Biomass Gas Cleaning and Utilization
The Topsøe Perspective

RESEARCH | TECHNOLOGY | CATALYSTS

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Greenhouse Gas Emission Mitigation Strategies

- Reduce consumption
- Increase Efficiency
- Use of biomass
- Use of renewable physical energy
  - Wind
  - Sun
  - Geothermal

Energy Consumption and Reserves 2008 - Gton Oil Equivalent

	Consumpt. per year	"Reserves"	R/P
NG :	2.8	167	60
Oil :	3.9	171	43
Coal :	3.3	454	122
Σ Fossil :	10.0	742	74

- Growth in world energy consumption 2001-05: 13%

	Potential	Total	
Biomass	4.5 - 11	56/year	1 * 10^9 ?

BP Statistical Review of World Energy (2009 Edition)
Berndes et. al.: Biomass and Bioenergy **25** (2003) 1

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Haldor Topsøe group – Key figures 2008

Head quarter in Lyngby, DK

- Turnover: DKK 5.0 billion ($ 920 MM)
- Result: DKK 533 MM ($ 97 MM)
- 2052 employees

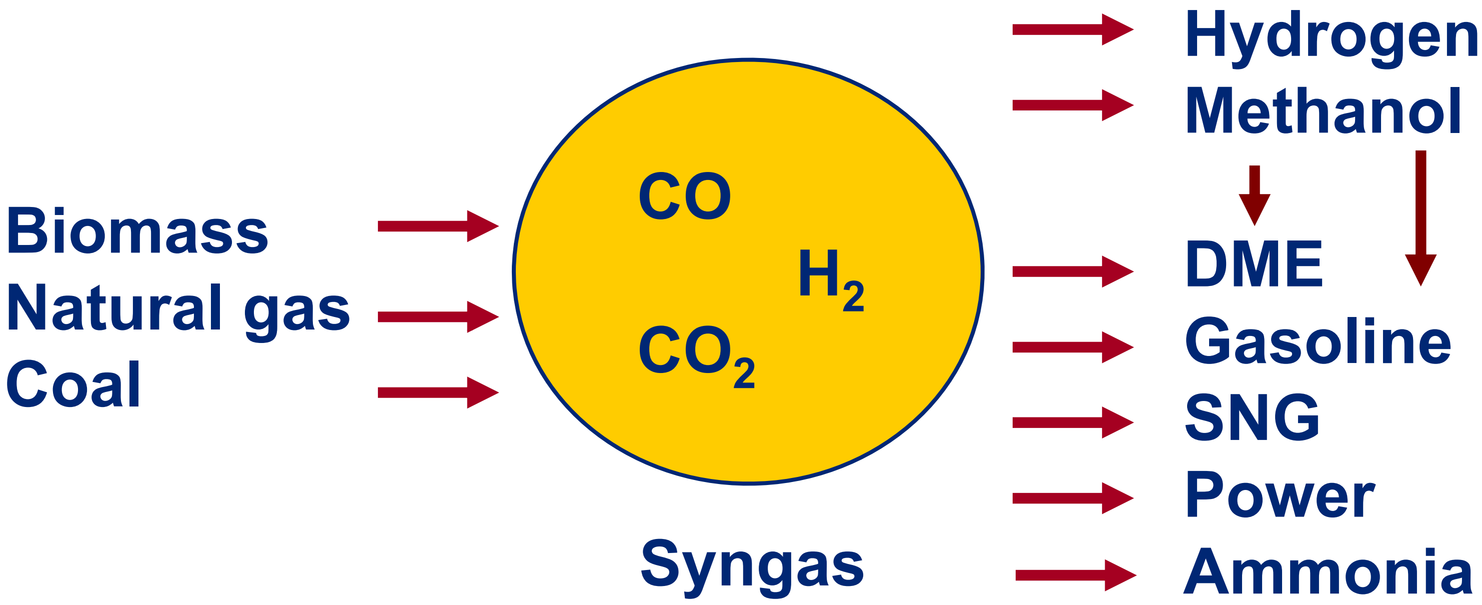
Catalyst plant in Frederikssund, DK

Catalyst plant in Houston, Texas

Topsoe and Renewables

- Gas cleaning in Gasification
  - Tar Reforming
  - Ammonia Decomposition
  - Sulphur Management
    - Hot gas cleaning
    - COS hydrolysis, Fine desulfursitaion
    - WSA
  - Shift
- Chemicals from biomass
  - Example Acetic Acid from Ethanol
- On board Ether production from Methanol or Ethanol
- Biogas to Syntheses: $H_{2,}$ SNG, MeOH, DME, Gasoline
- Solid Oxide Fuel Cells & Electrolysis and Synthesis

Gasification



Is Biogas Suitable for Synthesis?

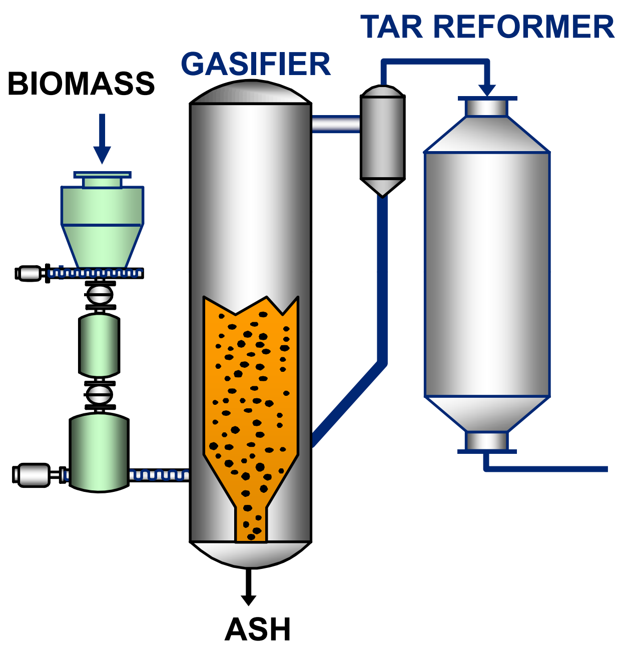
No!

Is conditioning possible?

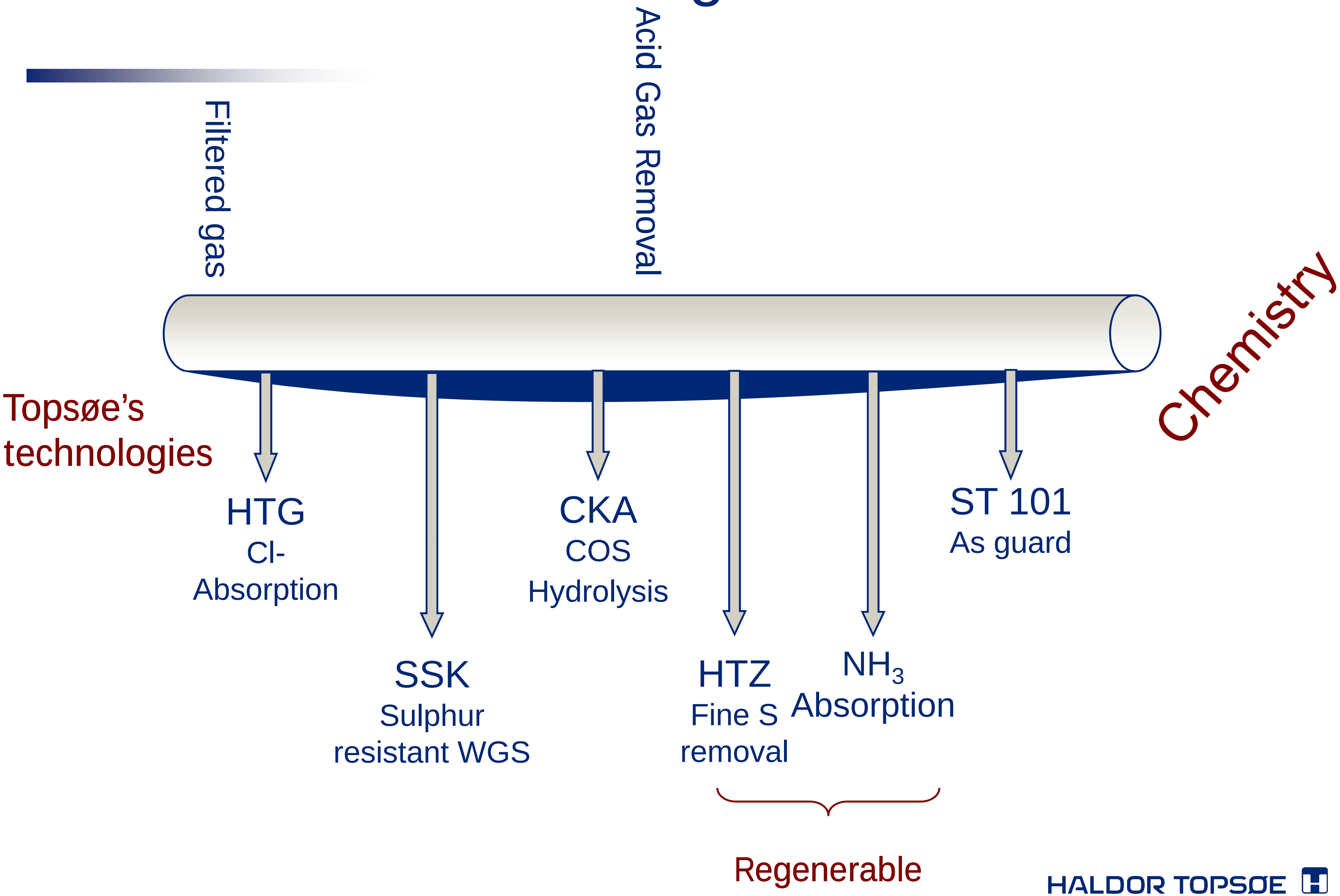
Yes! (but it is challenging)

Tar reforming – Enabling Technology for Biomass Gasification

- Gasification of biomass results in a syngas that contains tars and contaminants
  - 2500 ppm tar (toluene, benzene, naphthalene)
  - 100 ppm S, particulates
  - 850-930 °C, 1-20 bar g
  - Ammonia Decomposition



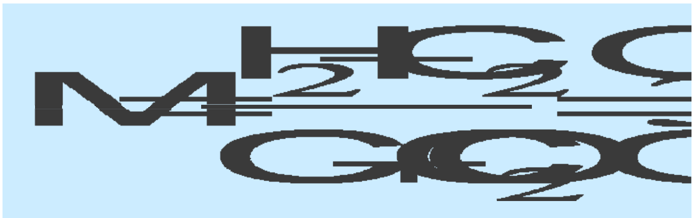
Sour Gas Conditioning



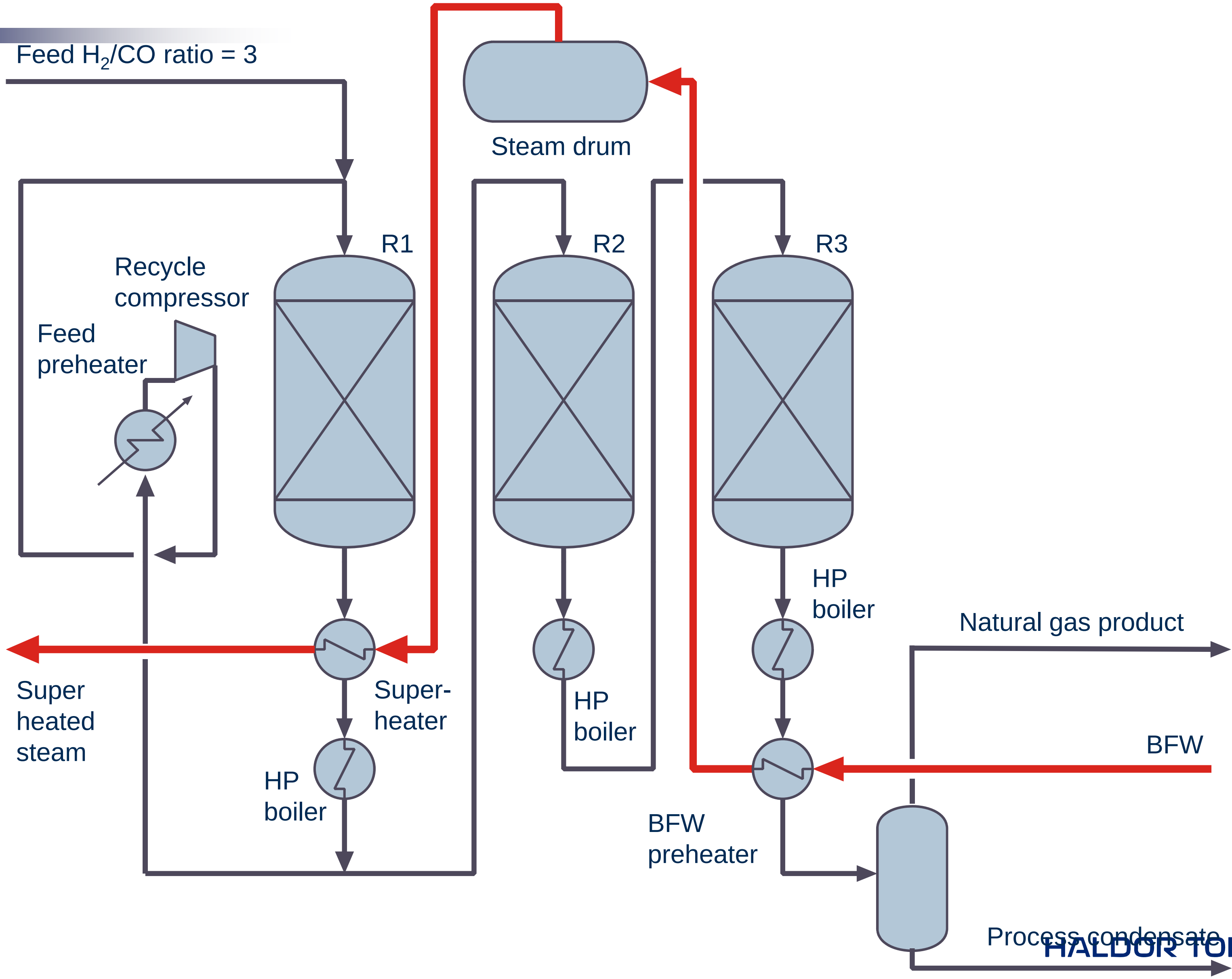
Methanation reactions

$$CO + 3H_2 \quad = \quad CH_4 + H_2O \qquad + 206 \text{ kJ/mol}$$

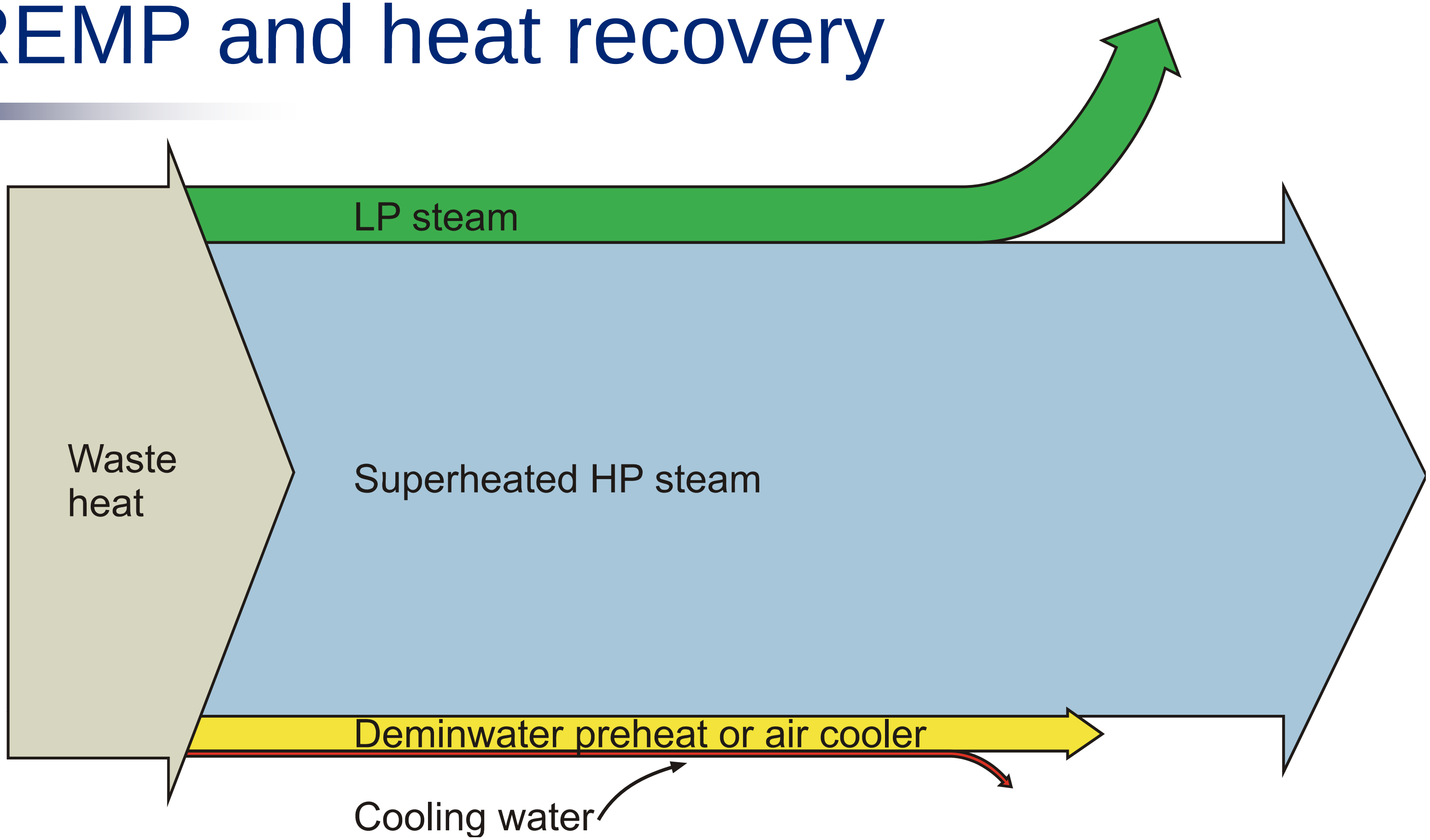
$$CO_2 + 4H_2 \quad = \quad CH_4 + 2H_2O \qquad + 165 \text{ kJ/mol}$$



TREMP™ technology

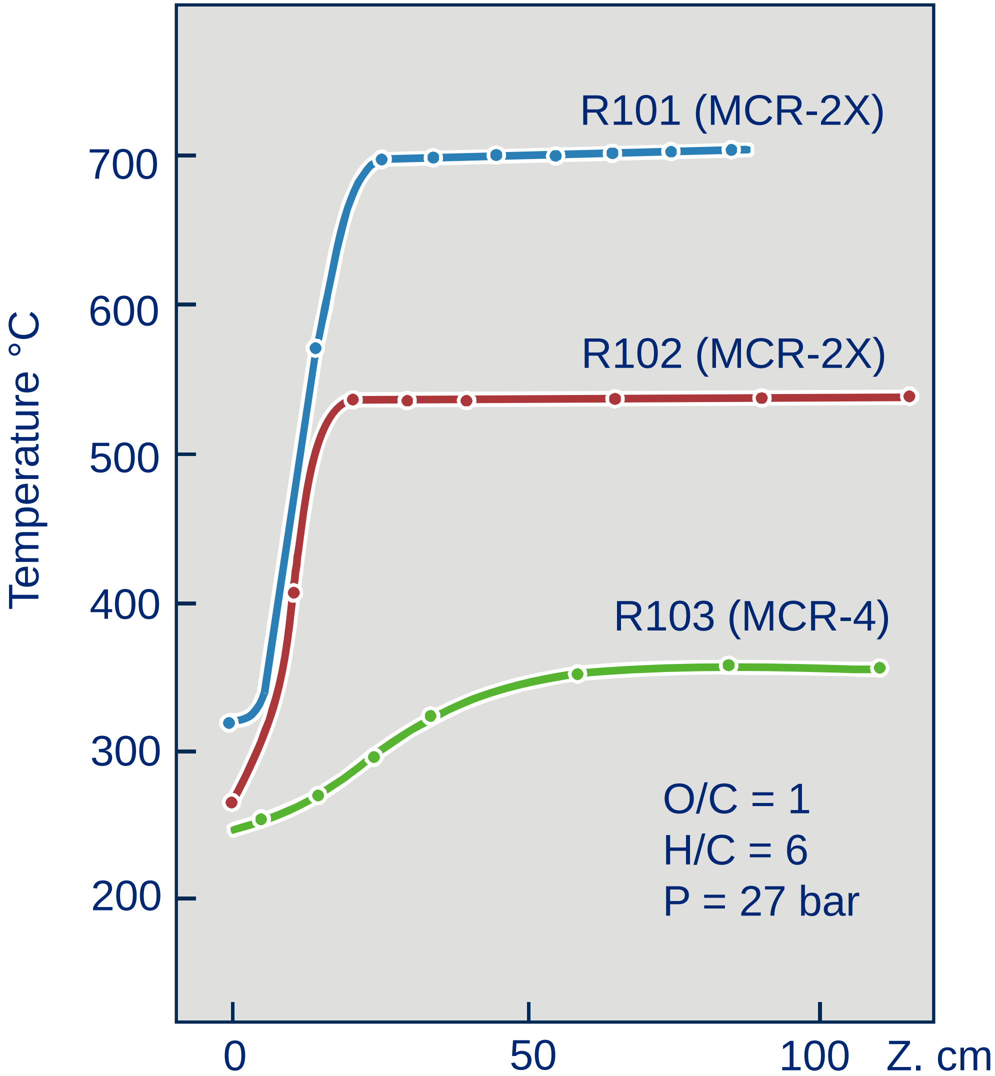


TREMP and heat recovery



One of the features of the TREMP technology is that 84% of the waste heat has been recovered as high pressure superheated steam for export. Only 0.5% of the waste heat ends up in cooling water.

Data from test unit. Temperature profiles



Temperature profiles from adam 1

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Methanol Synthesis reactions

$CO_2 + 3\ H_2\ =\ CH_3OH + H_2O\ \ + 41\ kJ/mol$

$CO + H_2O =\ CO_2 + H_2\qquad + 50\ kJ/mol$

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

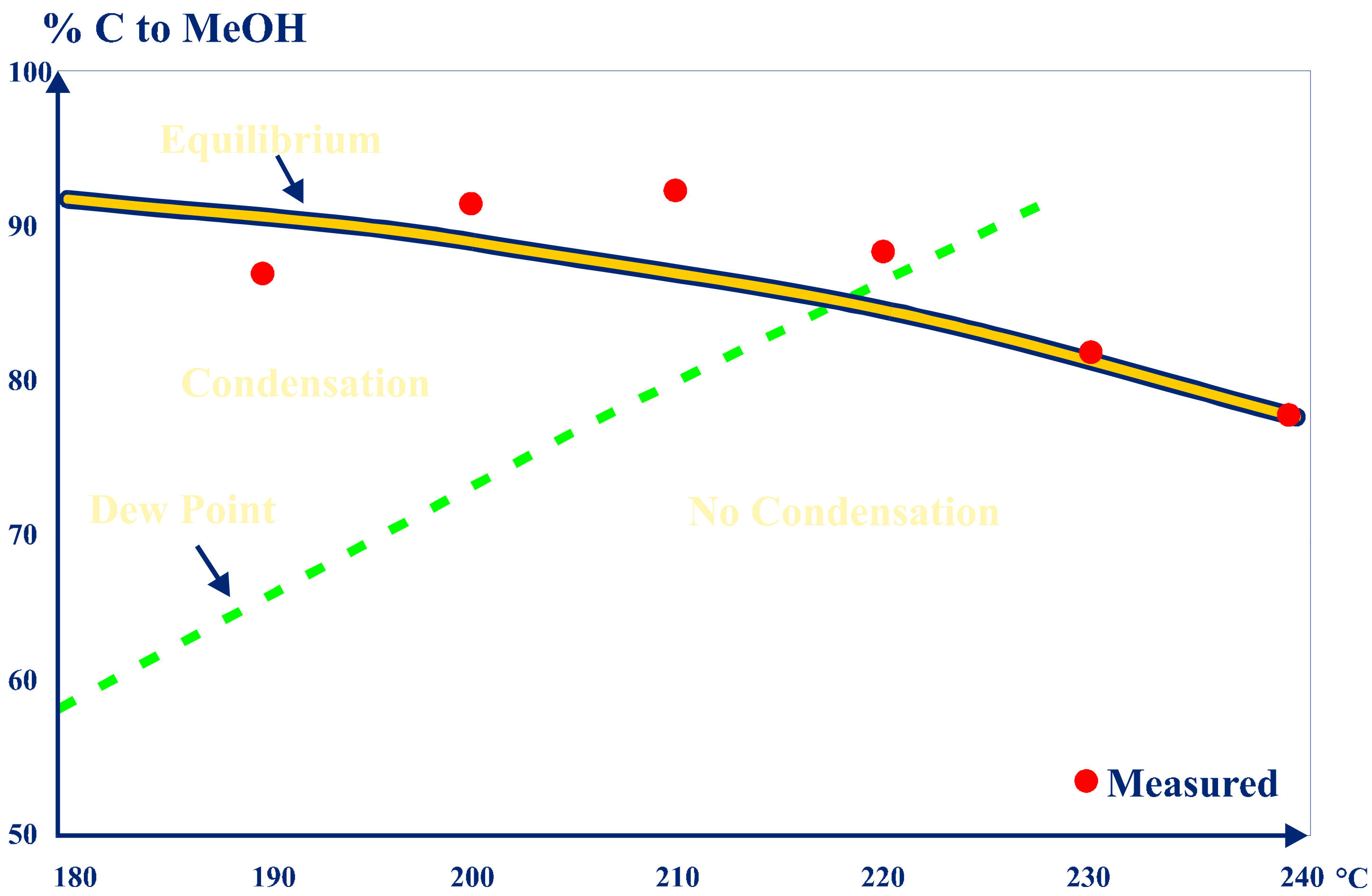
$CO + 2H_2$ Gas Ideal for MeOH Synthesis

- Once-through production is possible
- Very high reaction rates (special reactor is needed)
- Direct production of fuel methanol
- Very good catalyst stability

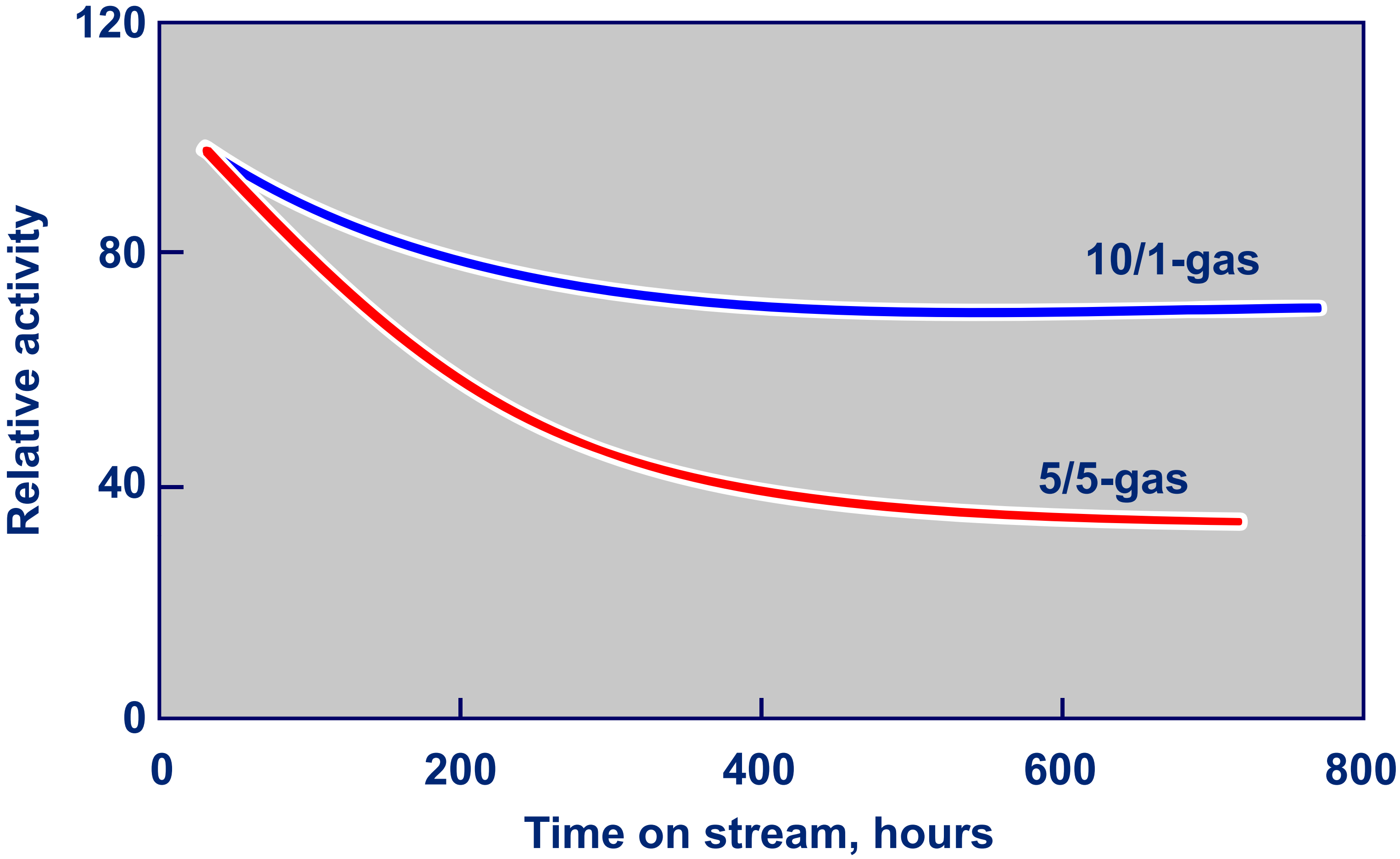
Today

- Small amounts of CO_2 are needed and optimal

Once-through Conversion of CO and CO_2 at 9.6 Mpa, 30% CO, 2% CO_2



MK in Normal and Dry Syngas



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MeOH/DME Synthesis

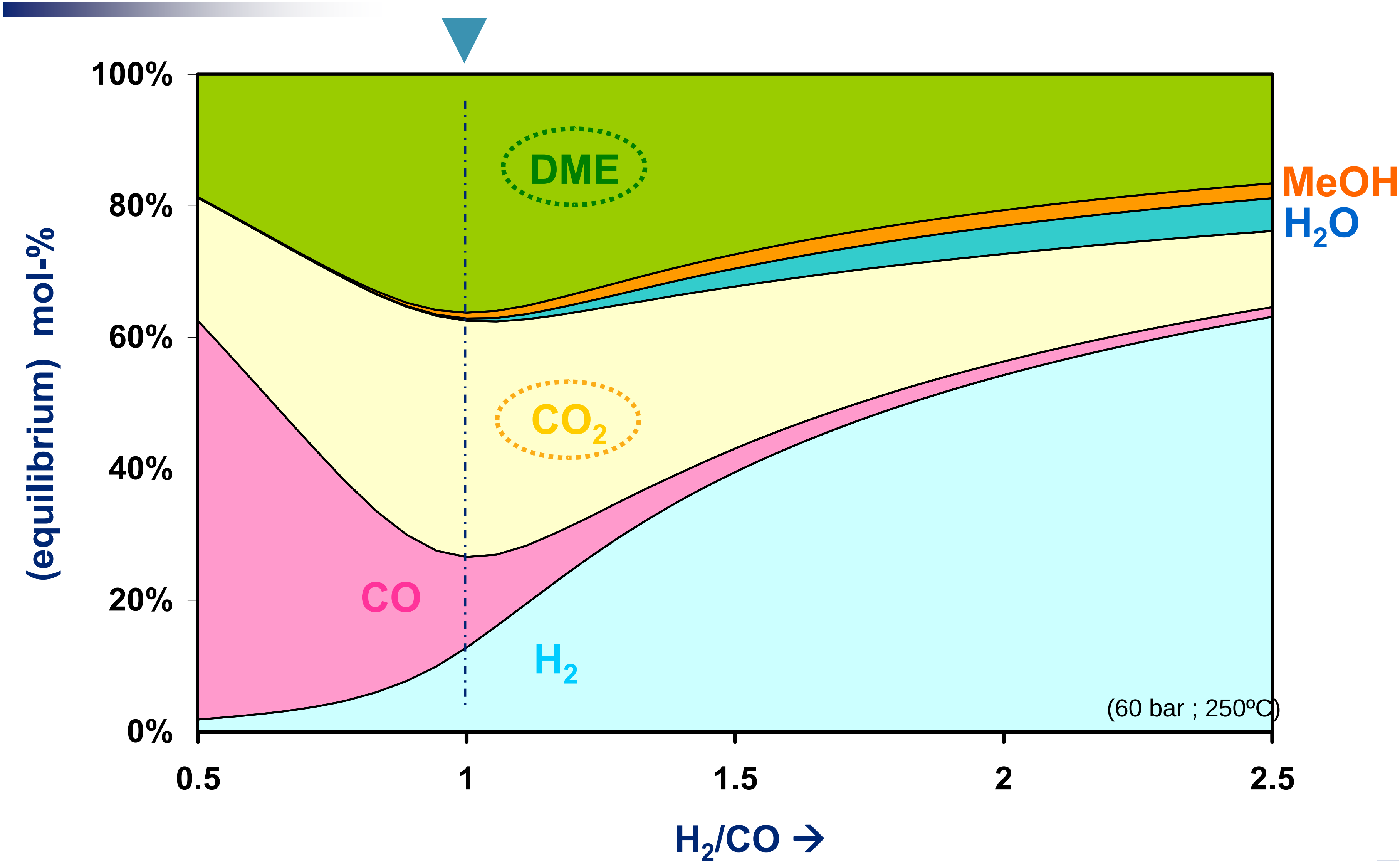
– Low H_2/CO

– ΔH (kJ/mol)

Reaction	– ΔH (kJ/mol)
$2H_2 + CO = CH_3OH$	90.7
$2CH_3OH = CH_3OCH_3 + H_2O$	23.6
$CO + H_2O = CO_2 + H_2$	41.1

$$3H_2 + 3CO = CH_3OCH_3 + CO_2$$

H_2/CO = 1 is optimum for DME



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Demonstration of biomass ”waste” to transportation fuel (DME)

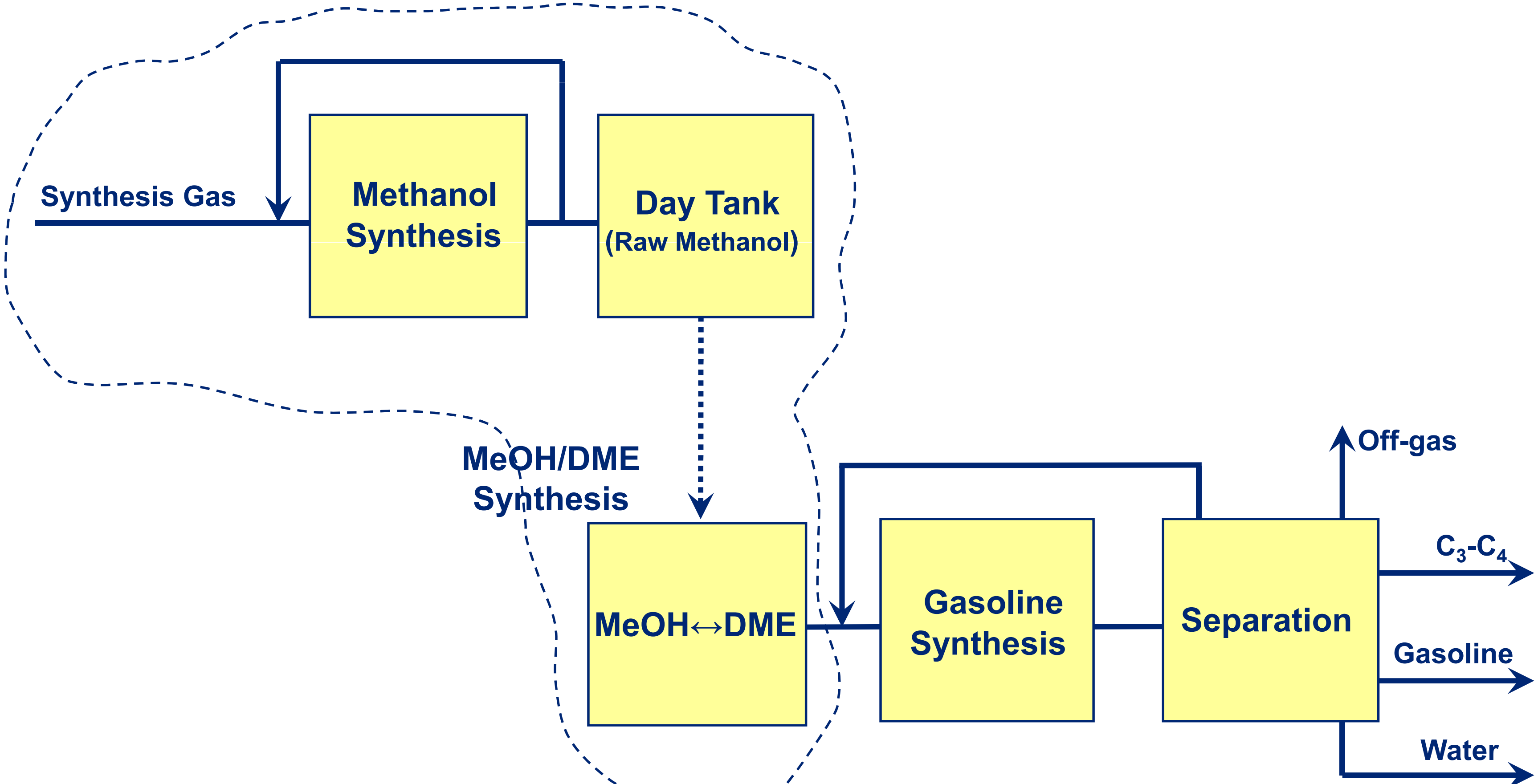
- Black Liquor → DME → Filling Stations → Trucks

TIGAS

MTG

Topsøe Integrated Gasoline Synthesis

Methanol To Gasoline



- Simple process layout
- Low recycle rates
- No methanol condensation / re-evaporation
- Moderate pressure

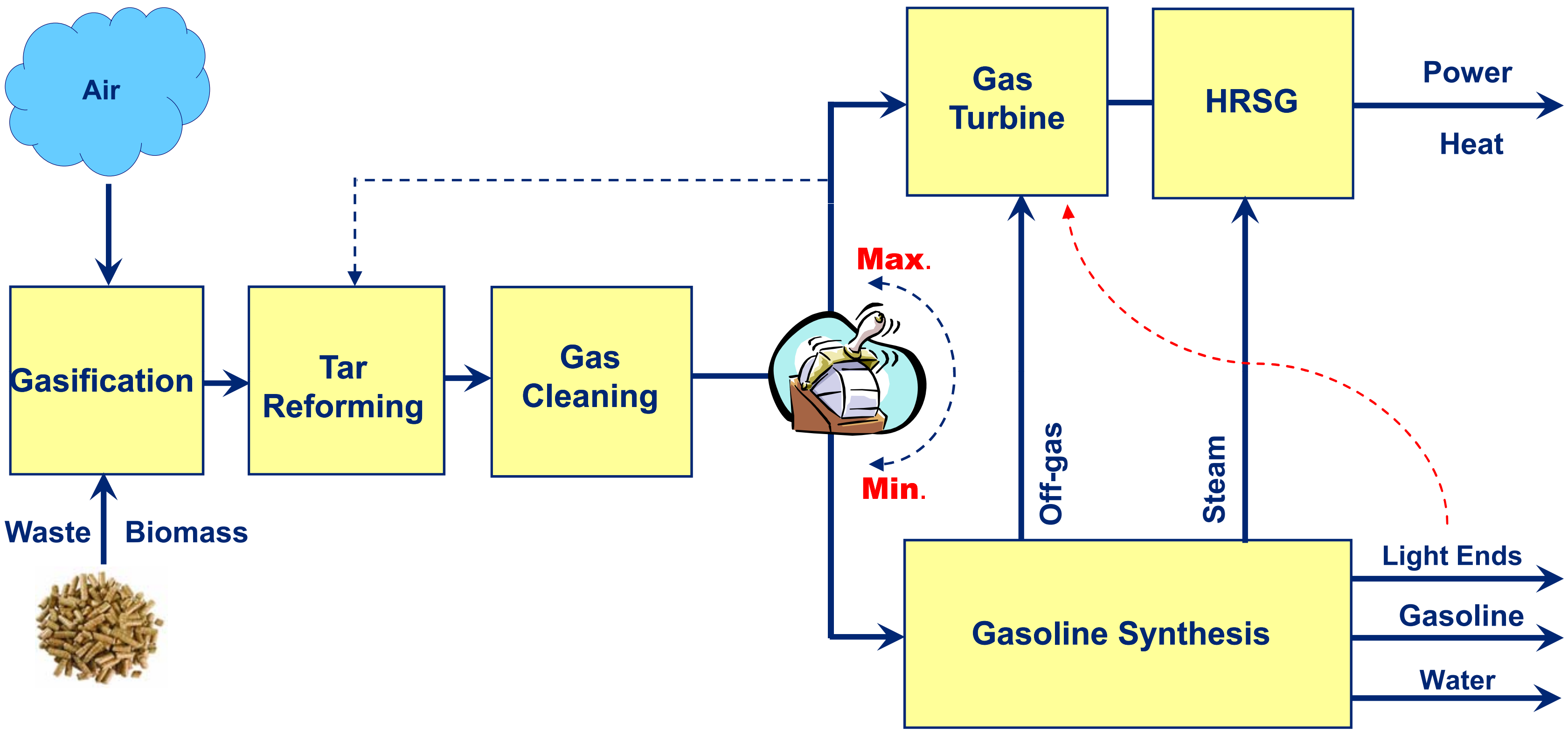
TIGAS Demonstration Plant

1 T/d **7000_+ Runhours** **Houston,TX**

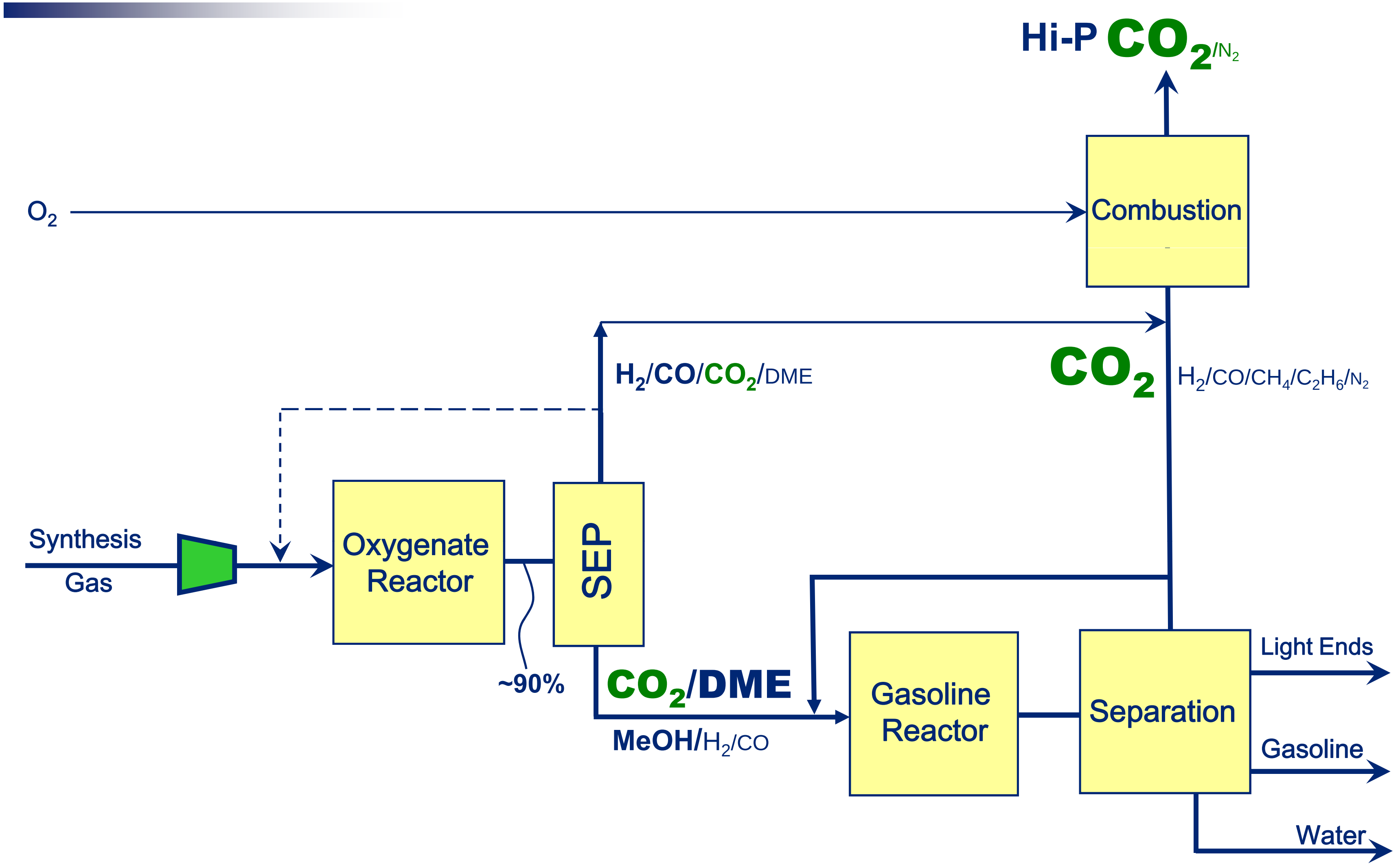
Fuel/Power Co-Generation

- **Fluctuating power prices**
  - Varying electricity demand
  - Fluctuating production from wind/wave/solar
  - Increasing contributions from waste and renewables
- **Objectives**
  - Increase operational flexibility at low additional investment
  - Improve energy system flexibility
  - Maximize product value at any time

Biomass to Gasoline & Power



TIGAS[CCSR]



Hi-P CO_2/N_2
Combustion
O_2
H_2/CO/CO_2/DME
CO_2
H_2/CO/CH_4/C_2H_6/N_2
Synthesis Gas
Oxygenate Reactor
SEP
~90%
CO_2/DME
MeOH/H_2/CO
Gasoline Reactor
Separation
Light Ends
Gasoline
Water

Conclusions

- Gas clean up is crucial for succesfull deployment of biomass gasification
- Tar Reforming is a truly enabling technology
- Many options and synergies
- The choice of end product depends on local conditions
  - Power price
  - Existing infrastructure (SNG)
  - Energy supply security
- Transportation fuels probably preferred choice in the long run