Tuesday, 19. September 2023

Session Climate and energy - Hydrogen and fuels II

17 – 21 September 2023 · City Cube Berlin · Germany

ECCE 14 & ECAB 7

14th European Congress of Chemical Engineering

7th European Congress of Applied Biotechnology

www.ecce-ecab2023.eu

COST EFFICIENT OPTIONS FOR FUTURE TRANSPORT

Techno- economic evaluation of synthetic natural gas (SNG) and hydrogen containing synthetic natural gas (HSNG) production for future sustainable transport in Germany

Ralph-Uwe Dietrich, Nathanael Heimann, Simon Maier, Yoga Rahmat, Francisco Moser Rossel, (DLR e.V., www.DLR.de/tt)

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Global e-fuel assessment for future sustainable German transport

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Energy transition in the transport sector (EiV) – Beniver: Scientific supervision

BEniVer
Begleitforschung Energiewende im Verkehr

- EiV: funding 99 Mio. € | 16 projects | 100+ partner
- Renewable electricity based fuels for aviation, road transport and shipping

Cluster	Fuels in focus	Application
C3-Mobility	synth. Gasoline, DME, OME$_{3-5}$, Methanol, Butanol, Octanol	
CombiFuel	Hythan (Hydrogen + Methane)	
E2Fuels	Methanol, OME$_{3-5}$, Methan, Hythan	
FlexDME	Dimethylether (DME)	
ISystem4EFuel	synth. Diesel, OME$_{3-5}$	
KEROSyN100	synth. Jet fuel	
LeanStoicH2	Hythan (Hydrogen+ Methane)	
MEEMO	Methanol	
MENA-Fuels	(Import strategies from MENA region)	
MethQuest	Methan, Methanol, Hydrogen	
NAMOSYN*	OME, Methylformiat (MeFo), Dimethylcarbonat (DMC)	
PlasmaFuel	synth. Diesel	
PowerFuel	synth. Jet fuel	
SHARC	(Smart energy management in harbors)	
SolareKraftstoffe	synth. Gasoline	
SynLink	synth. Diesel, synth. Jet fuel, Methanol	

DLR; izes gGmbH Institut für ZukunftsEnergie- und Stoffstromsysteme; FfE; HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ; DBFZ; GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH; DECHEMA; DGMK

- BEniVer – Scientific supervision of „Energy transition in the transport sector (EiV)"
- BEniVer funding - 9 Mio. € (8 partner)
- Goal: Multicriterial assessment of different options for GHG abatement in transport

Assessment of E-fuels concepts / options / configurations / locations / …

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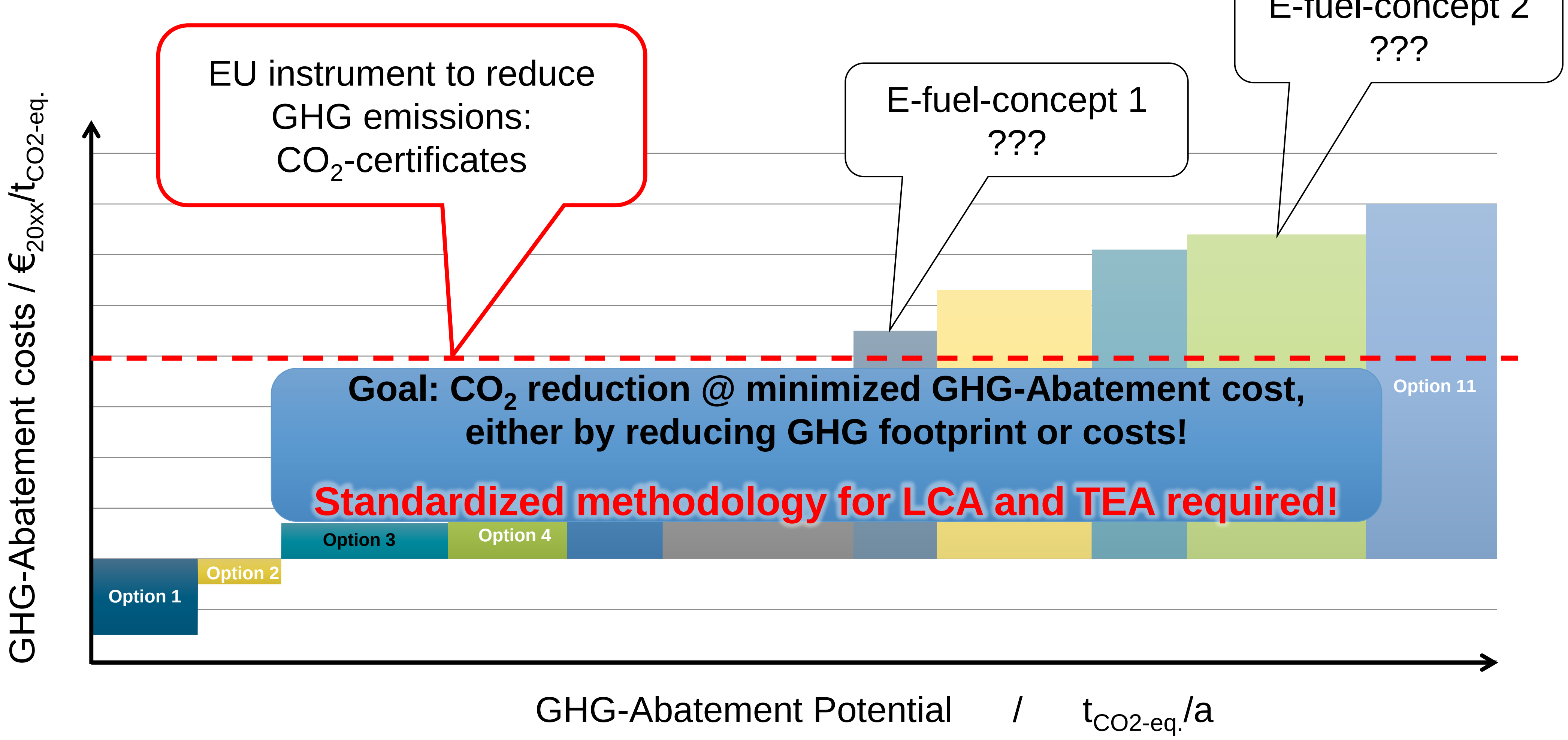
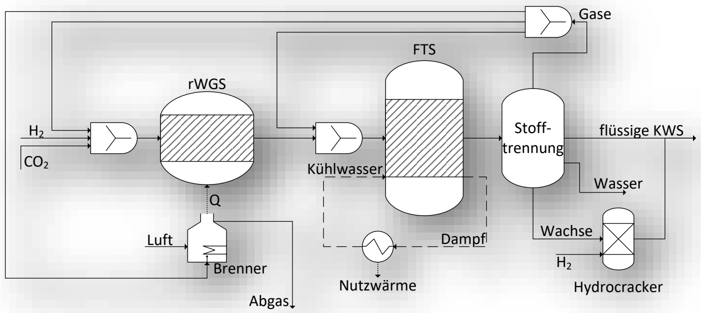
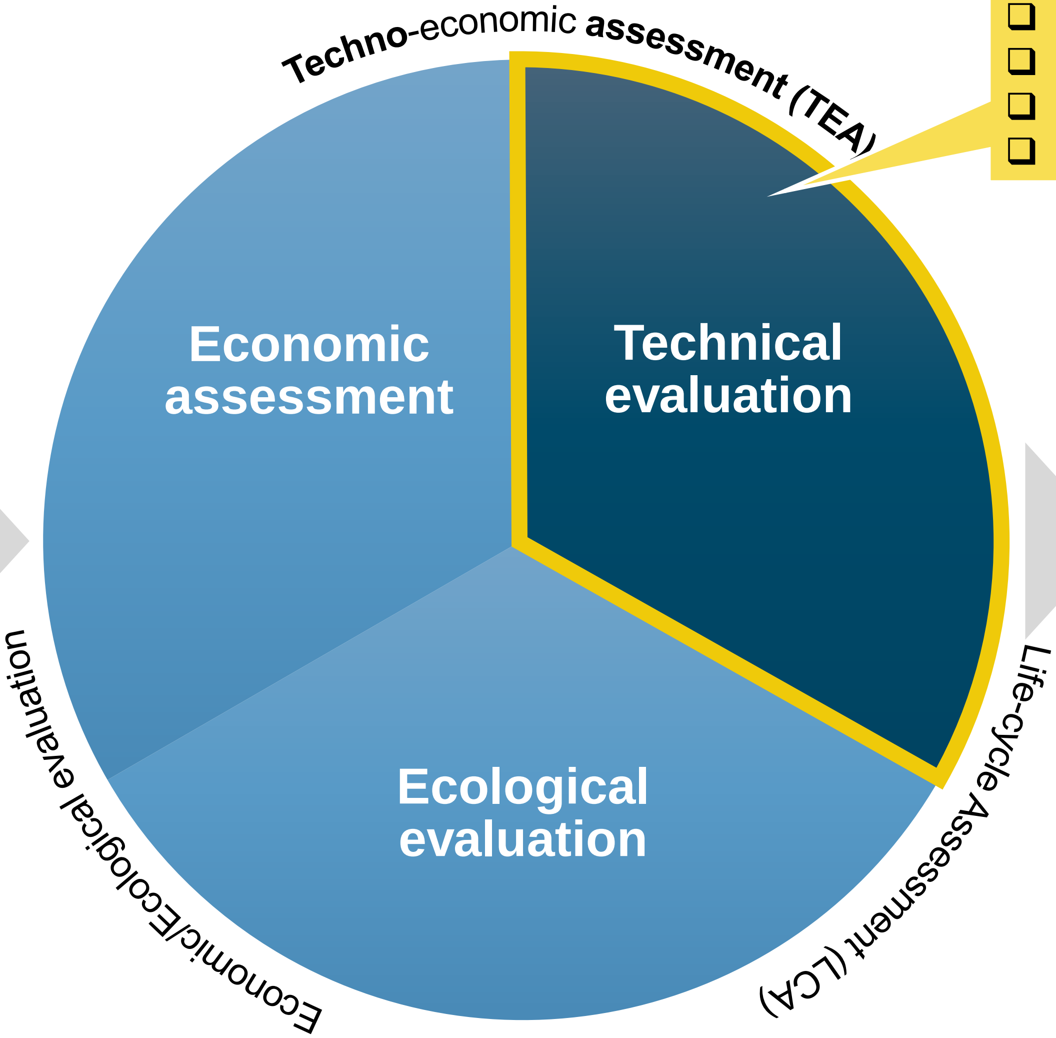
Merit-Order of GHG reduction technologies

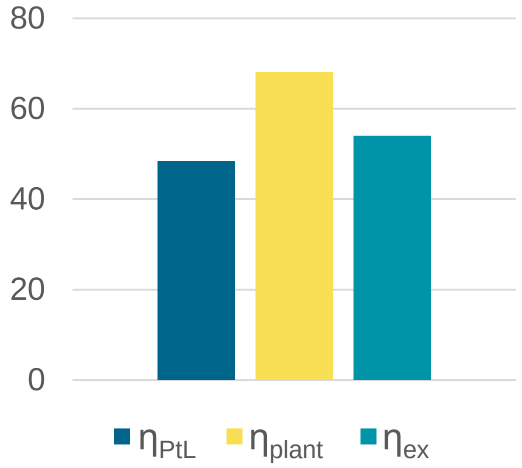


Techno-Economic and ecological assessment

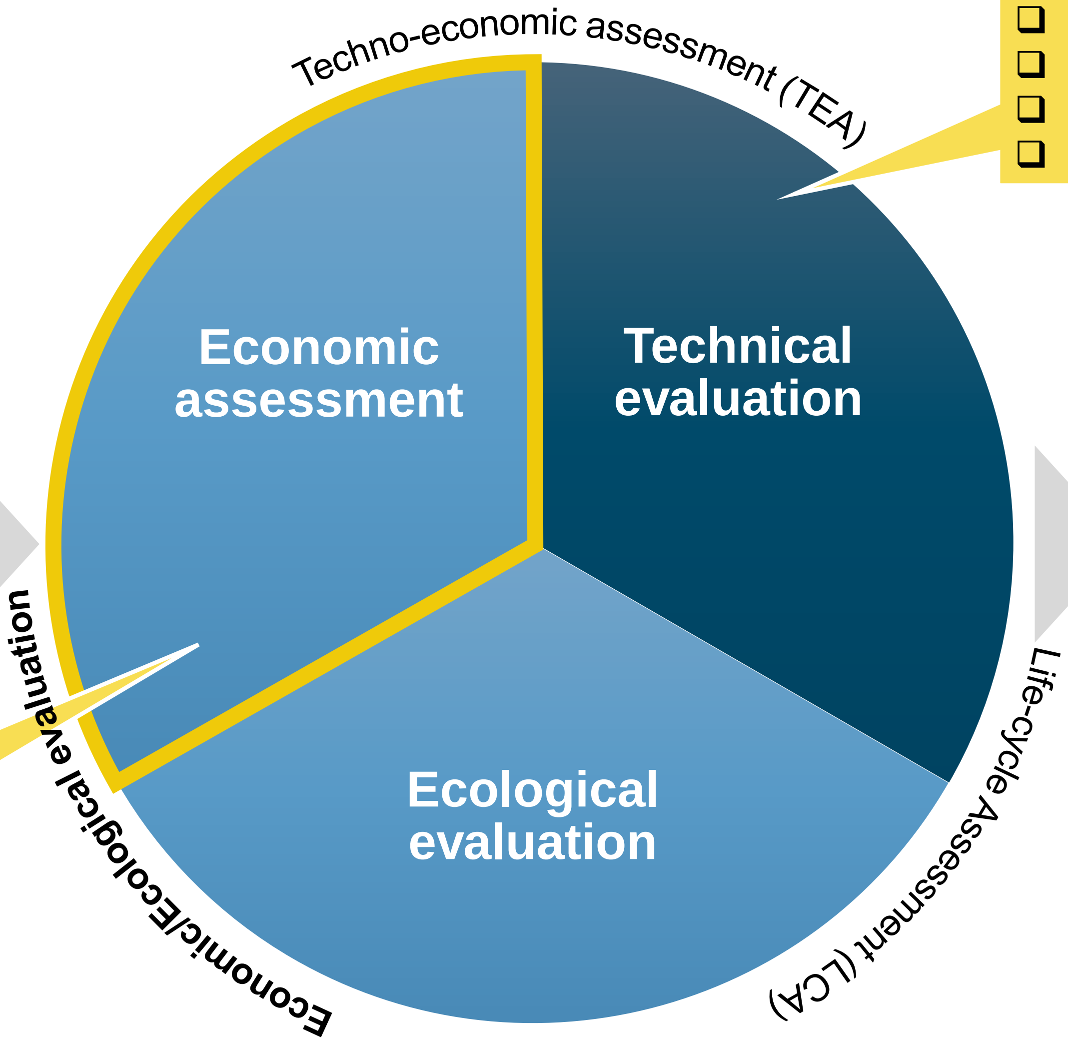
- ❑ Efficiencies (X-to-Liquid, Overall)
- ❑ Carbon conversion
- ❑ Specific feedstock demand
- ❑ Exergy analysis







Techno-Economic and ecological assessment



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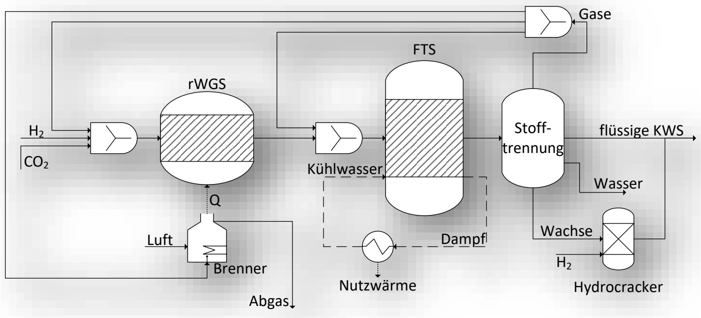

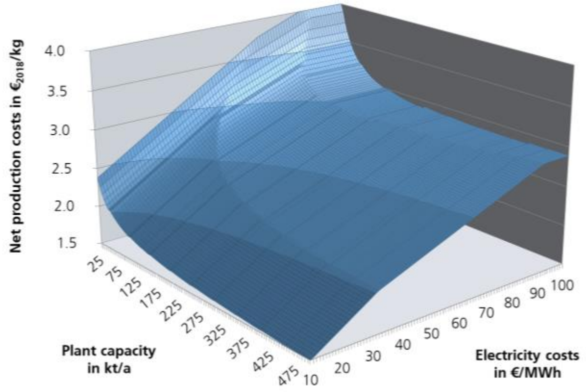

- ❑ CAPEX, OPEX, NPC
- ❑ Sensitivity analysis
- ❑ Identification of most economic feasible process design

Techno-Economic and ecological assessment

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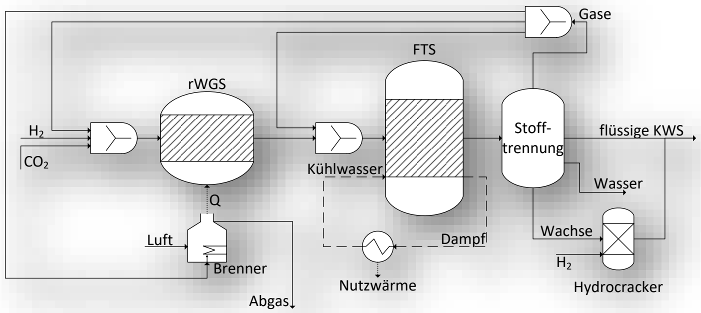

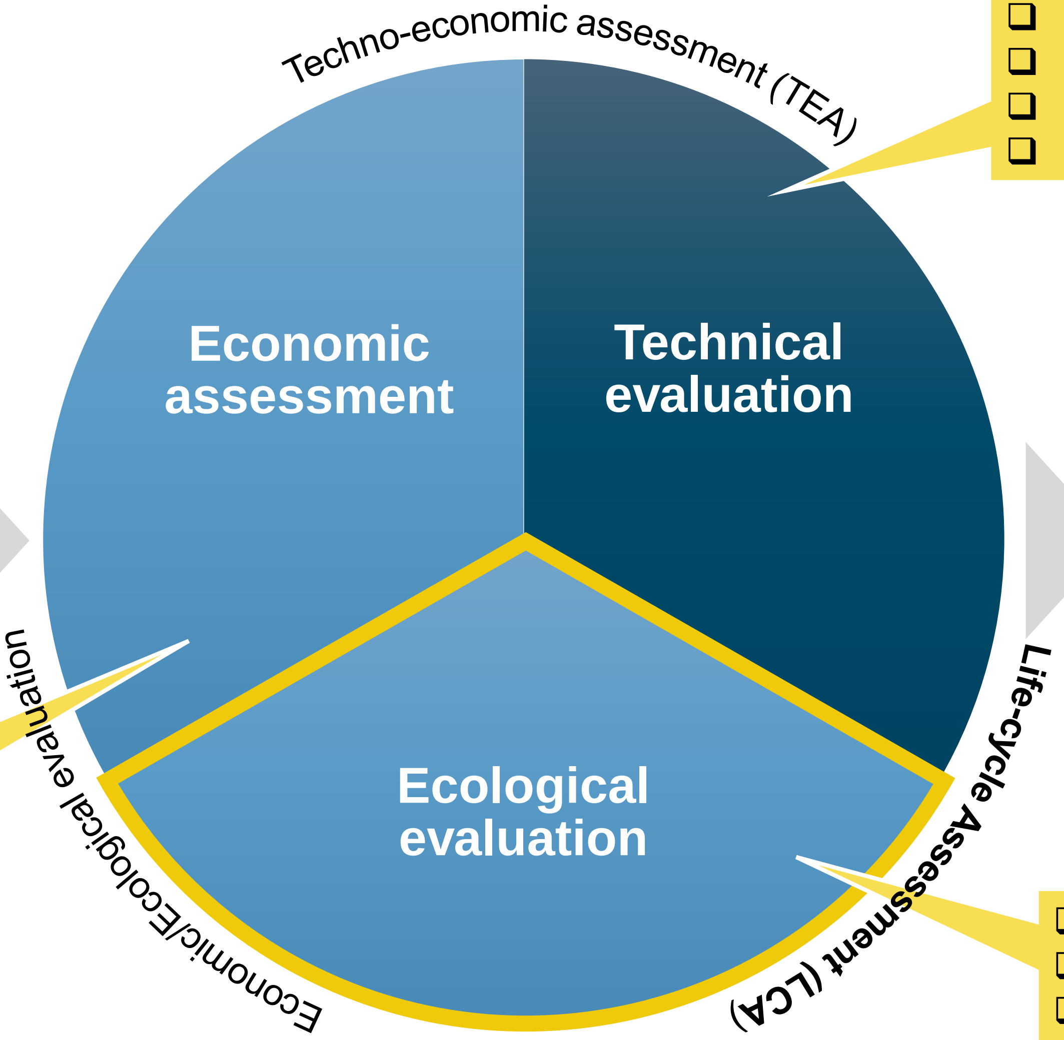

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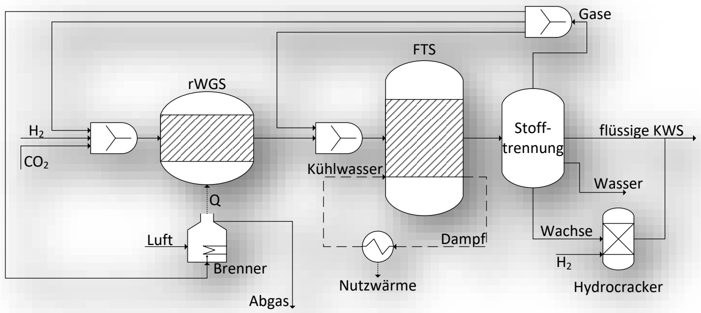
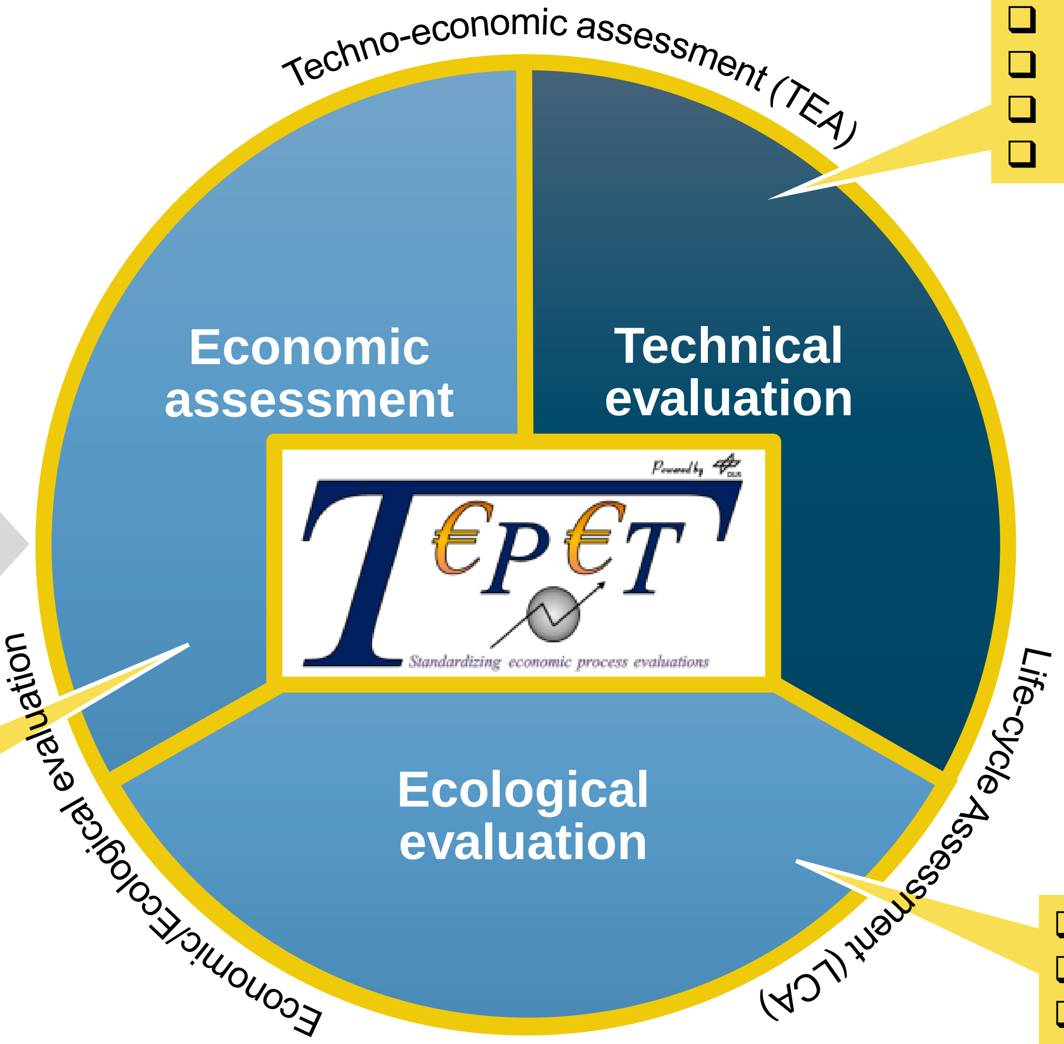
- ❑ GWP
- ❑ Other impact categories
- ❑ Identification of impact drivers

Techno-Economic and ecological assessment





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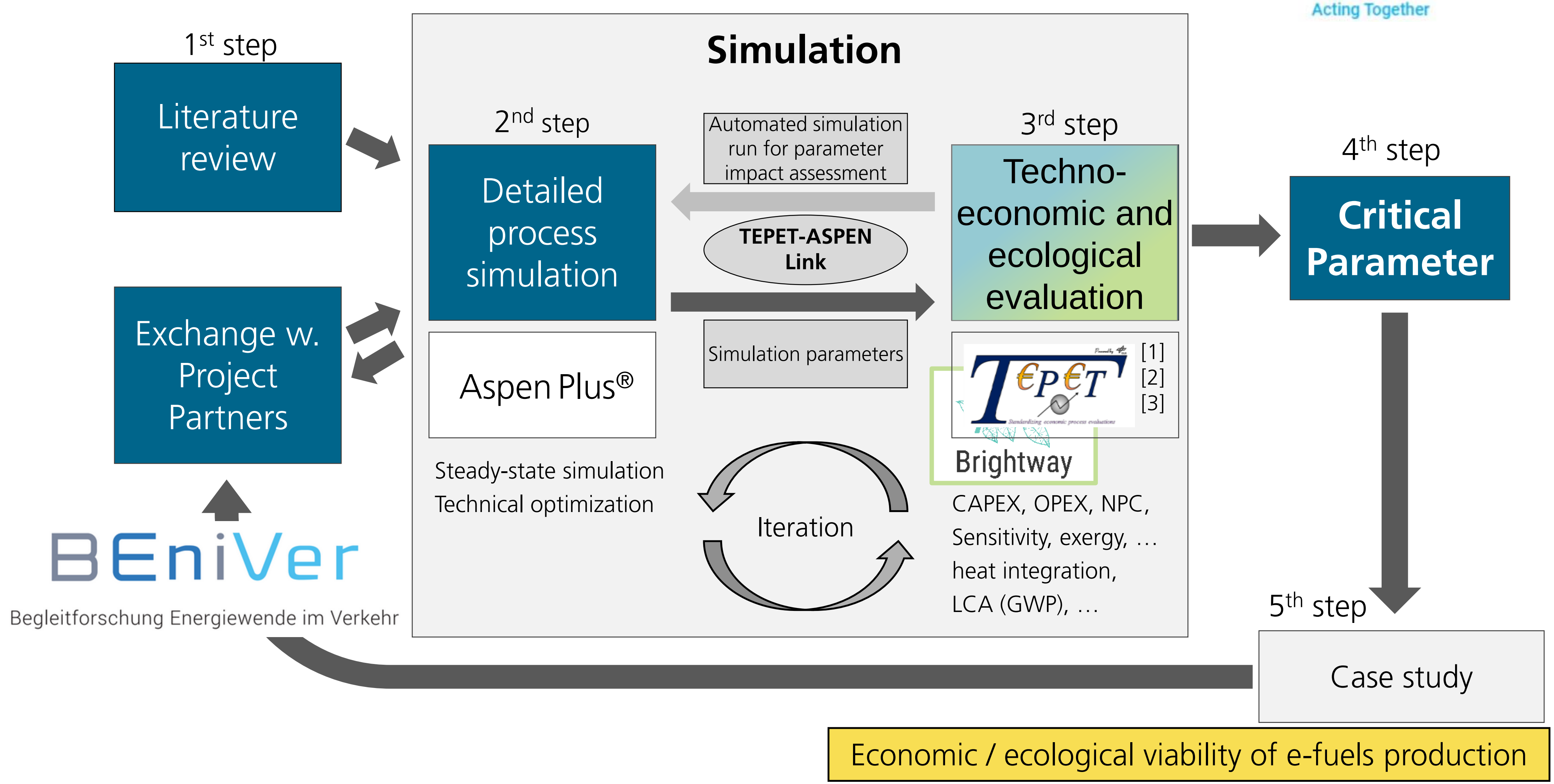
Assessment workflow



[1] Albrecht et al. (2017). A Standardized Methodology for the Techno-Economic Evaluation of Alternative Fuels
[2] Maier et al. (2021) Techno-economically-driven identification of ideal plant configurations for a new biomass-to-liquid process
[3] Weyand et al. (2023) Process design analysis of a hybrid Power-and-Biomass-to-Liquid process

Global e-fuel assessment – Summary

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BEniVer Begleitforschung Energiewende im Verkehr

NAMOSYN Nachhaltige Mobilität durch synthetische Kraftstoffe

Comparing generic fuels / designer fuels

	SNG	MeOH	FT	$OME_{3\text{-}5}$	DMC	MeFo
Production: technical						
η_{PtF} [%]	57		40	42	47	52
NPC [$€_{2018}$/MWh_{LH}						
GHG						

Other ECCE presentations about e-fuels assessment @ DLR:

Session (A6) Process Systems Analysis I

- S. Maier et … tifying the ideal process configuration for green methanol production

Session (A1): Clin… - Industry decarbonisation

- Y. Ra…

Ecological assessment necessary
Application advantages / drawbacks to be added

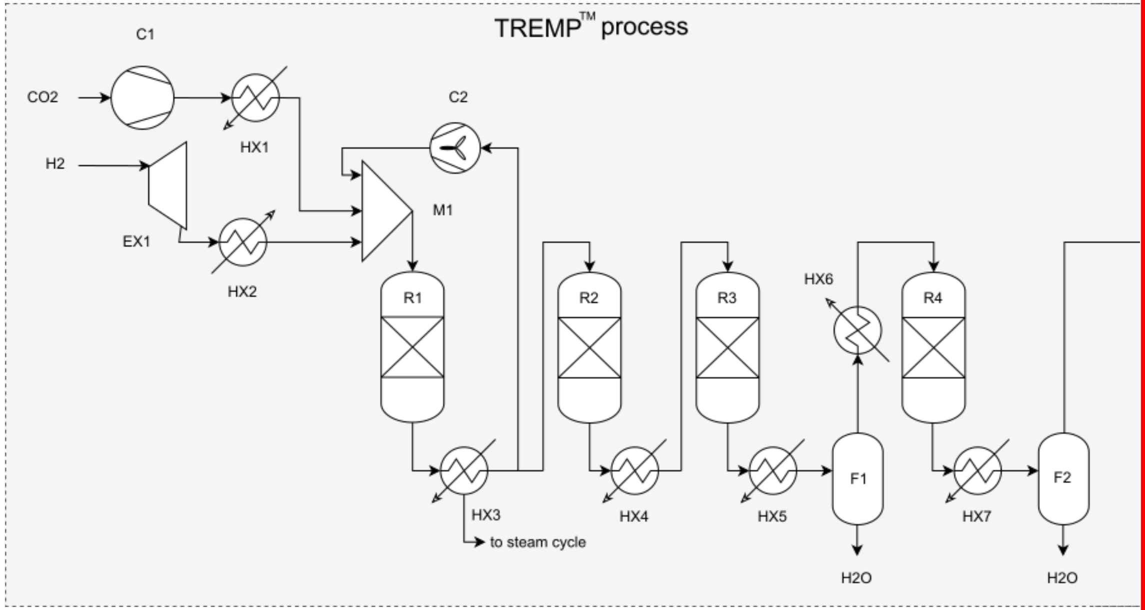
CO_2-certificates prizes need to reach some 1 000 €/t_{CO2}

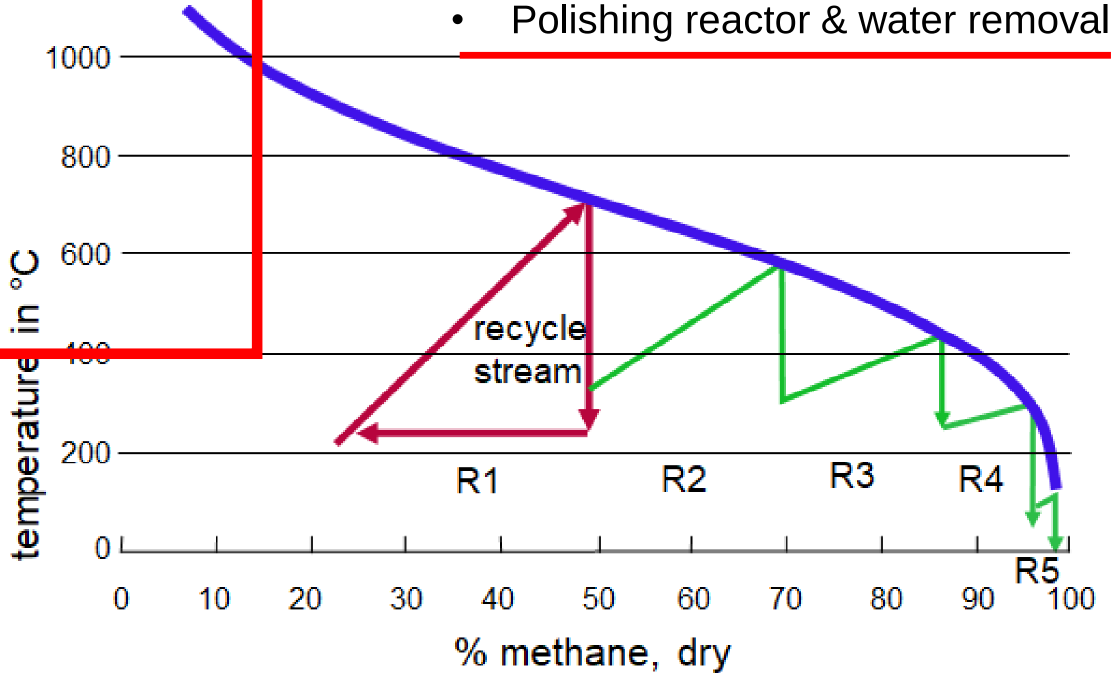
TECHNICAL ASSESSMENT OF SNG / HSNG

Large scale e-Methane production (SNG w. 98 vol.% CH_4)

Advanced TREMP™-process

[1] [2]





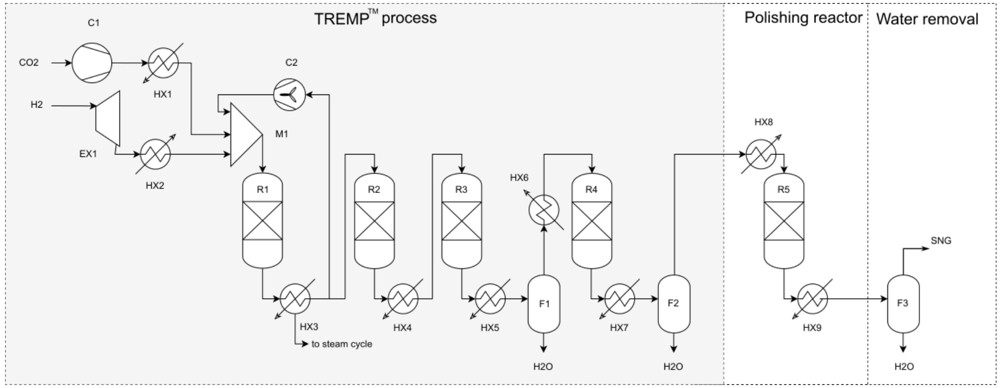
- High temperature in R1
  - Steam cycle
- Composition adjustment
  - Transport: DIN EN 16723-2:2017-10
  - Gas grid: DVGW G260
  - Polishing reactor & water removal

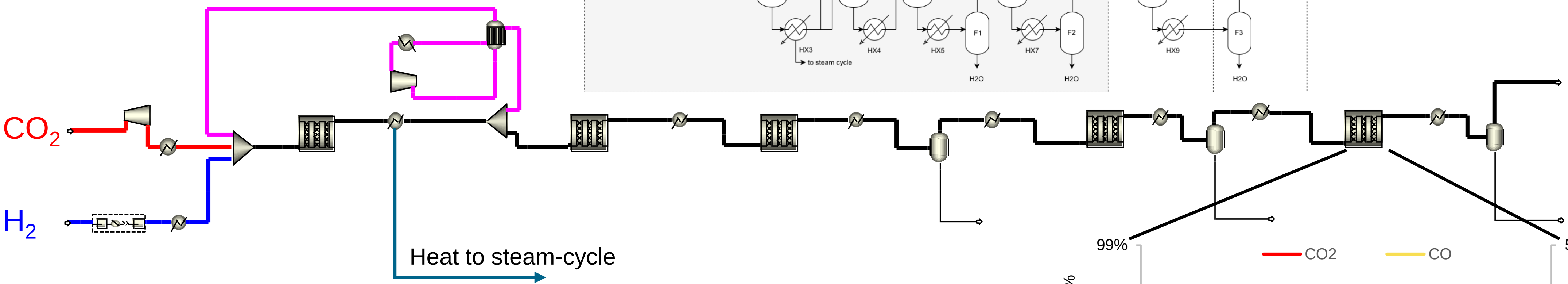
Assumptions in the simulation:
- No impurities
- No side reactions

[1] Rönsch, S., et al., 2016
[2] Heimann, N. et al (2023), Standardized tea of sCNG and HCNG, to be submitted

Large scale e-Methane production (SNG w. 98 vol.% CH_4)

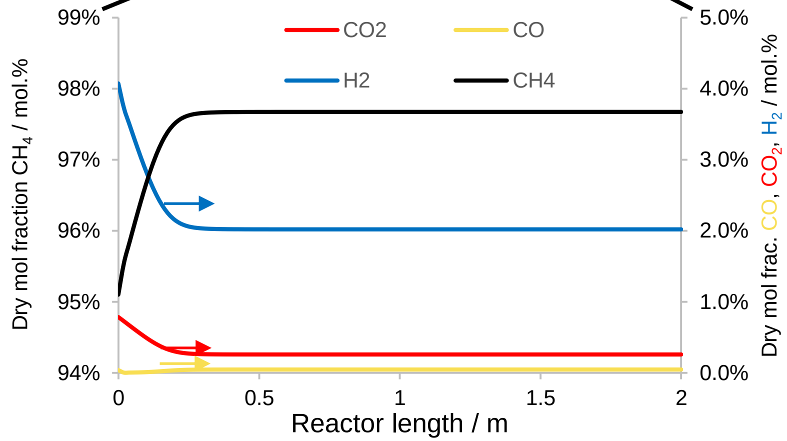
Process simulation Aspen Plus®





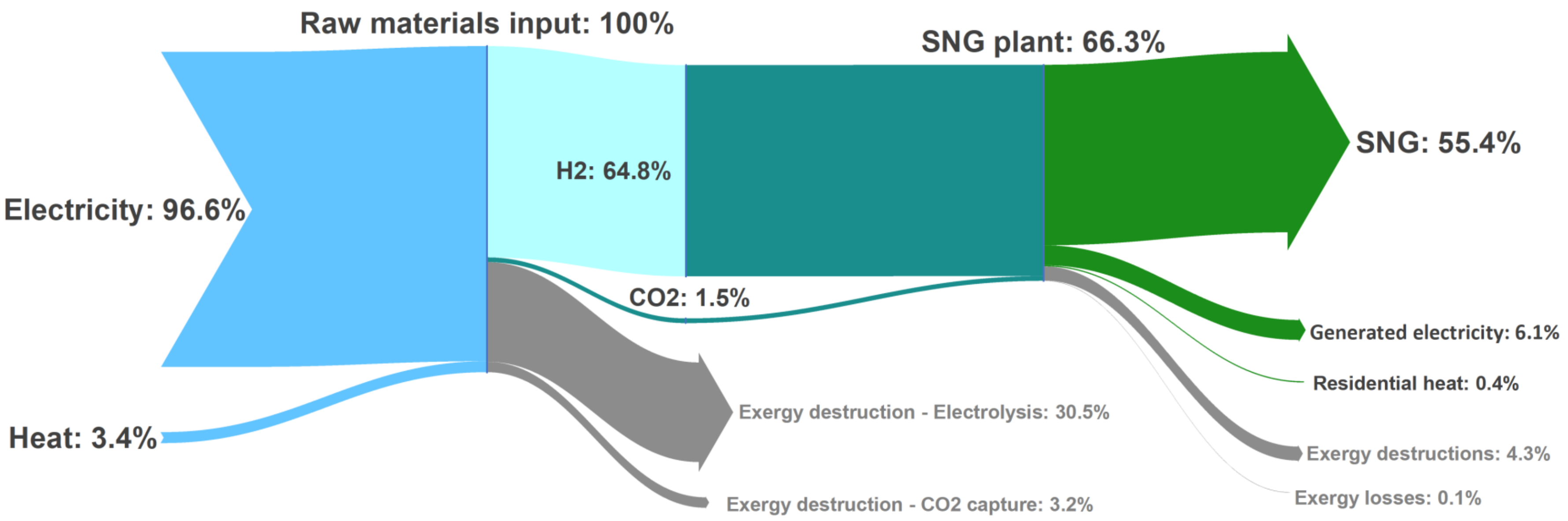
Design spec.:

- CH_4 ≥ 97.7 Vol.%
- H_2 ≤ 2 Vol.%
- CO_2 ≤ 0.3 Vol.%



Large scale e-Methane production (SNG w. 98 vol.% CH_4)

SNG production exergy flow [1]



- Exergy reuse: steam-cycle and residential heat
- Highly exergy efficiency optimized

[1] Heimann, N. et al (2023), Standardized tea of SNG and HSNG, to be submitted

Hythane (HCNG) in transport?

Combifuel project of Graforce GmbH, Berlin [1]

- Plasma-derived HCNG production from wastewater treatment plant
  - up to 60 % H_2 achievable
  - First driver experiences
- Synthetic production of Hythane?

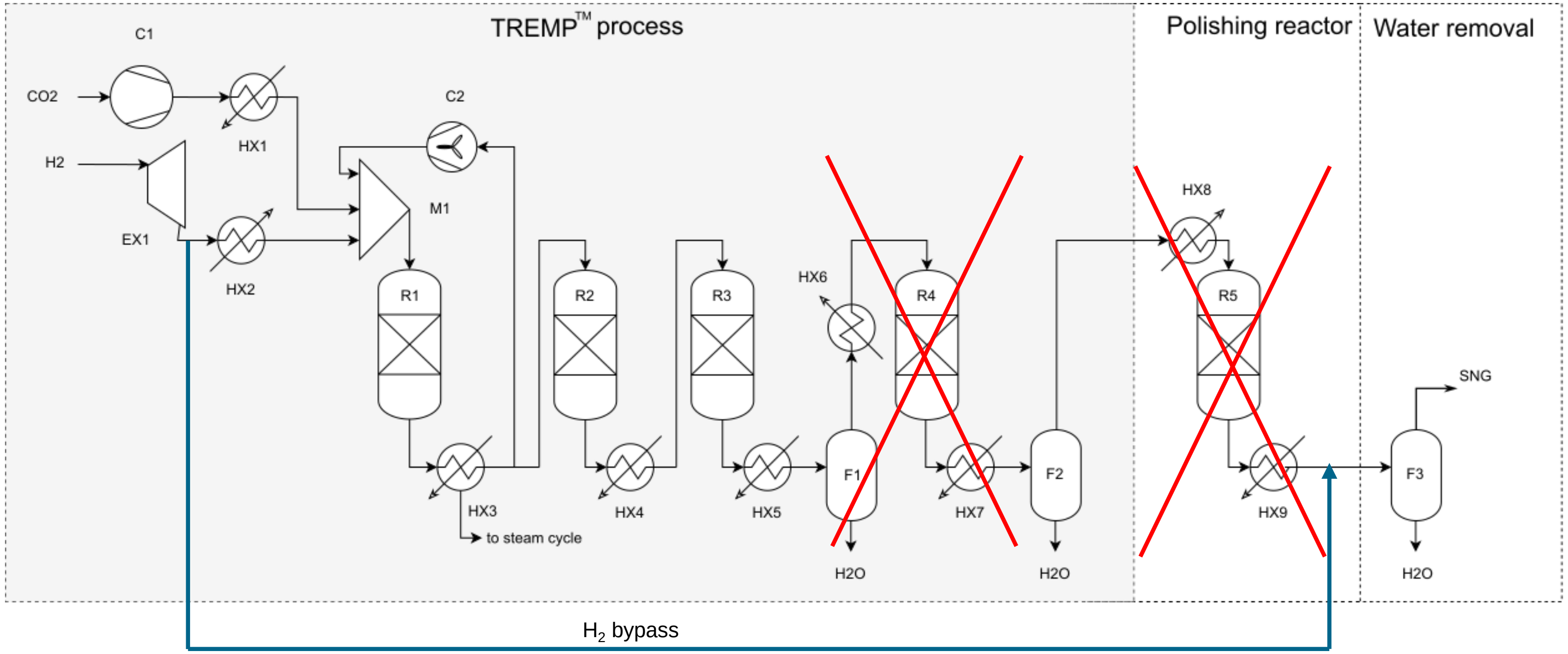
➔ Hythane versus SNG?

[1] Schlussbericht CombiFuel, FKZ 03EIV091A, Graforce GmbH, Synreform GmbH, 2022

Large scale e-Hythane production (HSNG w. 30 vol.% H_2)

Adopted TREMP™ process [2]

[1]



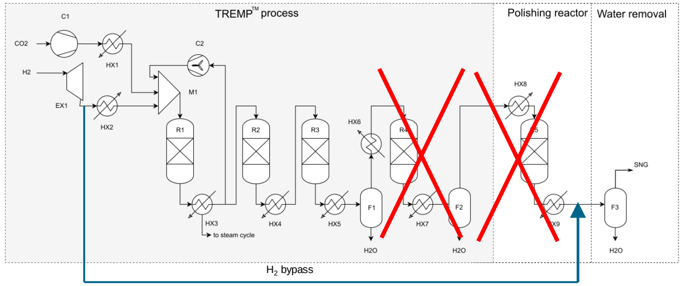
- High temperature in R1
  - Steam cycle
- Composition adjustment
  30 vol.% H_2 content → HSNG-30 [3]
  - Number of reactors reduced
  - Partial H_2 bypass
  - Smaller reactors for same output
  - less H_2O production

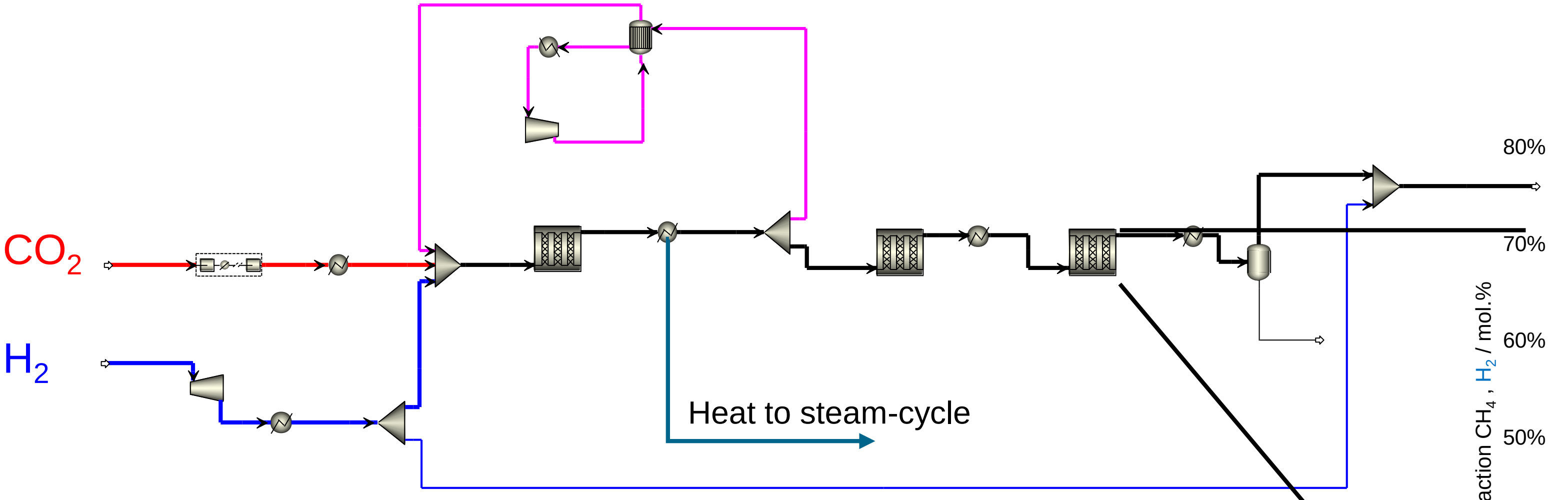
Assumptions in the simulation:
- No impurities
- No side reactions

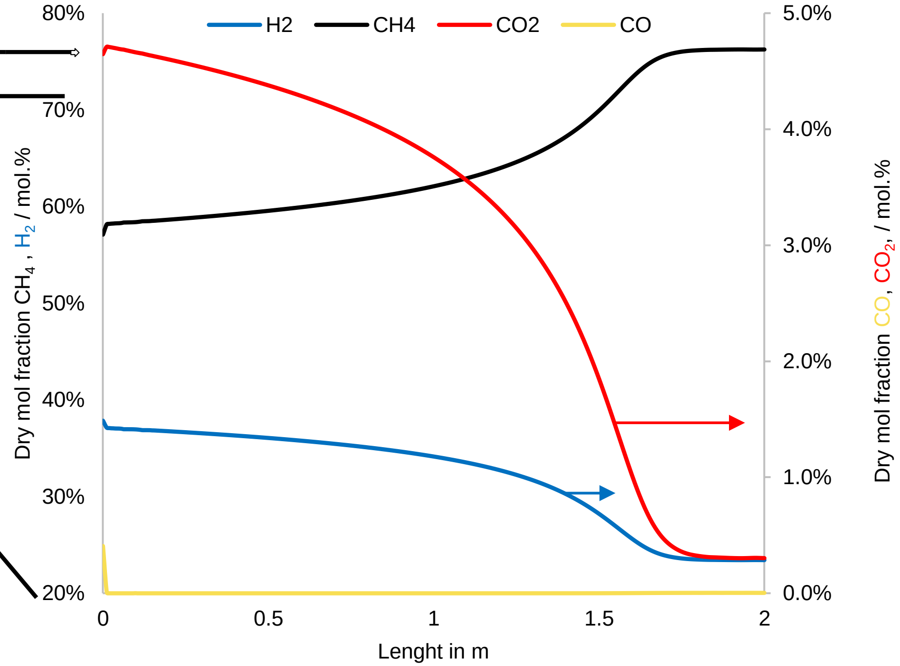
[1] Rönsch, S., et al., 2016
[2] Heimann, et al 2023, to be submitted
[3] Schlussbericht CombiFuel, FKZ 03EIV091A, Graforce GmbH, Synreform GmbH, 2022

Large scale e-Hythane production (HSNG-30)

Process simulation Aspen Plus®





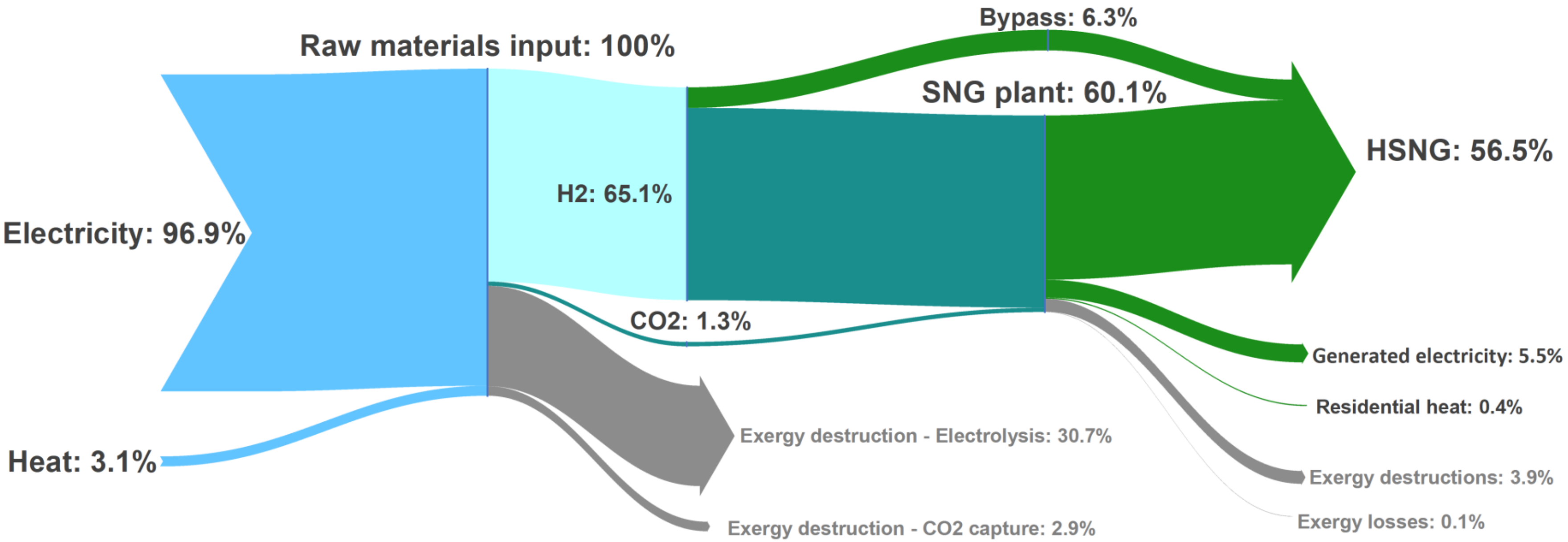


Design spec.:

- $CO_2 \leq 0.21$ Vol.%

Large scale e-Hythane production (HSNG-30)

HSNG production exergy flow [1]



- 1.1 % more power to fuel than SNG
- 5.5 % reused in steam-cycle (compared to 6.1 %)

[1] Heimann, N. et al (2023), to be submitted

ECONOMICAL ASSESSMENT OF SNG / HSNG-30

Comparison of e-fuels

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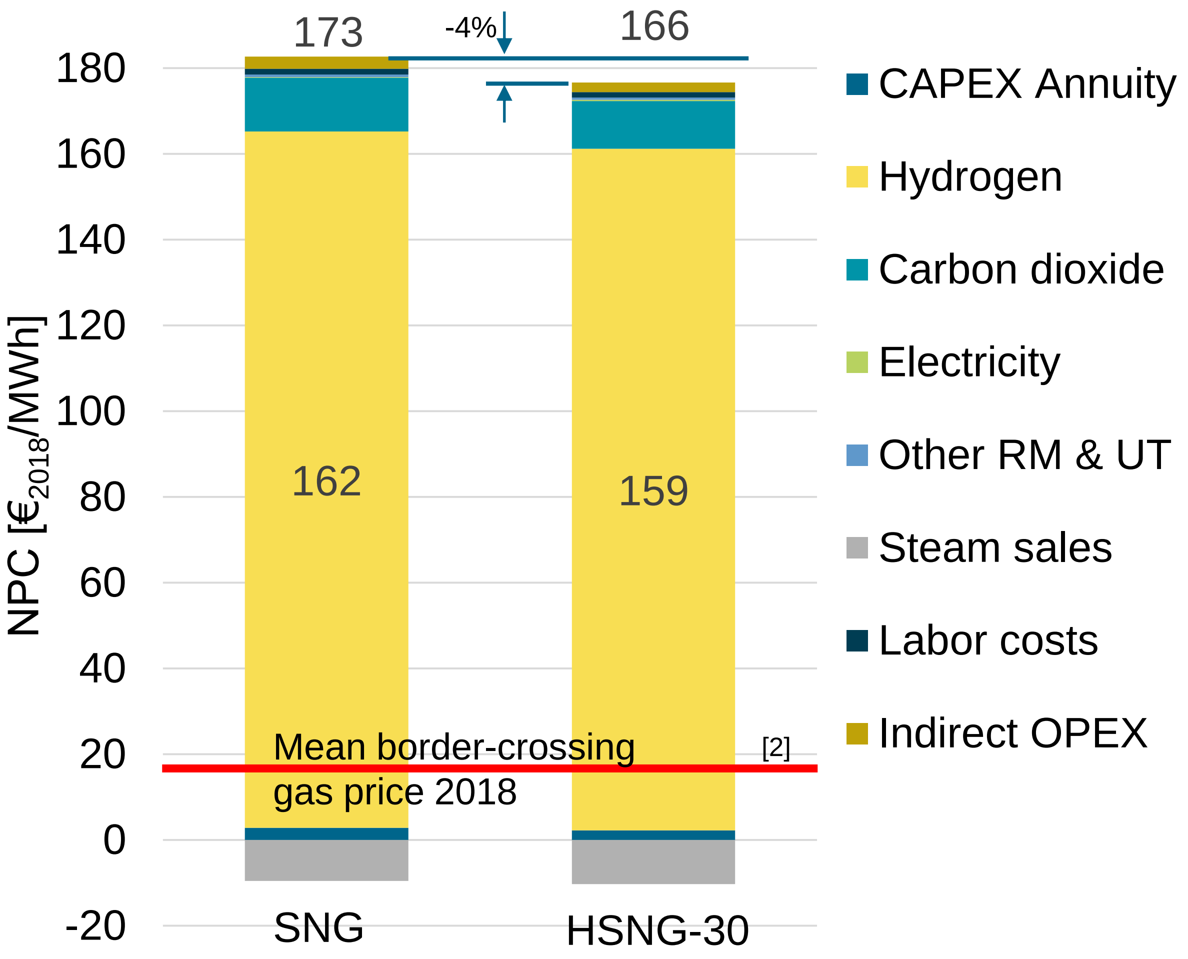
NPC breakdown (electrolyzer excluded)

BEniVer Begleitforschung Energiewende im Verkehr

Basic conditions	[1]
Base Year	2018
Location	Germany
Currency	$€_{2018}$

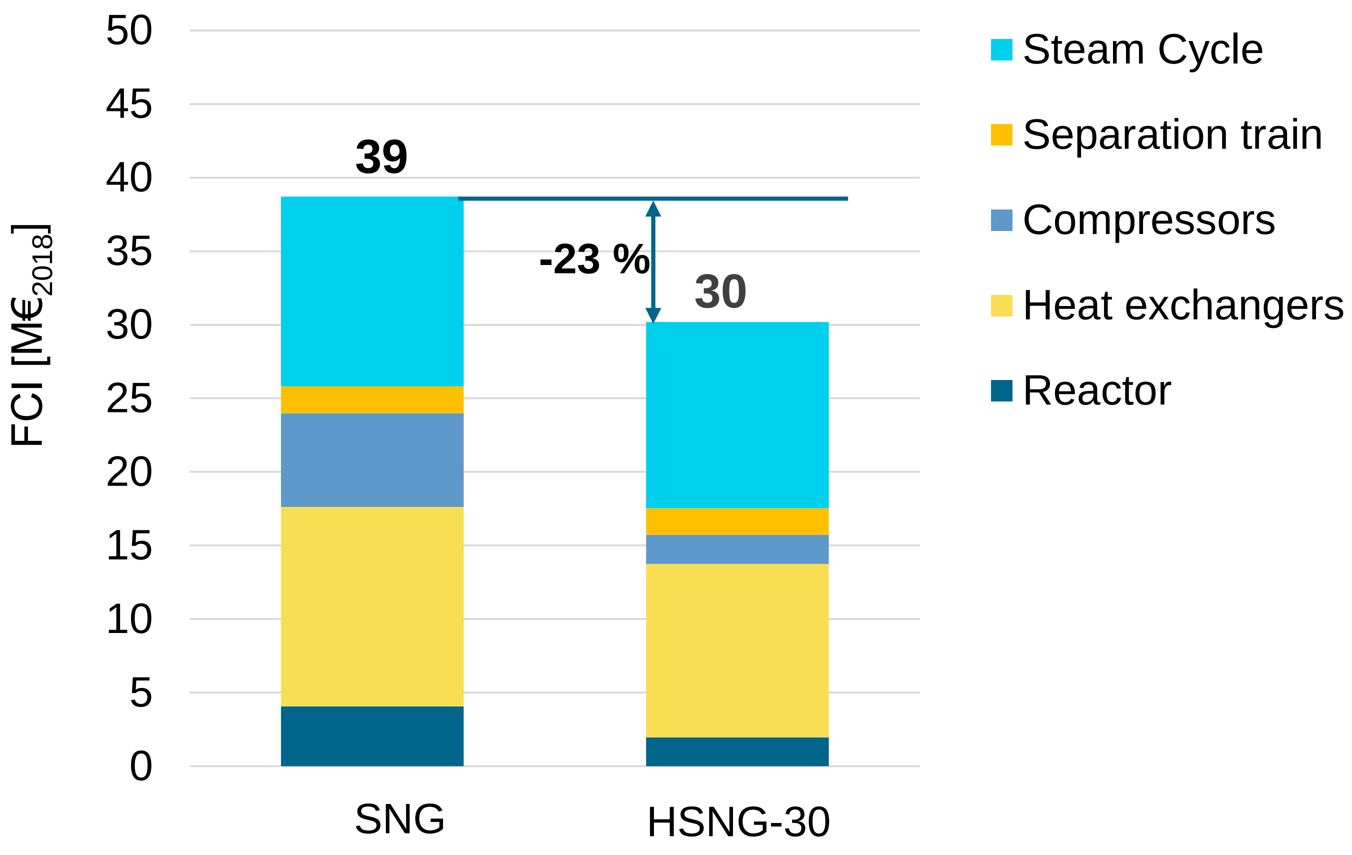


[1] Heimann et. al. 2023, to be submitted
[2] BAFA - Erdgasstatistik

Comparison of e-fuels

BEniVer
Begleitforschung Energiewende im Verkehr

FCI breakdown



FCI reduction for Hythan30 compared to SNG
➔ 23 %

Significant reduction in compressors and reactors

steam cycle, heat-exchangers remain significant FCI

Comparison of e-fuels

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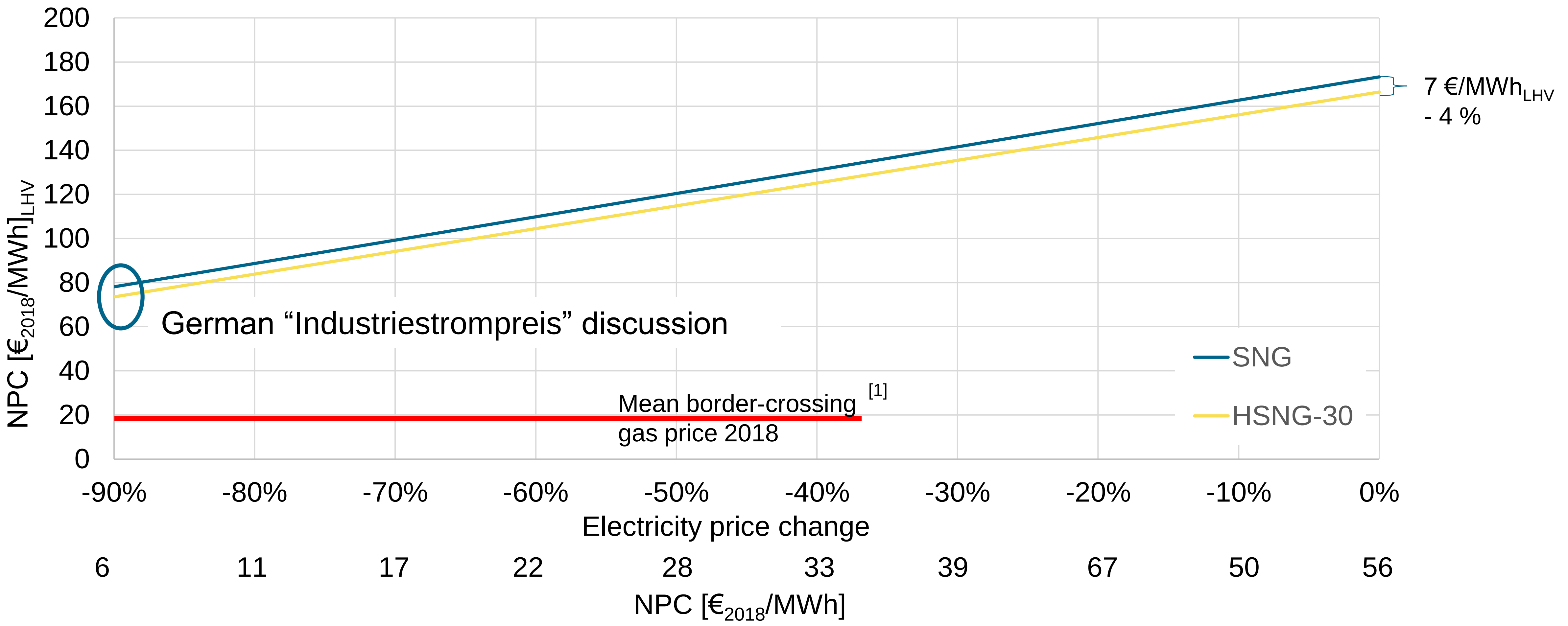
Sensitivity of NPC: electricity price



[1] BAFA - Erdgasstatistik

APPLICATION EXPERIENCE

Practical experience using HCNG in transport [1]

Chemical and Biochemical Engineering – Acting Together

Combifuel project of Graforce GmbH, Berlin

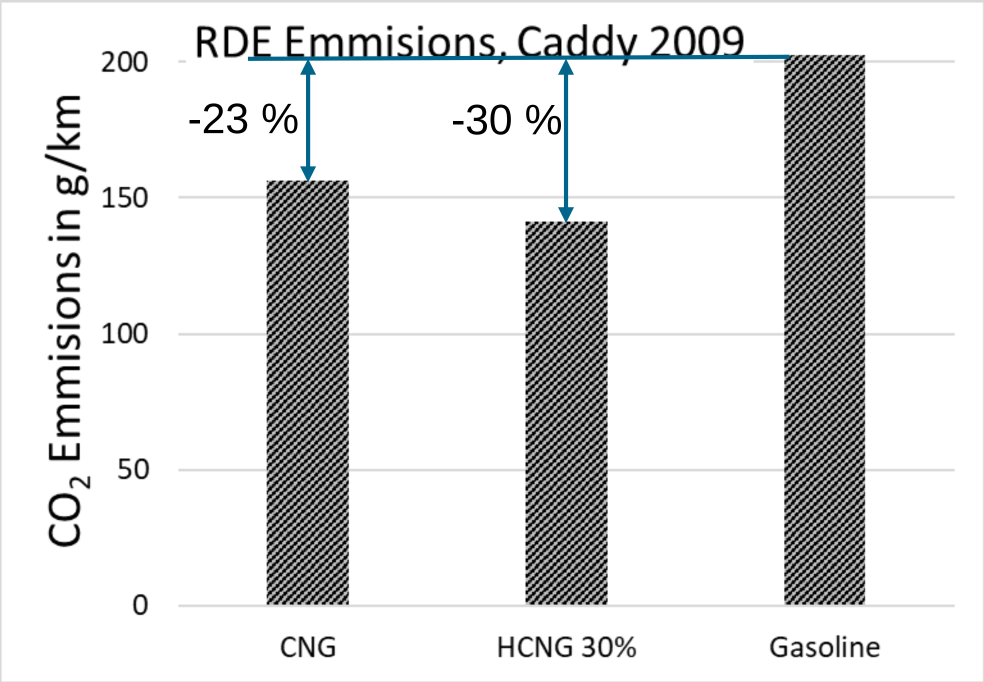
- Application on test fleet
  - Modification of gasoline passenger car (tank system of VW Caddy 2.0 EcoFuel, 2009)
  - Unmodified CNG passenger car (VW Caddy 1.4 TGI, 2020)
- Emission measurement program
  - Motor power testing station (HTW Berlin)
  - Portable Emission Measurement System (real life emissions, TU Berlin)
  - OEM tests (VW Innovation Group, Wolfsburg)

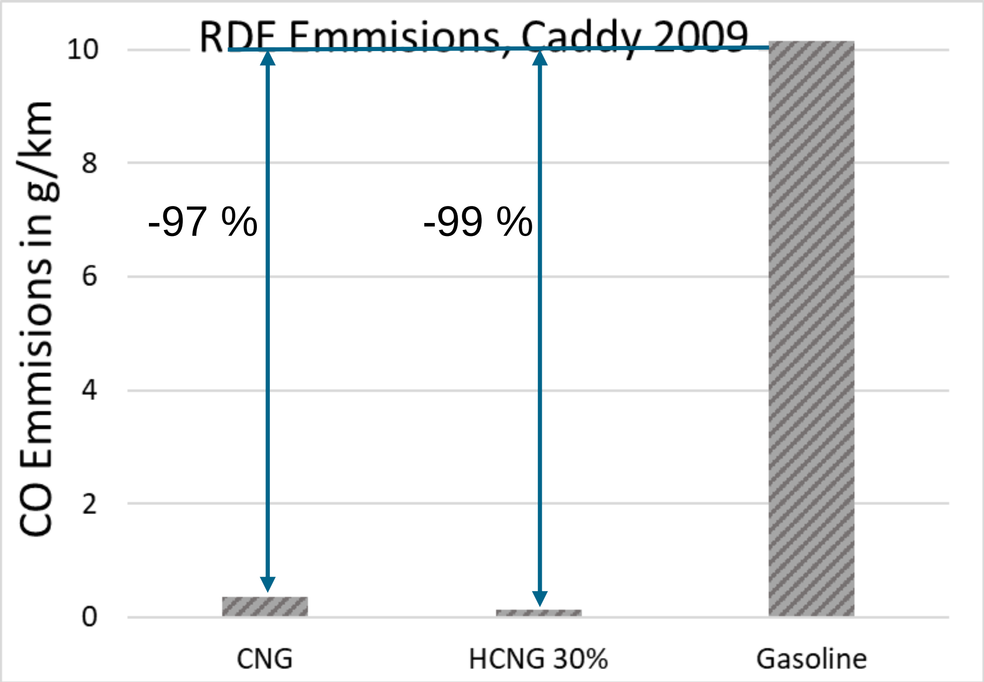
[1] Schlussbericht CombiFuel, FKZ 03EIV091A, Graforce GmbH, Synreform GmbH, 2022

Practical experience using HCNG in transport [1]

Combifuel project of Graforce GmbH, Berlin

- Power decrease 3.3 % HCNG-30 versus CNG @ 3 % less fuel consumption
- Emission reduction for CO_2, CO, HC, increase for NOx





[1] Schlussbericht CombiFuel, FKZ 03EIV091A, Graforce GmbH, Synreform GmbH, 2022

SUMMARY, CONCLUSION

Global e-fuel assessment – Hythane included

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Comparing generic fuels / designer fuels

	SNG	HSNG-30	MeOH	FT	OME_{3-5}	DMC	MeFo
η_{PtF} [%]	57	58	53	40	42	47	52
NPC [$€_{2018}/MWh_{LHV}$]	173	166	204	321	360	329	298
Application parameter examples	• Heavy truck • Drivetrain retrofit • …	• Combifuel • Heavy truck • Drivetrain retrofit • …	• Us... China • Low vapo... •	• Certified ...stainable	• Better combustion • Blendi...	• Better combustion • Blending ratio...	• Better combustion • Blending ratio...

HSNG-30 can be produced with highest efficiency
cheapest e-fuel of EiV
Ecological assessment still pending
Application assessment just started

Opportunities and challenges for electro-fuels in future aviation

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Summary

- Sustainable transport ➔ cheap, sustainable, scalable fuels required
- Cheapest carbon containing e-fuels are methane and hythane
- HSNG-30 (compared to SNG)
  - Efficiency: +1 %
  - NPC: -3.9 %
  - FCI: - 23 %
  - less emissions in production and drive tests

➔Outlook: Identical HSNG spec. for both heat and transport applications

Transparent, standardized DLR assessment methodology available

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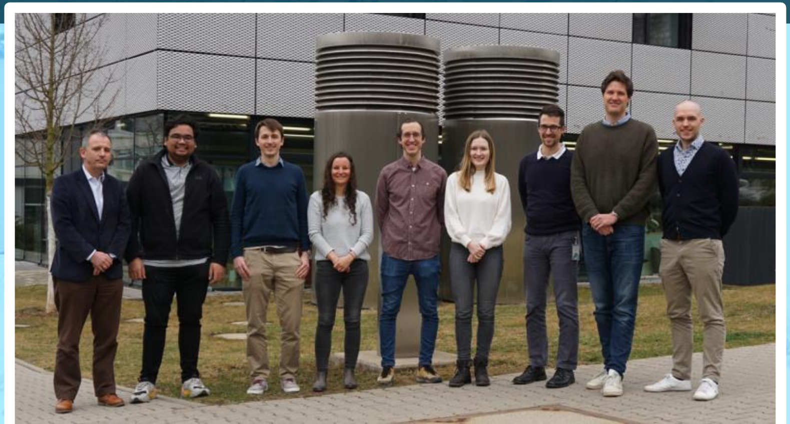
THANKS TO THE TEAM.
THANK YOU FOR YOUR ATTENTION.
QUESTIONS?

Techno- economic evaluation of the synthetic production of compressed natural gas (SNG) and hydrogen compressed natural gas (HSNG) for the future sustainable transport in Germany



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