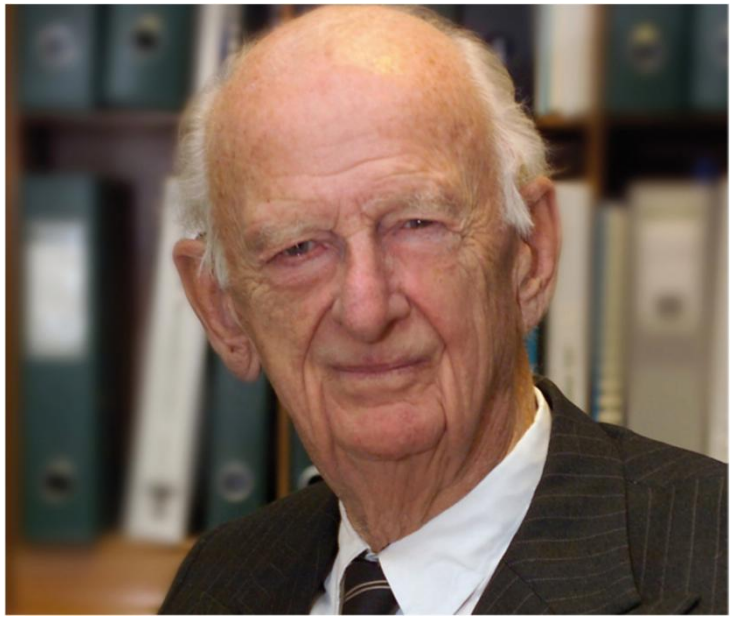
Refurbishment of catalytic tar reformer and project on green gasoline

John Bøgild Hansen, Haldor Topsøe A/S

IEA Meeting, Skive, October 25, 2017

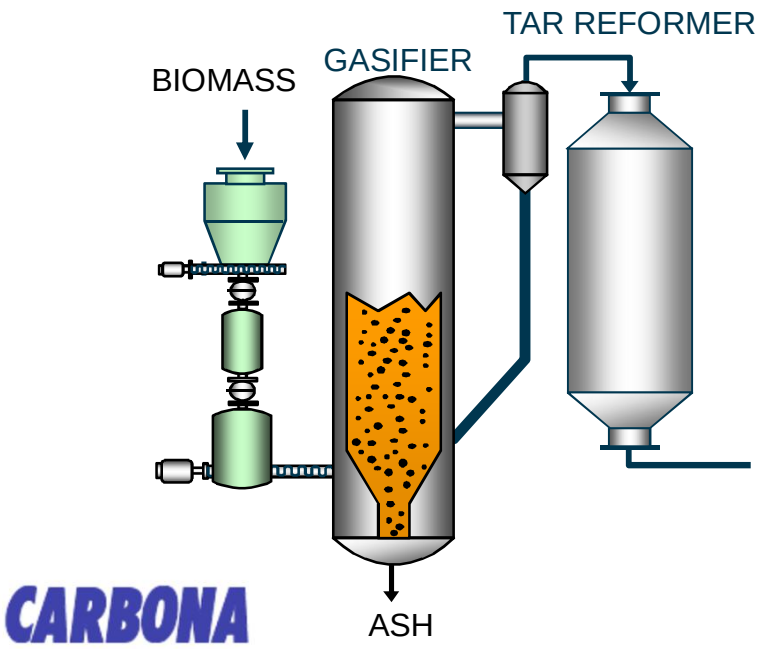
We have been committed to catalytic process technology for more than 70 years

- Founded in 1940 by Dr. Haldor Topsøe
- Revenue: 700 million Euros
- 2400 employees
- Headquarters in Denmark
- Catalyst manufacture in Denmark and the USA



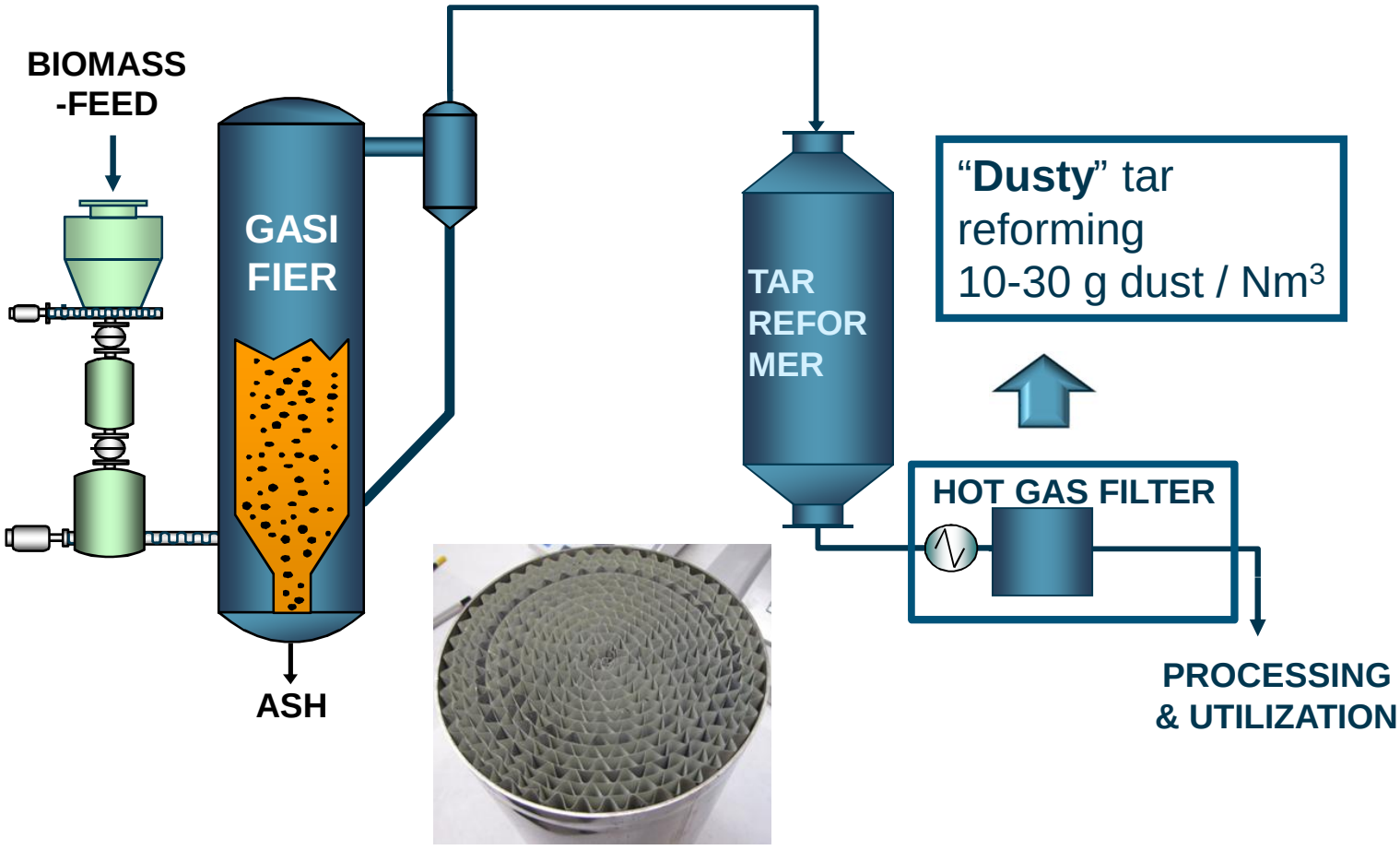
Tar reforming – Enabling technology for biomass gasification

- 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



CARBONA

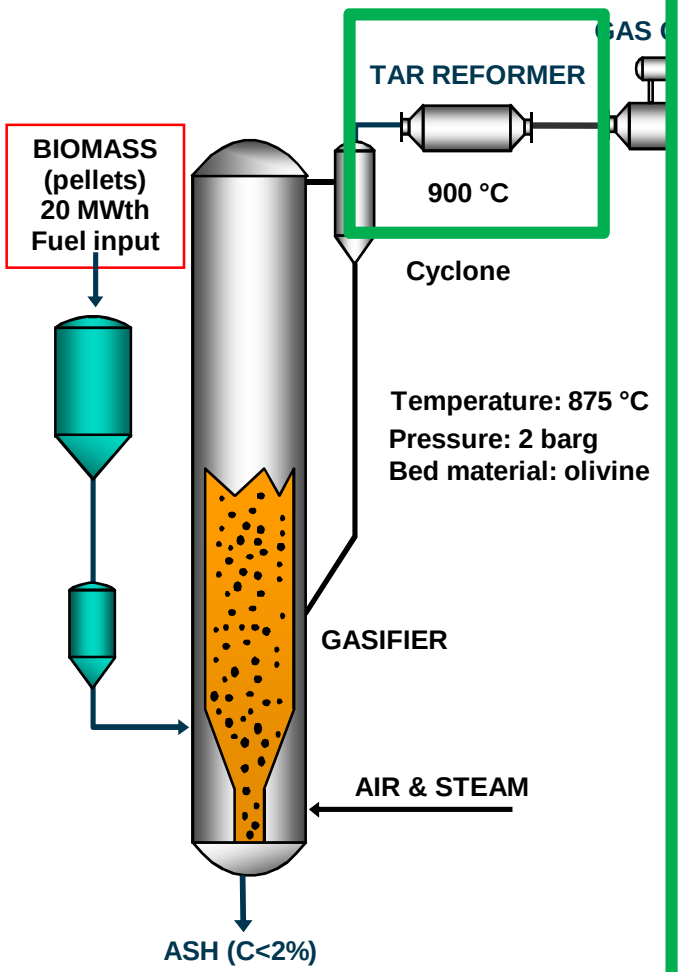
“Dusty” tar reforming



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

Biomass Gasification Gas Engine



Tar reforming reactor before revamp 2014:

- Poor control → Unstable operation
- Damaged internals
- Troublesome catalyst replacement
- Poor working environment.

Lower productivity

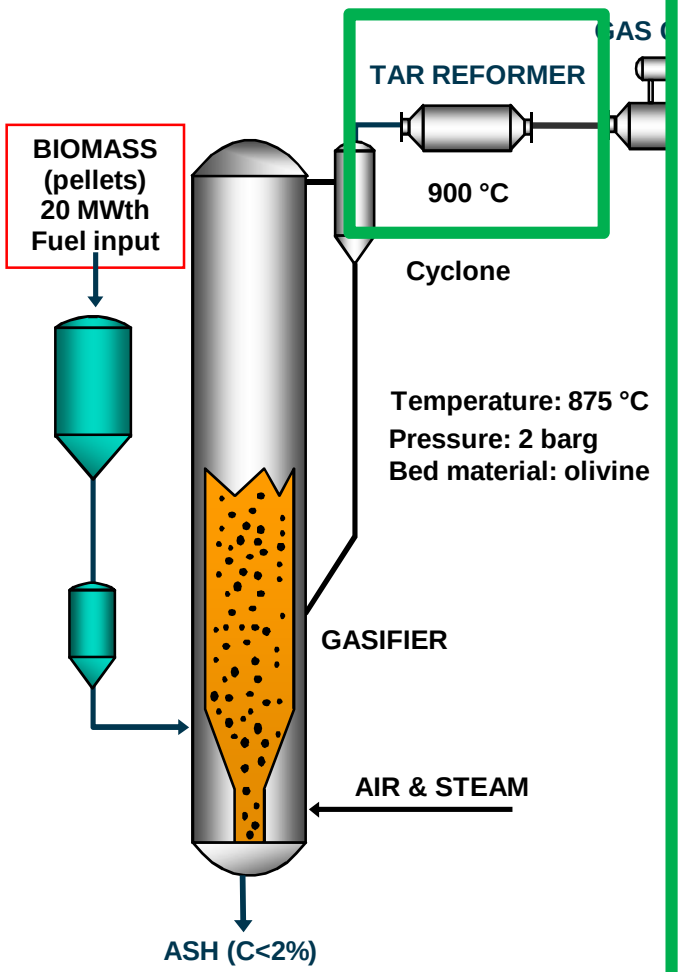
The rebuild tar reformer
has several advantages…

Improvements:

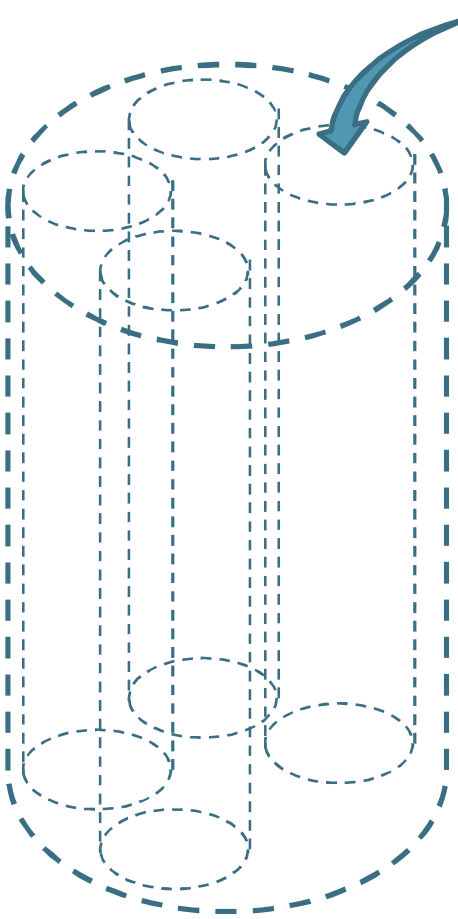
- Improved design of reactor internals
- Faster and easier catalyst replacement
- Much better working environment
- Efficient dust blowing
- Improved design of catalyst
- Better dust handling → increased utilization
- Improved process control
- Robust long-term activity → longer lifetime

→ Increased stable operation hours

Biomass Gasification Gas Engine



Tar reformer revamp:



- Pressure shell maintained
- New reactor internals
- New catalyst design

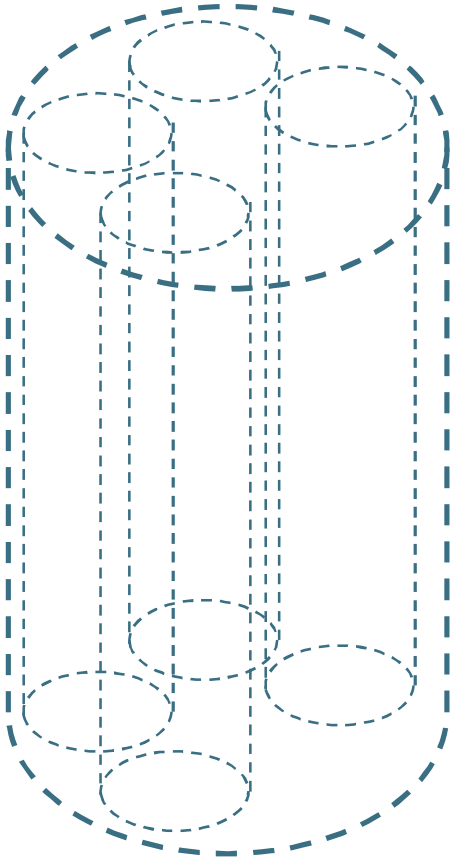
HALDOR TOPSØE

TACK

DISTRICT HEATING
11 MW_{th}

POWER
6,0 MWe

The robust tar reformer

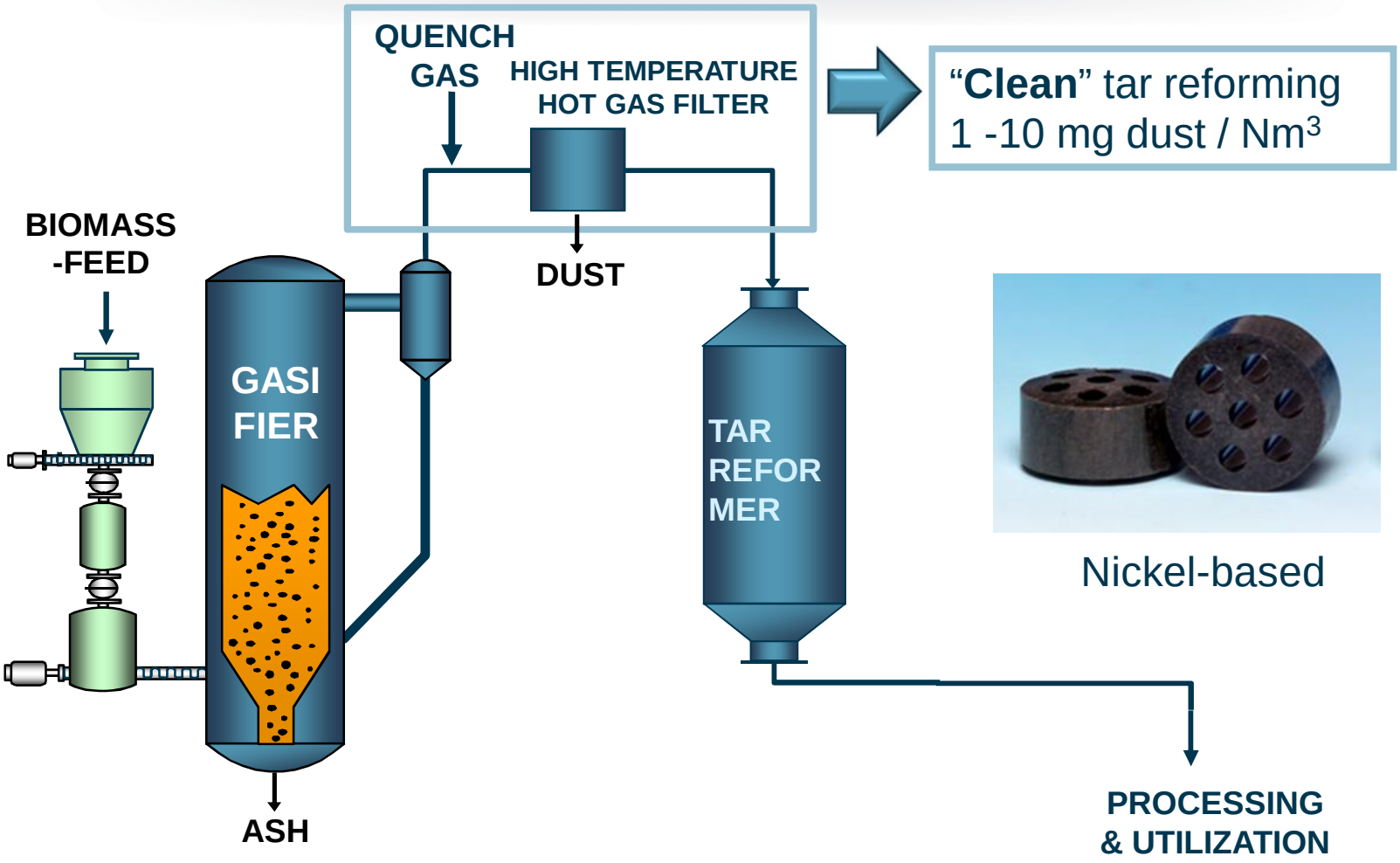


The new design of the reformer has led to

- less dust deposition
- better dust blasting
- controlled regeneration of the monoliths

Increased operation hours and longer lifetime of the monoliths.

“Clean” tar reforming

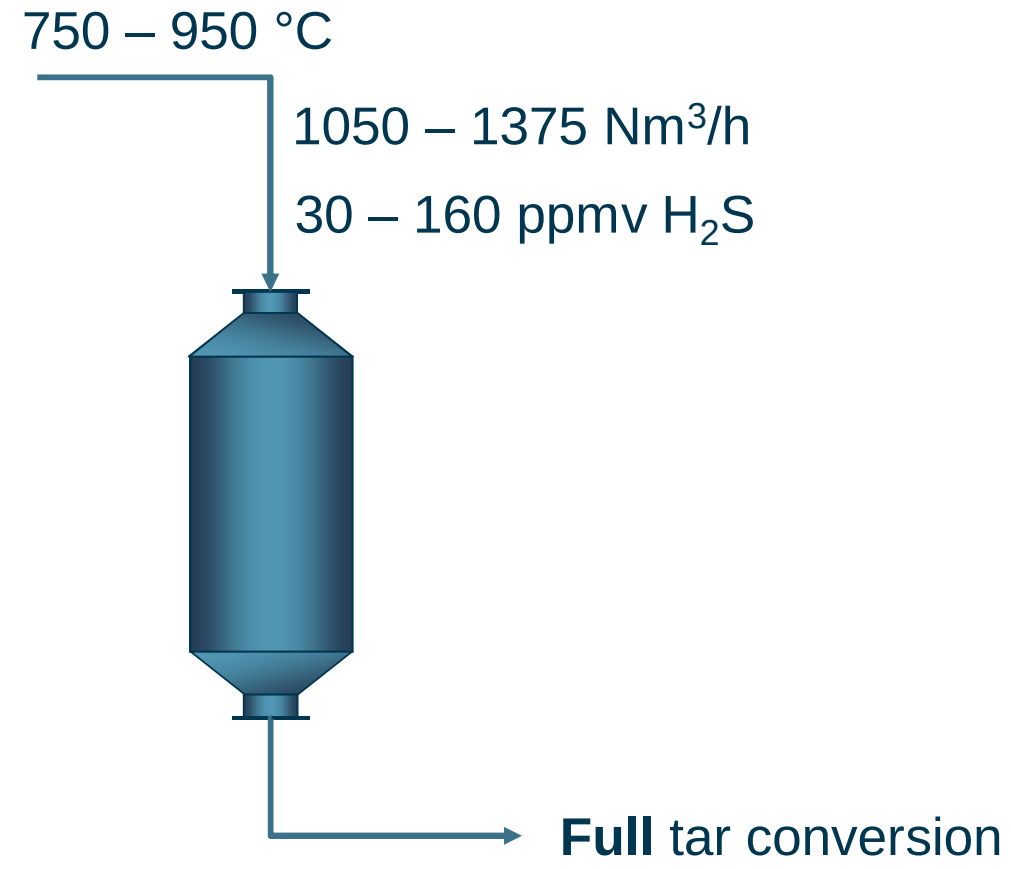


Gas Technology Institute, Chicago

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**

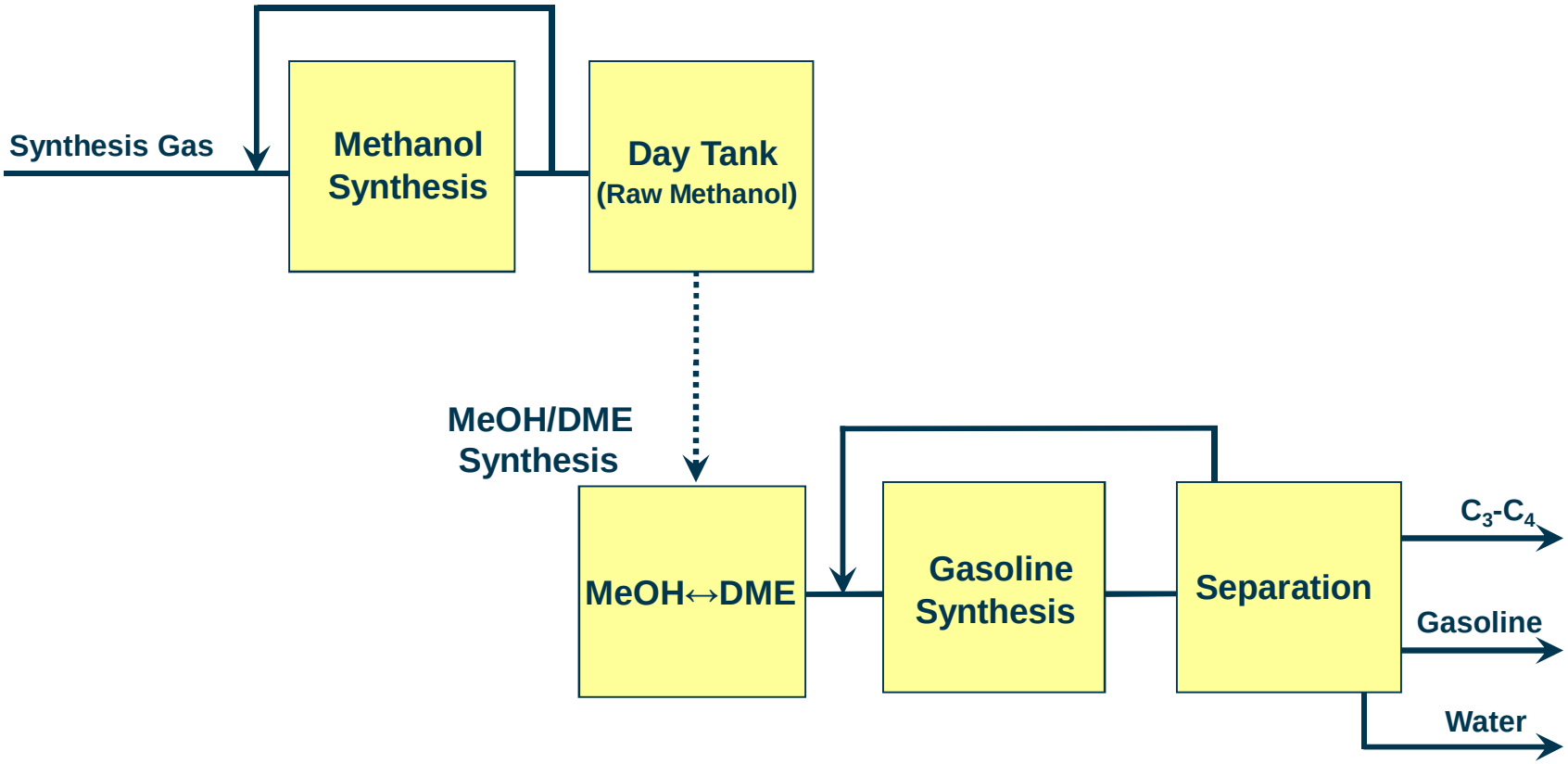
Gas Technology Institute, Chicago

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



TIGAS

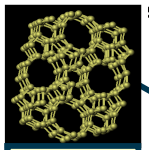
Topsøe Integrated Gasoline Synthesis



TIGAS Demonstrationsanlæg

- 1 T/d; > 7000 timer, Houston, Texas, USA

Historical Perspective

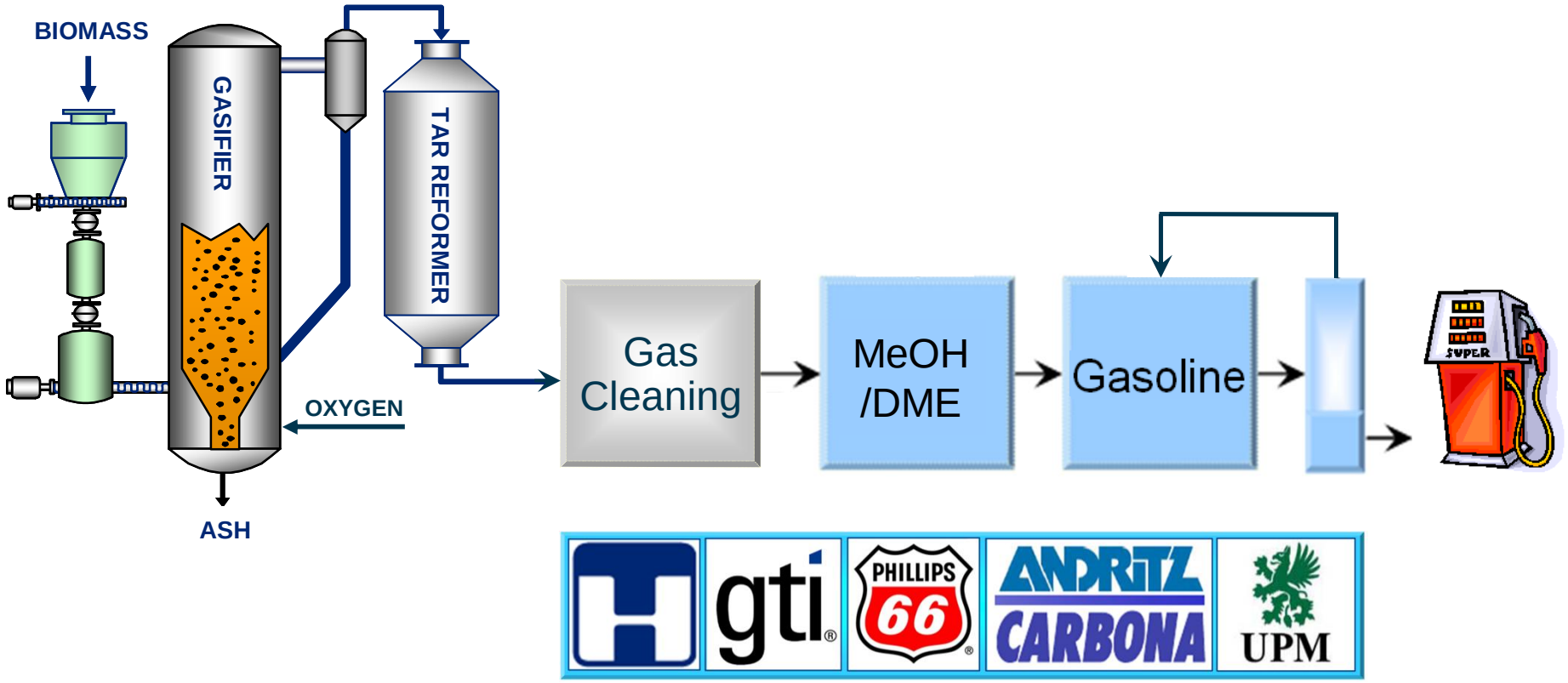


Nominal Monthly Ave. Oil Price
Inflation Adjusted Monthly Average Oil Price

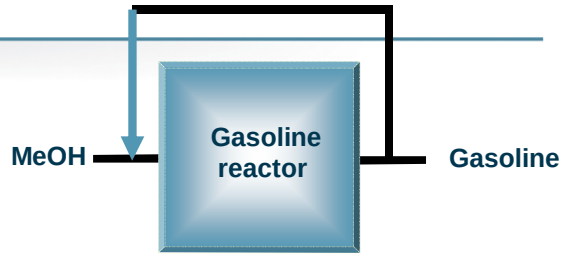
Source of Data:
Illinois Basin Crude Prices- www.ioga.com/Special/crudeoil_Hist.htm
CPI-U Inflation index- www.bls.gov

25 bbl/d Demonstration Plant

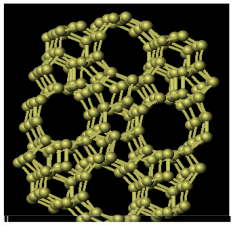
Green Gasoline from Wood Using Carbona Gasification and Topsoe TIGAS Processes

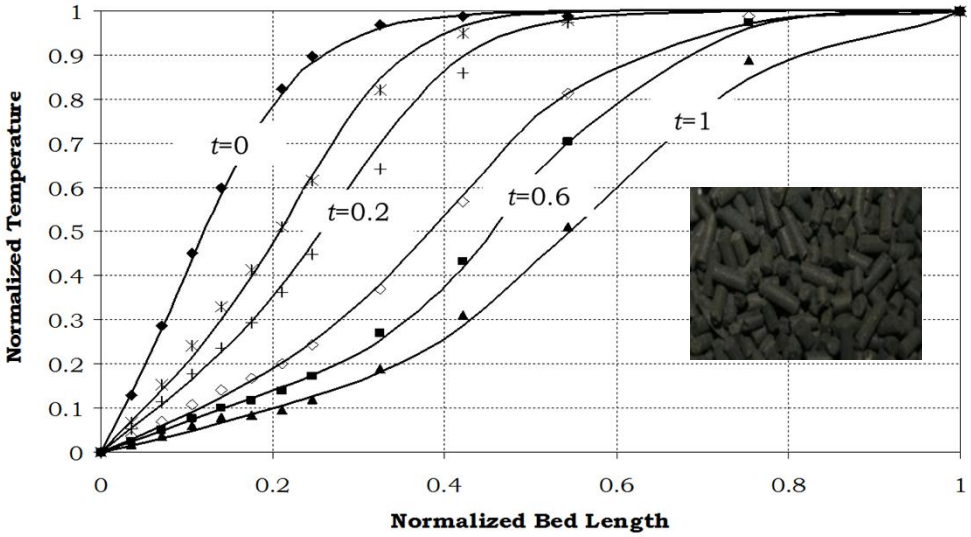


Methanol to gasoline (MTG)



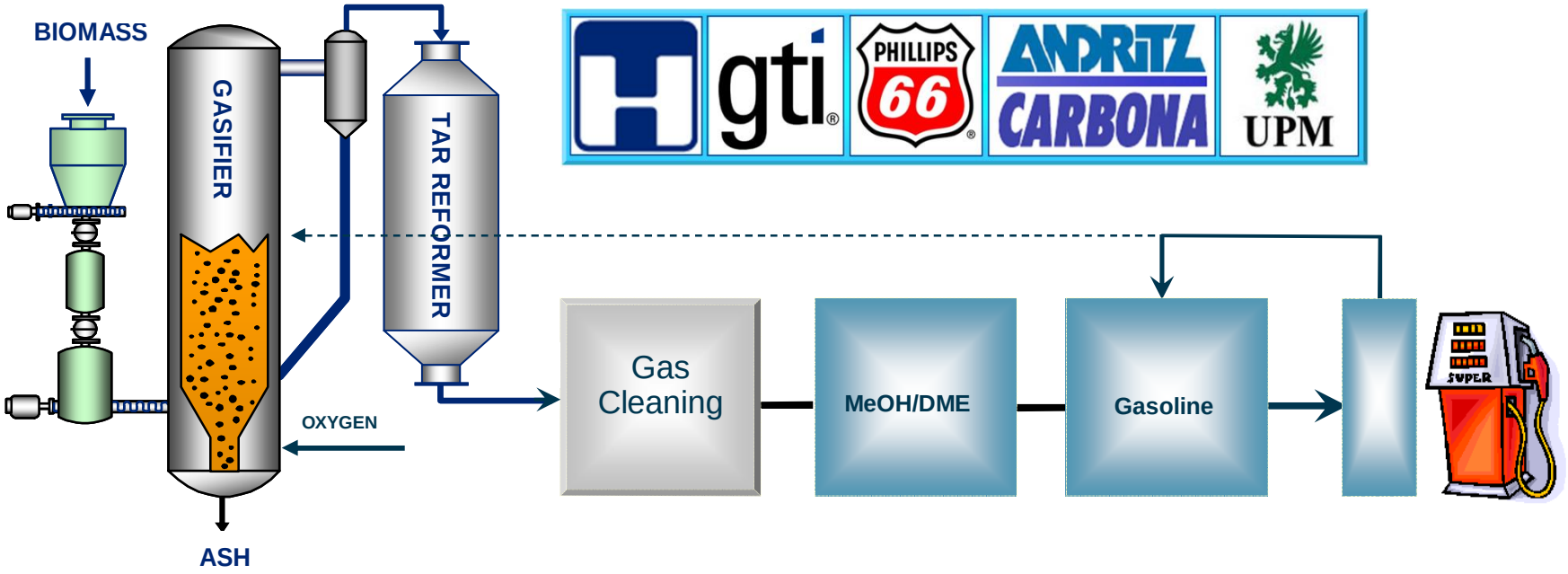
- 290-430°C
- 15-20 barg
- WHSV = 0.8 – 2.6 h^{-1} fixed bed
- Gasoline reactor: ZSM-5
- Cycle length: 10-40 days
- Lifetime: 1-2 years





Biogasoline Demonstration Plant

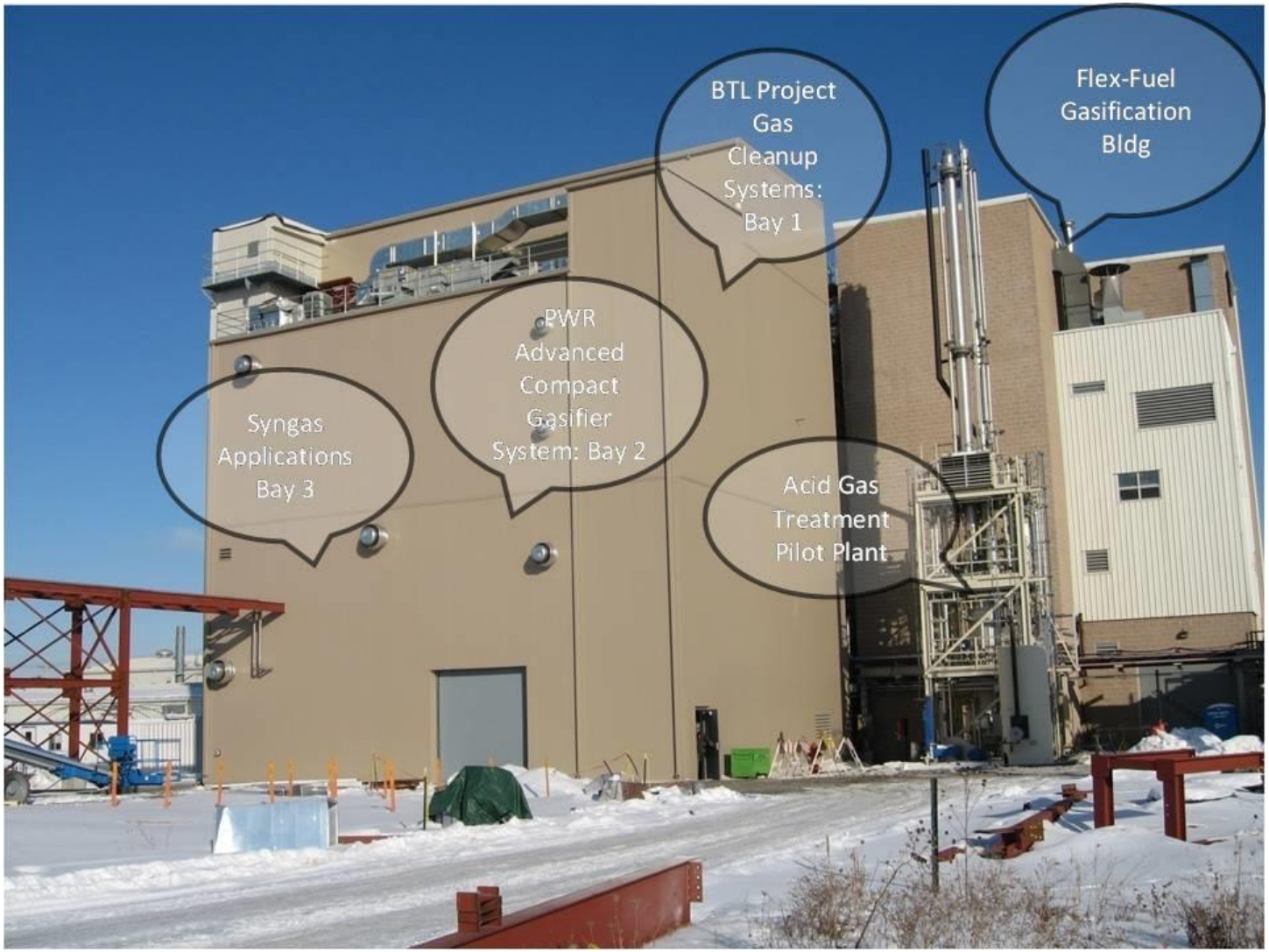
Green Gasoline from Wood Using Carbona Gasification and Topsoe TIGAS Processes



Entire value chain: biomass in → gasoline out

Biorefinery facility

- Gasification & Tar reforming (existing)
- Morphysorb® AGR unit (existing)
- Utility units & control system (existing)
- Syngas compression (new)
- TIGAS synthesis unit (new)
- Gasoline & waste water tanks (new)


BTL Project Gas Cleanup Systems: Bay 1
Flex-Fuel Gasification Bldg
PWR Advanced Compact Gasifier System: Bay 2
Syngas Applications Bay 3
Acid Gas Treatment Pilot Plant


TRANSCRAFT DTL-3000
320
KHD
TRUCK & TRAILER
OAKVILLE, ON.
1-800-265-6291

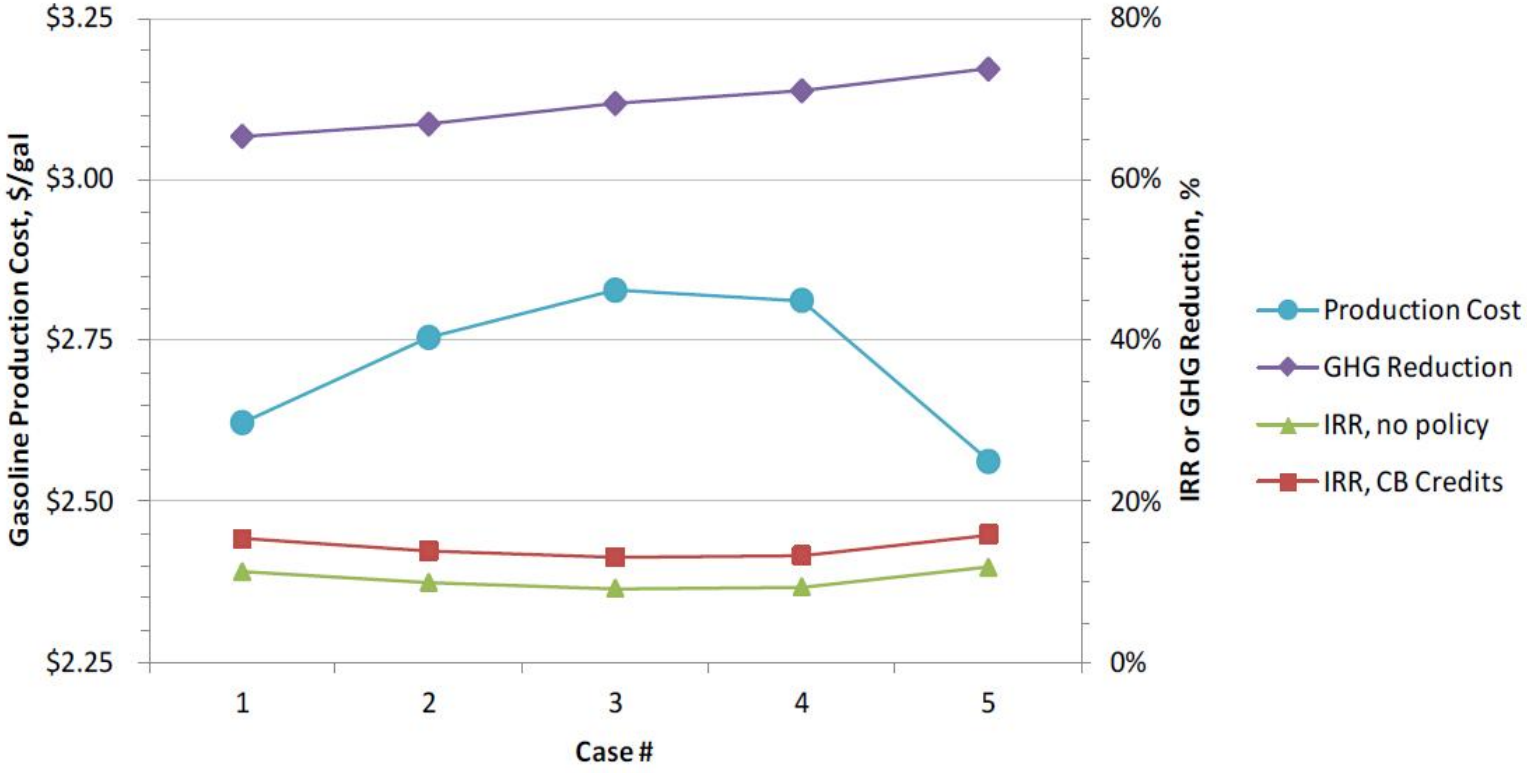
Gasoline testing

- Engine emissions testing at Southwest Research Institute
  - Tested a 80/20 high biomass TIGAS/gasoline blend.
  - Emission levels better than for conventional gasoline.
  - Found to be ”substantially similar” to conventional gasoline

- Fleet test
  - Testing 8 vehicles (EPA Standard Road Cycle)
    - 2 Camry (2.5 L PFI),
    - 2 Corolla (1.8 L PFI)
    - 2 F-150 (3.5 L V6 EcoBoost®),
    - 2 Fusion (1.5 L EcoBoost®)
- Commercial gasoline vs. 50% biogasoline blend
- Accumulate 75,000 miles per vehicle
- Engine inspections
- Engine emission tests @ 4000 & 75,000 miles

Economics

5 cases: Gasoline production cost, IRR, and GHG reduction



Grid Power

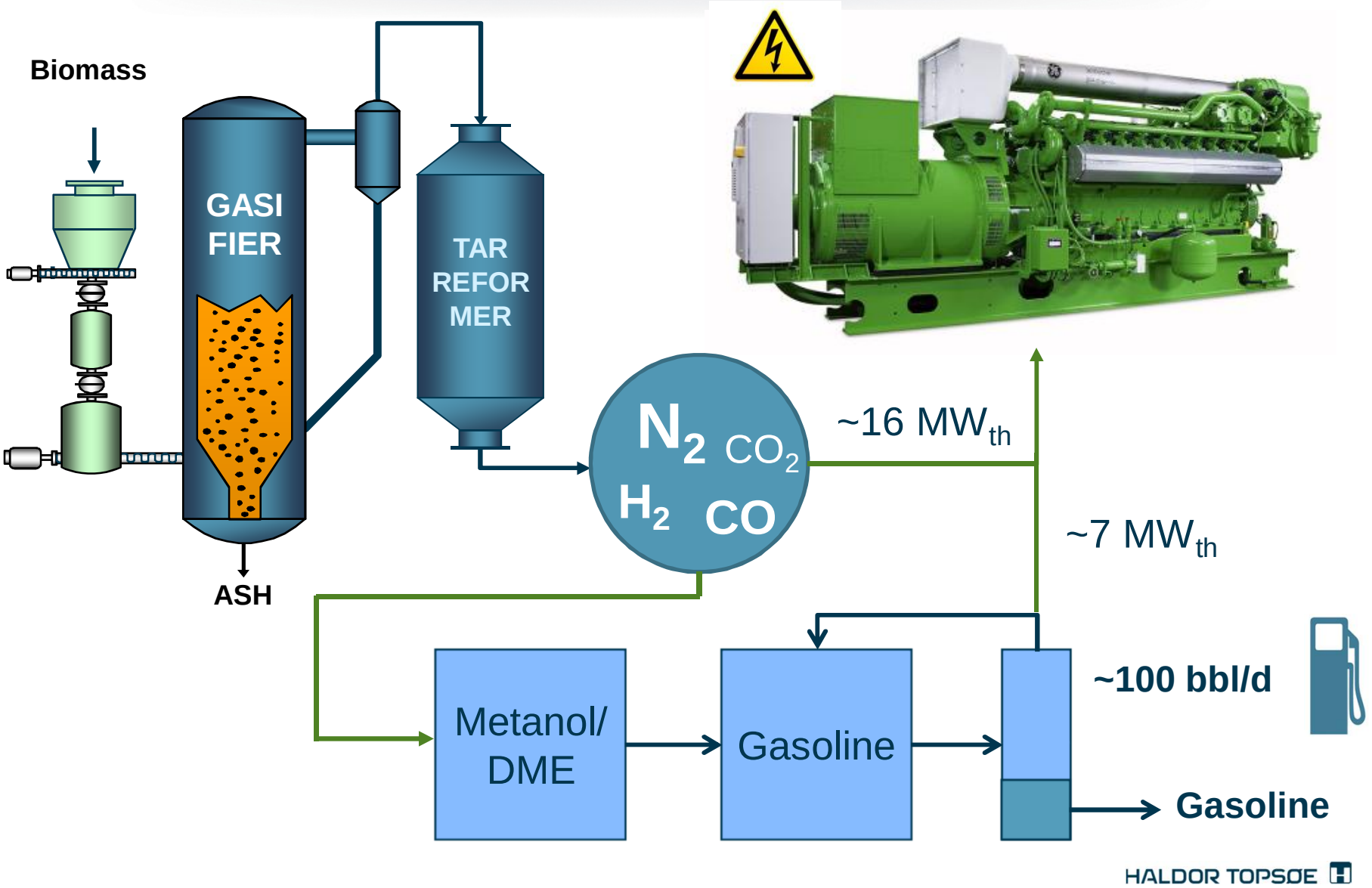
Fuel gas and/or LPG fraction used for power generation

Gas Turbine

Summary

- MTG: direct conversion of methanol to gasoline
- Topsøe MTG: TIGAS is a versatile technology for conversion of syngas to gasoline
- Escalating share of unpredictable renewable energy
  - is a challenge to balancing supply/demand balance in the power grid
  - adds increasing demand to standby backup capacity
  - increases overflow frequency
- Co-production of power and fuel
  - is a feasible solution to counteract imbalances
  - improves overall system flexibility
  - maximizes operator revenue
- Simplicity and efficiency makes TIGAS suitable for co-generation
  - through integration with IGCC or traditional power plants
  - enabling air-blown gasification of biomass
  - providing fast response to load variations
  - and providing maximum fuel/power flexibility

Thought experiment



Skive > 20.000 citizens

6.000 households

6.000 cars

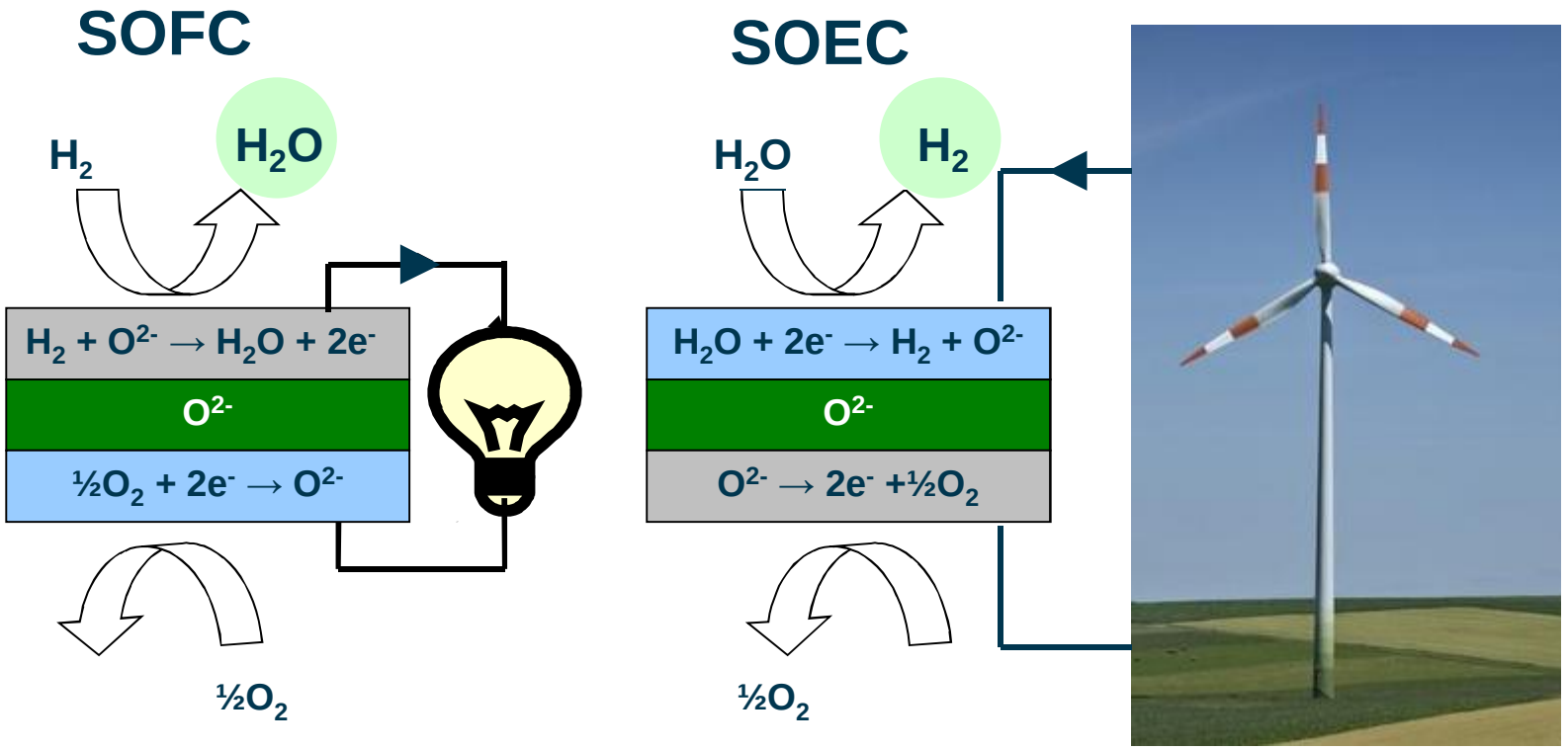
30 km/d (180.000 km/day)

11,3 km/l Gasoline

15.900 l Gasoline/day

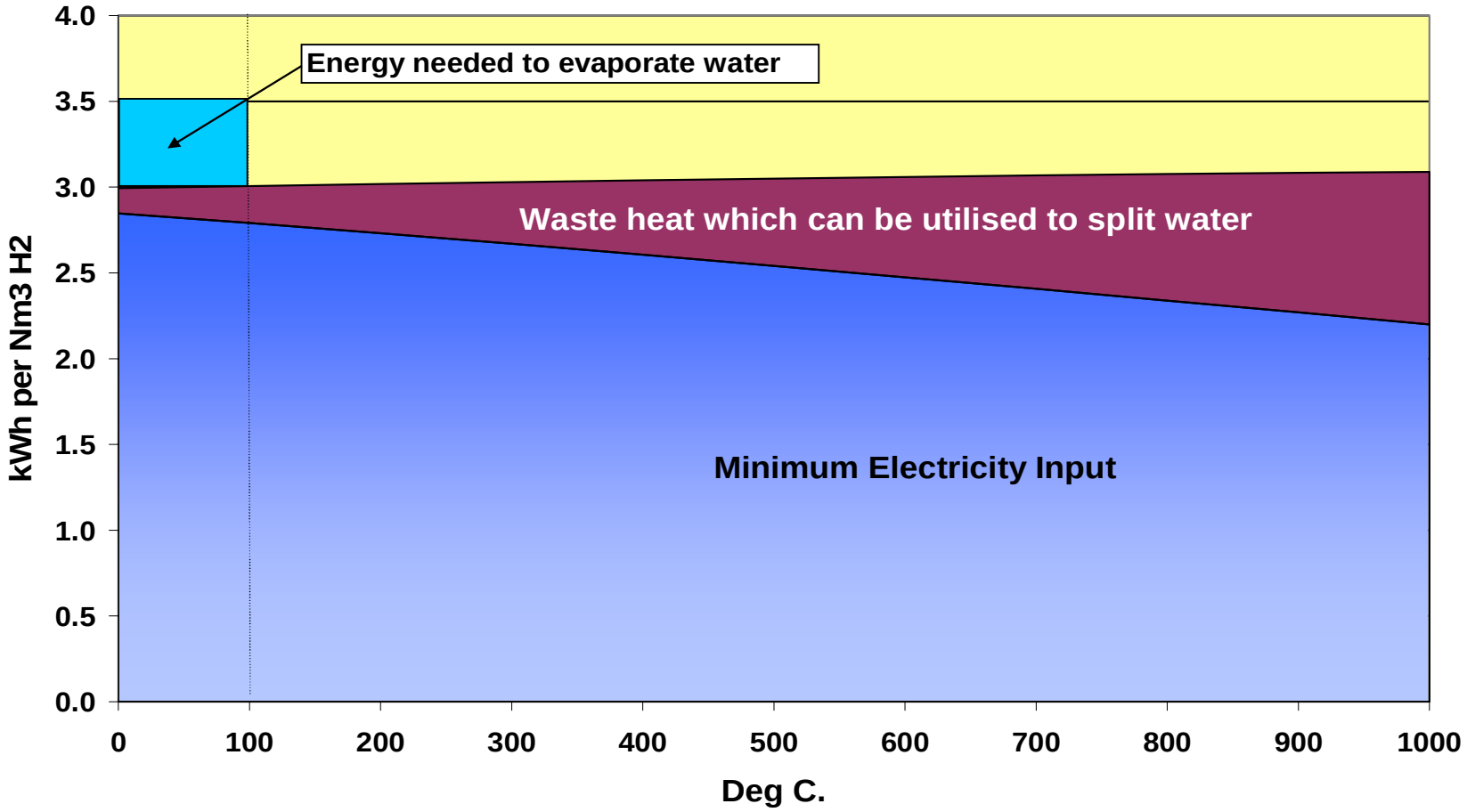
100 bbl./day

Fuel Cell and Electrolyser



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

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



Biogas upgrade by means of SOEC

$$CH_4 + CO_2 + 3H_2O + El \rightarrow 2CH_4 + H_2O + 2O_2$$

New EUDP project
50 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

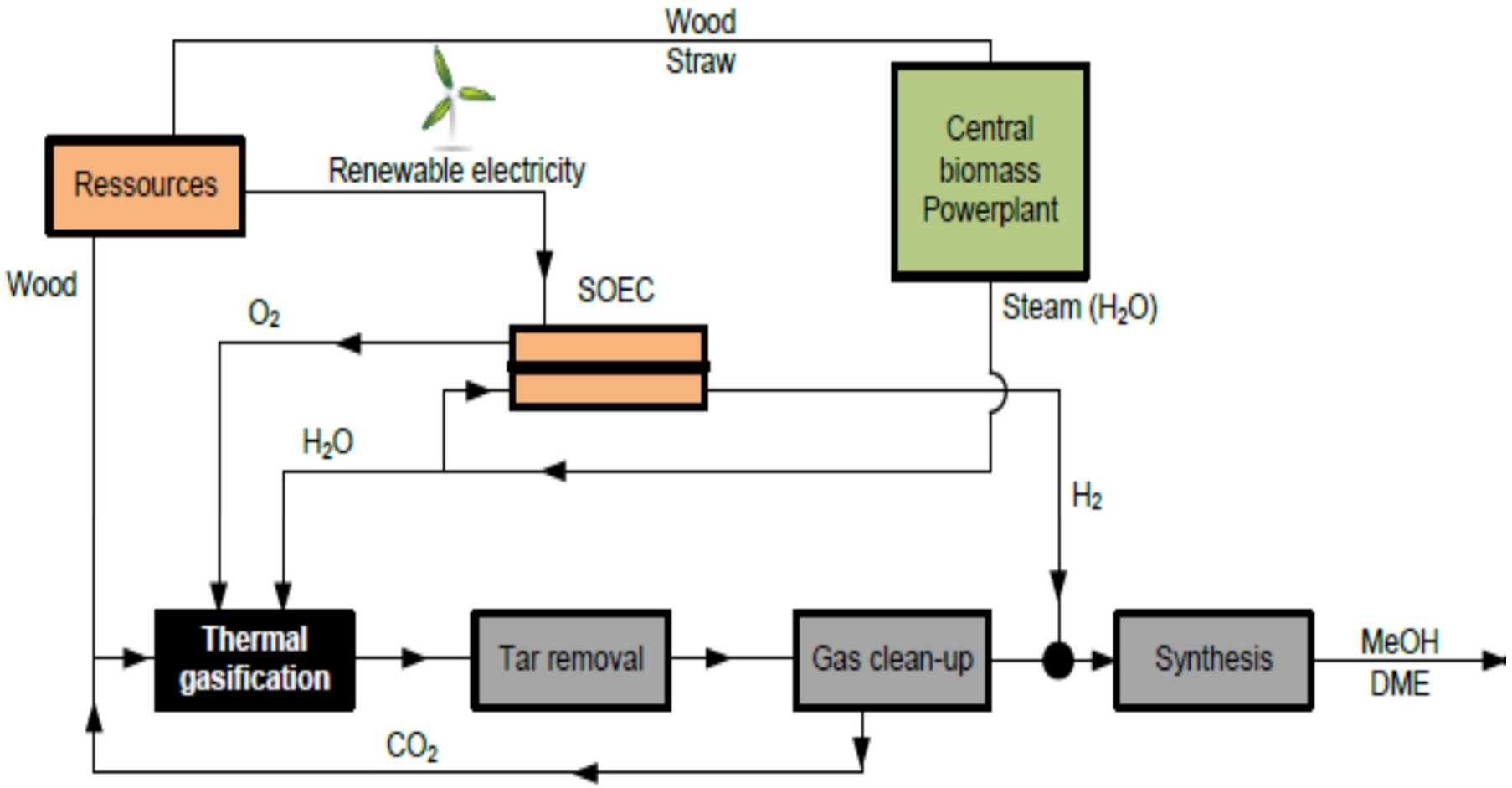
Coordinator:

HALDOR TOPSØE
CATALYSING YOUR BUSINESS

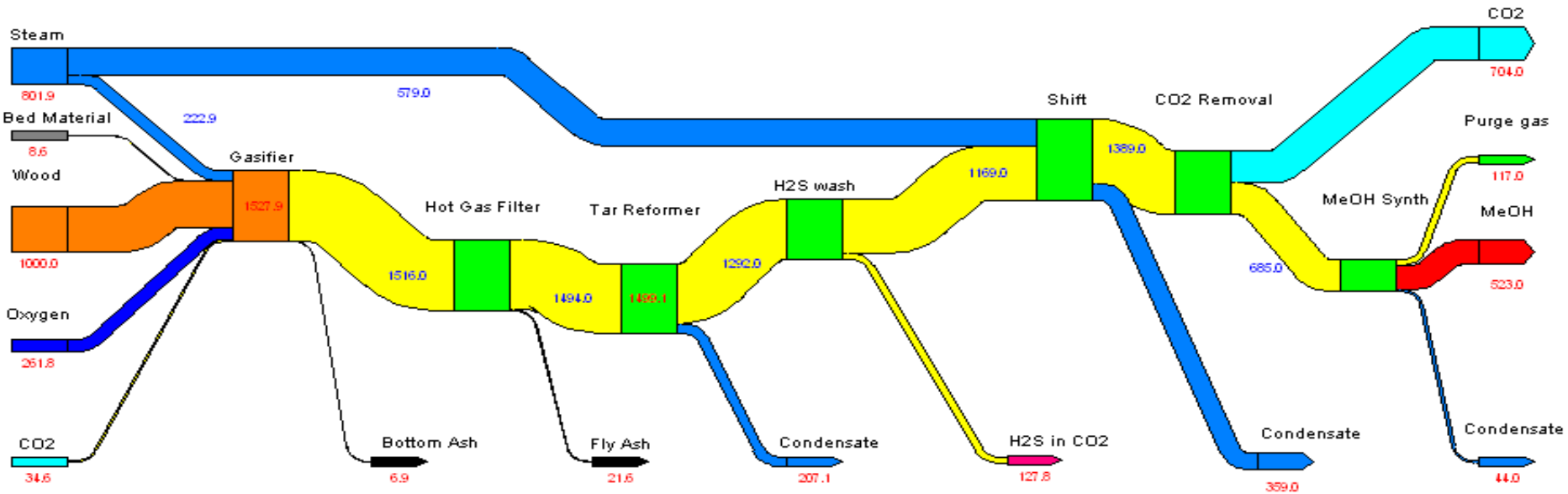
Duration:
June 2013 -
Dec. 2017
Project sum:
5.3 mio €
Location:
Foulum

Methanation and SOEC at Foulum

GreenSynFuel Project



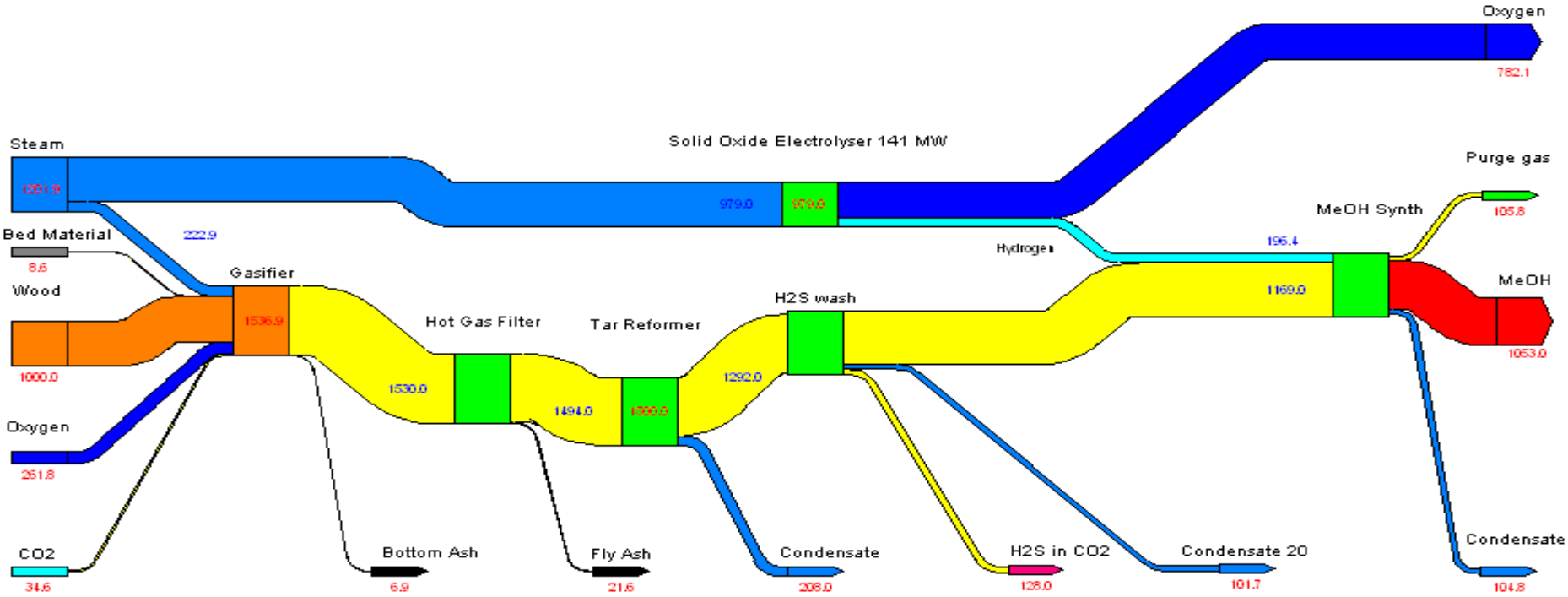
Mass Flows in Wood to MeOH



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

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