CO_2 utilisation for Fuel and Chemical Production

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European Methanol Policy Forum

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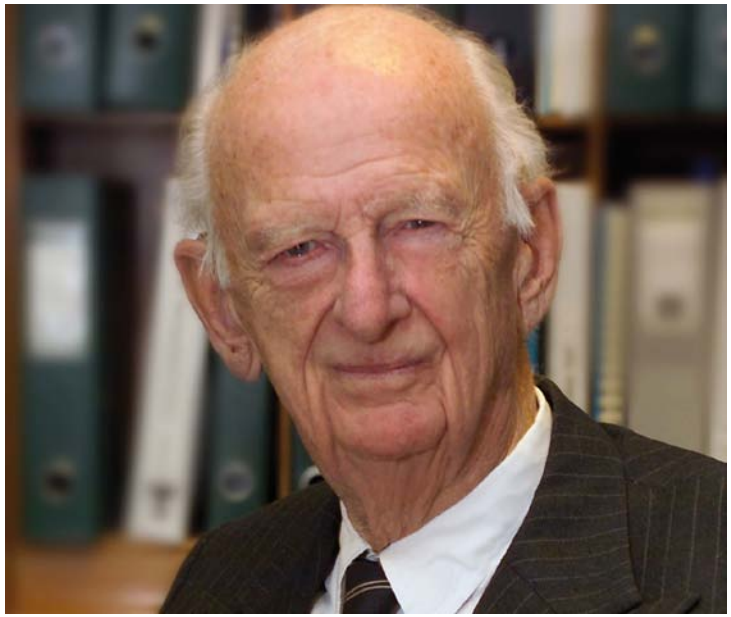
HALDOR TOPSOE

We have been committed to catalytic process technology for more than 70 years

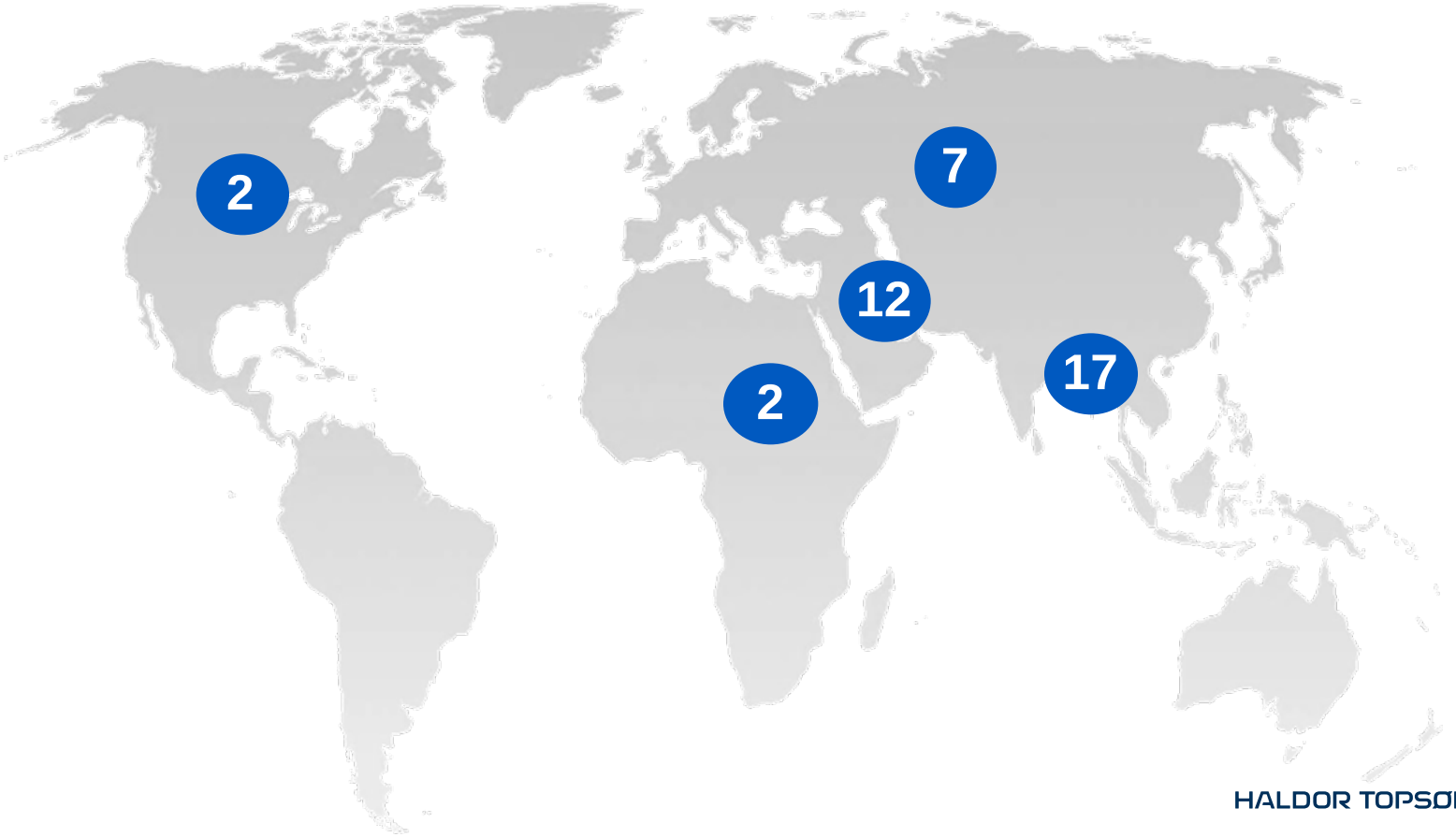
- Founded in 1940 by Dr. Haldor Topsøe
- Revenue: 700 million Euros
- 2700 employees
- Headquarters in Denmark
- Catalyst manufacture in Denmark and the USA



Topsoe methanol plants

Since 2000

Number of plants:	40
Accumulated capacity, MTPD:	97,075
Number of catalyst charges:	168



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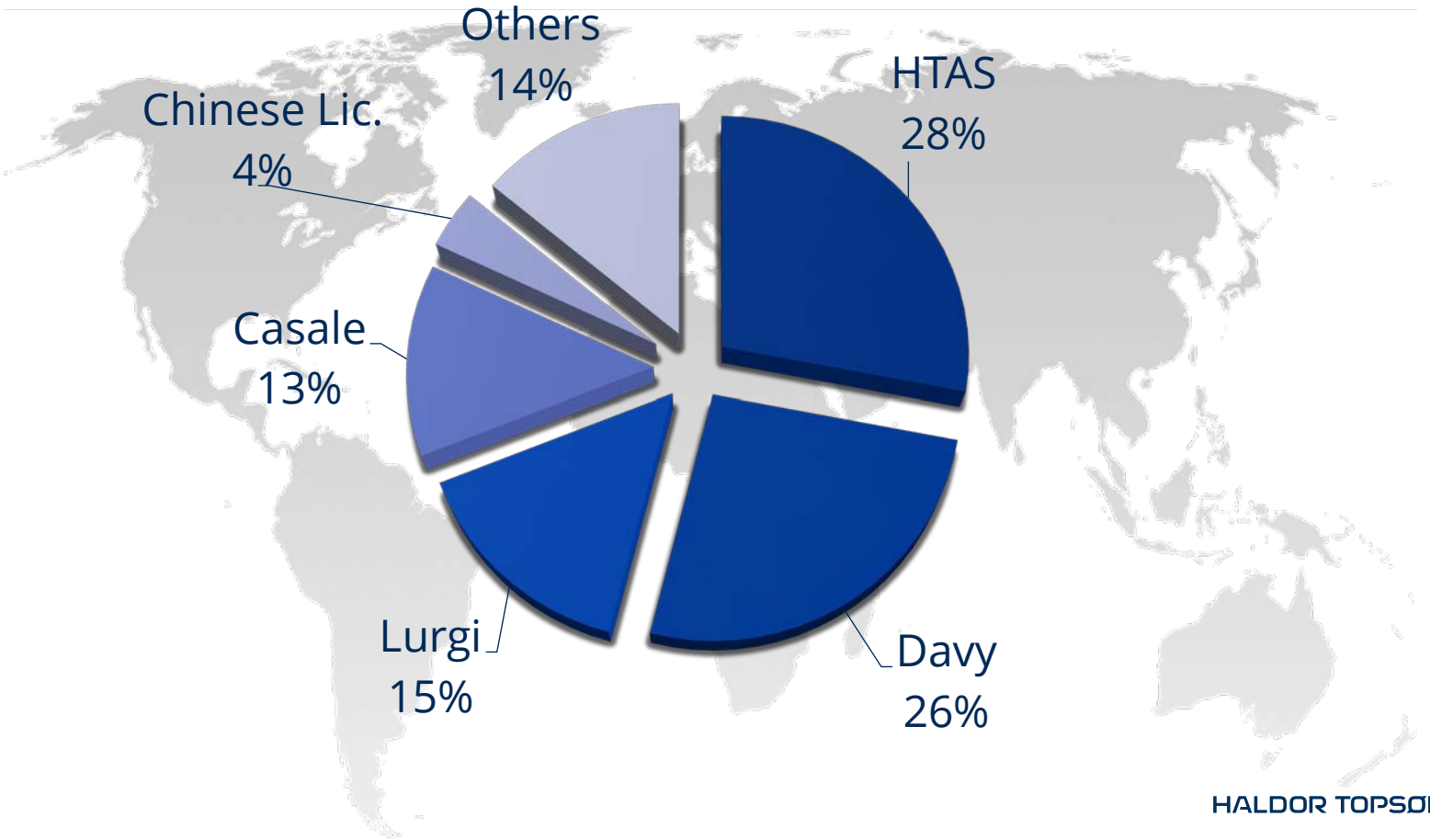
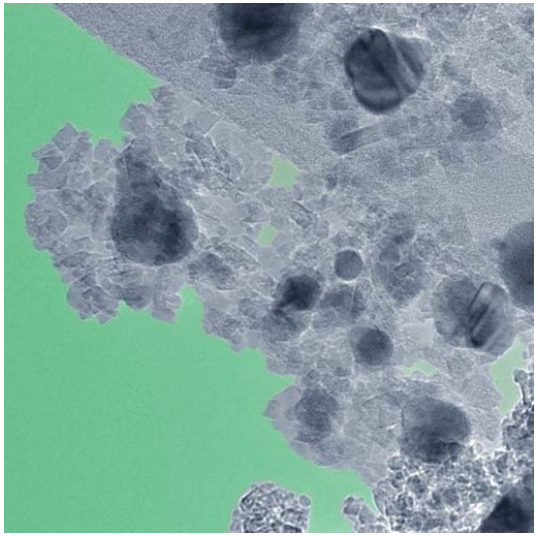
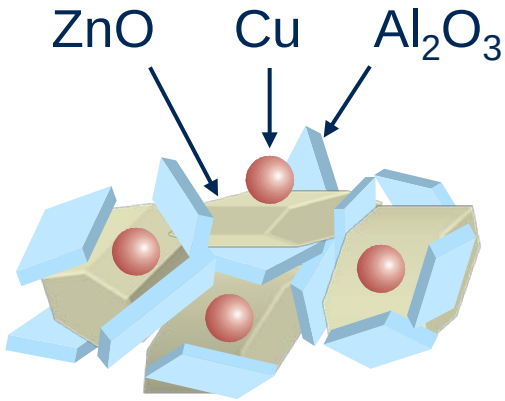
Methanol market share
Awarded capacity 2003-2014



FENCE™ technology

- Optimising sintering barriers
- Cu crystals separated by picket fence of metal oxides
- The FENCE™ technology inhibits sintering





Industrial benefits

Statoil, Norway, 2500 MTPD
28.8 GJ/MT => 69 % effeiciency

- Increased loop efficiency
  - Production gain
  - Inc
  - Lo
- Long
  - Le
  - Inc

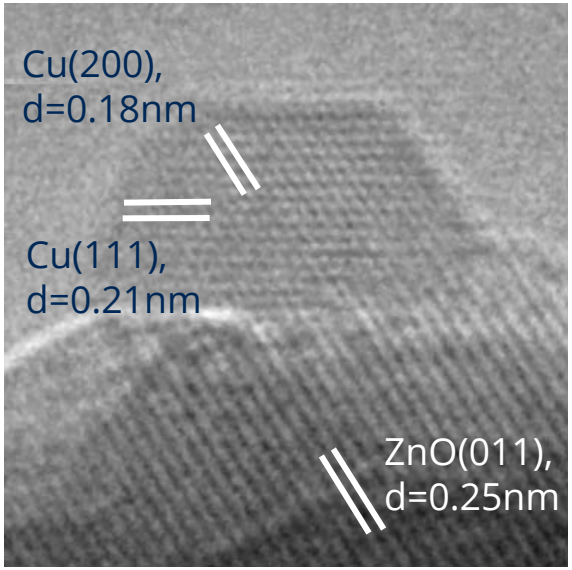
Methanol synthesis

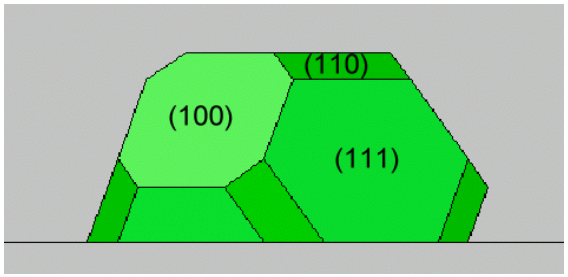
- $CO + 2H_2 = CH_3OH + 91$ kJ/mol
- $CO_2 + 3H_2 = CH_3OH + H_2O + 41$ kJ/mol

$$M = \frac{H_2 - CO_2}{CO + CO_2} = 2$$

The Active Site of Syngas Catalyst

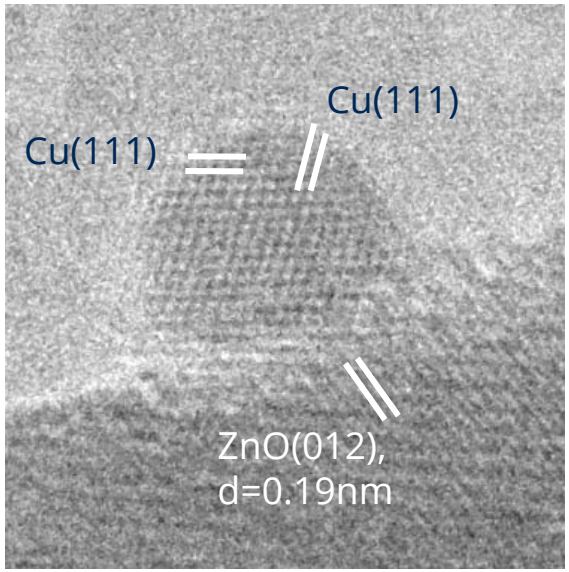
H_2

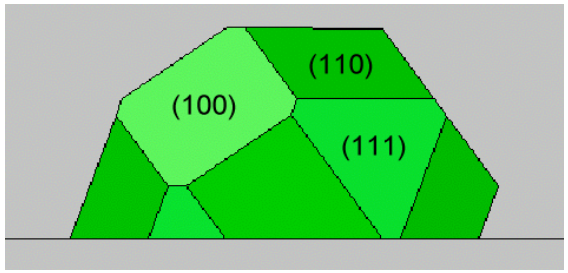




1.5mbar, 220°C

H_2/H_2O





1.5mbar, H_2/H_2O=3/1, 220°C

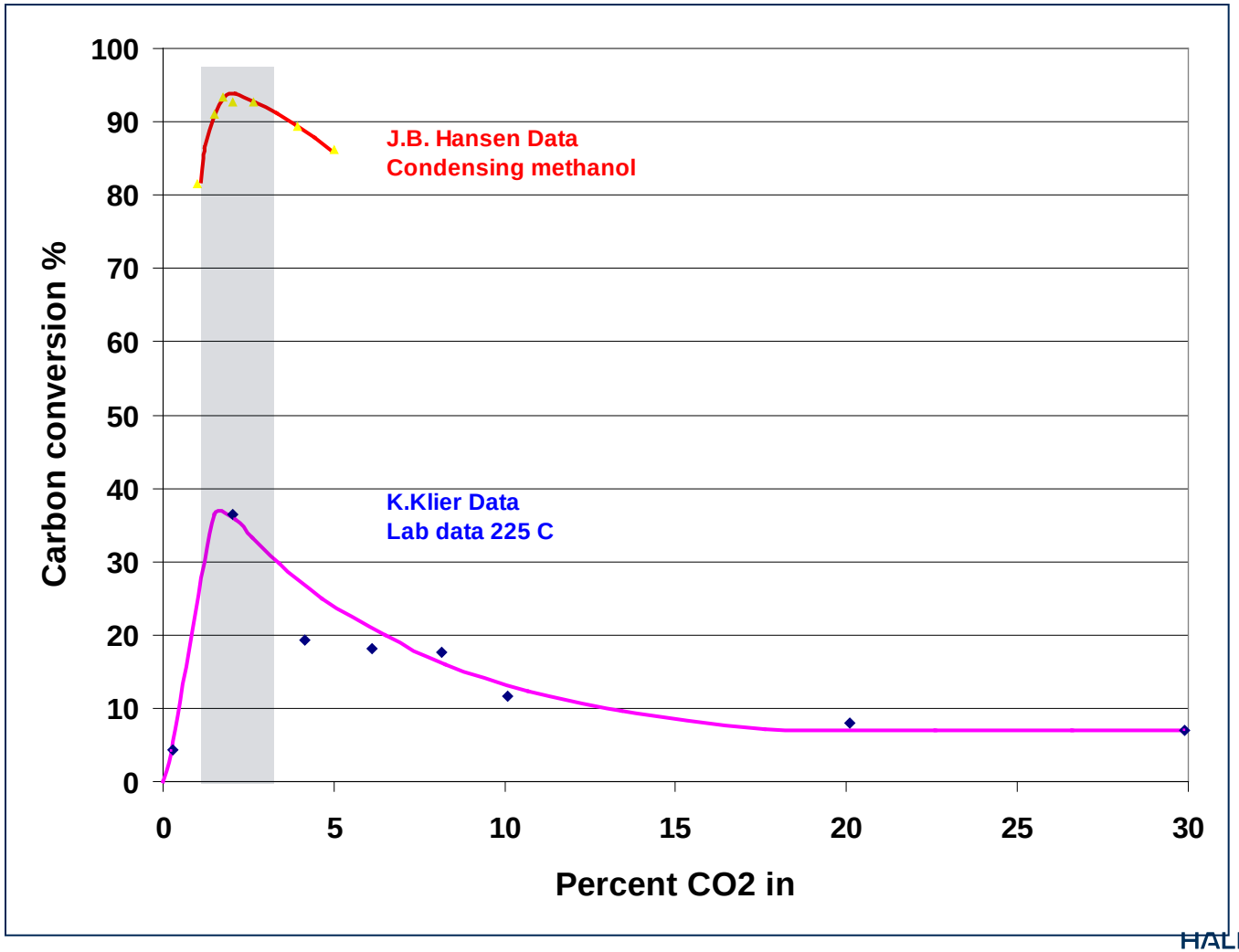
Cu is metallic when catalyzing

- WGS
- MeOH synthesis
- MeOHreforming

Catalyst dynamic

- Number of active sites depends on conditions

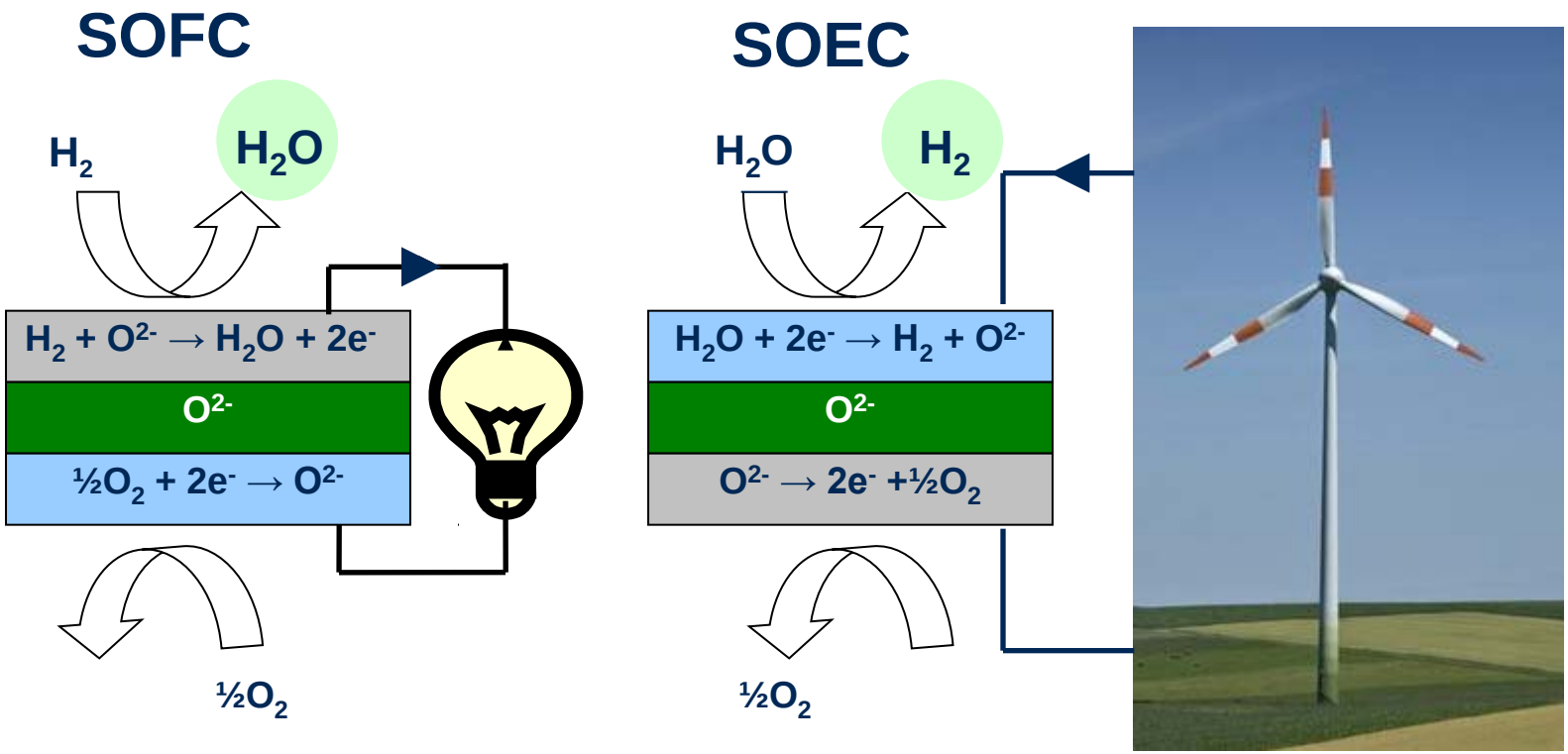
Conversion of methanol as function of CO_2 content in stoichiometric gas



Reformers for Methanol Plant utilising CO_2

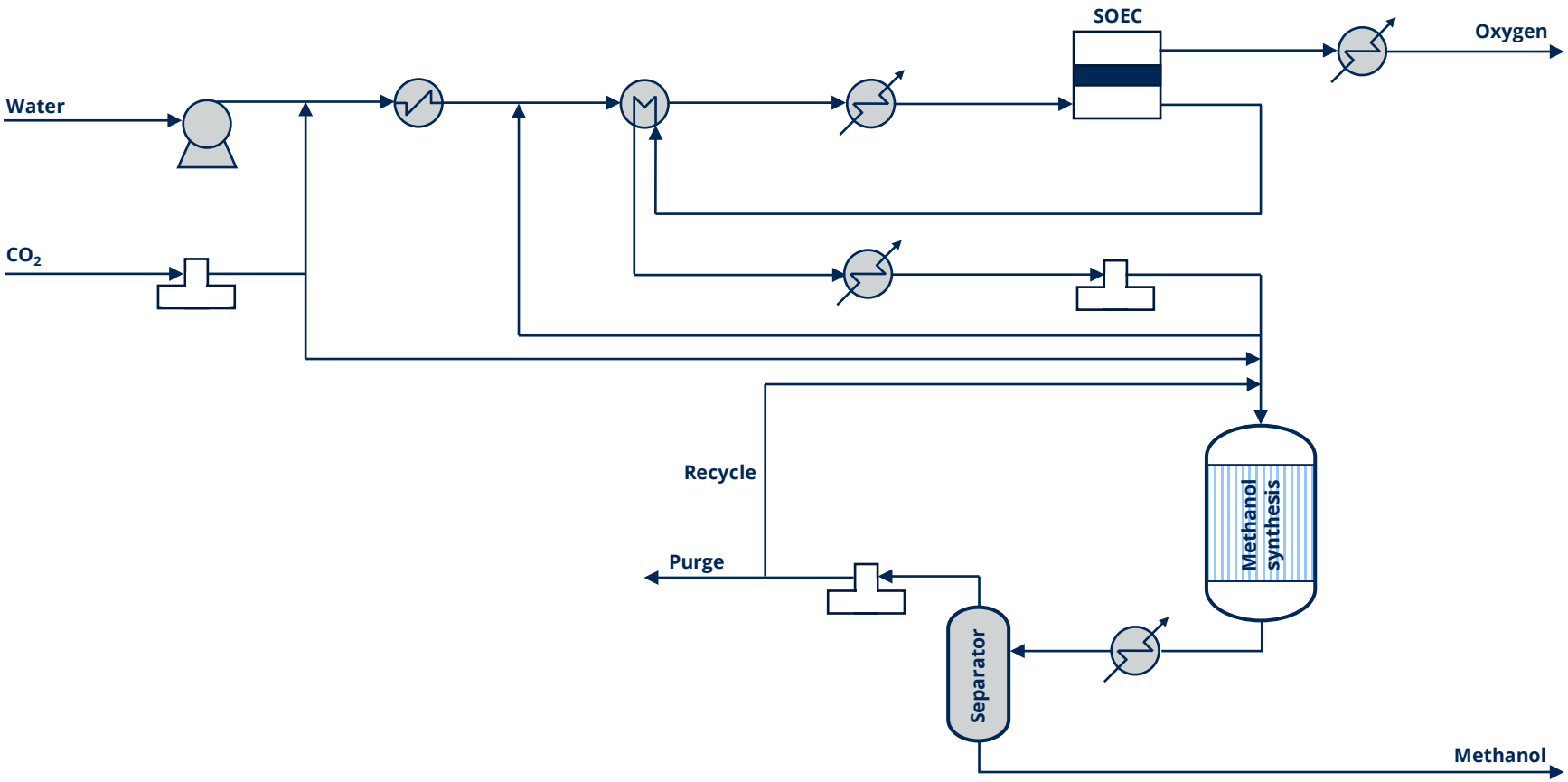
$¾CH_4 + ½H_2O + ¼CO_2 = CH_3OH$

Fuel Cell and Electrolyser

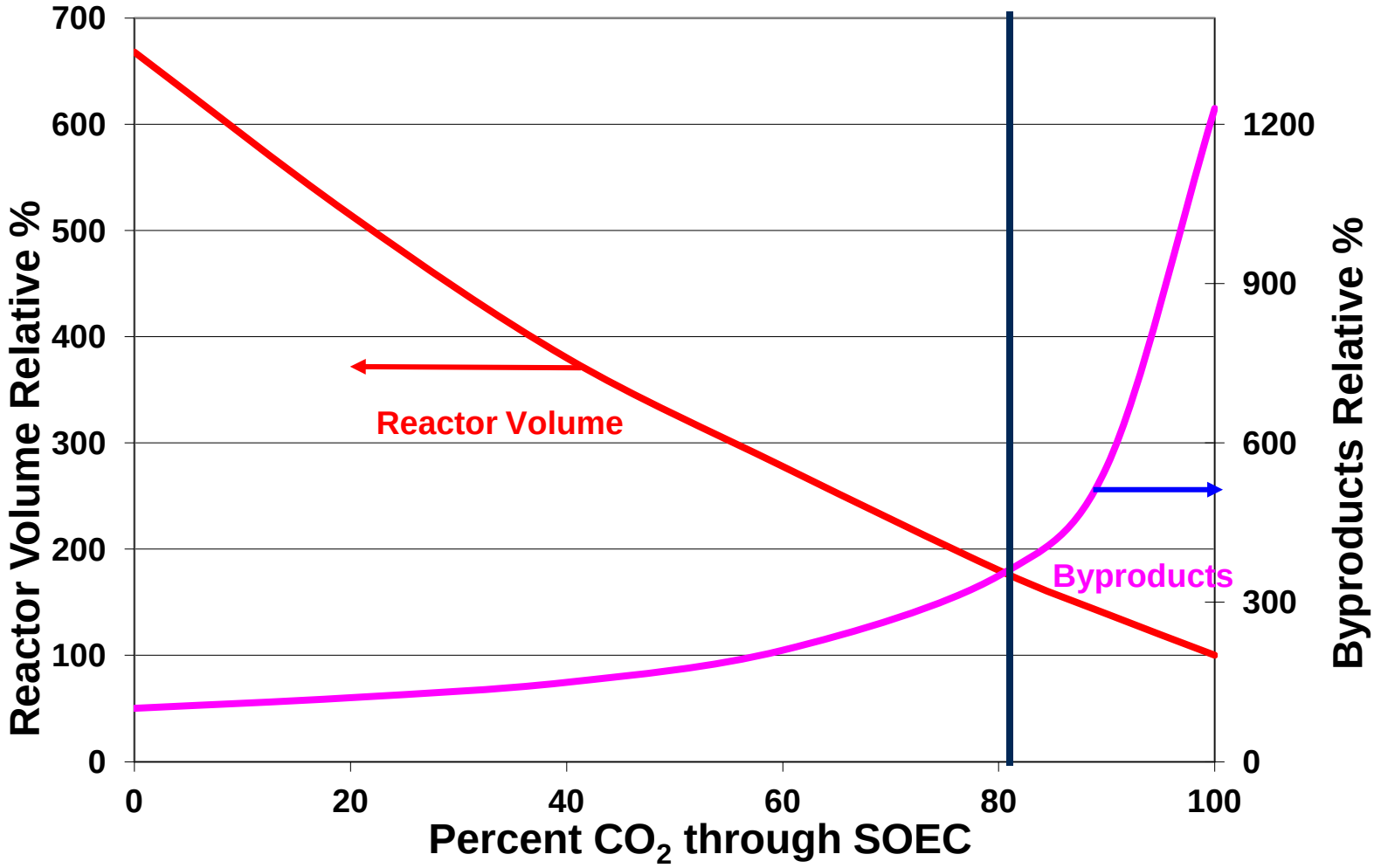


$$H_2 + CO + O_2 \underset{\text{SOEC}}{\overset{\text{SOFC}}{\rightleftharpoons}} H_2O + CO_2 + \text{electric energy } (\Delta G) + \text{heat } (T\Delta S)$$

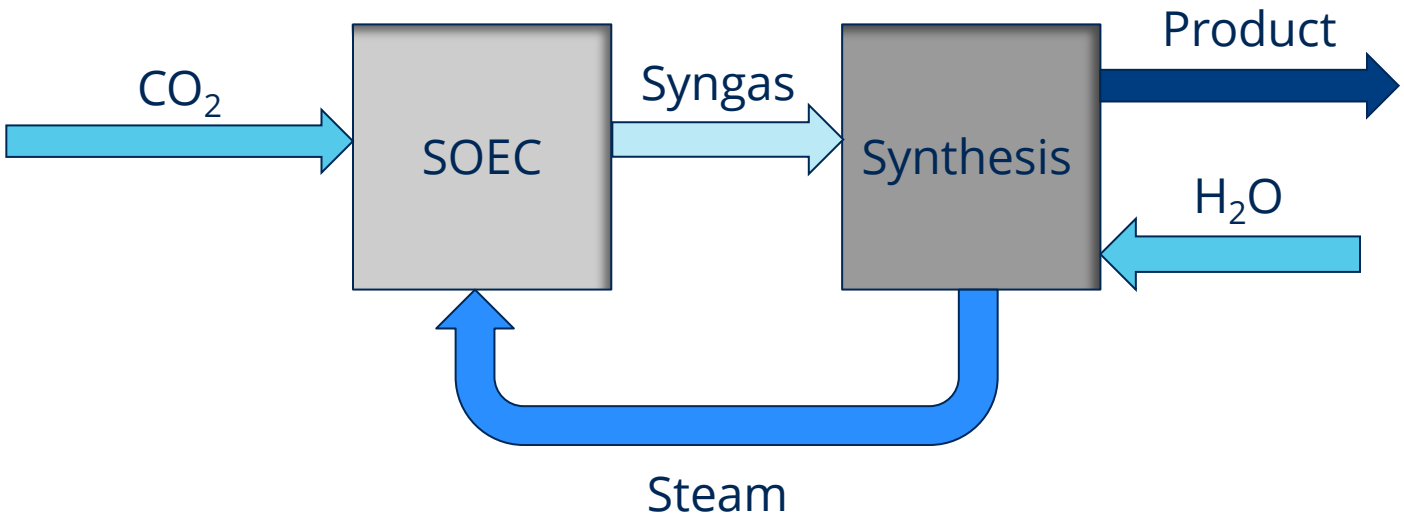
Methanol
From CO_2 and Steam



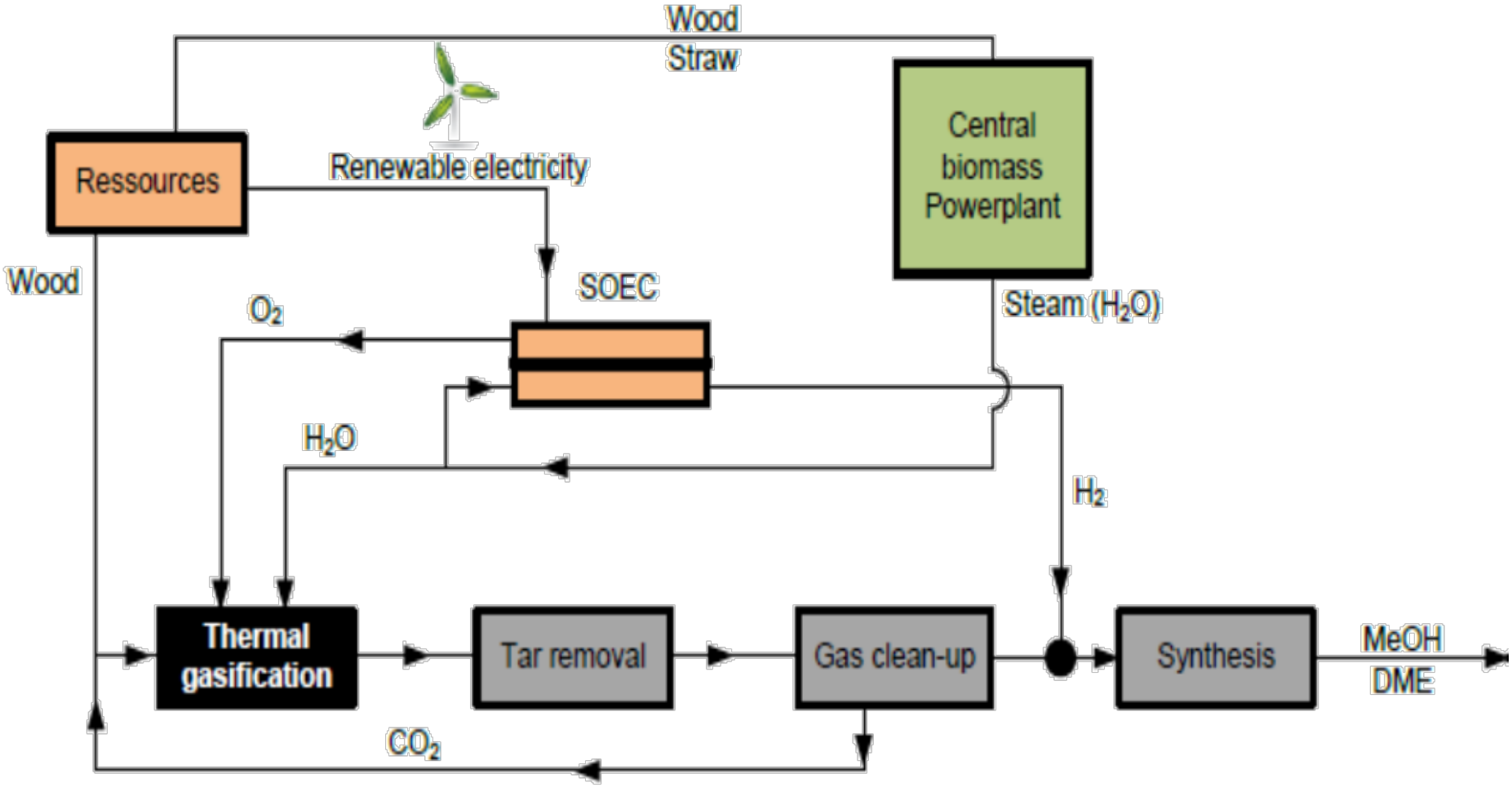
Reactor volume and byproducts as function of CO_2 converted in SOEC



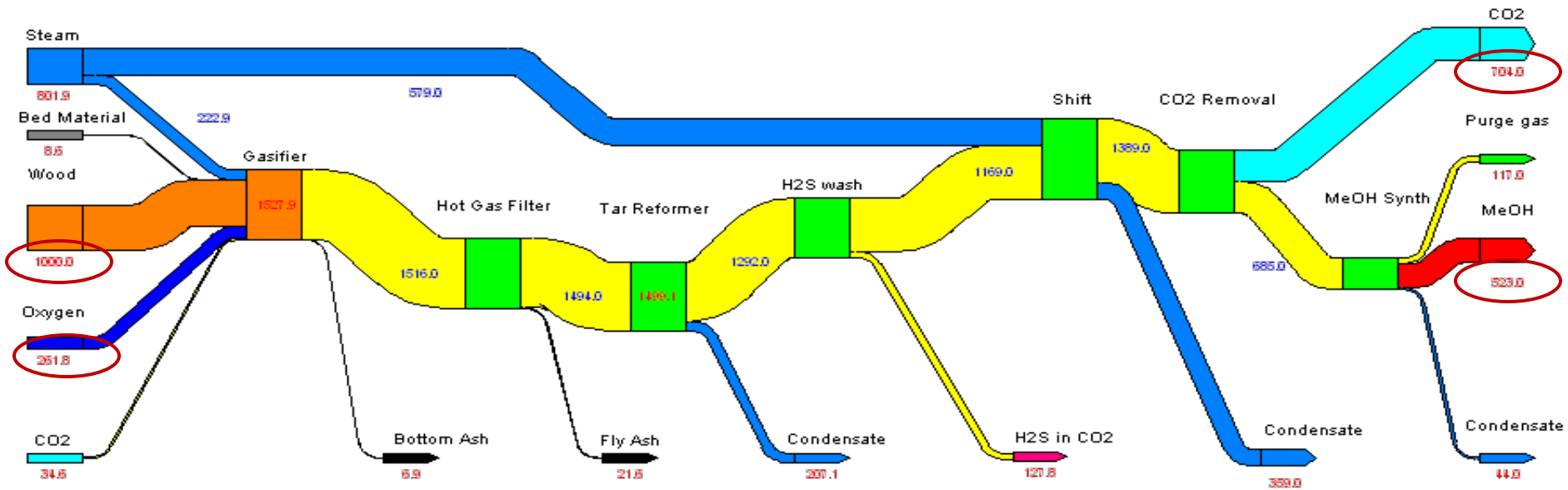
Synergy between SOEC and fuel synthesis
Effciencies electricity to MeOH = 76-79 % possible



GreenSynFuel Project



Mass Flows in Wood to MeOH



Mass balances for Wood Gasification to MeOH

Flows in Metric Tons per day

1000 tons Wood

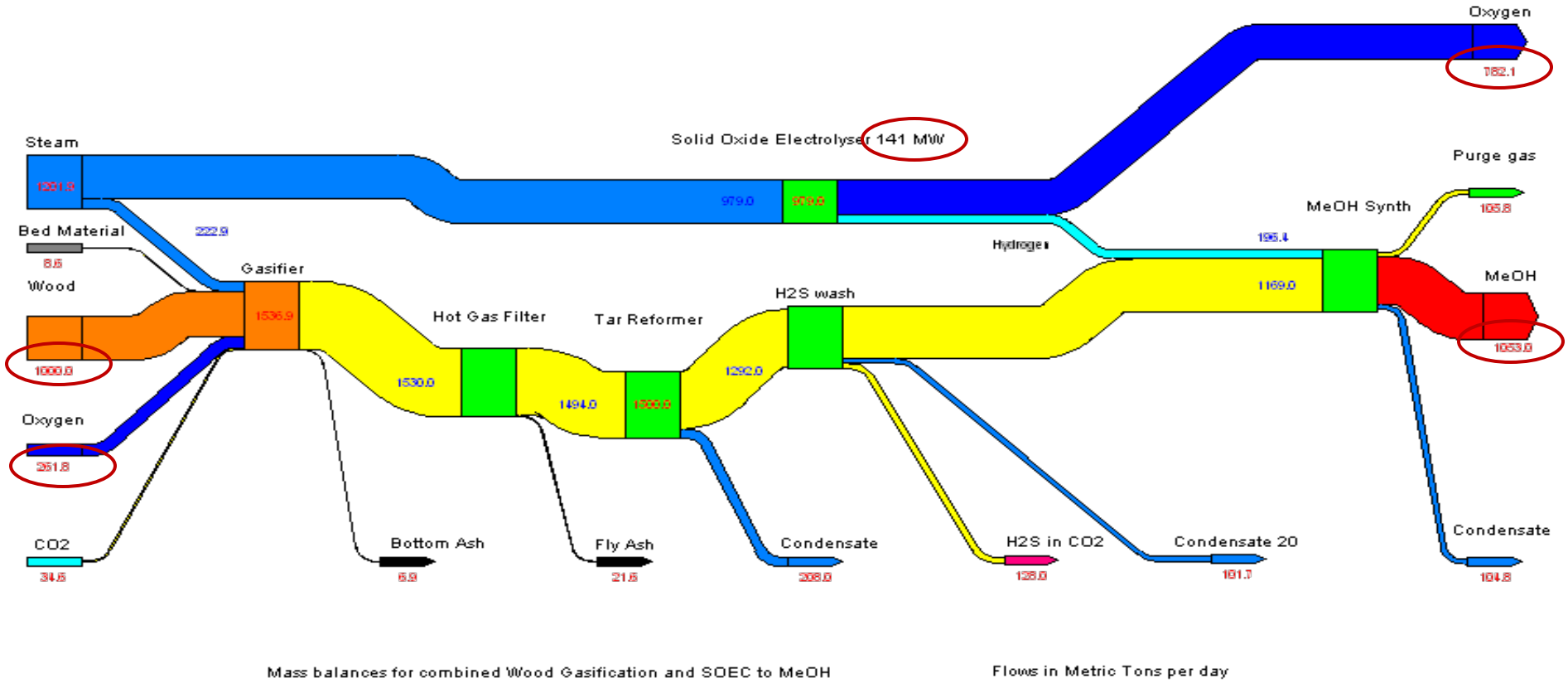
262 tons Oxygen

704 tons CO_2

523 tons MeOH

59 % LHV efficiency

Mass Flows in Wood + SOEC to MeOH



Mass balances for combined Wood Gasification and SOEC to MeOH

Flows in Metric Tons per day

1000 tons Wood

262 tons Oxygen

141 MW electricity

71 % LHV efficiency

782 tons Oxygen

1053 tons MeOH

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Conclusions

- Haldor Topsøe is a major player within the methanol industry
- CO_2 is already today used to enhance methanol production based on natural gas steam reforming
- Very efficient methanol plants based on power, steam and CO_2 is possible via SOEC
- Co-electrolysis offers the opportunity to reduce methanol synthesis catalyst volumes by a factor around 5
- Pressurising the SOEC stacks can eliminate synthesis gas compressor and increase efficiency
- Coupling SOEC with biomass gasification can double the biomass potential by converting excess carbon.

To find out more or get in contact

www.topsoe.com

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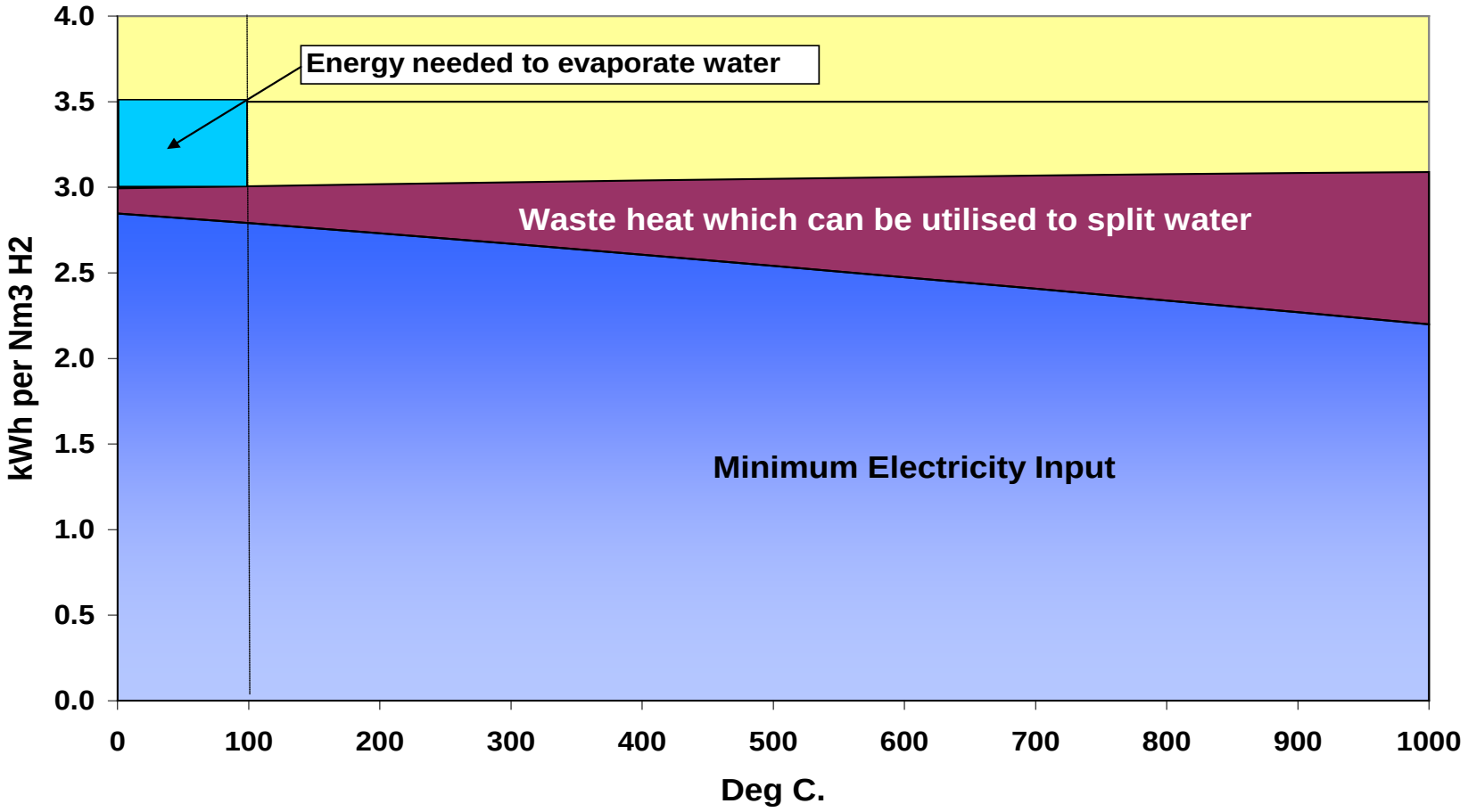
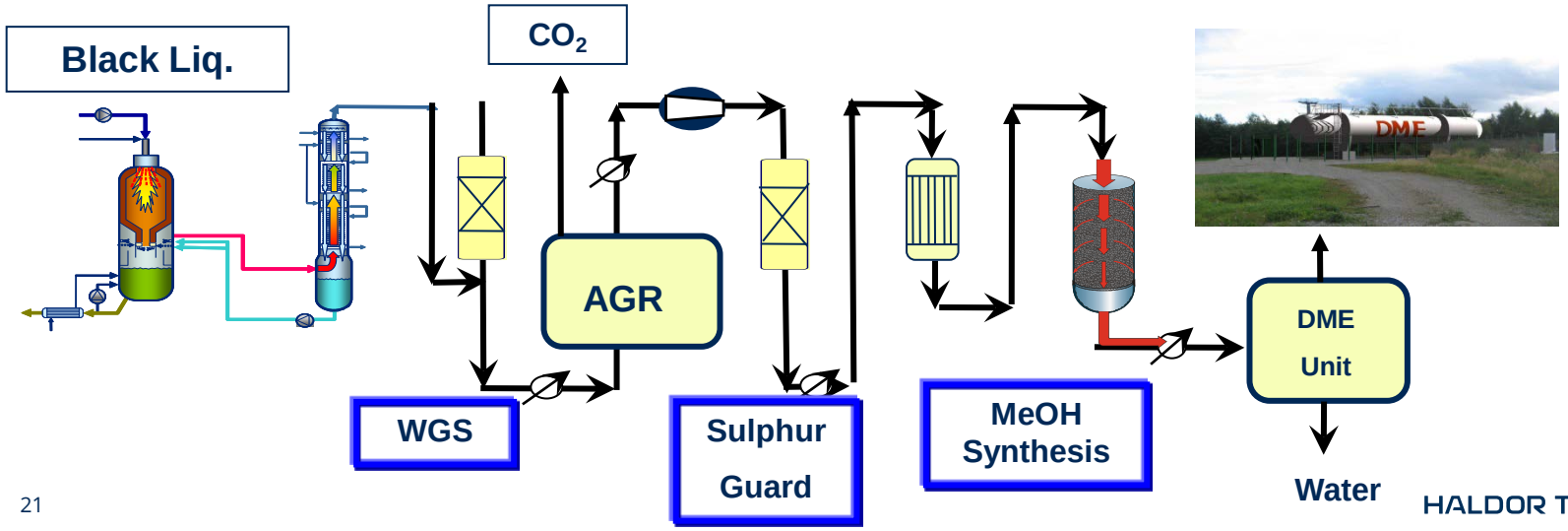
SOEC more efficient than present Electrolysers
Internal waste heat used to split water



Methanol from sustainable sources
BioDME Black Liqour to Green DME Demo



Wood to Gasoline
DOE Project

Green Gasoline from Wood Using Carbona Gasification and Topsoe TIGAS Processes

Results of ”to pressurize SOEC stacks or not”

SOEC Pressure	Syngas Comp, %	CO_2 Comp	LHV Efficiency, %
Atmospheric	6.8	0.1	75.8
@50 bar	0.0	1.9	79.5
Max. theoretical			83-88

Effciencies

Stand alone wood gasifier and gasifier plus SOEC

LHV Efficiency %	Wood Gasifier alone	Wood gasifier Plus SOEC
Methanol	59.2	70.8
District Heat	22.6	10.8
Total	81.8	81.6