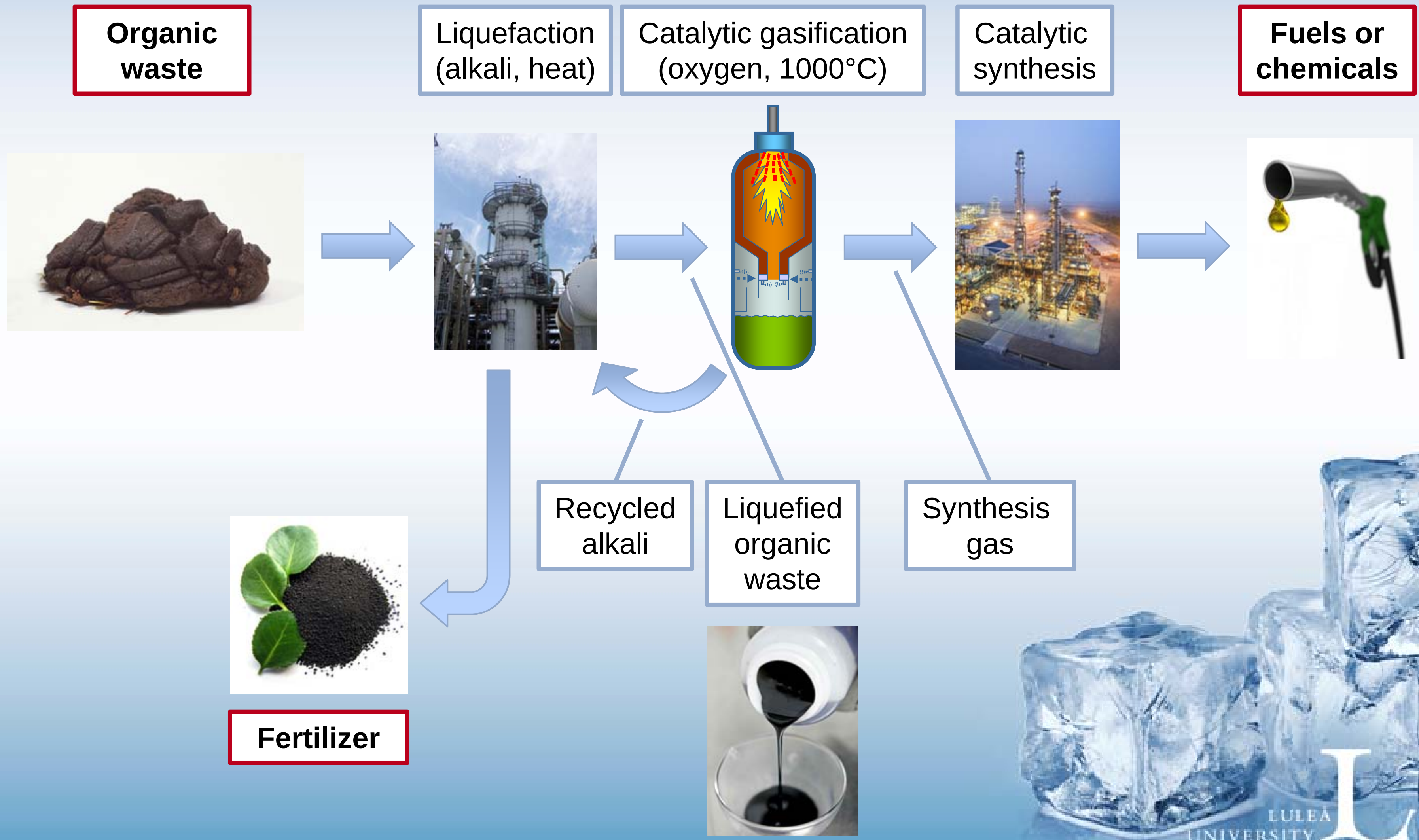
Vision for a Methanol based Energy System

5. + providing system with renewable methanol from waste

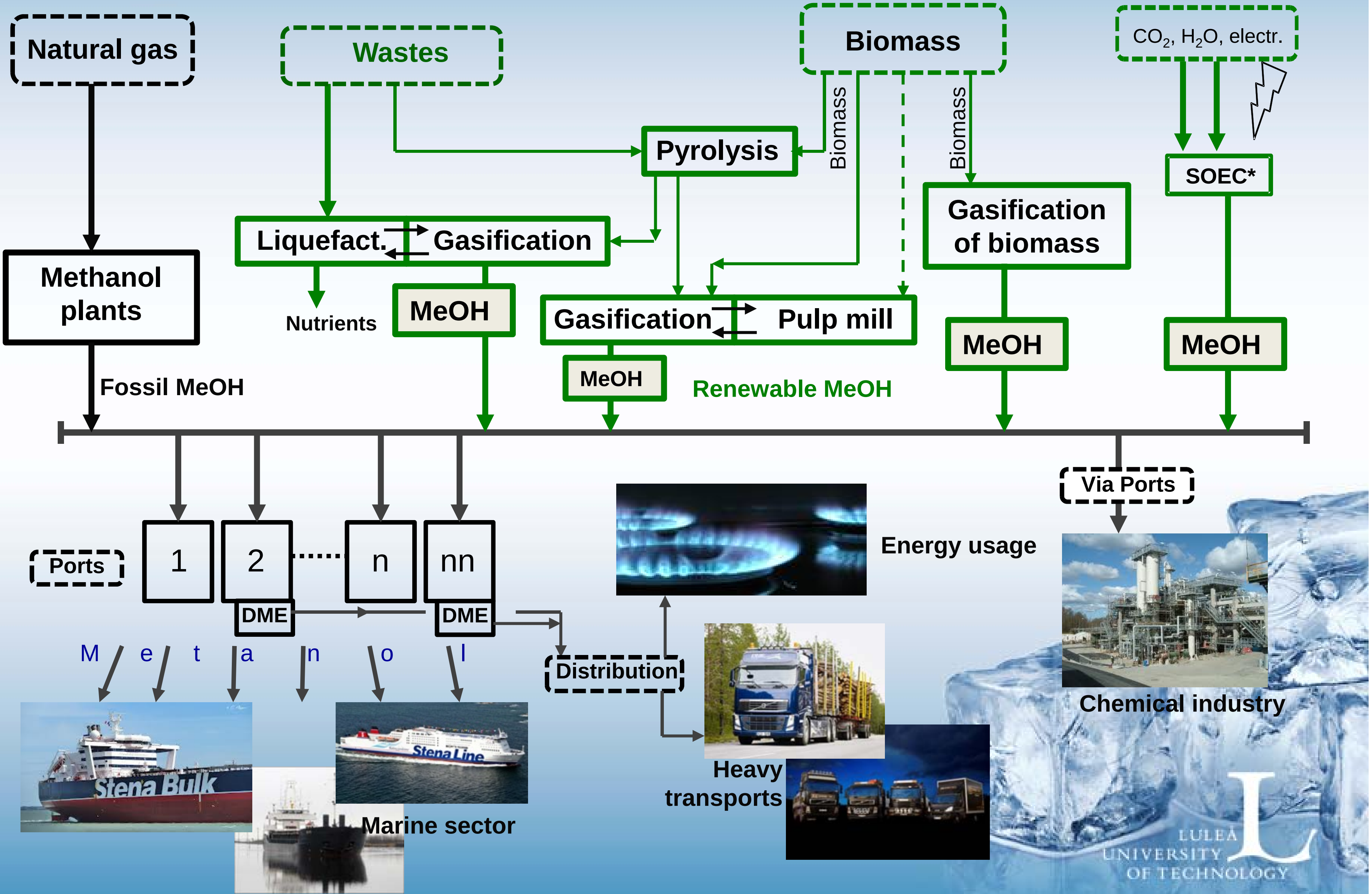


Fuels from organic waste
- via liquefaction, gasification, synthesis

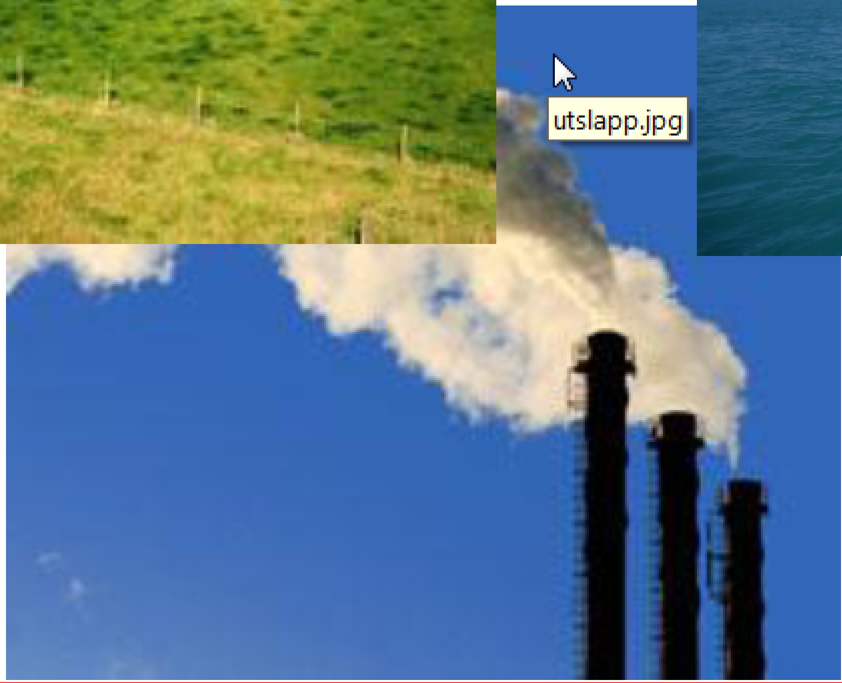


Vision for a Methanol based Energy System

6. + providing system with renewable methanol solar and wind



Sun Energy + CO_2 + H_2O



= Methanol

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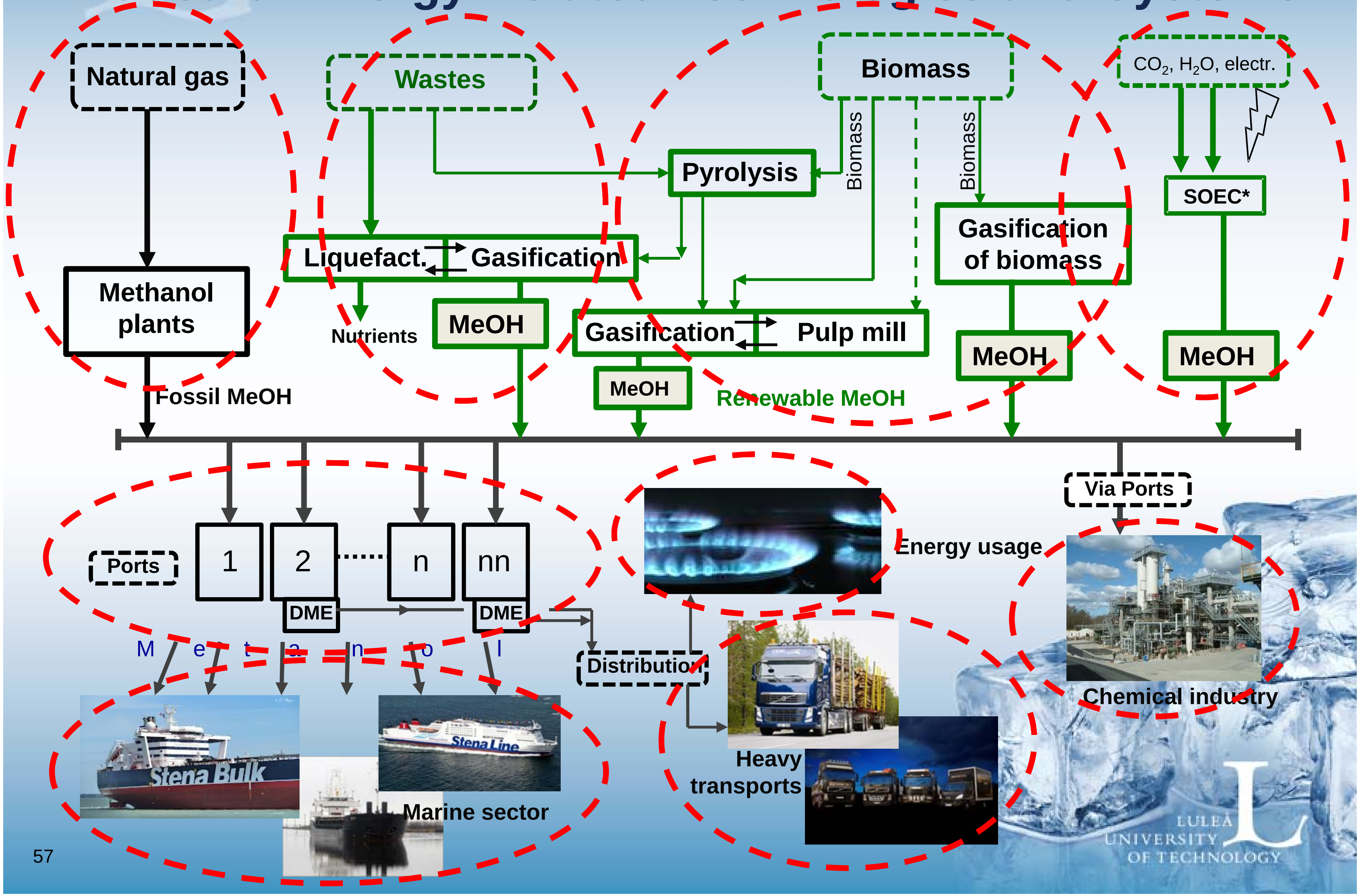
Source : Stena Rederi

Maybe an interesting area to study for the “Industrial Energy-Related Technologies and Systems”



In Summary – Part 1

- Black liquor (BL) gasification works.
- Presence of alkali in the BL fuel results in complete carbon conversion at around 1000 deg C gasification temperature
- Laboratory work indicates that pyrolysis oil can be mixed with BL in significant amounts and that the catalytic effect still results in full carbon conversion at around 1000 deg C
- At a mix of 25% PO in 75% BL (dry basis) the syngas generation increases with about 100%
- Lab scale tests indicates that alkali supported gasification can be extended to other feedstocks such as manure, WWT sludge and meet and bone meal.

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In summary – Part 2

- New SECA regulation demands new, low sulphur bunker fuels
- Methanol can become a cost effective bunker fuel alternative, cheaper and simpler to use than LNG
- Bunker Methanol infrastructure in harbors can stimulate DME production at optimum locations from a distribution point of view
- BioMethanol can be transported to the bunker Methanol infrastructure / DME production facilities and make the DME (and methanol) partly renewable
- It is cost effective and comparably simple to introduce a new fuel in the HD transport sector which uses about 25% of all transportation fuels (relates to Sweden but is similar in rest of Europe)

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