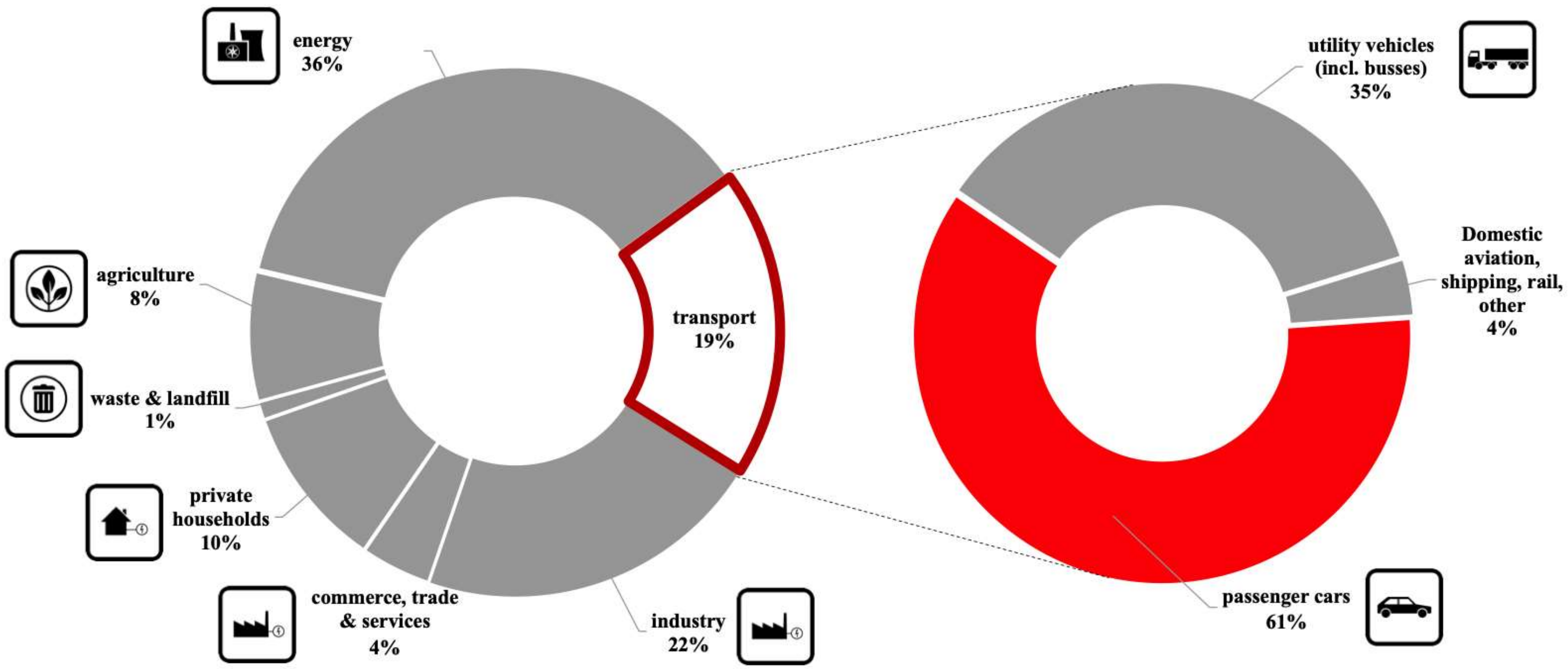
Oil Scenarios: Future Components

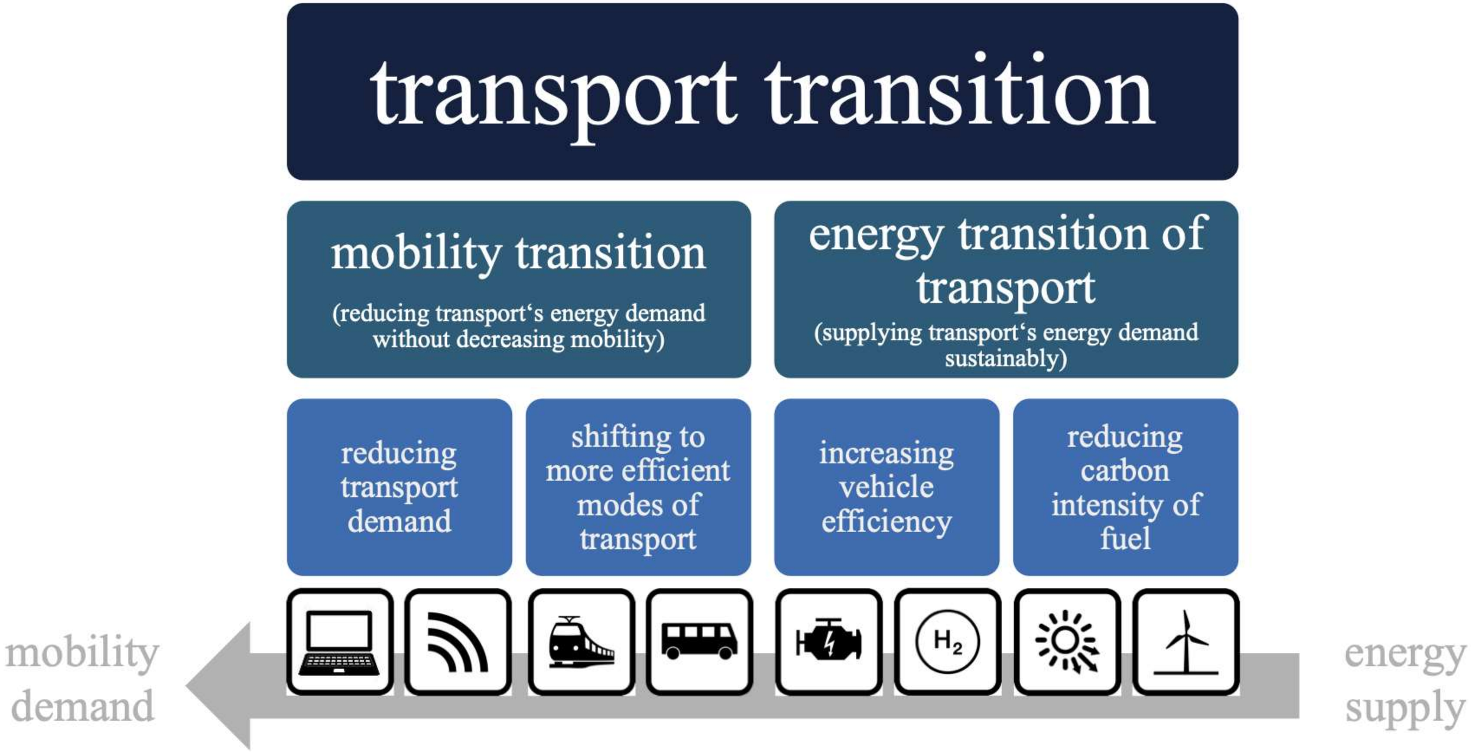
Prof. Dr. Frank Behrendt | Institute of Energy Engineering | CAETS 2021 – The Future of Energy

Share of transport in German greenhouse-gas emissions



Source: BMU – Klimaschutz in Zahlen (2019)

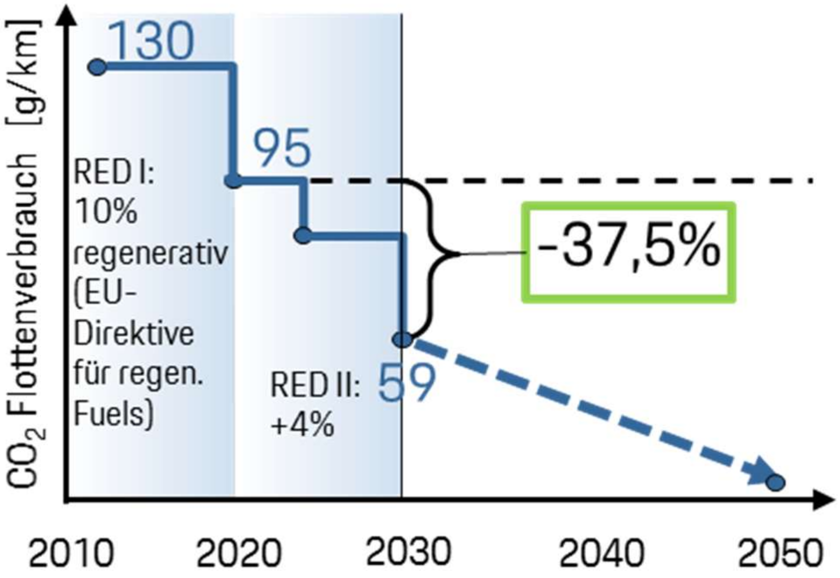
Guiding elements of a sustainable transformation of the transport system



Sources: Agora-Verkehrswende (2019), PhD thesis A. Wanitschke, TU Berlin (2021)

Pressure to act due to legal requirements

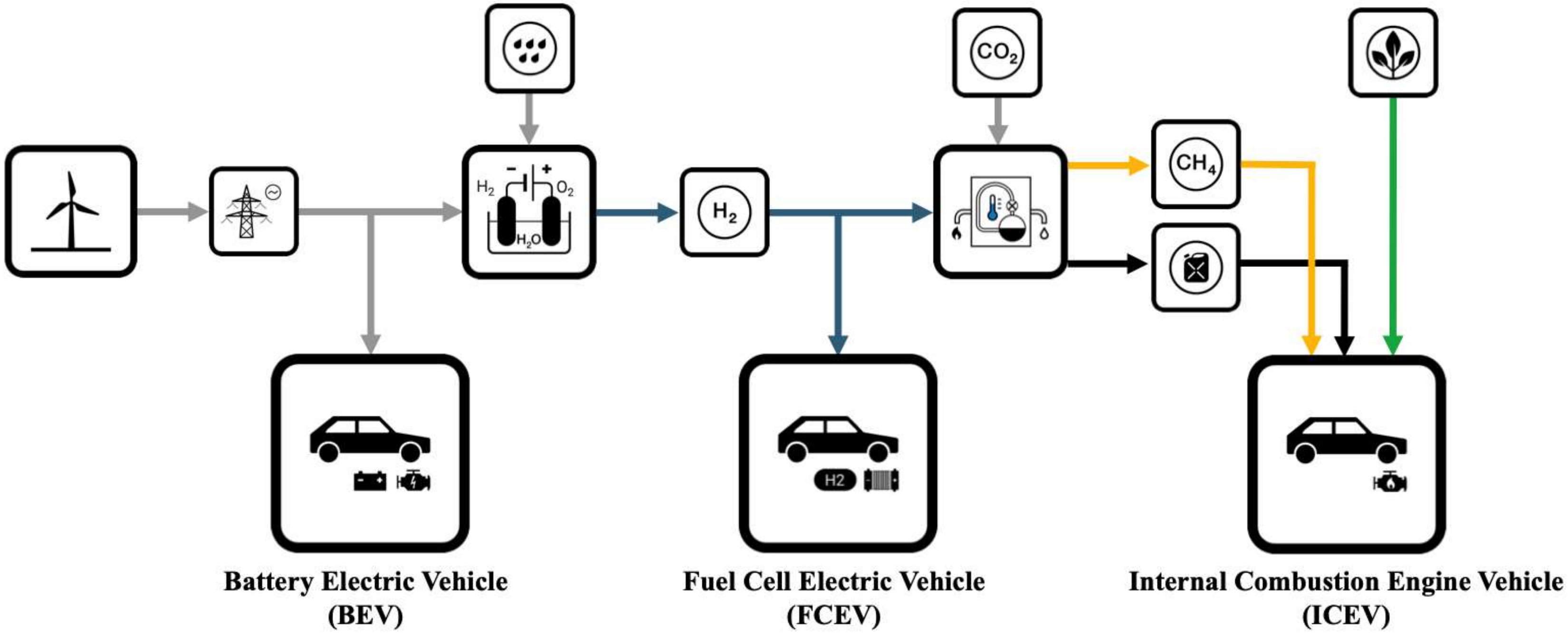
CO_2 regulation EU post 2020
(New-car fleet consumption
+ RED II (for energy carriers))
Review 2018 (every 5 years)



Quelle: VDA 2019

- 75 - 85% of CO_2 emissions occur during the use phase of a vehicle
- Green setting of the use phase

Technology options for a low-carbon transport sector



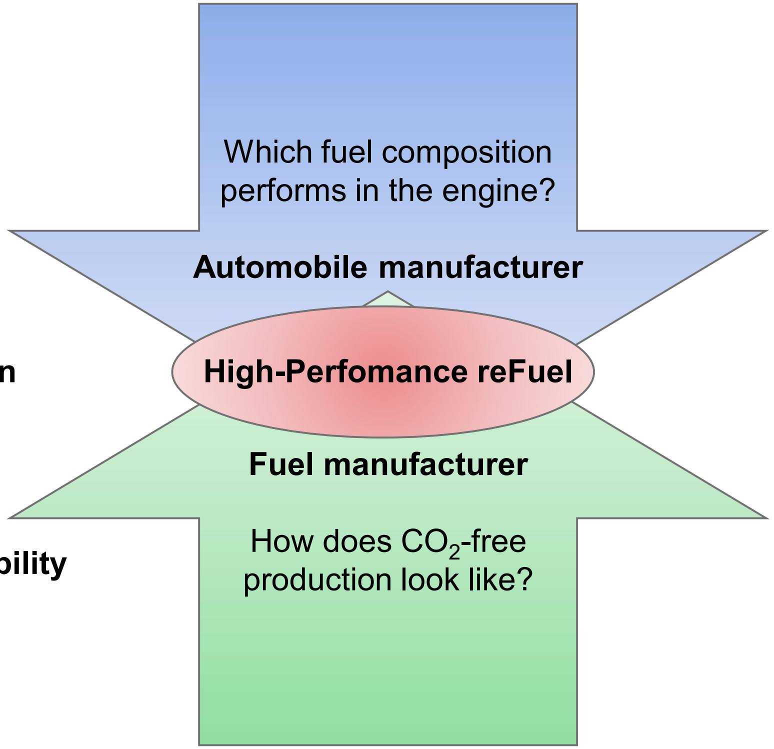
Source: PhD thesis A. Wanitschke, TU Berlin (2021)

Important aspects of fuel design

Performance
- Energy density
- Knock resistance
- Emissions
- Compatibility
- Standard

Business Model
- Laws
- Global market
- Sector coupling

Exchange of information



Cooperation

CO_2-free manufacturability
- Process development
- Industrialisation
- Economic efficiency

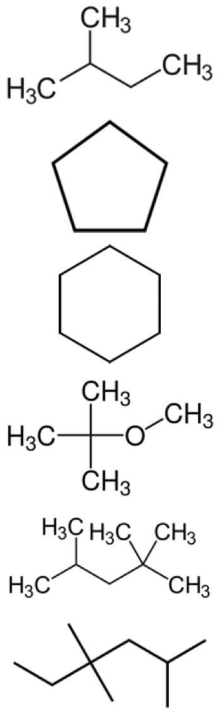
Environmental compatibility
- Environmental and social sustainability
- Safety compliance

Source: Master thesis A. Shamshidin, TU Berlin (2019)

Fuel design - Modular petrol system

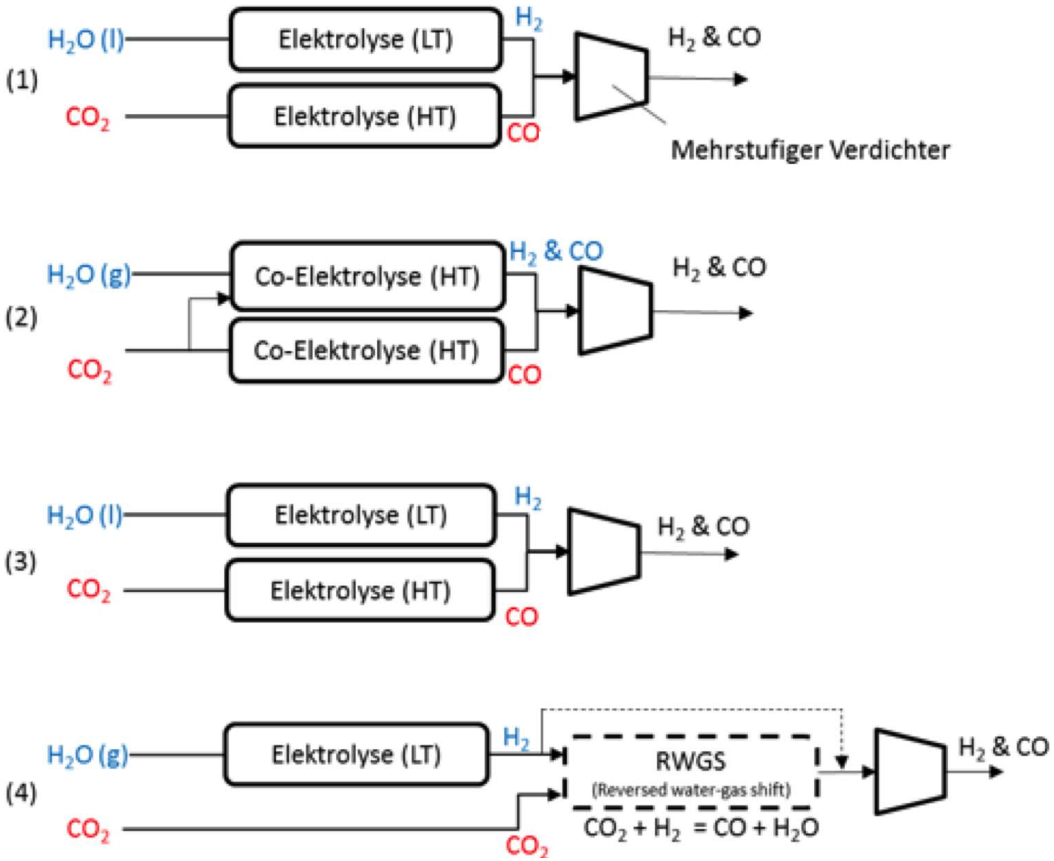
- Simulation of the physico-chemical properties of different fuel compositions (software from MiRO)
- Experimental validation of the results

No	Substance groups	Mass fraction	Function
1	C5-Isoparaffins	10 %	Adjustment of the vapour pressure Smoothing of the boiling process
2	C5-Naphthen	22 %	Adjustment of the vapour pressure and volumetric density
3	C6-Naphthen	10 %	Adjustment of volumetric density
4	Oxygenat	15 %	Increase of knock resistance and adjustment of volumetric density
5	C8-Isoparaffin	36 %	Base fuel (RON~100)
6	C9/10-Isoparaffin	6 %	To adjust the boiling point and volumetric density



Source: Master thesis A. Shamshidin, TU Berlin (2019)

Manufacturing pathways of e-fuels: Fischer-Tropsch and Methanol-to-Gasoline synthesis



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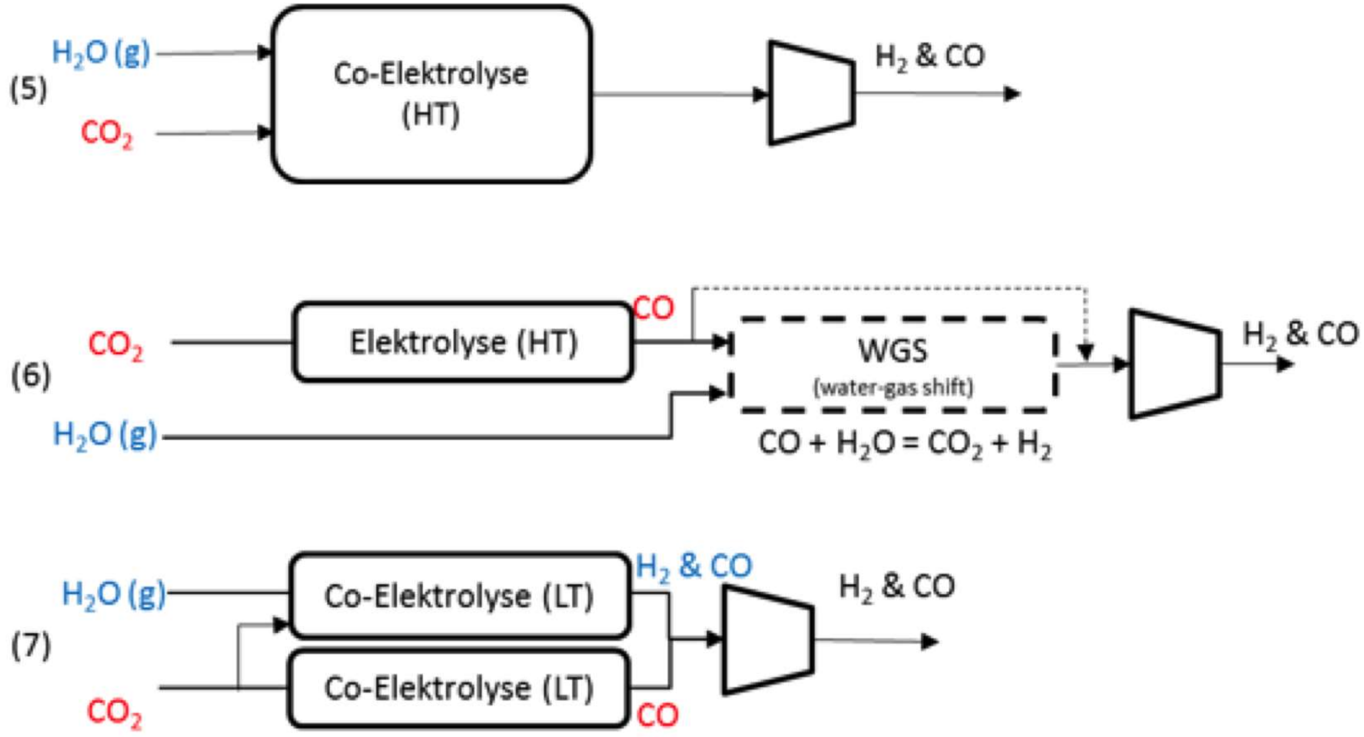
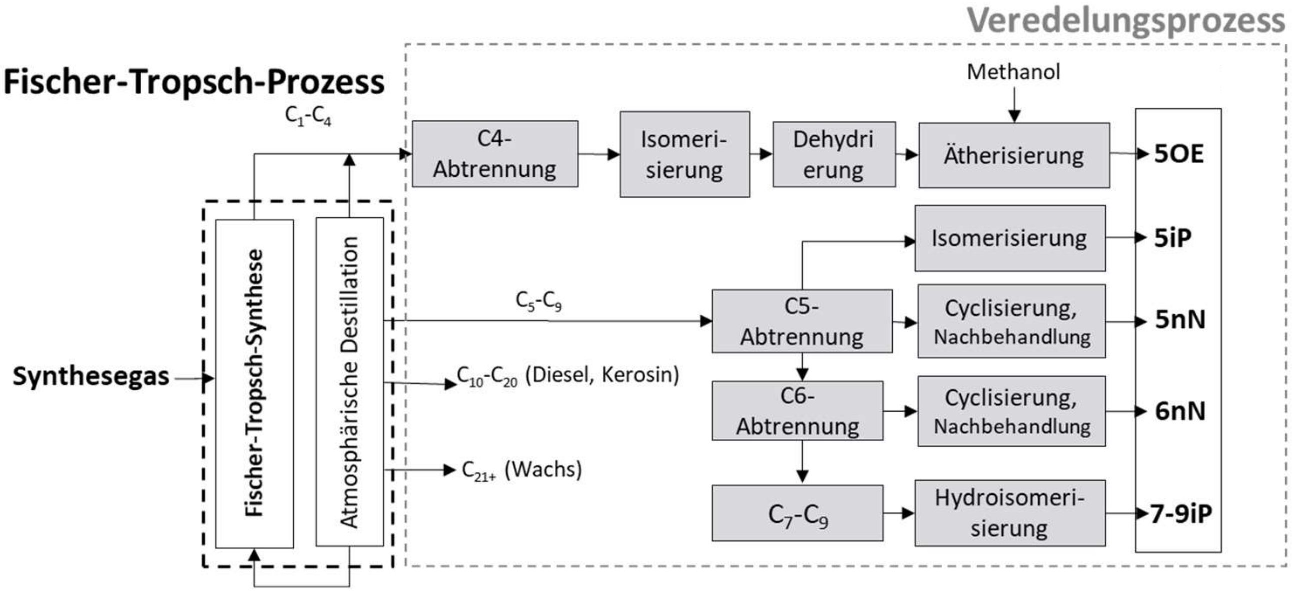


Source: Master thesis A. Shamshidin, TU Berlin (2019)

Evaluation of the manufacturing pathways: Fischer-Tropsch synthesis

$$n\,CO + (2n+1)H_2 \rightarrow H(CH_2)_nH + n\,H_2O$$ n = 1 … 200



Yield 80-95 %

Classical FT process

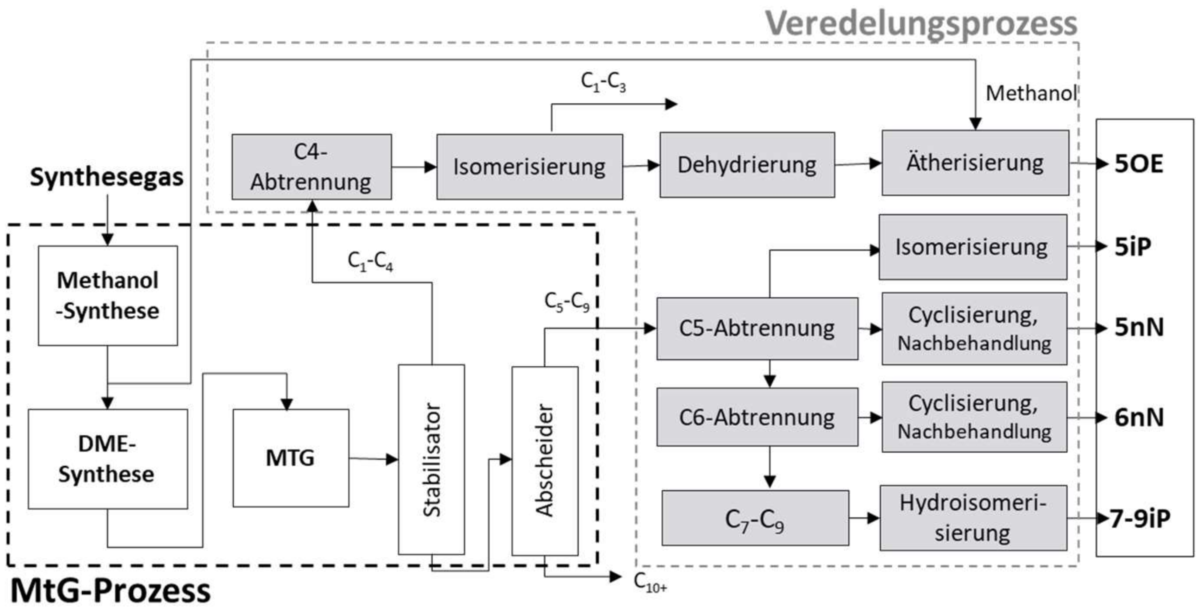
Catalyst: cobalt-based
Pressure: 20 - 70 bar
Temperature: 180 - 250 °C

Reactor types:
Multiple fixed-bed reactors,
Slurry reactors

Source: Master thesis A. Shamshidin, TU Berlin (2019)

Evaluation of the production pathways: Methanol-to-gasoline synthesis

$$n\,CO + (2n+1)H_2 \rightarrow n\,CH_3OH \rightarrow \frac{n}{2}CH_3OCH_3 + \frac{n}{2}H_2O \rightarrow (CH_2)_n + n\,H_2O \quad n = 1 \ldots 20$$



Yield 80-95%

MtG process from Exxon

Catalyst: ZSM
Pressure: 22 bar
Temperature: 360 - 415 °C

Reactor:
Multiple fixed-bed reactors

Source: Master thesis A. Shamshidin, TU Berlin (2019)

Evaluation of the production pathways: Comparison of FT and MtG synthesis

Comparison criteria	Fischer-Tropsch-Synthesis	Methanol-to-Gasoline
TRL	9	8
Selectivity	21 – 43 %	48 – 95 %
Carbon efficiency	80 – 95 %	80 – 95 %
Carbon efficiency target fuel	17.7 – 45.7 %	69.3 – 82.3 %
Chem. energy efficiency	60.7 – 75.0 %	60.2 – 71.5 %
Energy eff. target fuel	13.8 – 36.5 %	52.5 – 62.3 %
Prim. energy consumption [$MJ/MJ_{Product}$]	1.91 – 2.28	1.90 – 2.25
Prim. energy consumption target fuel [$MJ/MJ_{target\ fuel}$]	3.97 – 10.15	2.18 – 2.58

Carbon efficiency

$$\mu_C = \frac{\sum \dot{m}_{Produkt} \cdot w_{C,Produkt}}{\sum \dot{m}_{Edukt} \cdot w_{C,Edukt}}$$

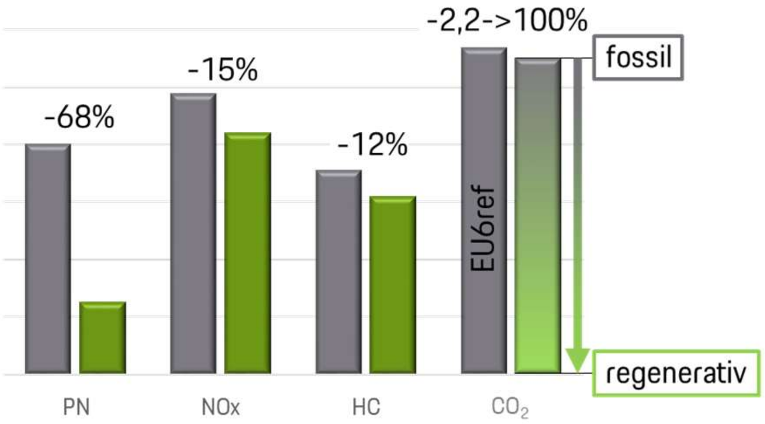
Chemical energy efficiency

$$\eta = \frac{\sum m_{Produkte,i} \cdot HHV_{Produkte,i}}{\sum m_{Edukte,j} \cdot HHV_{Edukte,j}}$$

Source: Master thesis A. Shamshidin, TU Berlin (2019)

Positive potential of fuel design

Starting point



Fahrzeugmessungen mit Kraftstoffen auf Basis EN 228

Optimisation of the composition

- Ecological improvement
- Manufacturability
- Conformity to standards (EN 228)
- Cost

Target fuel

Developed on the basis of a paraffinic first-fill petrol

With synthetic fuels, emissions from existing vehicles can be reduced. With renewably produced fuel, almost no new CO_2 emissions are released.

Source: Master thesis A. Shamshidin, TU Berlin (2019)

Summary and outlook

Fuel design

- Modular petrol fuel system as orientation for fuel design within the EN 228 standard

Evaluation of the production pathways

- MtG pathway has more than 2x selectivity for synthetic target fuel than FT pathway

Cost model for calculating re-fuel costs: 0.88 - 1.20 €/l

Roadmap for CO_2 reduction up to 80% in the automotive industry


Thank you very much for your attention

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