Syngas Routes to Alternative Fuels from Renewable Sources

RESEARCH | TECHNOLOGY | CATALYSTS

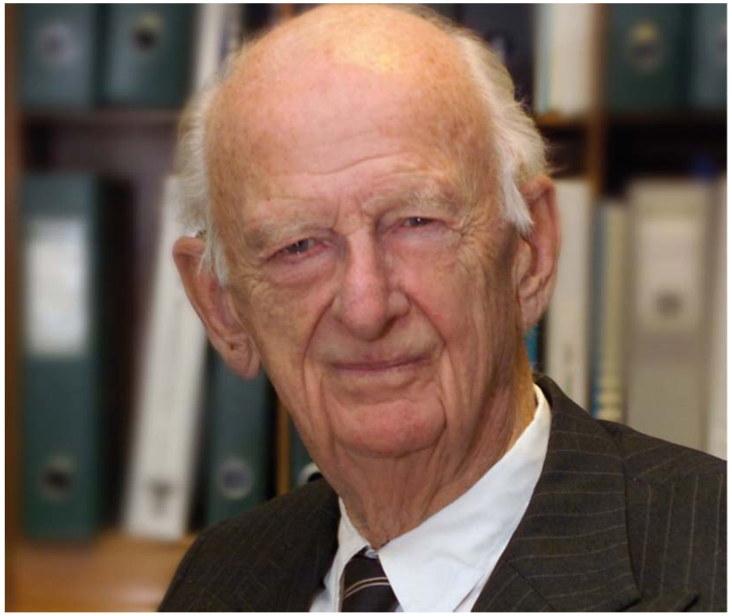
John Bøgild Hansen - Haldor Topsøe

Karlsruhe, November 4, 2014

HALDOR TOPSØE

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

- Founded in 1940 by Dr. Haldor Topsøe
- Revenue: 600 million Euros
- 2900 employees
- Headquarters in Denmark
- Catalyst manufacture in Denmark and the USA



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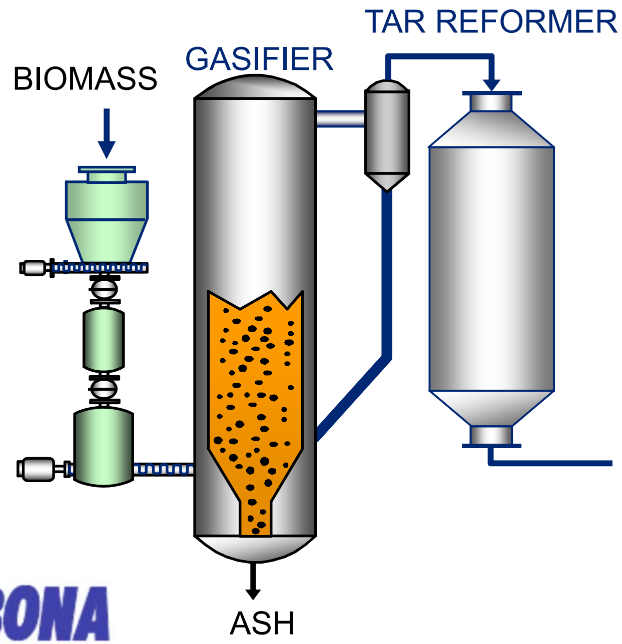
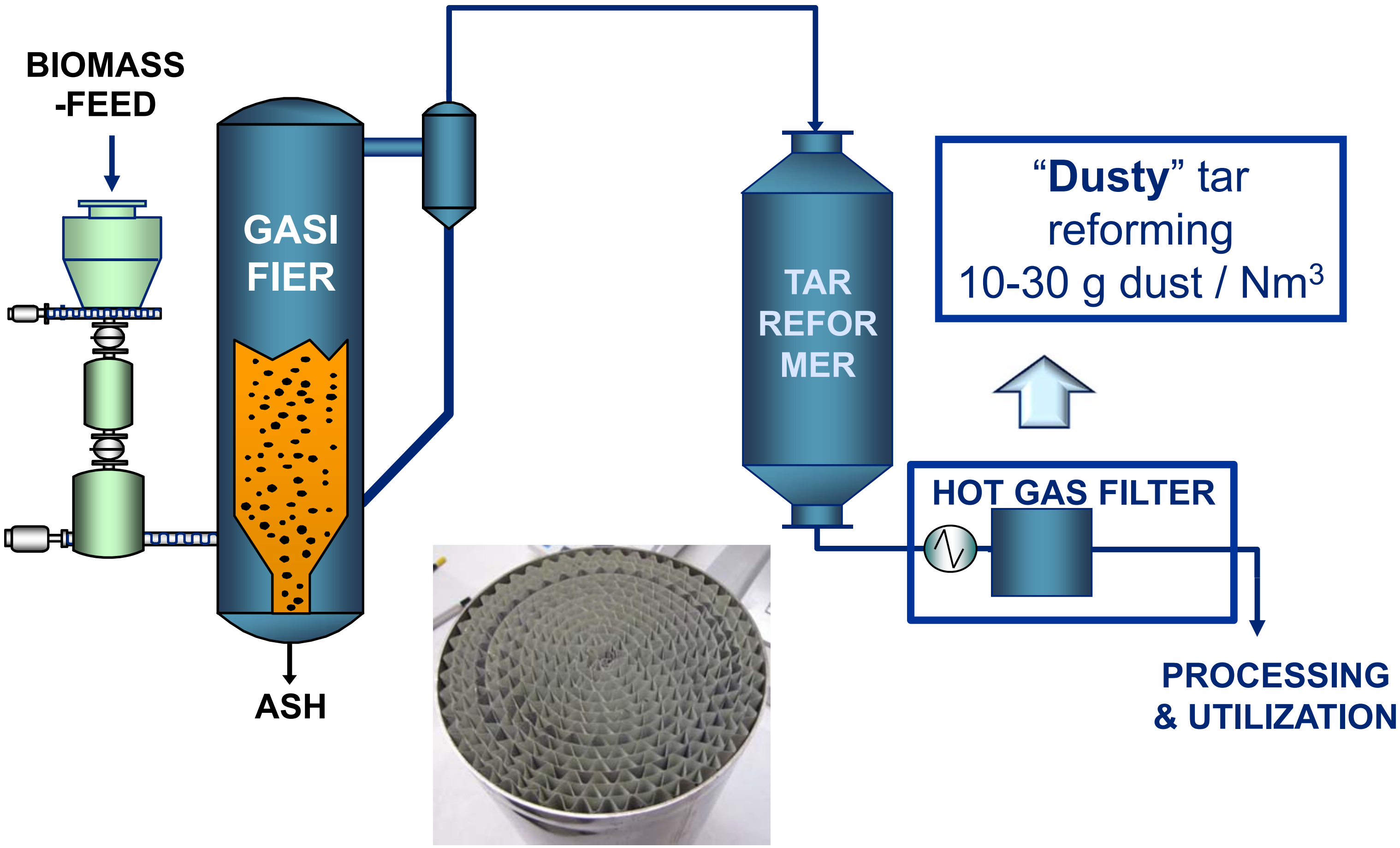
Tar reforming – Enabling technology for biomass gasification

- Gasification of biomass results in a syngas that contains tars and contaminants
  - 1000 -2500 ppm tar
  - 50 – 100 ppm S, particulates
  - 850-930°C, 1-30 bar g
  - Ammonia decomposition



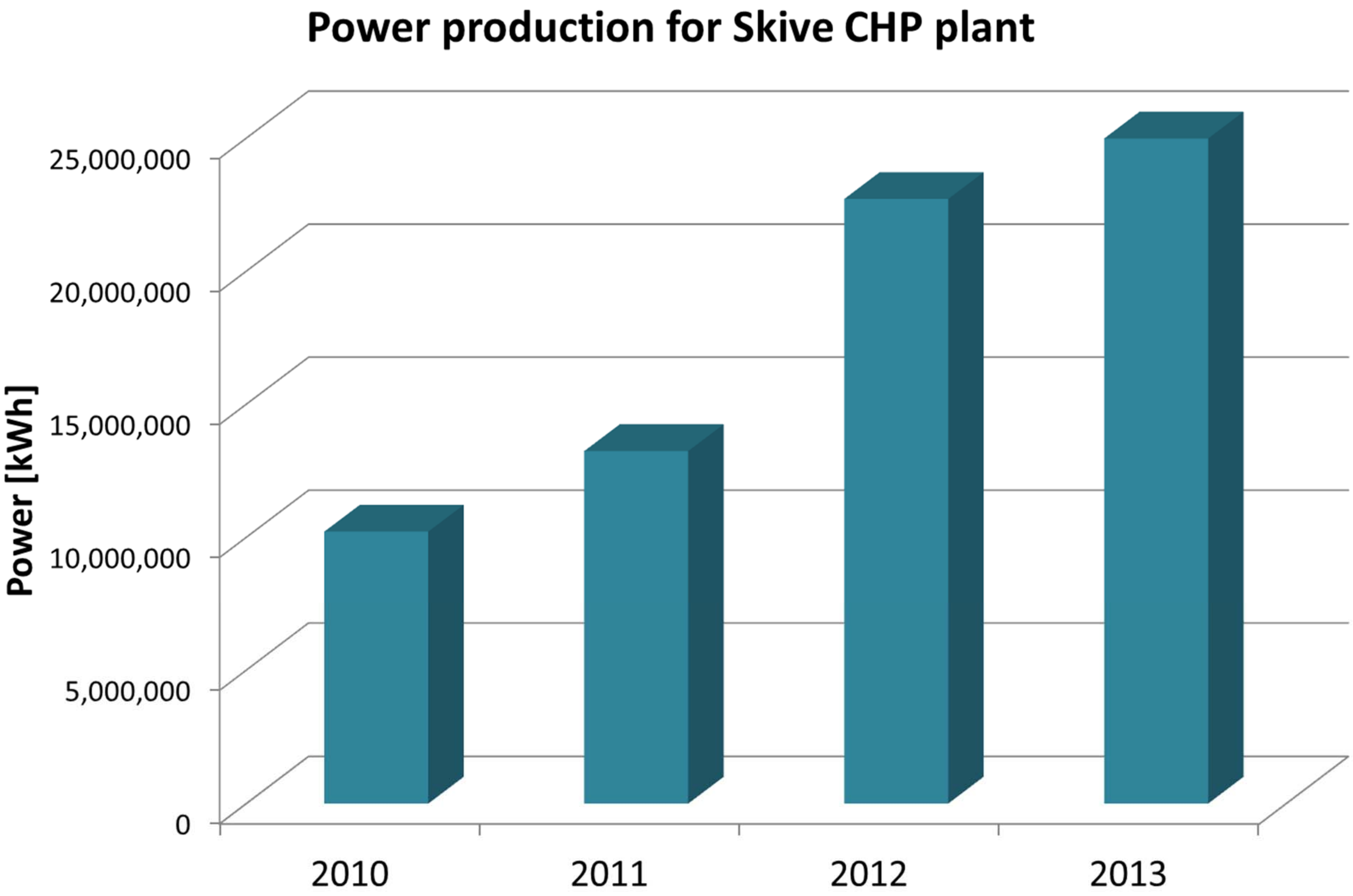
"Dusty" tar reforming



Skive Fjernvarme a.m.b.a. (Skive CHP)

Location	Skive, Denmark
Capacity	**21 MW_{th}**, Max 28 MW_{th}
Operational year	2009
Fuel consumption	100 TPD
Fuel	Biomass, wood pellets
Gasification techn.	Air blown, bubbling fluidized bed
Pressure range	**1 – 3 bar g**
Power generation	Gas engines

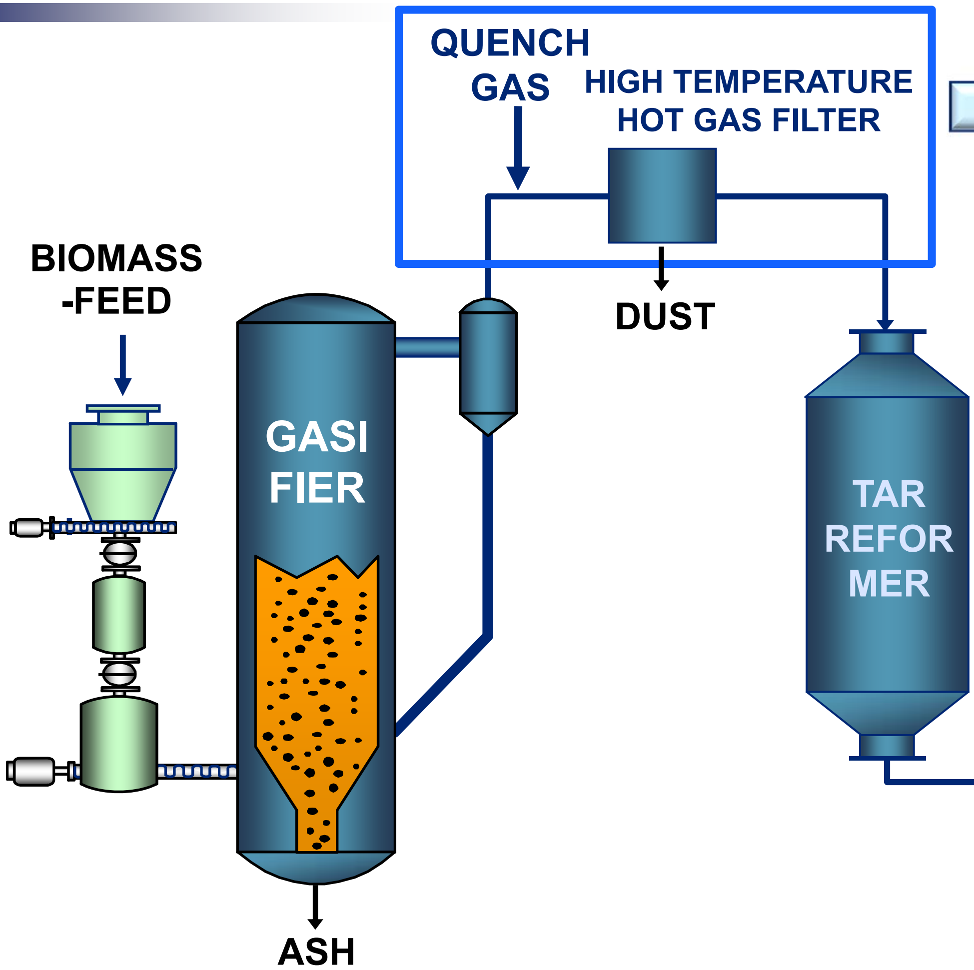
Skive Fjernvarme a.m.b.a. (Skive CHP)



Gas Technology Institute, Chicago

Location	Chicago, USA
Capacity	~ 4 MW_{th}
Fuel consumption	18 TPD
Fuel	Biomass, wood pellets
Gasification techn.	Oxygen blown, bubbling fluidized bed
Pressure range	**1-9 bar g**

“Clean” tar reforming

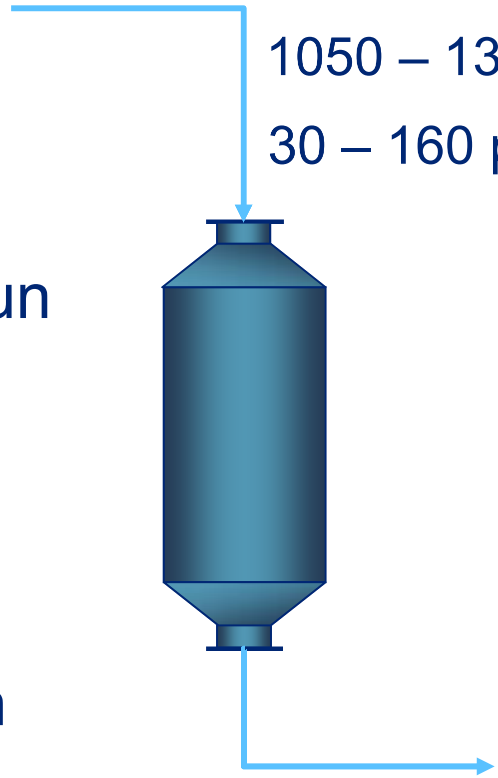


“**Clean**” tar reforming
1 -10 mg dust / Nm^3

Nickel-based

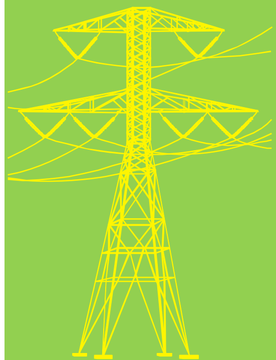
Gas Technology Institute, Chicago

- Tar reformer ~ 1150 run hrs
- No soot formation
- 15 min. lack of oxygen
  - **No deactivation!**



DME the versatile fuel

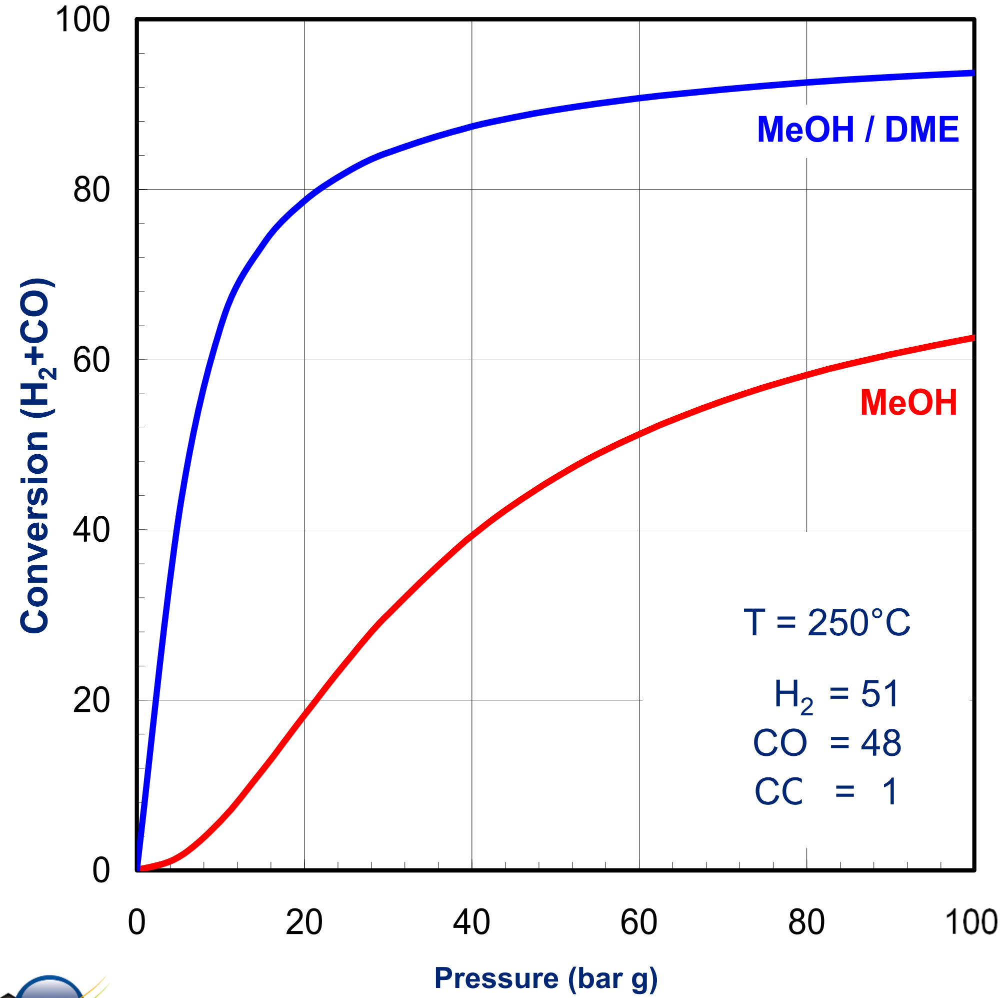
* Aerosol Propellant 150.000 TPY
* Energy Production

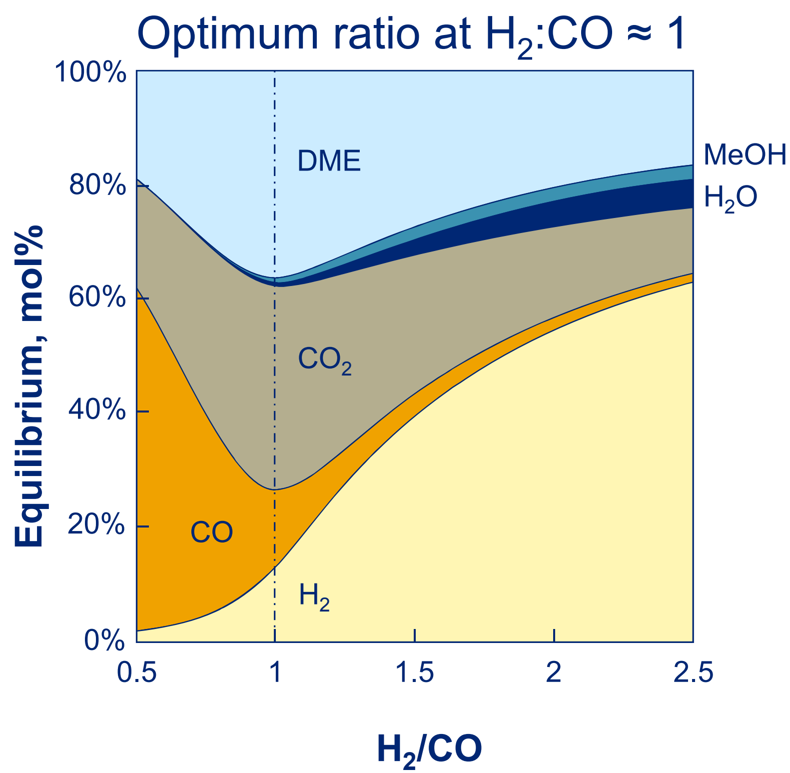


* Olefines

* Gasoline
* Acetic Acid
* LPG Substitute & Make-Up
* Transportation Fuel for Diesel & Fuel Cells

Syngas to MeOH/DME Equilibrium





World CTL 2012

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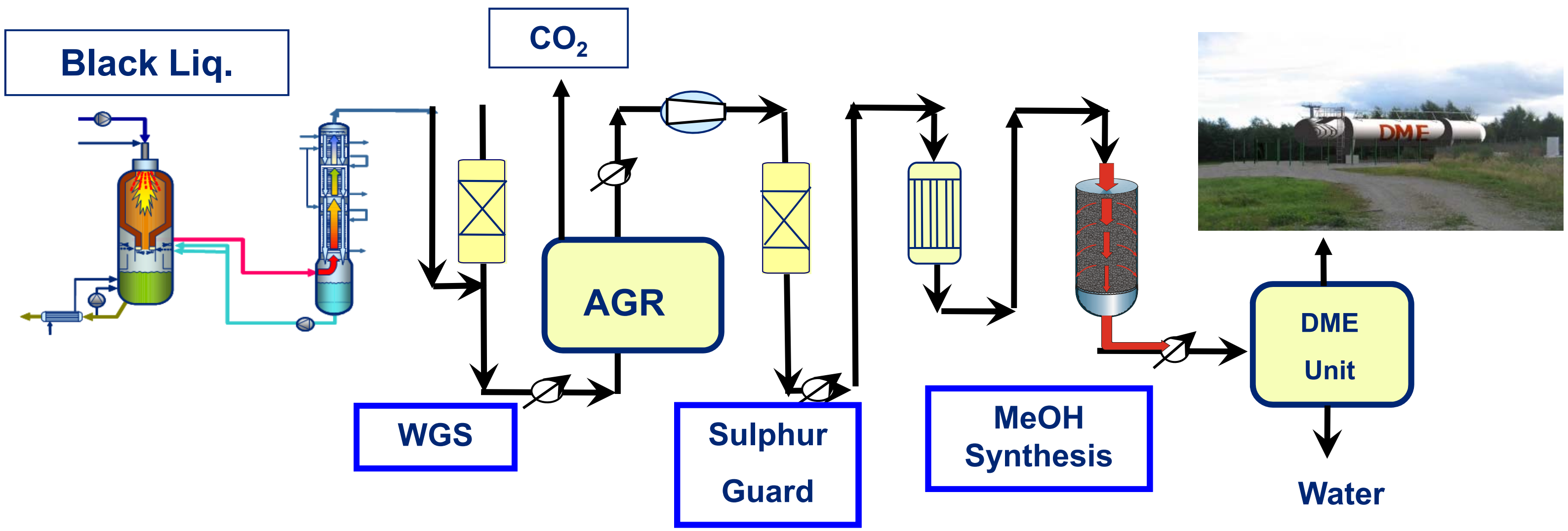
Methanol from sustainable sources

BioDME Black Liqour to Green DME Demo

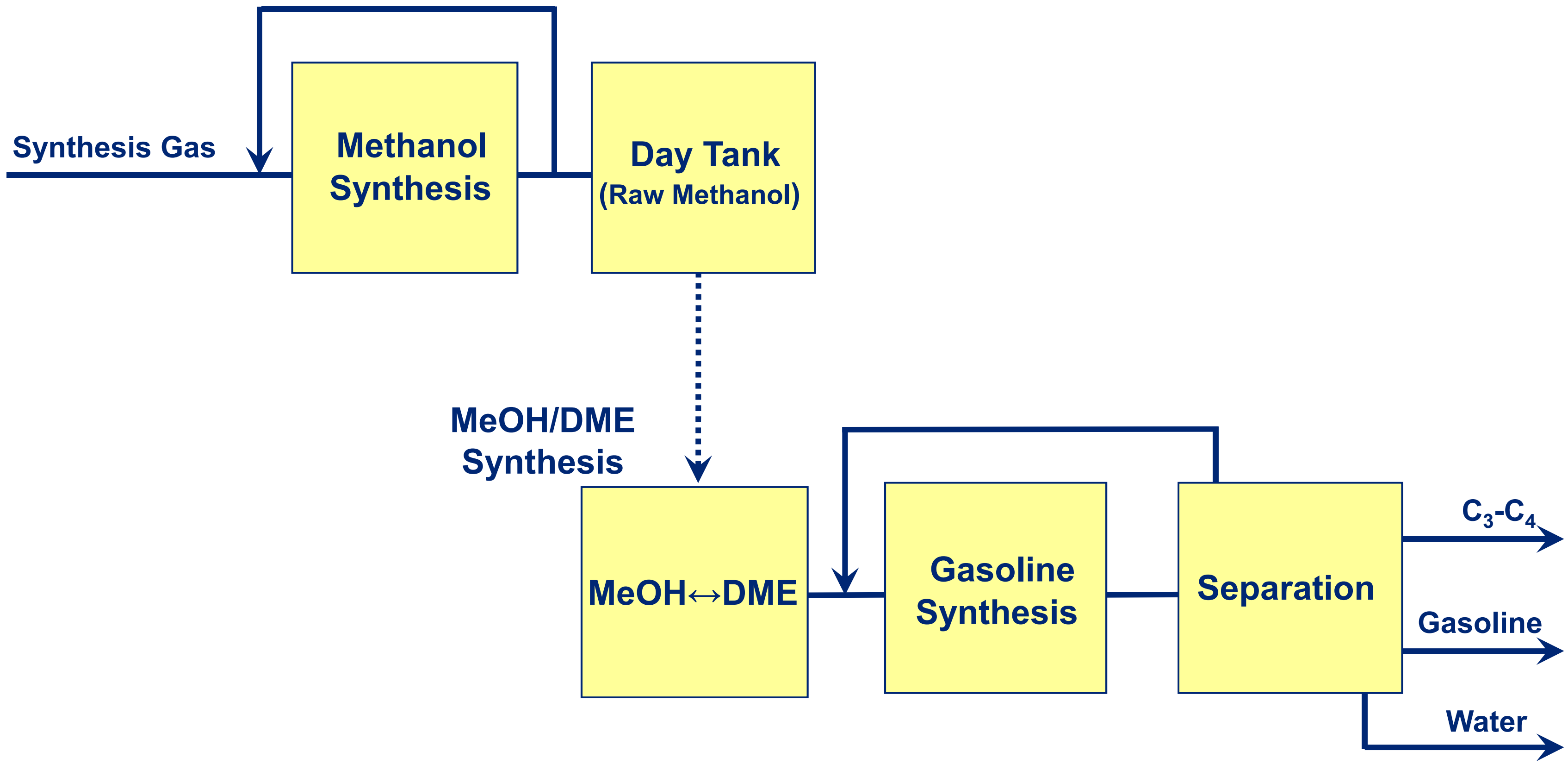


TIGAS

Topsøe Integrated Gasoline Synthesis

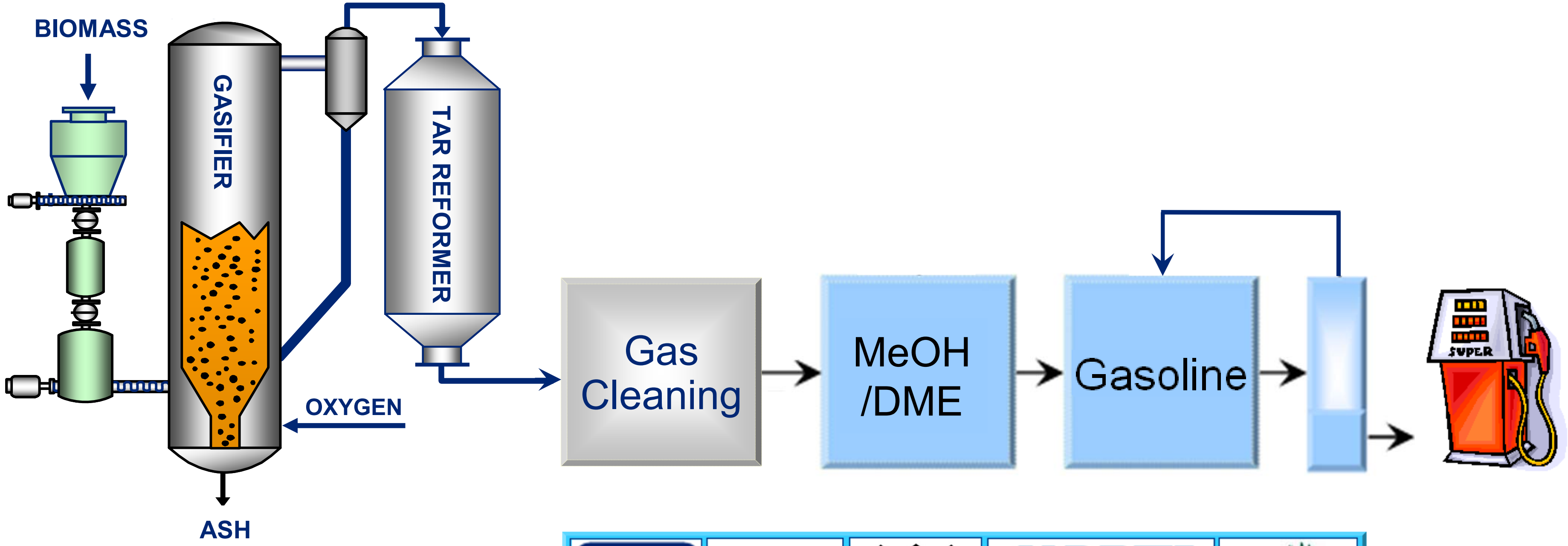
MTG

Methanol To Gasoline

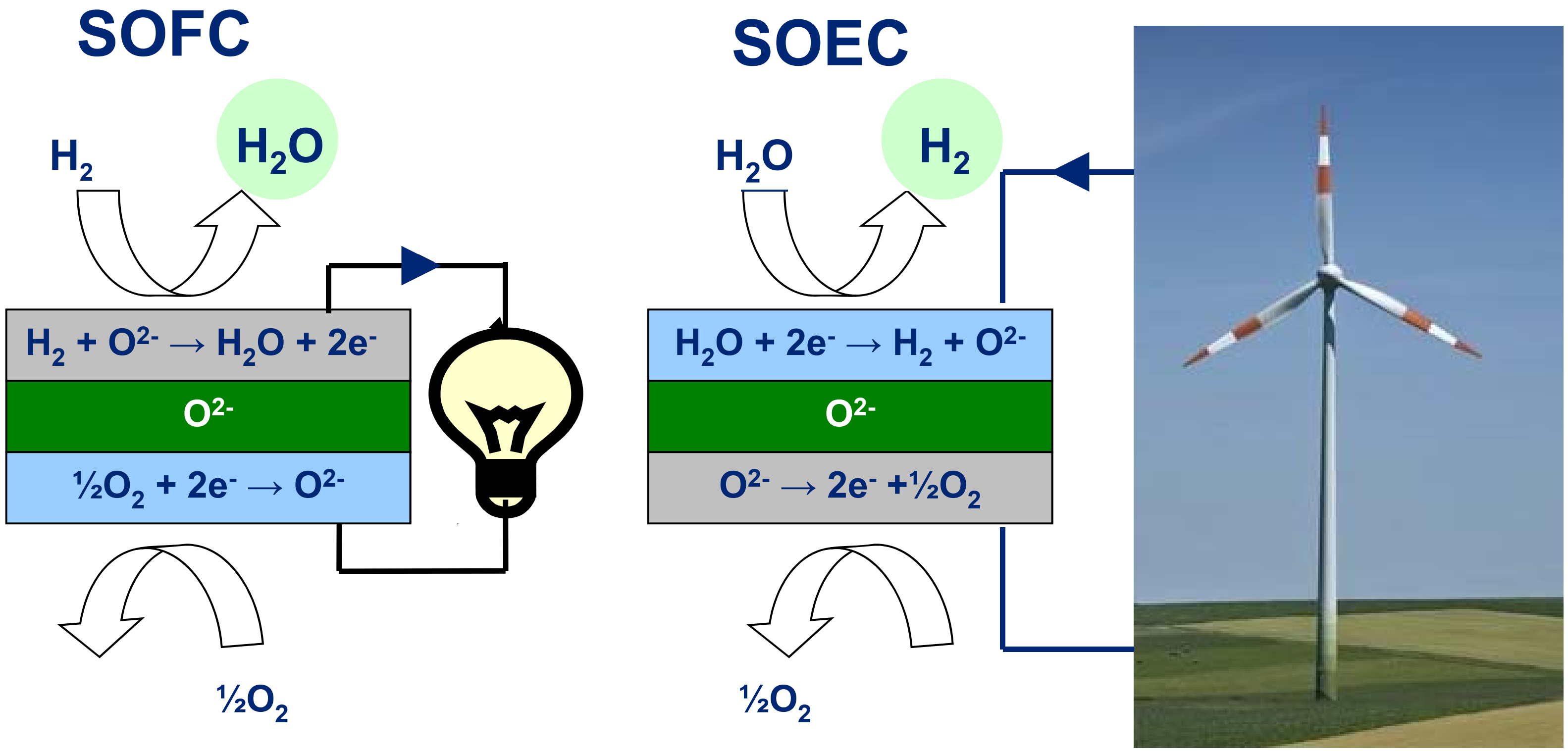


25 bbl/d Demonstration Plant

Green Gasoline from Wood Using Carbona Gasification and Topsoe TIGAS Processes



Fuel Cell and Electrolyser



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

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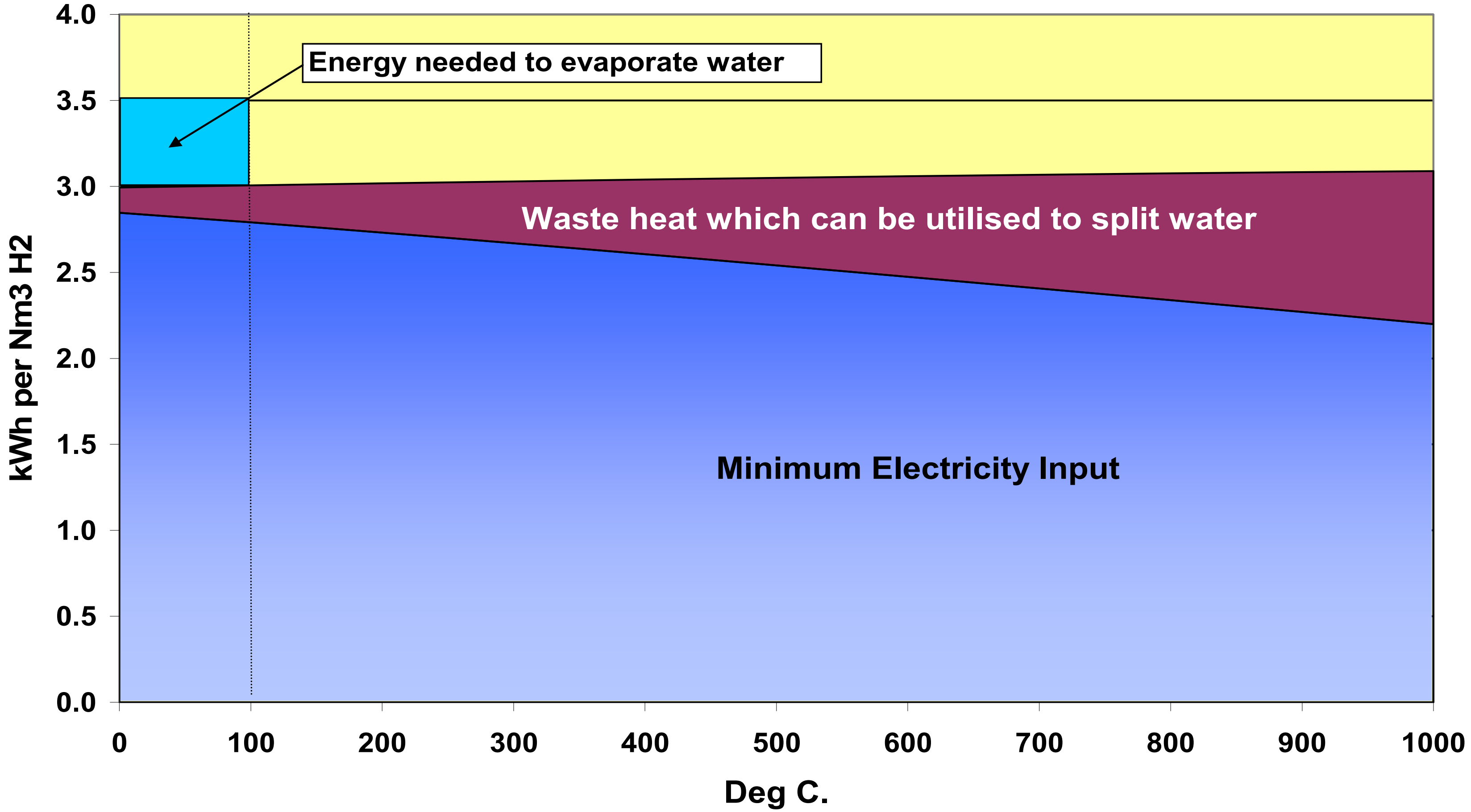
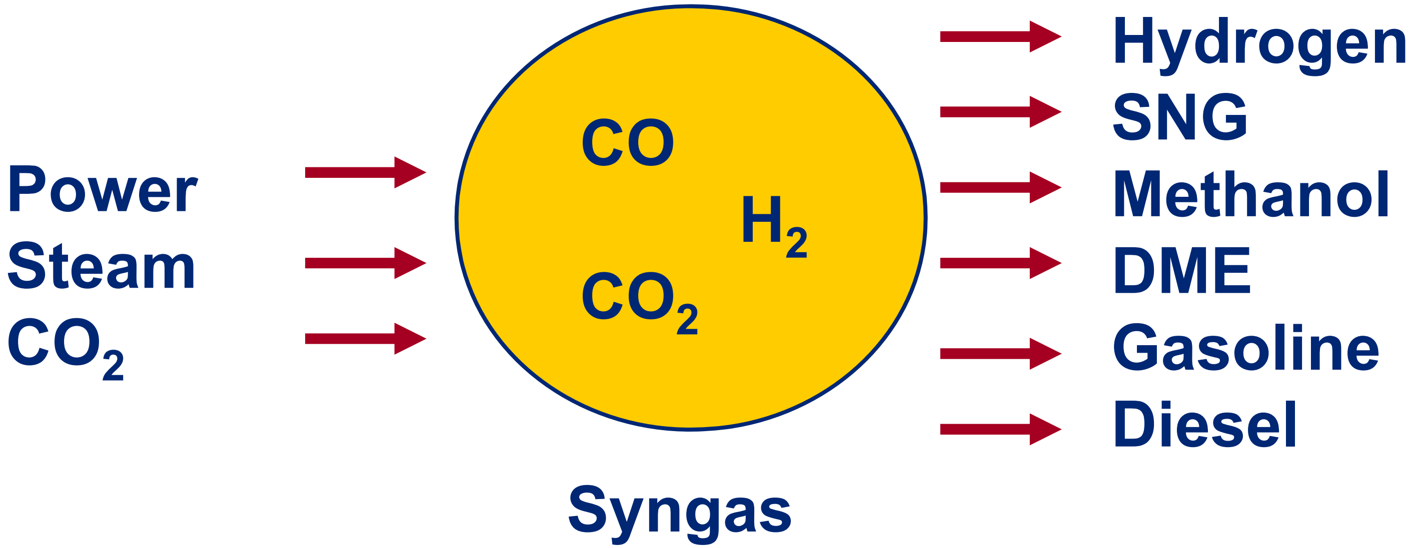
SOEC more efficient than present Electrolysers
Internal waste heat used to split water

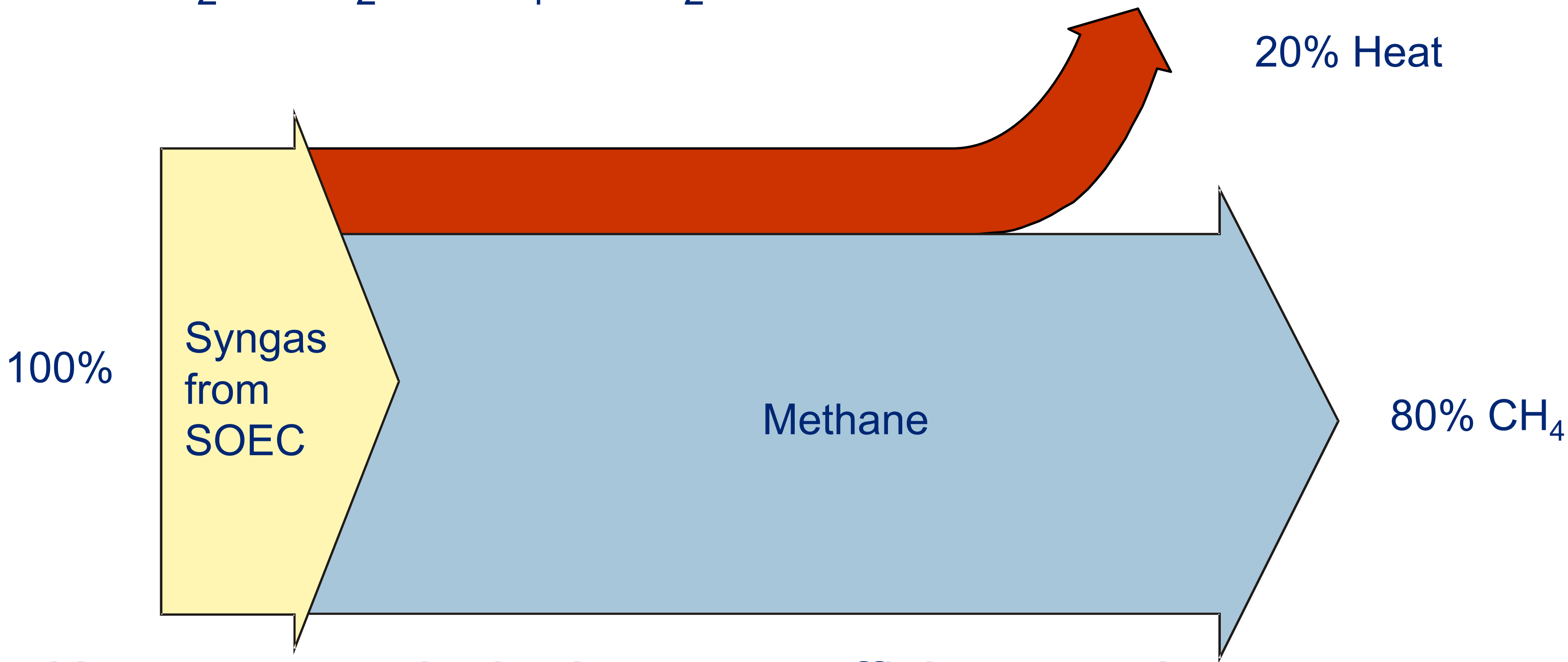


Electrolysis



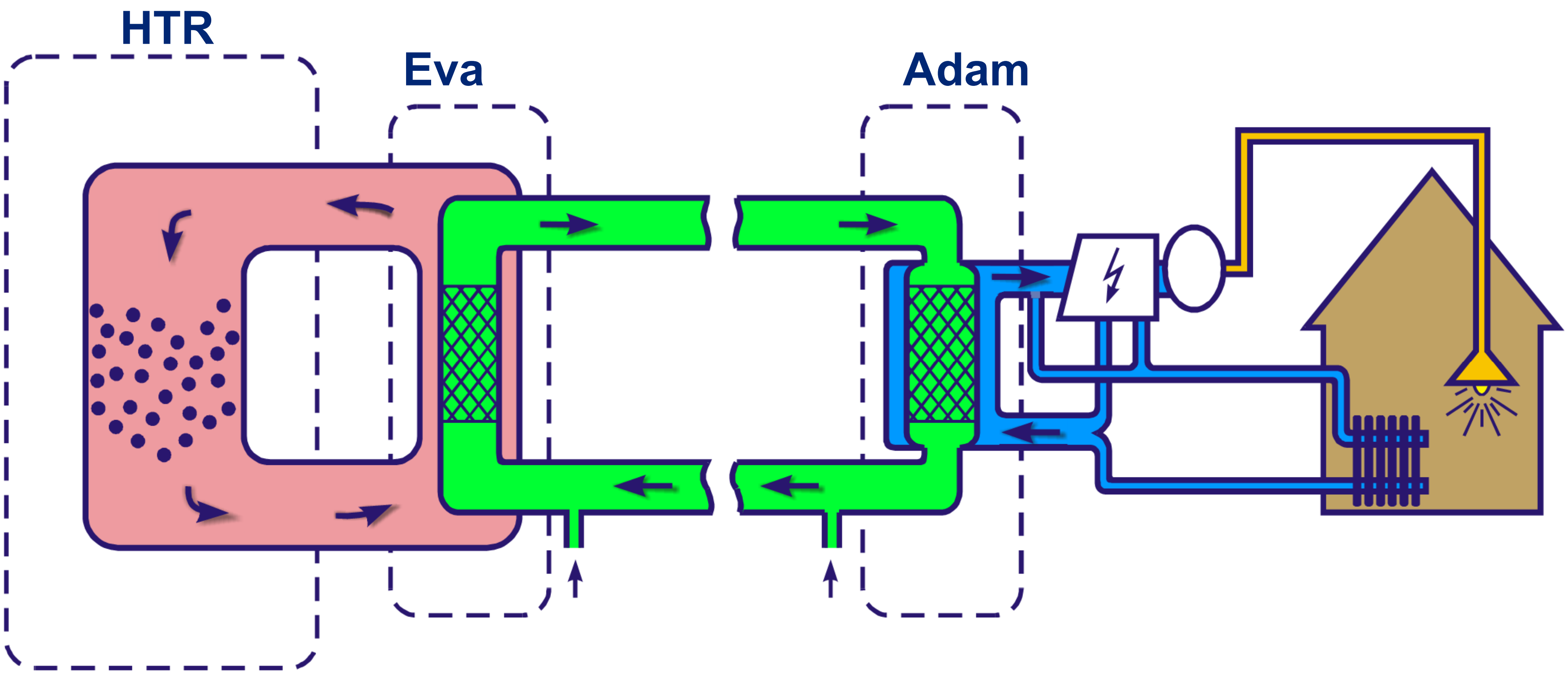
Methanation essentials

- $CO + 3H_2 = CH_4 + H_2O$
- $CO_2 + 4H_2 = CH_4 + 2H_2O$



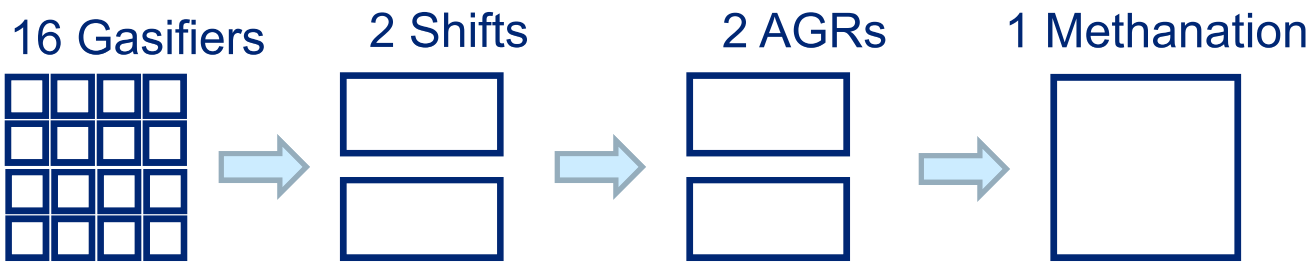
Heat recovery is the key to an efficient plant!

Energy transportation system
Chemical recuperation of nuclear energy
Experiments in Jülich 1980's

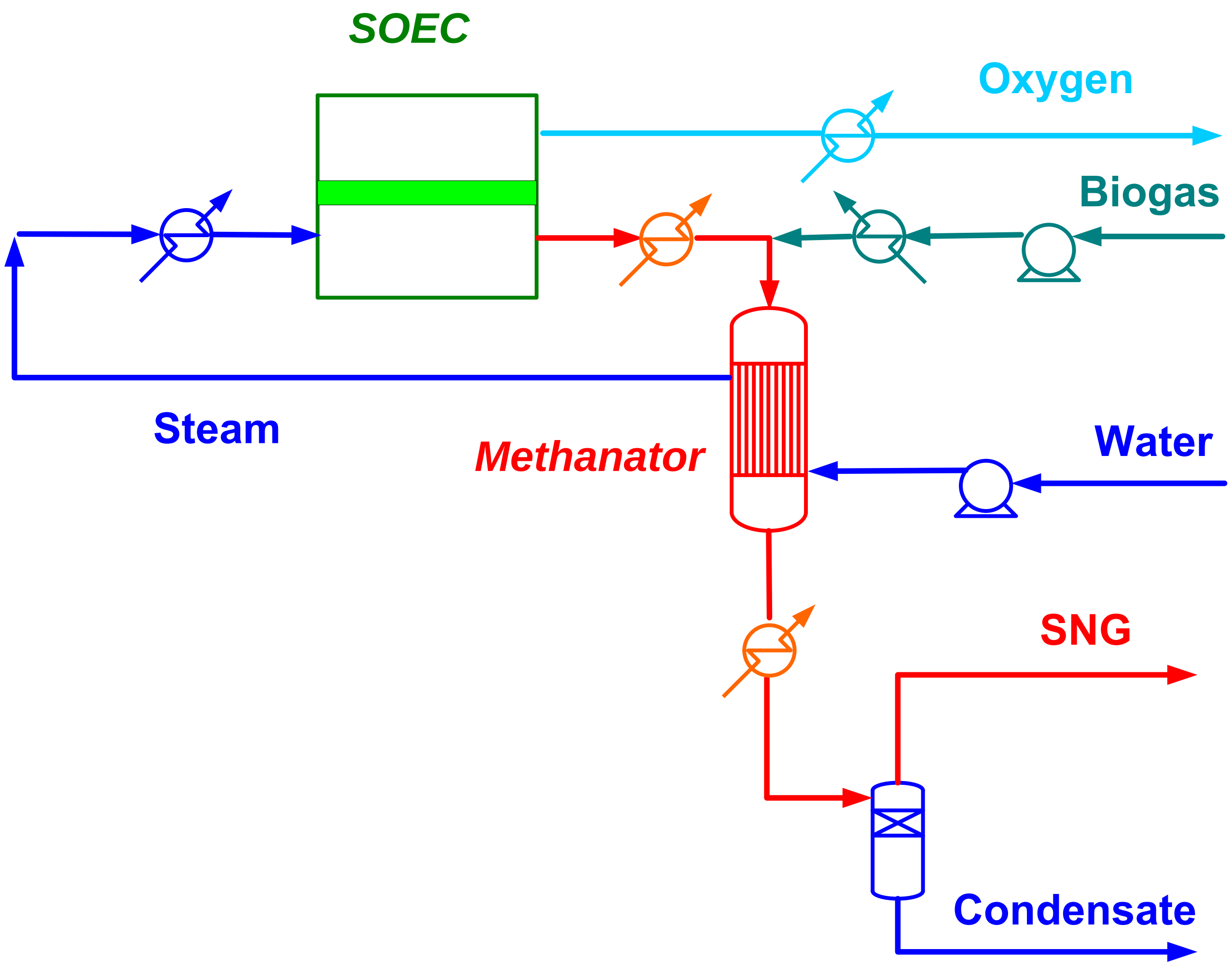


How to build the world largest SNG plant

- Qinghua plant is largest single line SNG (methanation) in world.

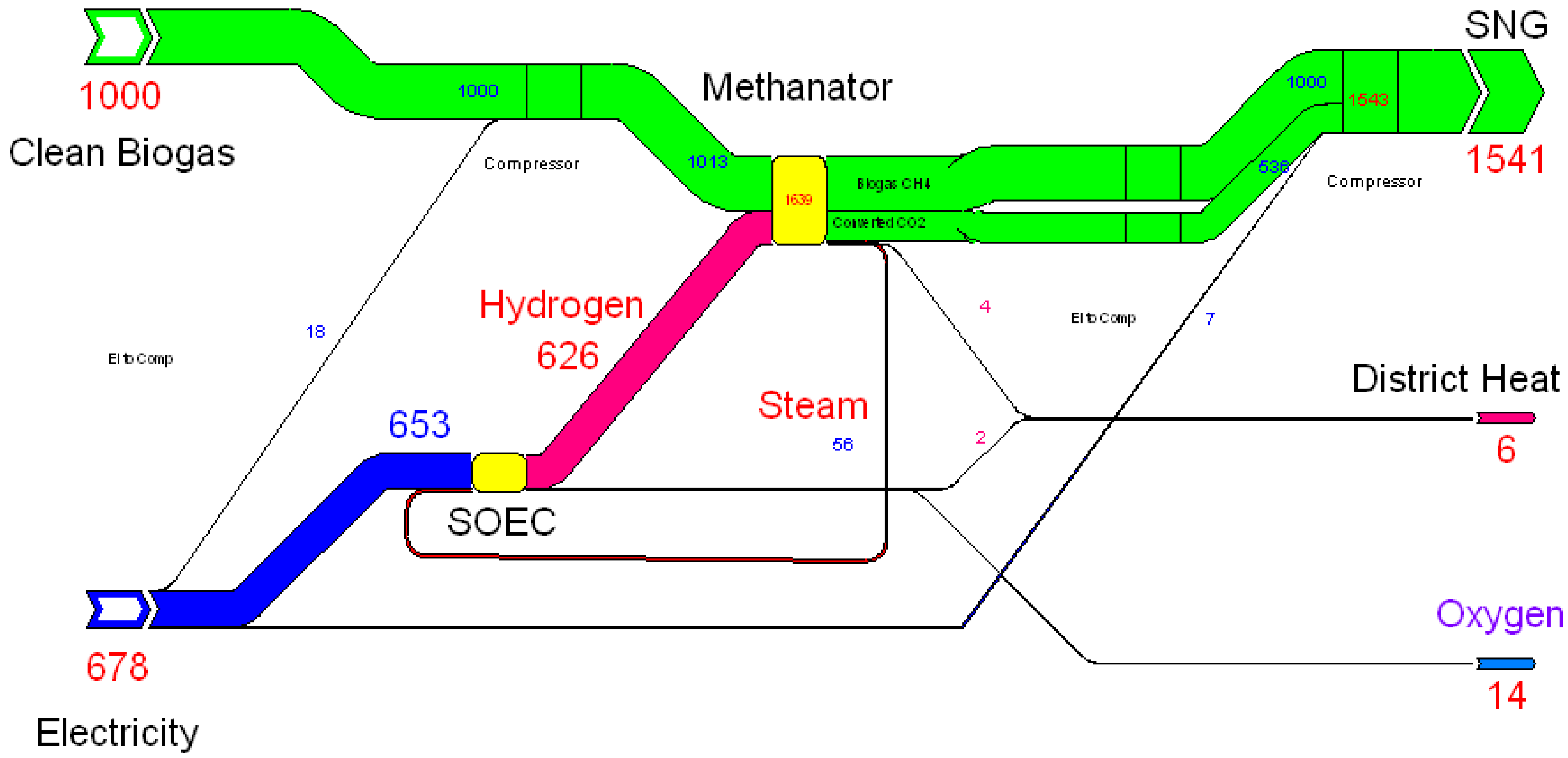


Biogas to SNG via SOEC and methanation of the CO_2 in the biogas



Exergy Flows in CO_2 case

Power to Gas Exergy Efficency 79.8 %



New EUDP project
40 kW SOEC and 10 Nm^3/h methane

Participants:
Haldor Topsøe A/S
Aarhus University
HMN Naturgas
Naturgas Fyn
EnergiMidt
Xergi
DGC
PlanEnergi
Ea Energianalyse
Cemtec

Coordinator:
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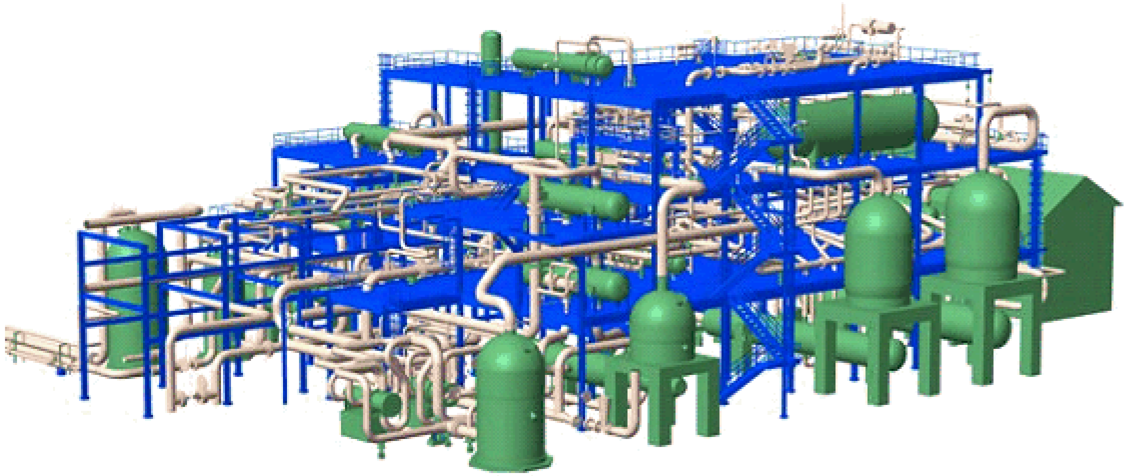
Duration:
June 2013 -
July 2016
Project sum:
5.3 mio €
Location:
Foulum

Challenges no 2: Biogas plants are small

- First modern SNG plant

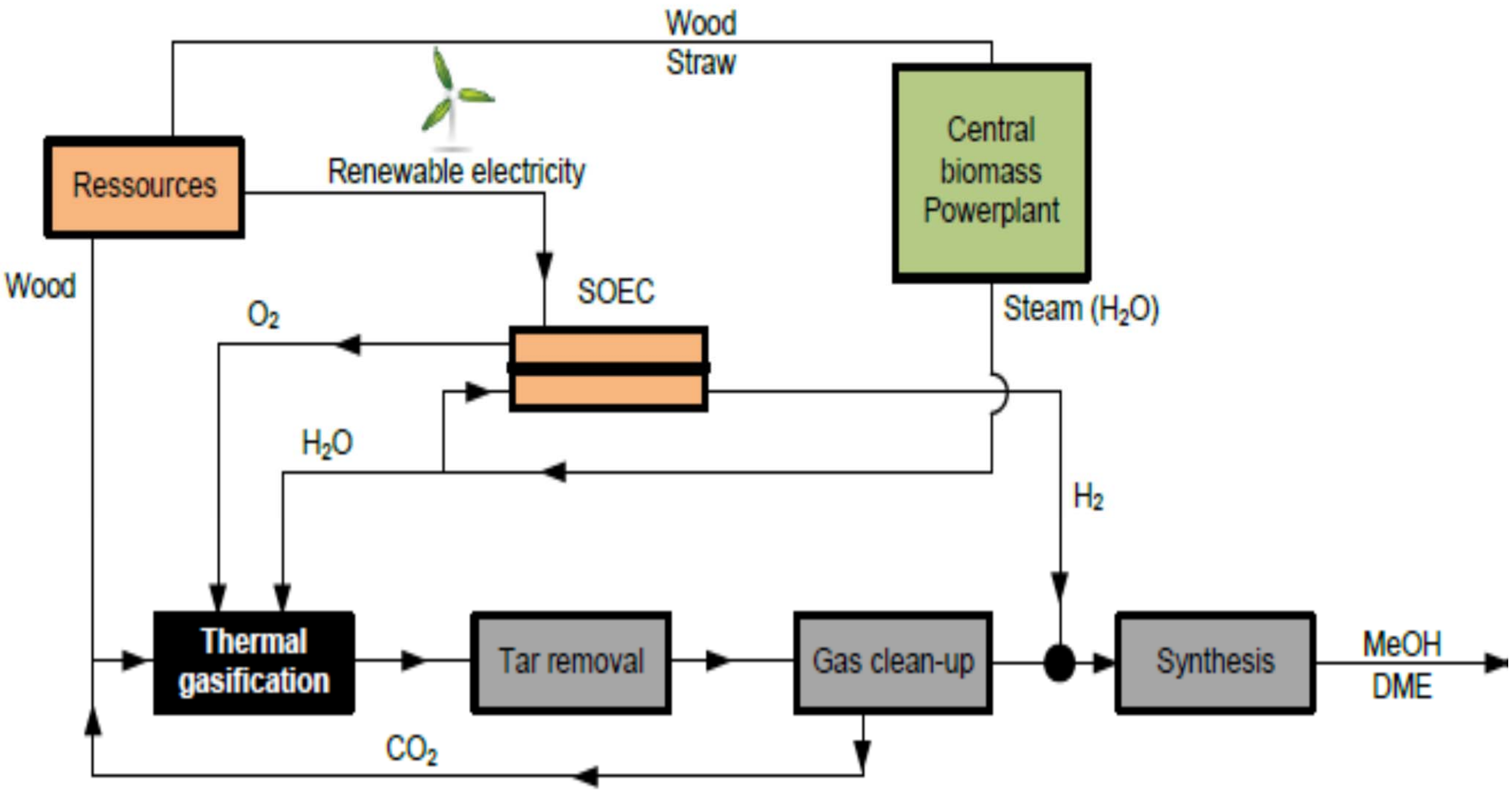
  to start up is in China:
  Xinjiang Qinghua



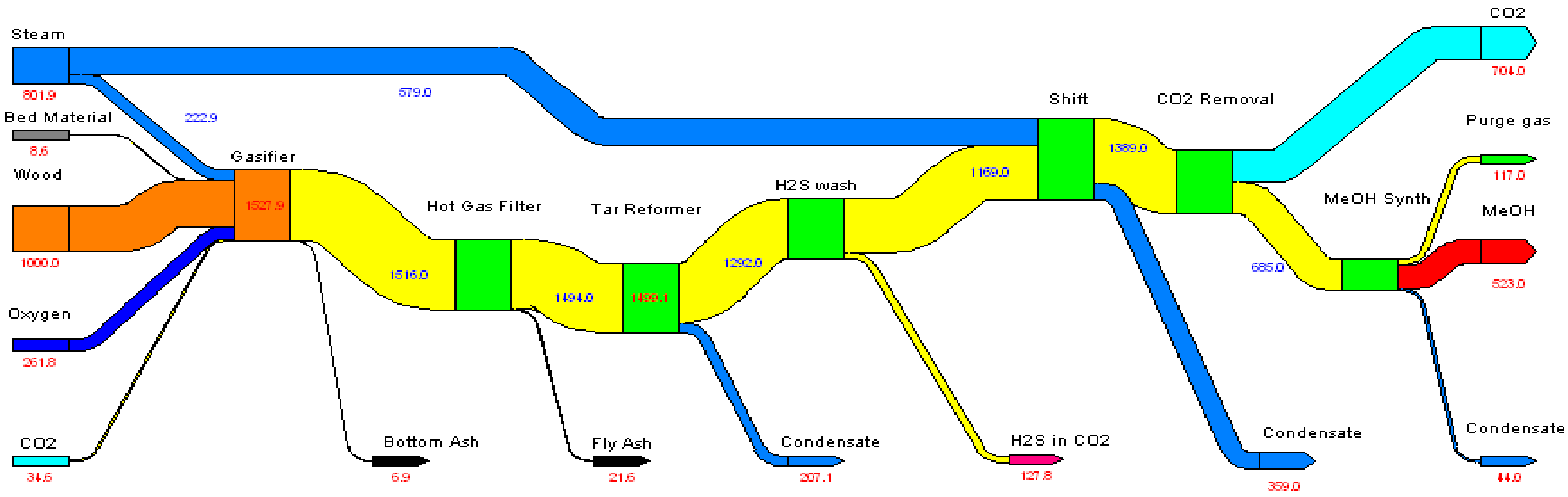
- Largest single train SNG plant ever: 1,4 billion Nm^3/year = 50 PJ/year
- One biomass gasification plant @ 200 MW wood = 4 PJ/year
- One biogas upgrading plant @ 5 million Nm3 biogas = 0,06 PJ/year

We need economy of numbers not scale !

GreenSynFuel Project



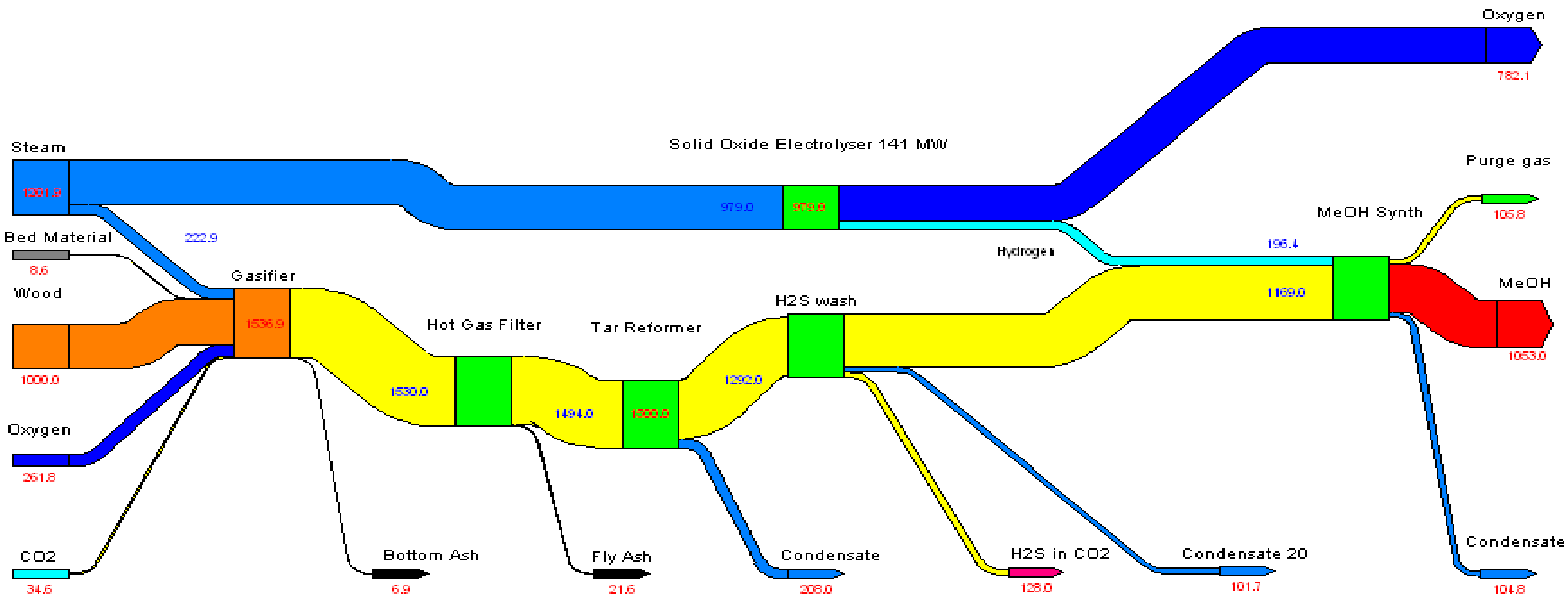
Mass Flows in Wood to MeOH



Mass balances for Wood Gasification to MeOH

Flows in Metric Tons per day

Mass Flows in Wood + SOEC to MeOH



Mass balances for combined Wood Gasification and SOEC to MeOH

Flows in Metric Tons per day

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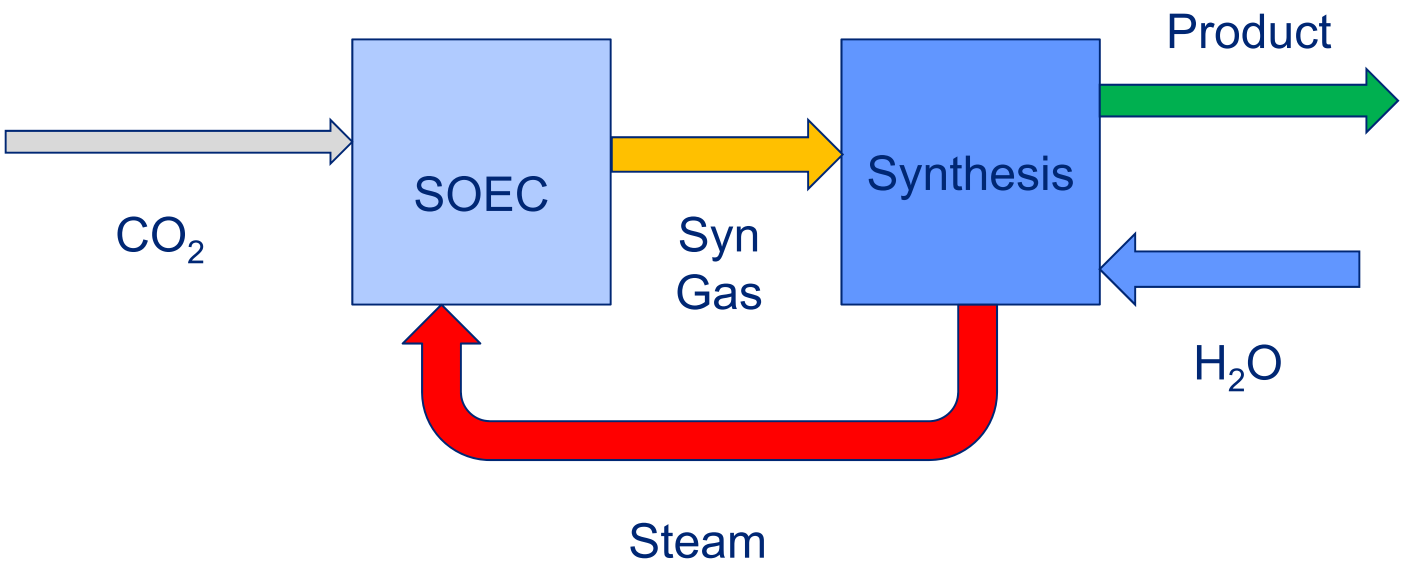
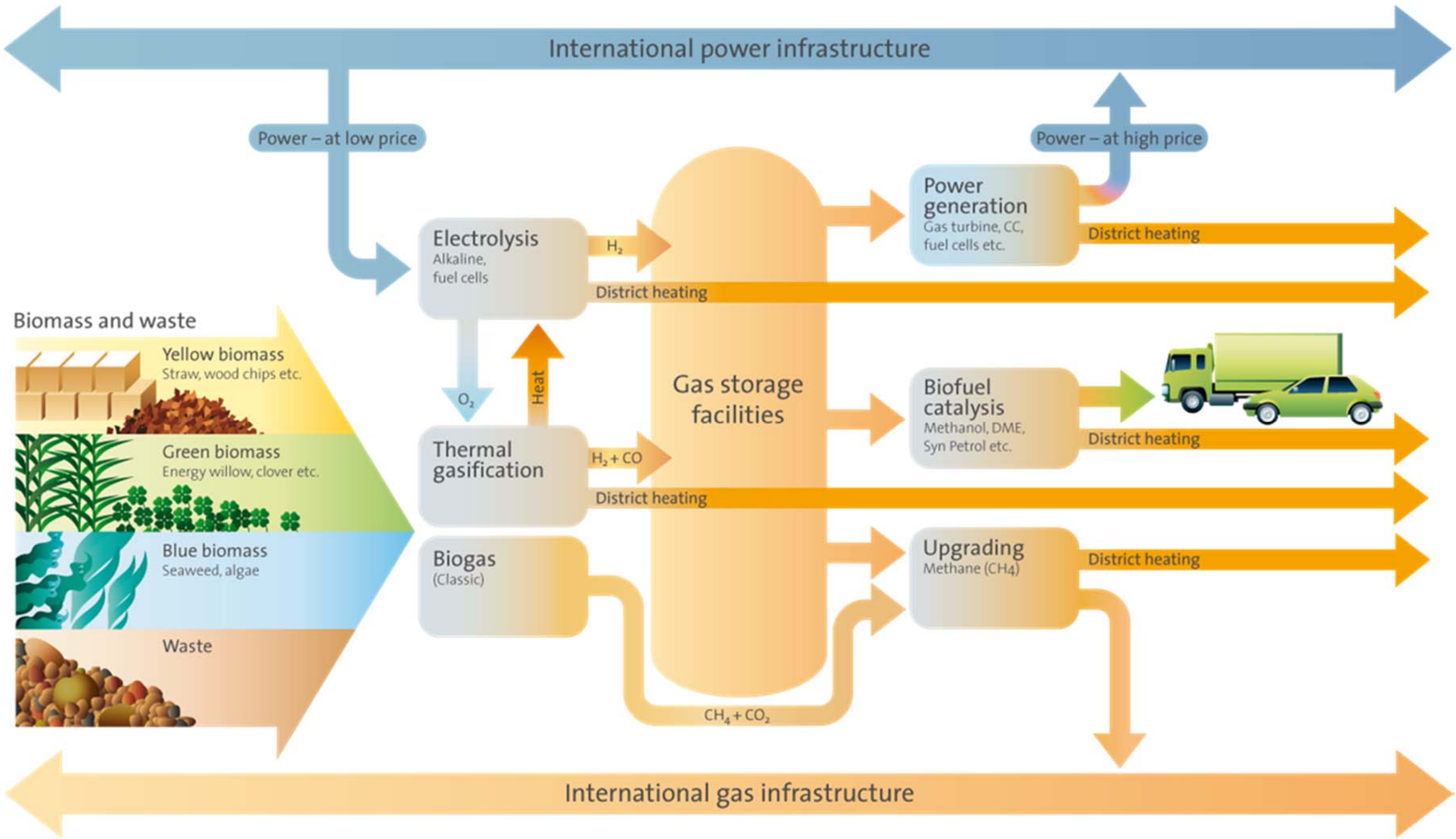
Effciencies: Stand alone wood gasifier and gasifier plus SOEC

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

Synergy between SOEC and fuel synthesis



Using the gas system as a key integrator



Biogas in the future
integrated energy system

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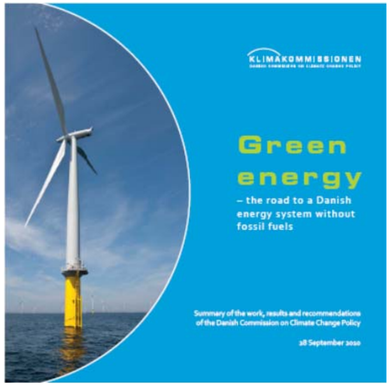
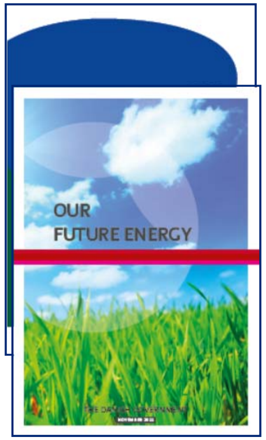
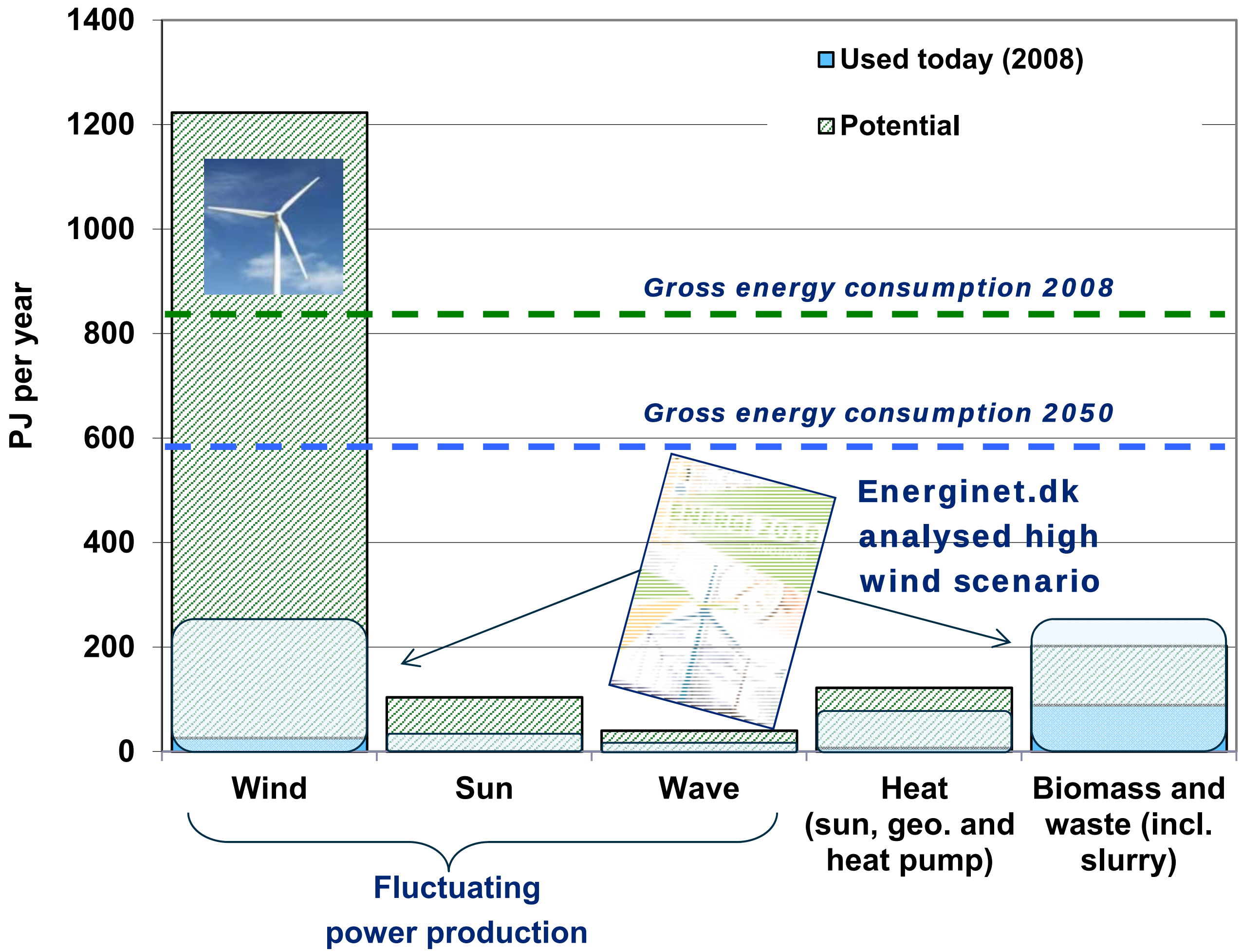
Domestic renewable resources to reach 100 per cent renewable energy by 2050

Danish Commission on Climate Change Policy, 2010







Source: ENERGINET.DK

Storage of Wind Energy

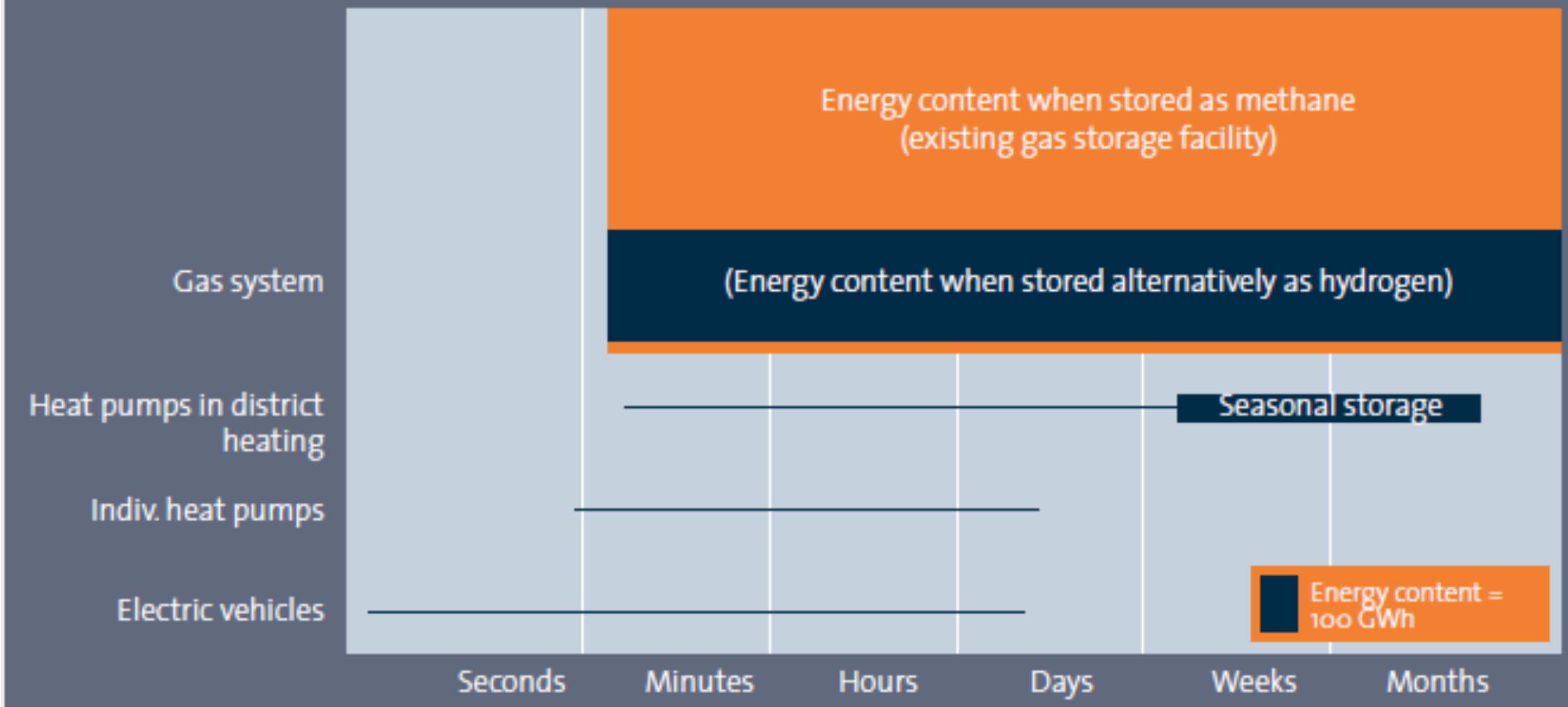
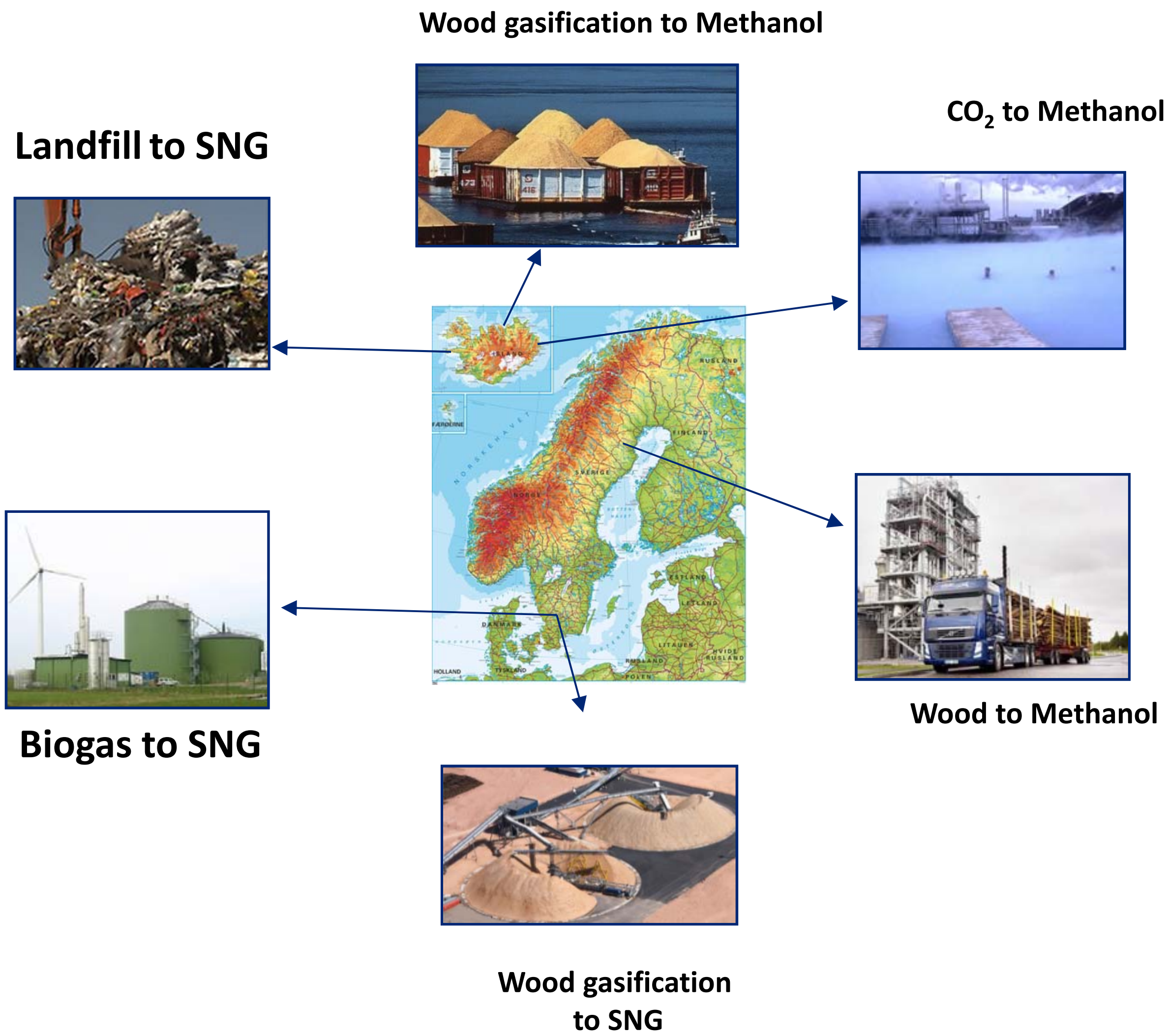


Figure 1-8: Energy content (electricity input) of different storage types in the energy system. The orange areas show the size of the potential energy storage. For gas, the small black box indicates the content if the gas is stored as hydrogen rather than methane.

CO_2 Electrofuel Project Sponsored by NER



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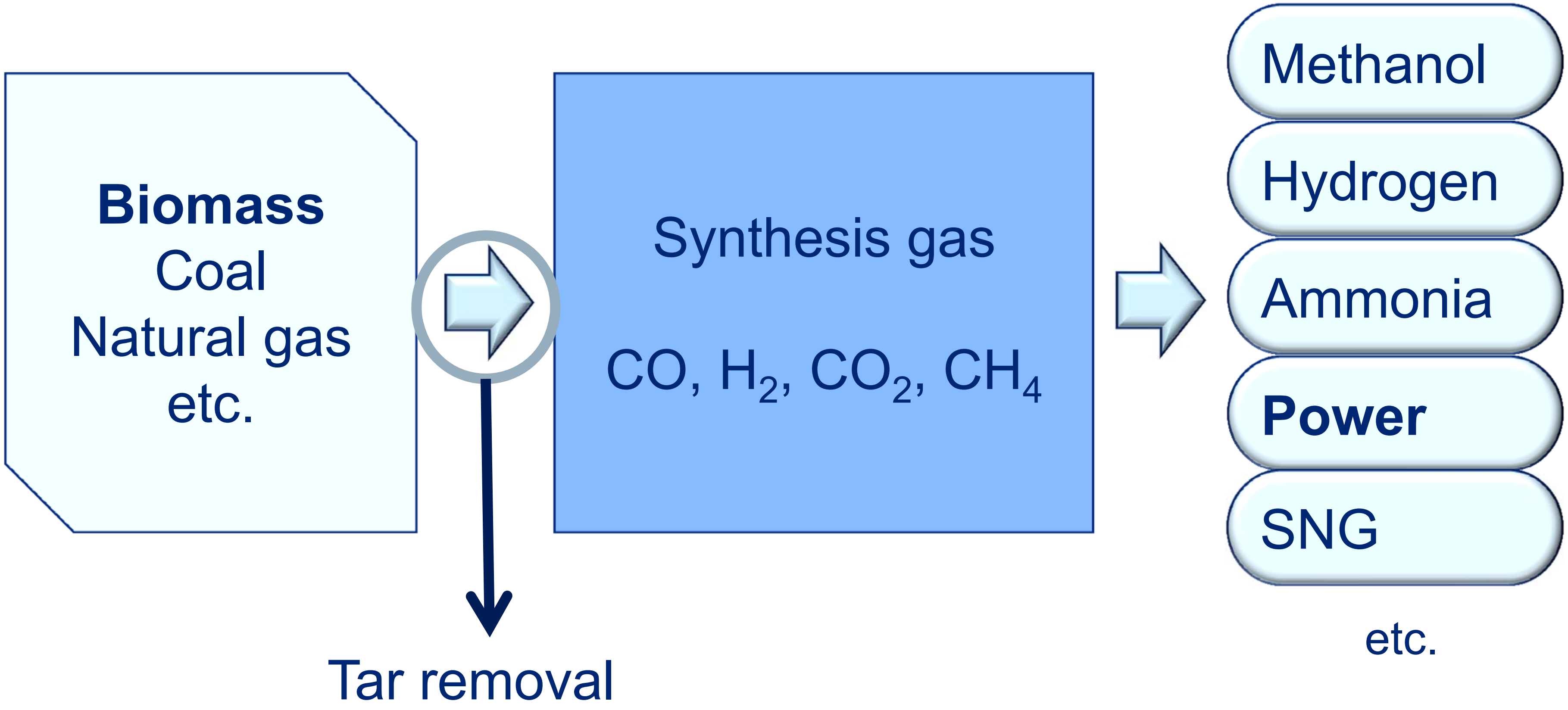
Conclusions

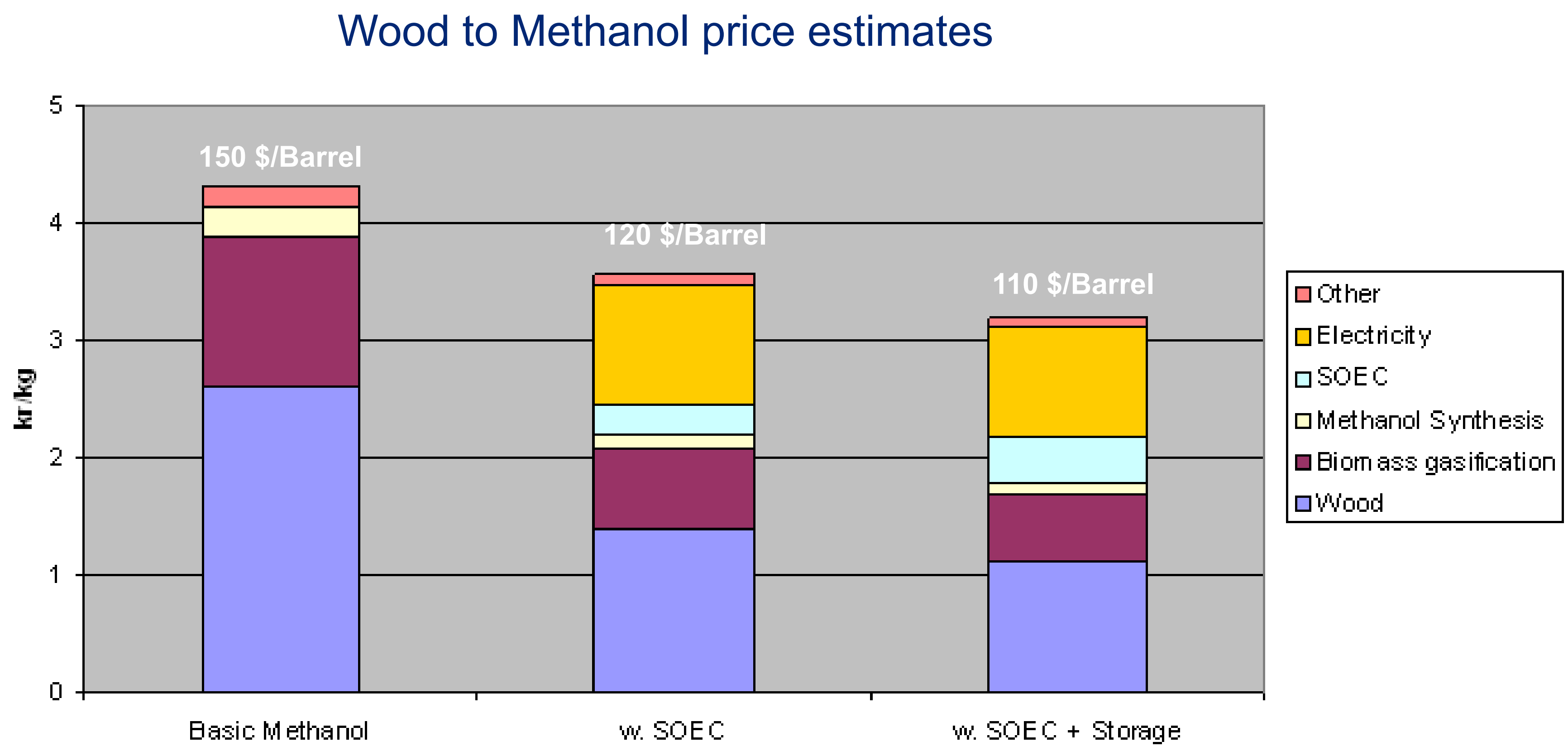
- Dusty tar reforming is now commercially proven
- Clean tar reforming has been demonstrated in connection with succesful meOH/DME and gasoline synthesis at 25 bbl/day
- Sustained black liquor to DME has been proven at 4 MTPD scale and truck operation as well
- Coupling SOEC with biomass gasification can double the biomass potential by converting excess carbon.

Gasification process

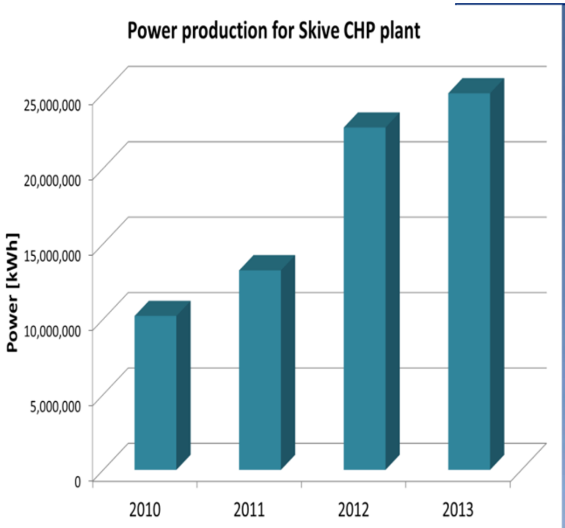
Raw materials for gasification | **Building blocks** | **Products**

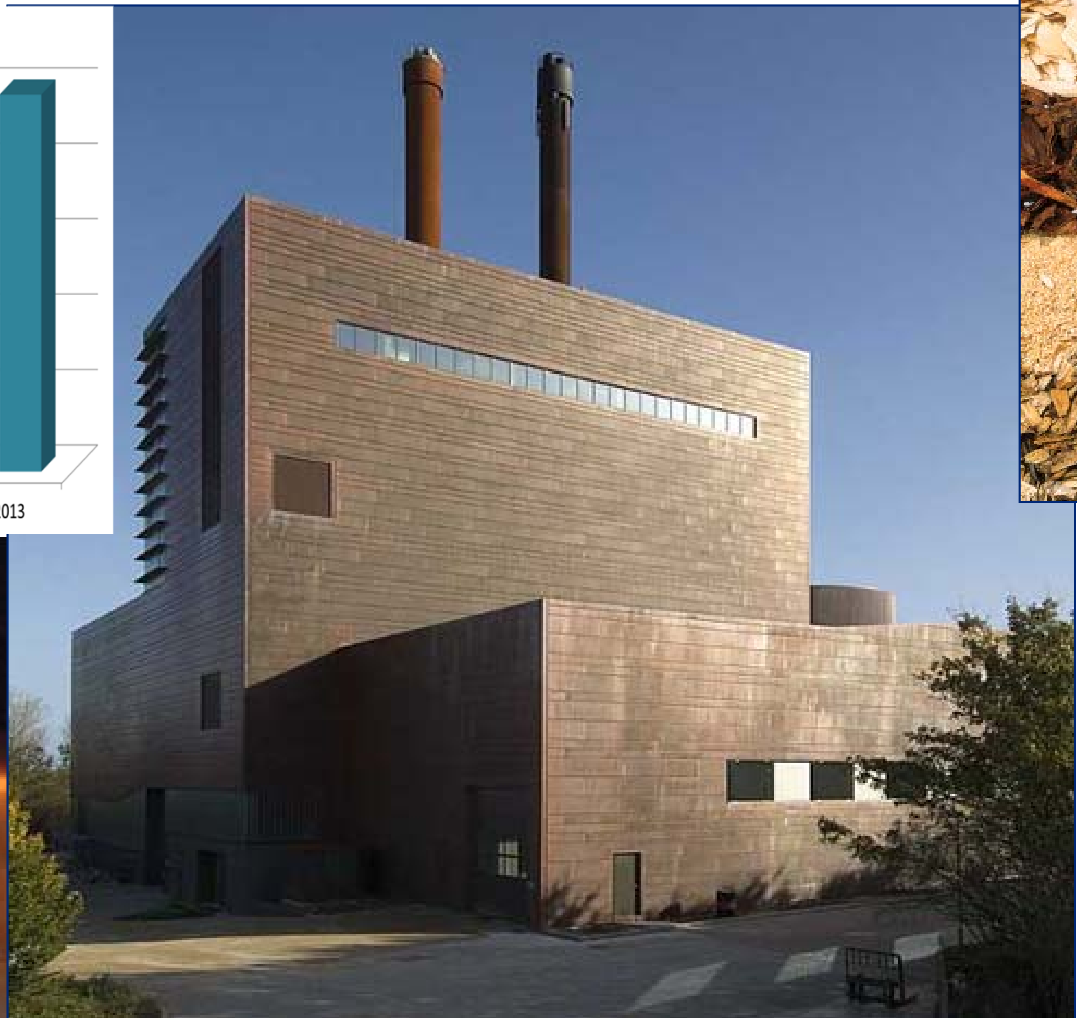


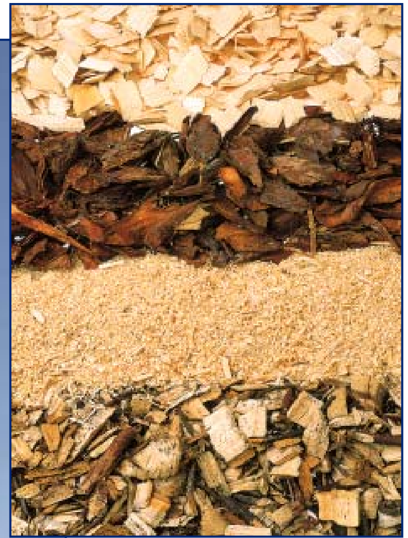
Is this (economically) viable?



Skive District Heating/Power Plant







CO	23.41
CO_2	9.90
H_2	20.71
H_2O	3.32
CH_4	0.93
C_2H_4	0.001
C_xH_y	0.001
N_2	41.72

≈ 16 MW_{th}

Topsoe SNG plants

Client	Location	Capacity Nm^3/yr	Year awarded	Start-up
Qinghua	China	1.4 billion	2009	**2013**
Gobigas (Bio-based)	Gothenburg, Sweden	19.4 million	2010	2014
Petrochina (COG)	Wuhai, Inner Mongolia, China	2 x 450 million	2011	**2013**
Huineng	Inner Mongolia, China	400 million	2011	2014
CNOOC (COG)	Shandong, China	160 million	2011	**2013**
CPI	Yili, Xinjiang, China	2 x 1 billion	2011	2015
POSCO	South Korea	700 million	2010	2014
Guizhou	Guizhou, China	290 million	2013	2015
SANJU (COG)	Inner mongolia	470 million	2014	2014