Renewable Olefins, comparison of production over Methanol or Fischer Tropsch route

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Figures and Facts of KIT

Karlsruhe Institute of Technology

5 Campuses – **200** ha area

37 Spinoffs and Startups

367 Trainess

385 Professors and executive scientists

22,225 Students

300 Buildings with a usable area of **492,000 m²**

3,100 Doctoral students

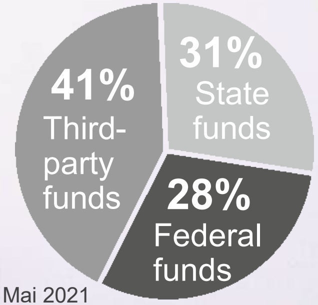
51 Patent applications

9,783 Employees

1,405 international scientists

KIT budget 2021

EUR 1090,7 million



Status: Mai 2021

Big Research Infrastructures at KIT

Acoustic Four-wheel Roller Dynamometer

KARA Synchrotron Radiation Facility

Biomass to Liquid (bioliq®)

EnergyLab 2.0

European Zebrafish Resource Center

High-perfomance Computer for Research

Grid Computing Centre Karlsruhe (GridKa)

Karlsruhe Nano Micro Facility (KNMF)

Karlsruhe Tritium Neutrino Experiment

Theodor Rehbock River Engineering Laboratory

Vehicle Efficiency Laboratory

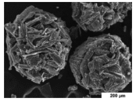
AIDA Cloud Chamber

Engler-Bunte-Institut
Chemical Energy Carriers– Fuel Technology

Karlsruhe Institute of Technology

Thermo – chemical processes
Prof. Kolb

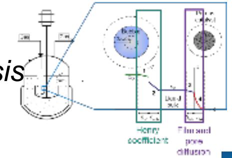
Heterogenous reactions of fuels and wastes (pyrolysis / gasification)



- Particle/droplet conversion-modell
- Processparameters T, $\mathrm{d}T/\mathrm{d}t$, τ, p
- Reaction, mass-/heat transfer
- Experiments in Lab and pilot scale
- Validation of Modells in REGA and bioliq-EFG, ITC vgt

Catalytic – chemical processes
Dr. Bajohr

Reaction Engineering (C1-Synthesis



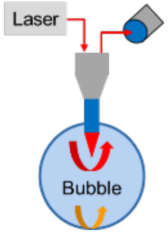
- Reaction kinetics and mechanisms
- Heat and mass transport

Development of Technologies

- 3-phase-Reactors (bubble column, Trickle-Bed,…)
- (metallic) honeycomb reactors
- Usage of CO_2 as carbon source
- Modelling of reactors (stationary & dynamic)

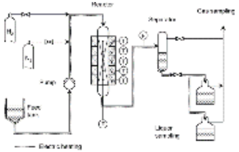
Physico – chemical processes
Dr. Graf

Processdesign for multi-phase reactors



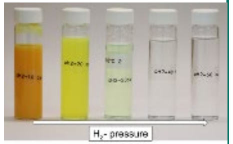
- Trickle-Bed-Reactors (e.g. für CO_2-Abtrennung)
- Bubble column reactors (e.g. für methanisation)
- Characterisation of materials (e.g. IL)
- Fundamental R&D of Hydrodynamics of multi-phase systems (g/l/s)
- Modelling of technologies

Chemical Conversion of Renewable Energy
Prof. Rauch



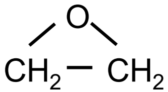
Production / Conversion of liquid energy carriers

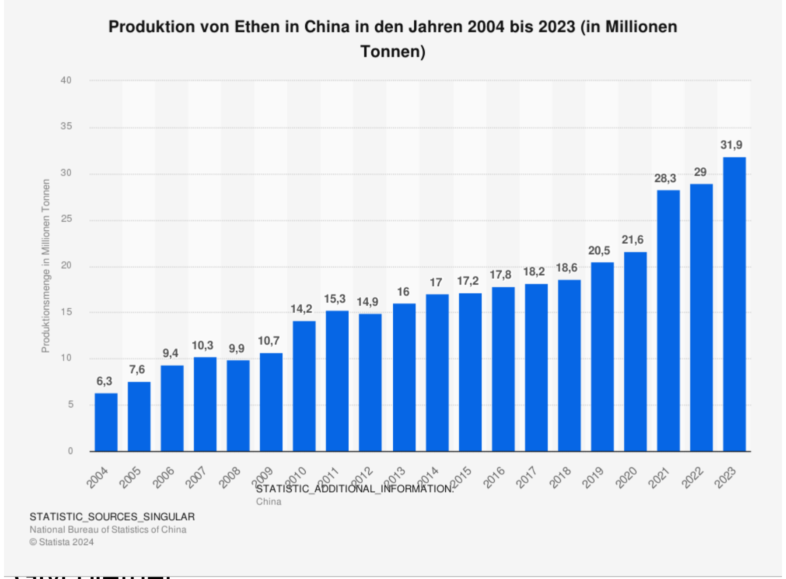
- Fischer Tropsch Synthesis in Slurry-Reactor using biogenic or CO_2 based synthesis gas
- Hydroprocessing of FT waxes, MtG Schwerbenzin or Pyrolysis products
- Sorption enhanced Synthesis (in situ water removal)



Ethene

$CH_2=CH_2$ →

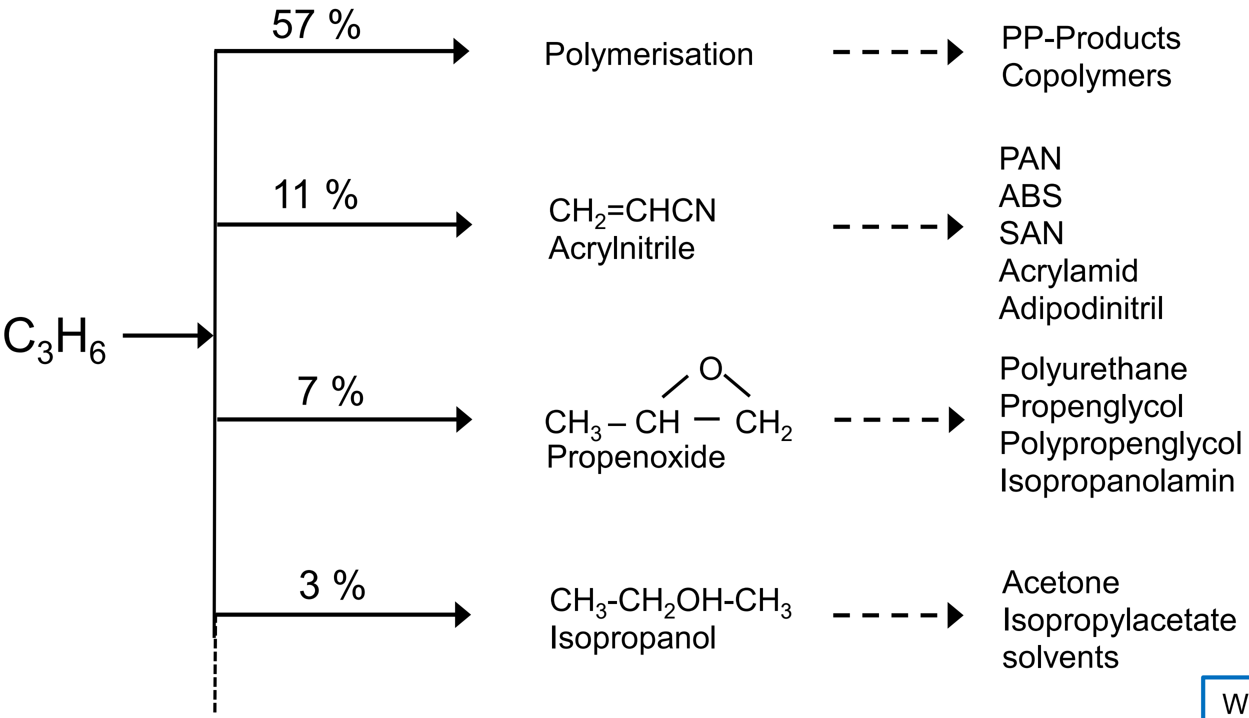
- 58 % → Polymerisation
- 14 % → $CH_2=CHCl$ Monochlorethene
- 7 % → Ethylbenzene
- 2 % → $CH_3\text{-}CHO$ Acetaldehyde
- 13 % → 
- 6 % → others, e.g. Ethanol, Vinylacetate, α-Olefins



Glycolether
Ethanolamine

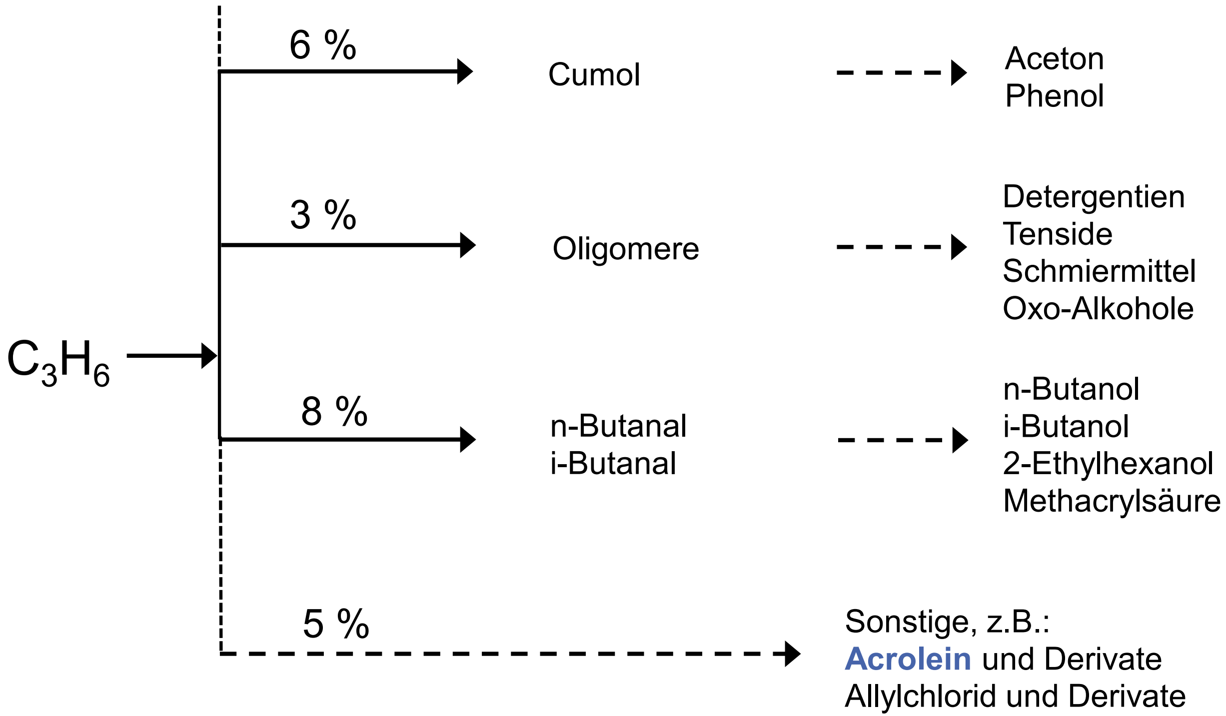
Worldwide consumption of Ethene in 2013: ca. $130 \cdot 10^6$ t

Propen (I)

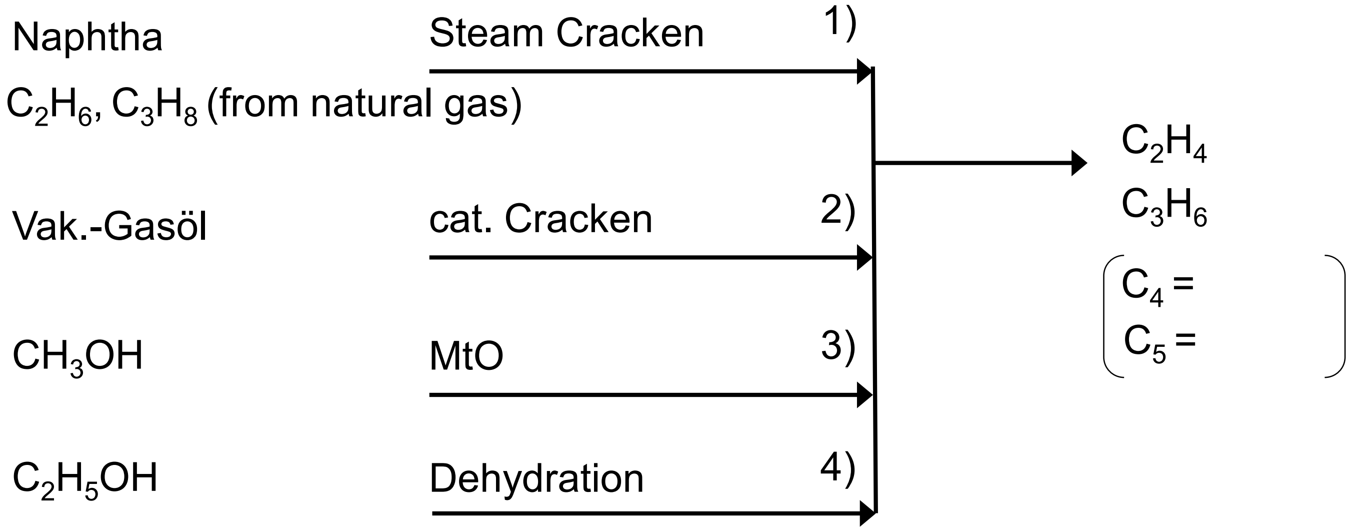


Worldwide consumption of Propen in 2013: ca. $90 \cdot 10^6$ t

Propen (II)


6 %
Cumol
Aceton
Phenol
3 %
Oligomere
Detergentien
Tenside
Schmiermittel
Oxo-Alkohole
C_3H_6
8 %
n-Butanal
i-Butanal
n-Butanol
i-Butanol
2-Ethylhexanol
Methacrylsäure
5 %
Sonstige, z.B.:
Acrolein und Derivate
Allylchlorid und Derivate

Production of Alkens



Renewable Olefins

- Renewable olefins can be produced from synthesis gas over the MeOH or FT pathway or by dehydration of alcohols
- The aim of this study was the comparison of MtO and FT pathway based on syngas from an entrained flow gasifier
- Input was 100MW syngas for both cases at 40 bar and ambient temperature
- H_2:CO ratio for MtO was 2.0 and for FT it was 2.27
- Internal recycles were not modeled in detail, but included
- Separation of raw olefins is done is both cases by cryogenic distillation

Methanol to Olefins

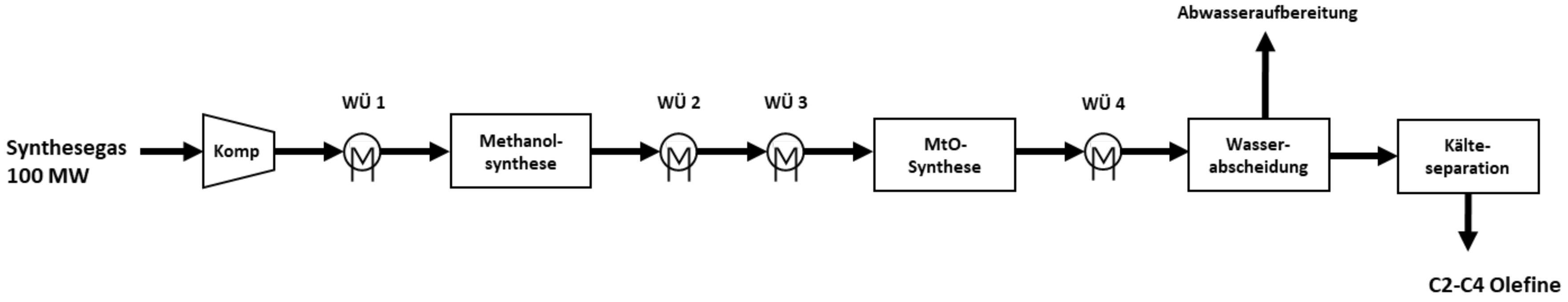
$$CO + 2\,H_2 \rightleftharpoons CH_3OH$$

$$CO_2 + 3\,H_2 \rightleftharpoons CH_3OH + H_2O$$

$$\mathrm{n}\,CH_3OH \rightarrow [C_\mathrm{n}H_{2\mathrm{n}}] + \mathrm{n}\,H_2O$$

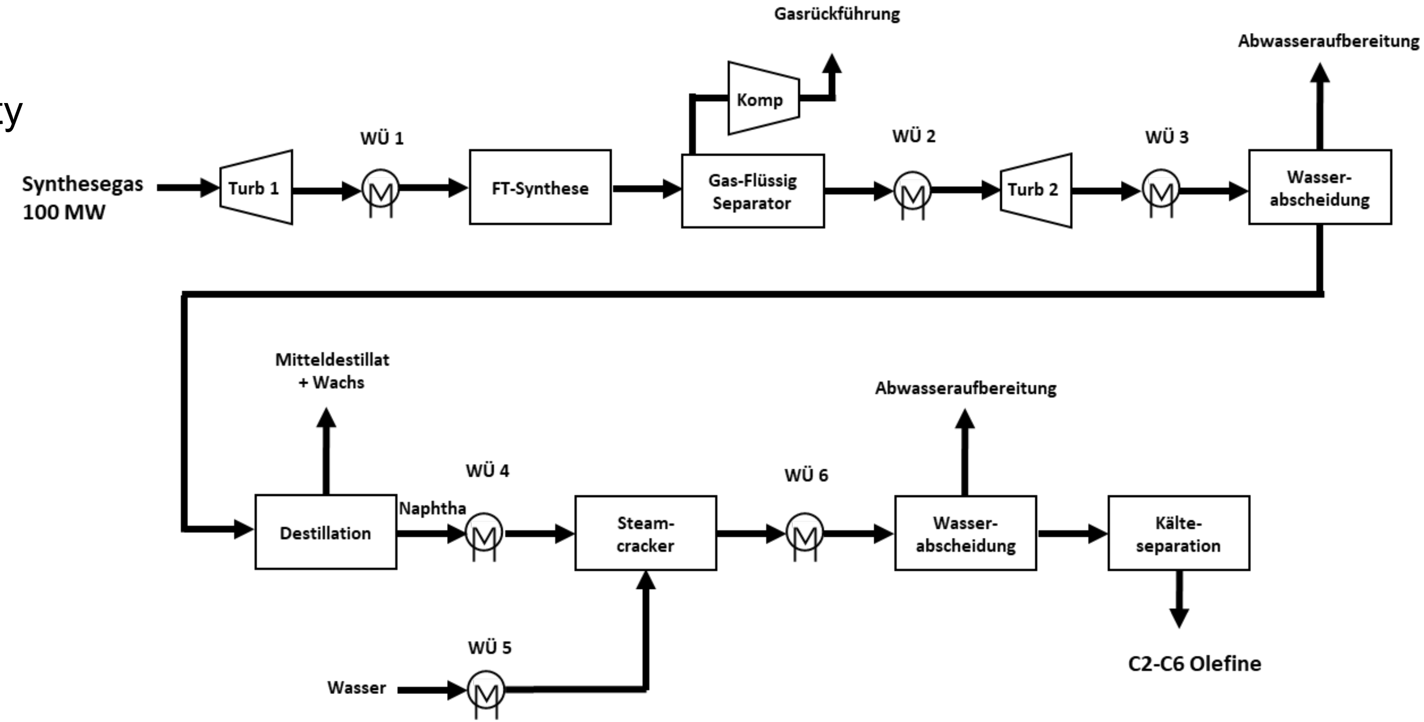
- MeOH synthesis at 80 bar and 250°C
- MtO at 2 bar and 500°C
- Composition at exit of MtO was fixed and given in following table:

Product	water	Ethene	Propene	Butene	Ethane	Carbon
mass x_i in %	56,2	21,9	13,5	5,2	0,2	1,3

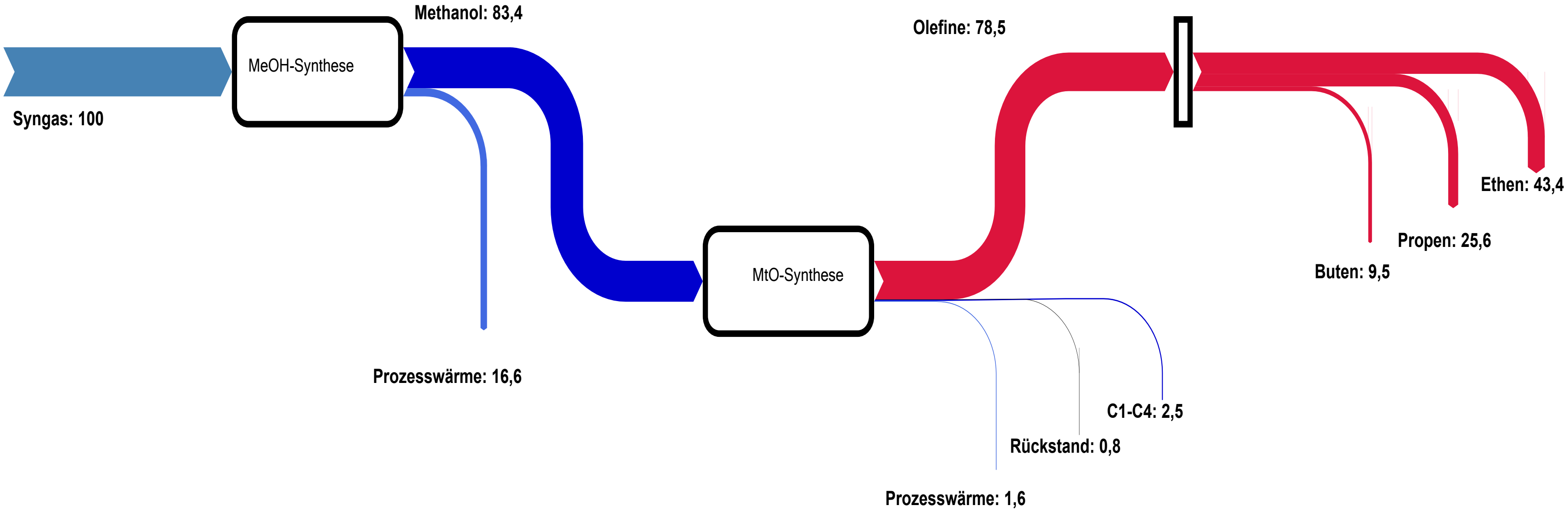


Fischer Tropsch to Olefins

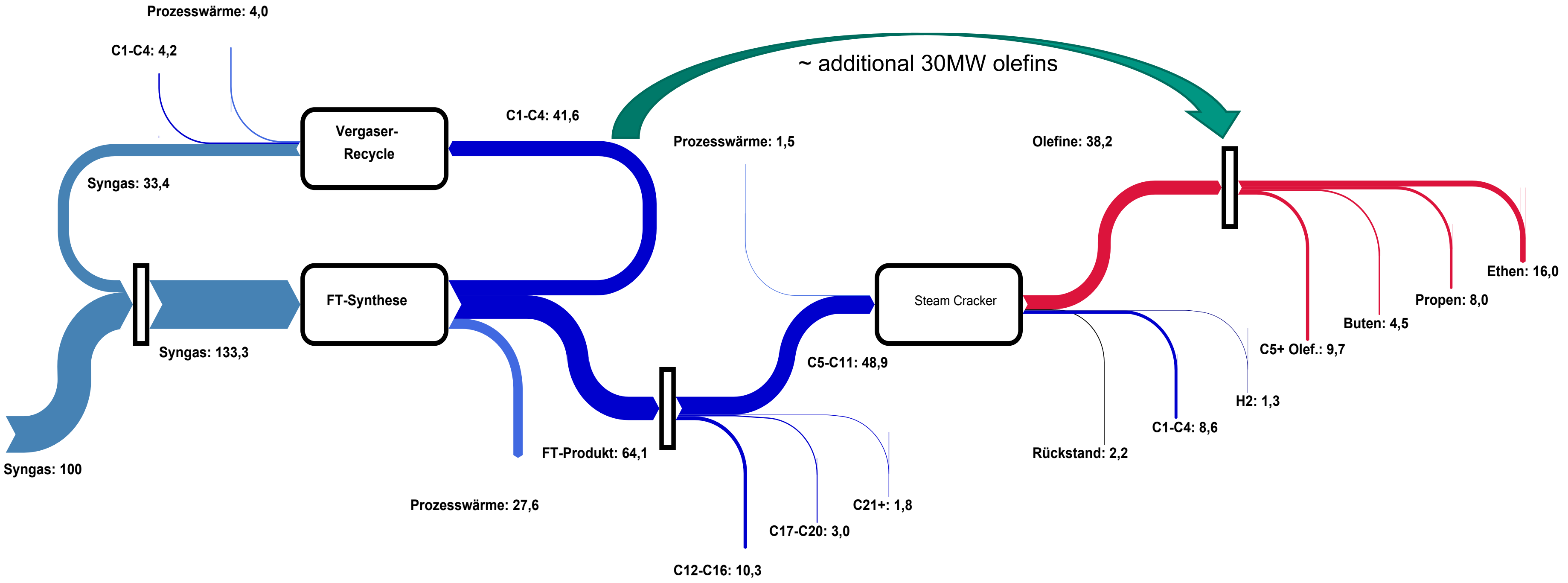
- High temperature FT at 350°C and 15 bar
- Chain grow probability α = 0,75
- Only the naphtha fraction (C_5-C_{11}) is used in the cracker
- In the steam cracker an internal recylce of paraffins is included



Energy balance of MtO



Energy balance of FT to Olefins



Conclusion

- MtO has higher efficiencies, but can be realised only as greenfield plant
- MtO could be also realised easily with CO_2 and renewable H_2 as feedstock
- FT can be easily integrated into existing steam cracker, but has more byproducts and lower efficiency to olefins
- For FT recycle of gaseous byproduct into gasifier make sense

- Additional study with low temperature FT producing jet fuel and naphtha as byproduct would be interesting

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