ASME ICEF 2022 Internal Combustion Engine Fall Conference

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University of Stuttgart
Institute of Automotive Engineering (IFS)

CO_2-neutral mobility
powertrain systems
electric/molecular energy carriers

potential for eFuels as a drop-in replacement for ICE

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Institute for Automotive Engineering,
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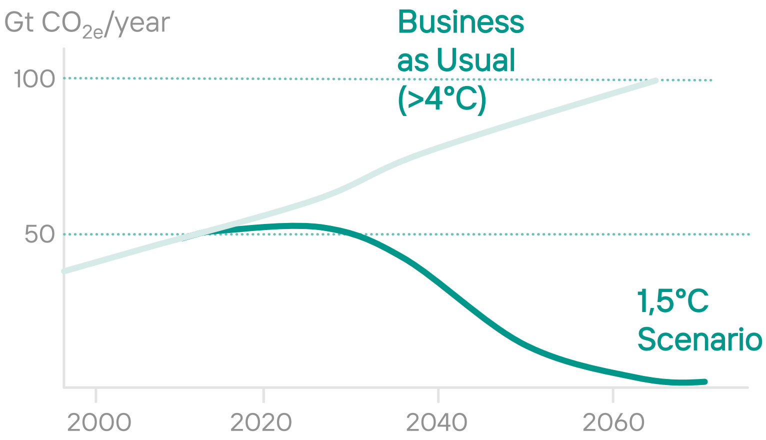
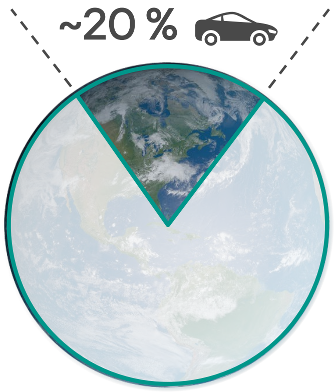
13.04.2022 ASME Webinar ICEF 2022

Paris Climate Agreement

Commitment needed!





- Is electrification of new cars enough for sufficient GHG reduction?
  → unfortunately not!
- Is there enough renewable electricity and infrastructure?
  → build-up necessary!
- How can we involve the existing car fleet?
  → with eFuels!

PARIS2015 COP21·CMP11

Only sustainable resources harvesting and drastic decrease in additional CO_2 emissions can reduce the climate change impact

Worldwide road transportation (1.4 billion vehicles) is responsible for approximately one fifth of the global CO_2 emissions

IEA 2021 report: global pathway to net zero CO_2 by 2050

Sustainable mobility will be possible by electrification + renewable fuels$_{\text{CO2-neutral}}$

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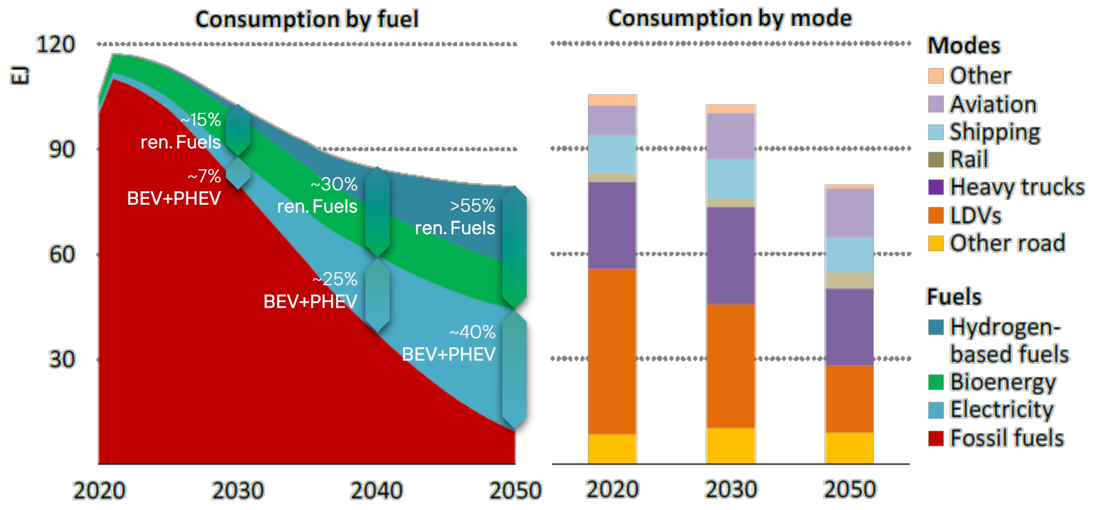
Future mobility trends

- Integrated mobility
  - Autonomous driving
  - Connectivity
  - Shared mobility
- Electrification

Figure 3.22 ▷ Global transport final consumption by fuel type and mode in the NZE global pathway to net-zero CO_2 emissions in 2050



Electricity and hydrogen-based fuels account for more than 70% of transport energy demand by 2050

Note: LDVs = Light-duty vehicles; Other road = two/three wheelers and buses.

Source: International Energy Agency, 2021 Report
*renewable Fuels: CO_2-neutral bioFuels and eFuels

Lifecycle CO_2 of BEV vs ICEV compact class vehicles

Renewable energy carriers (electric or molecular) lead to a diverse future!

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Input variables

Vehicle basis

- Golf 8 and ID.3: production, utilization 200,000 km
- Most representative engine-gearbox combination and standard equipment
- Maintenance: Flat rate derivative
- ID.3 (1st Edition) Range: 440km

Fuel and power consumption (well-to-tank)

- EU fuels
- Energy mix EU-27

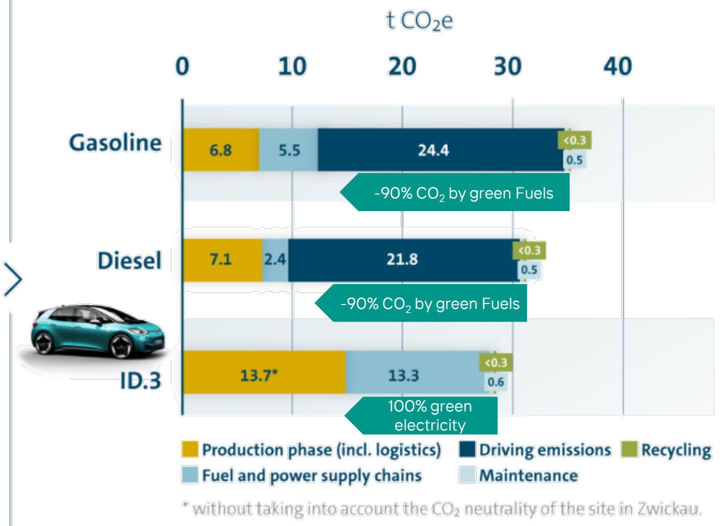
Consumption data (tank-to-wheel)

- WLTP

BEV

- 62 kWh NMC 622 lithium-ion battery, one battery over entire service life

Comparison vehicles have similar equipment and performance.



Zero g_{CO2} emission vehicle (or ZEV) does not exist. But circular CO_2 economy can, by reusing CO_2 (closed-cycle-CO_2) for electricity and renewable fuels

Source: Volkswagen

ID.3 Electricity consumption combined 15.4 - 14.5 kWh/100 km; CO_2 emissions combined 0g/km, efficiency class A+

Fig.1 CO_2 balance comparison of electric, diesel and gasoline vehicles in the European compact class.

https://www.volkswagenag.com/en/news/stories/2021/02/e-mobility-is-already-this-much-more-climate-neutral-today.html

Green hydrogen based eFuels production

e.g. MtG path

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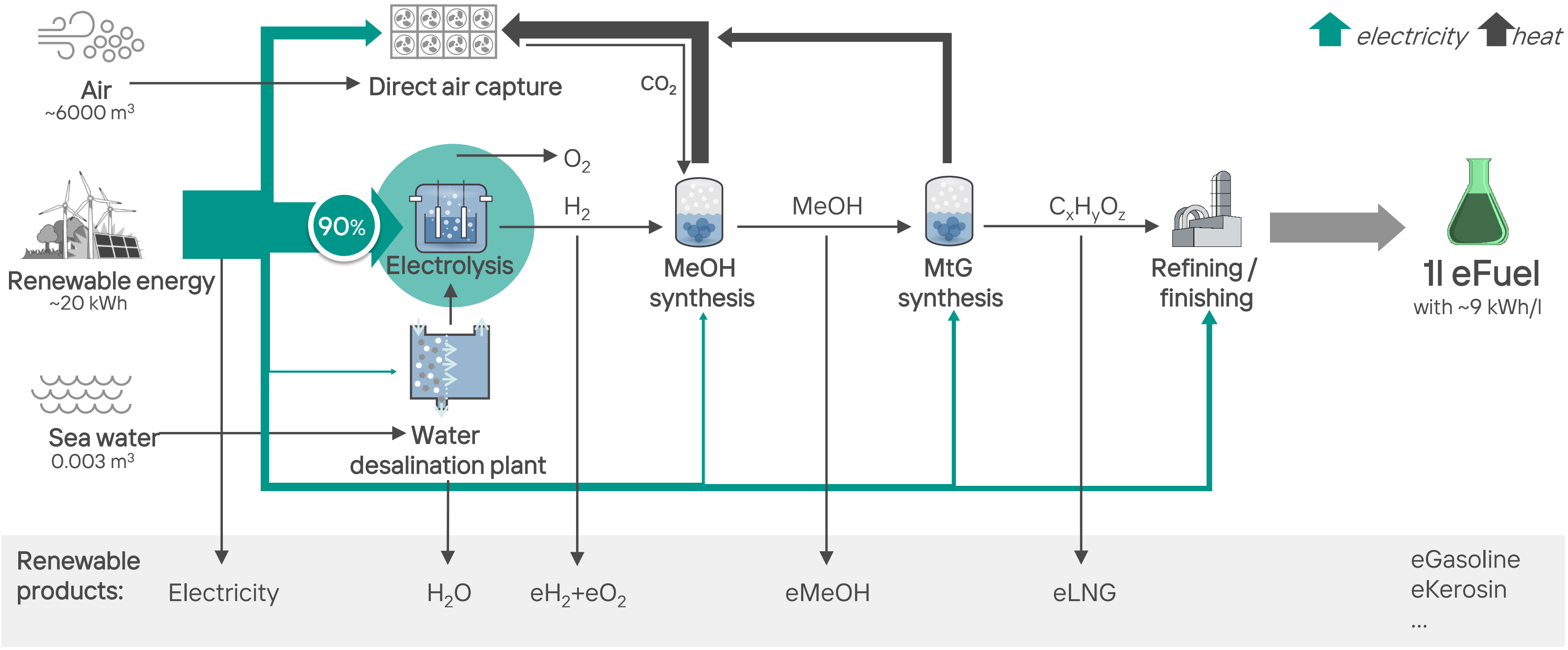

Source: SAE Capri 2021 "eFuels: a further step towards sustainable mobility", A. C. Kulzer, keynote speech

Industrialization of eFuels is a worldwide task

Relevant issues: renewable energy cost, population density, technology competence, competitive situation

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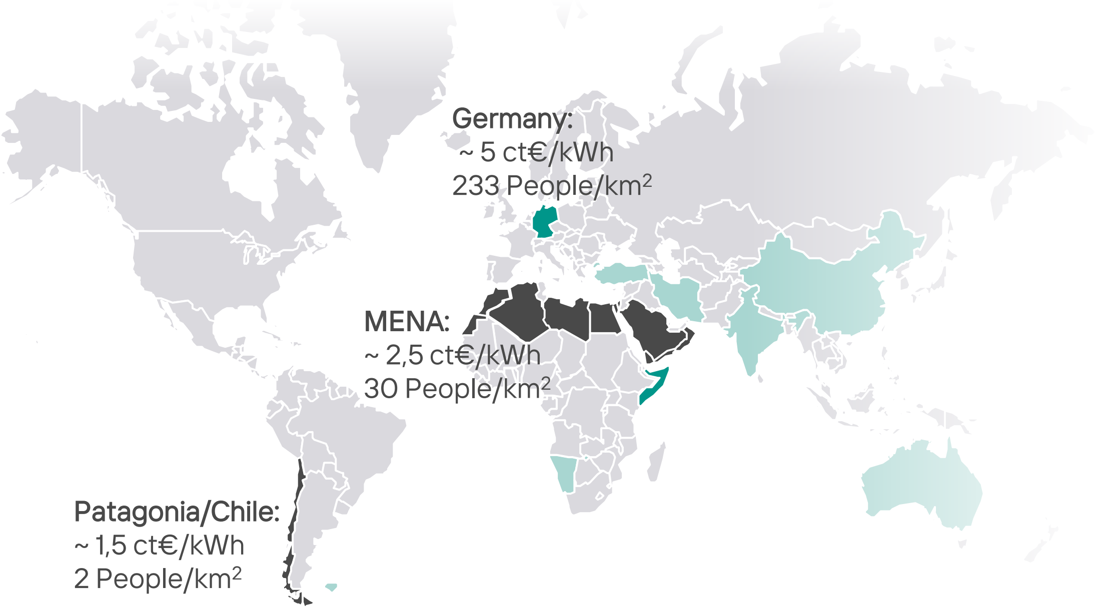
Worksplit/assets on the path to eFuels:

Technology driven countries

- Drivers of international defossilization
- High technological competence
- Development of large industrial projects

MENA/Chile/...

- Competence and experience in developing regional projects
- Best locations for renewable energy guarantee w/ competitive costs
- Surplus of renewable energy
- Readiness for economic participation



Source: LBST International Hydrogen Strategys 08/2020, Statista BMBF 2020; Dr. Ing. h.c. F. Porsche AG; Frontier Economics

eFuel price can compete with fossil fuel prices

CO_2-closed cycle (neutrality) regulatory influence reasonable and necessary

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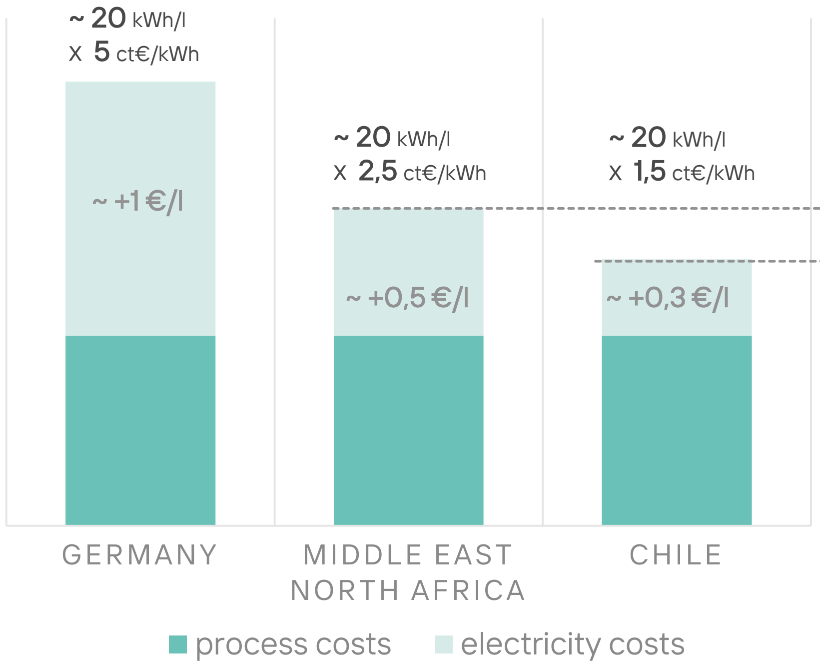
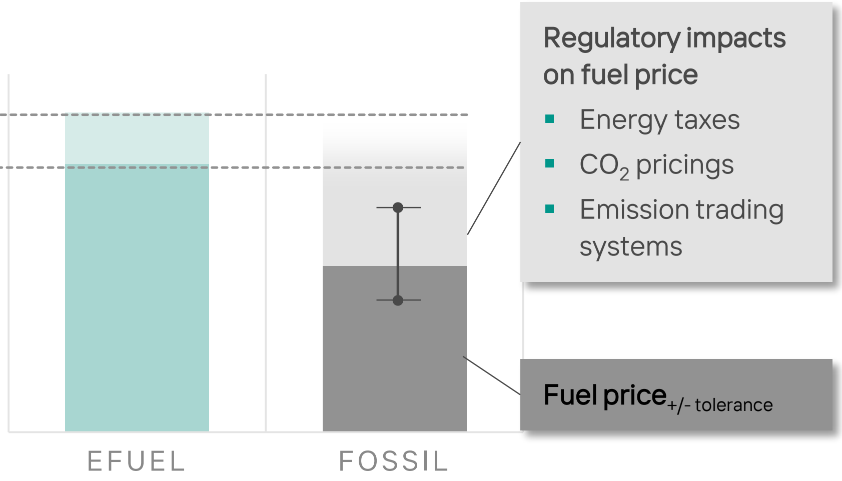
eFuels large scale production cost



Comparison of eFuel vs. fossil fuel



Source: SAE Capri 2021 "eFuels: a further step towards sustainable mobility", A. C. Kulzer, keynote speech; fossil fuel prices adapted (April 2022)

Haru Oni – strong wind!

eFuels pilot plant

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Pilot plant for technology verification of the interlinked process steps:

- Technology path: from power supply to finished eGasoline.
- Process steps: Wind power, direct air capture, electrolysis, methanol synthesis, gasoline synthesis.
- Partners:

Source:
https://www.haruoni.com/#/en
https://www.siemens-energy.com/global/en/news/magazine/2021/haru-oni.html
https://newsroom.porsche.com/en/2021/company/porsche-construction-begins-commercial-plant-production-co2-neutral-fuel-chile-25683.html

Development method for eFuel formulation

Formulation, testing, analysis, simulation, optimization as an iterative process

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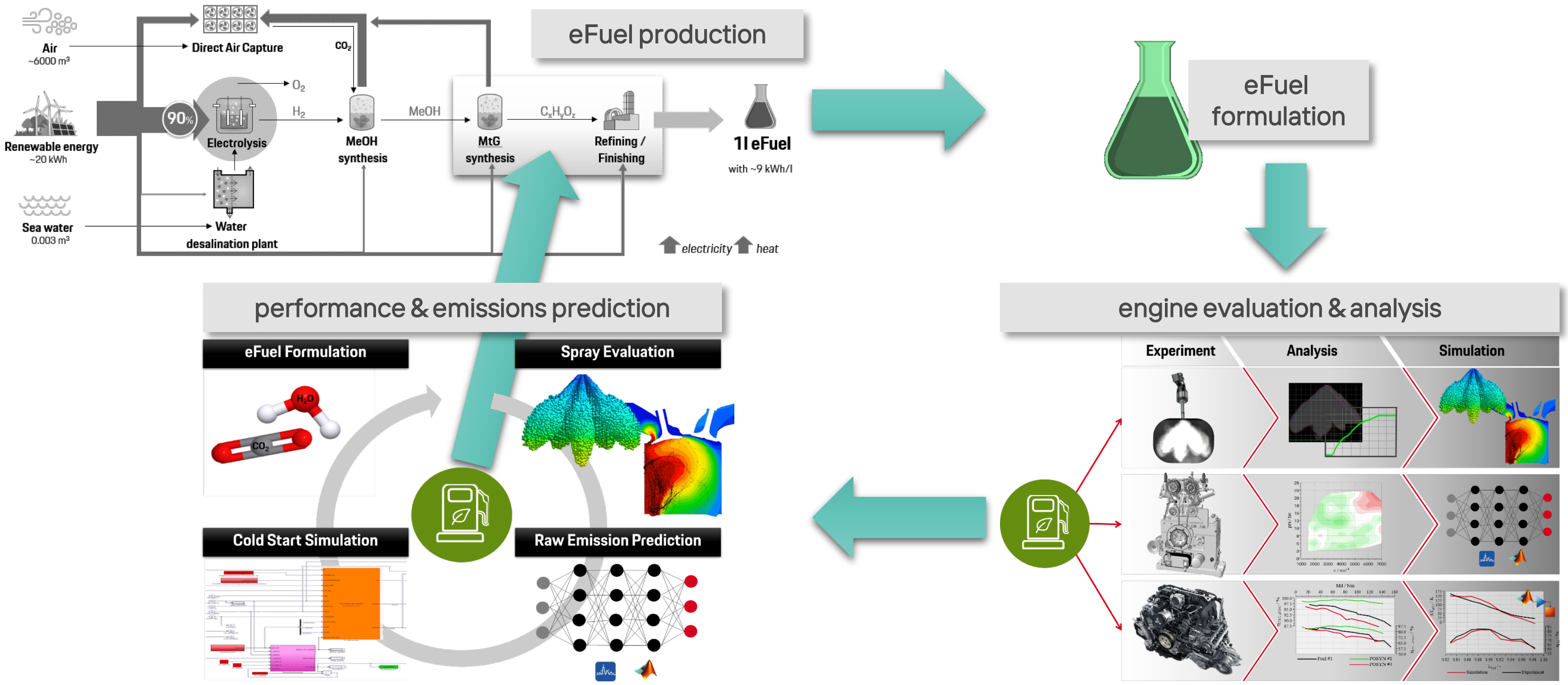

Source: SAE Capri 2021 "eFuels: a further step towards sustainable mobility", A. C. Kulzer, keynote speech

eFuel performance & emission assessment >50 fuels tested !

Porsche high-performance single cylinder engine & existing fleet vehicle testing

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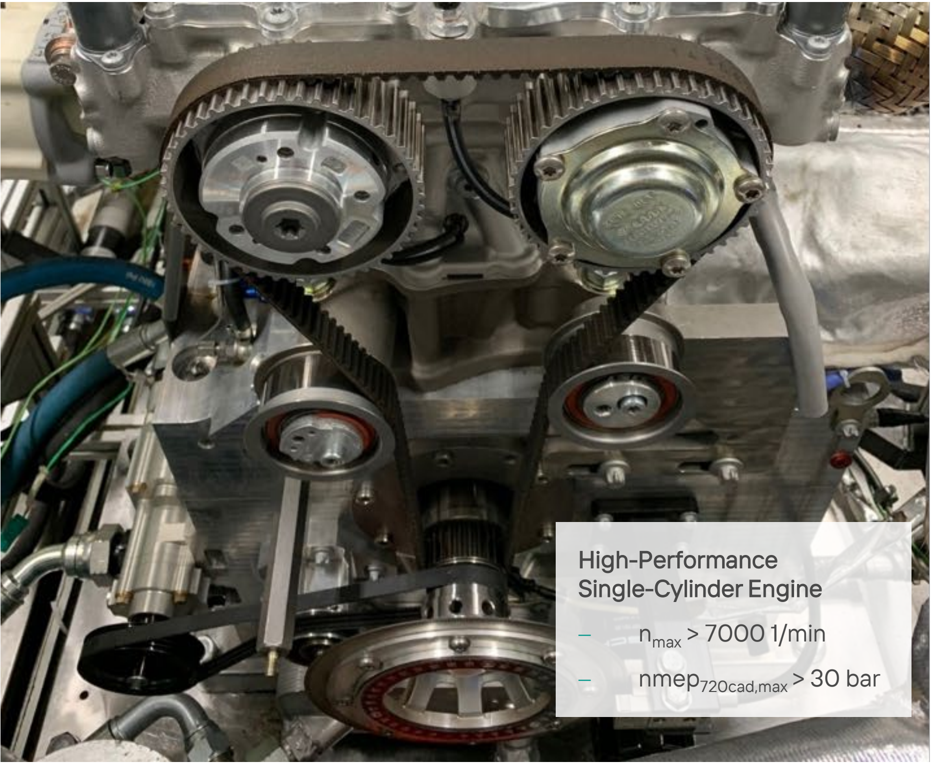

Source: SAE Capri 2021 “eFuels: a further step towards sustainable mobility”, A. C. Kulzer, keynote speech

EN228/eFuel blend capability & existing fleet compatibility

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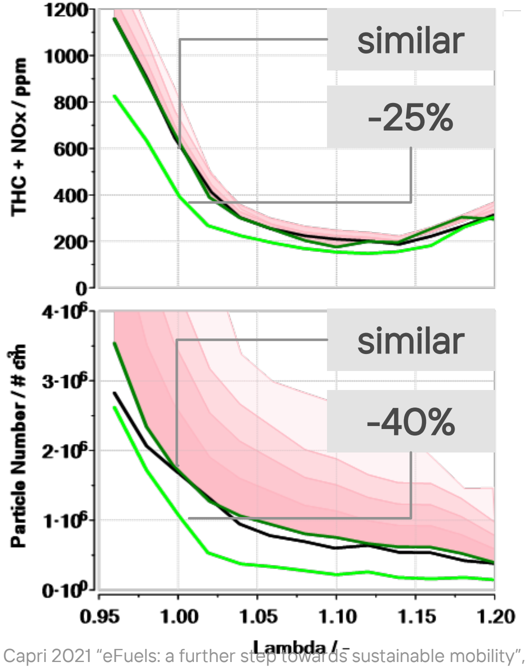
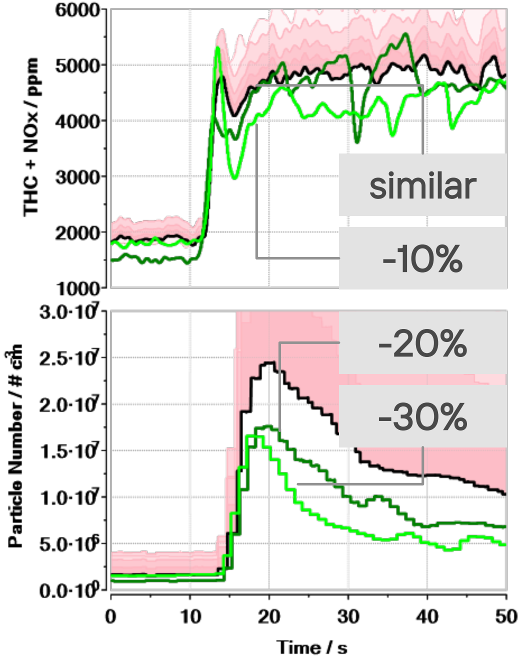
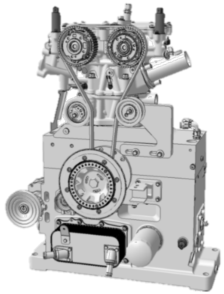
Benchmark reFuel & POrsche SYNthetic at cold start & load jump @Porsche single cylinder engine

CatHeating 1500/750mbar, TWA 40°C



Cold Load Jump 1500/2bar→WOT, TWA 40°C





Source: SAE Capri 2021 "eFuels: a further step towards sustainable mobility", A. C. Kulzer, keynote speech

MtG based eFuel blending aspects vs. Next Gen eFuel

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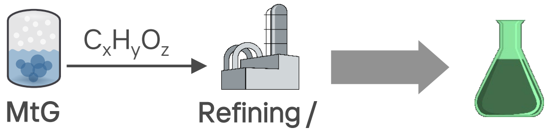


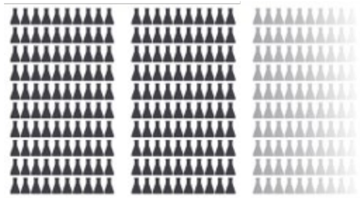
MtG synthesis

Refining / Finishing

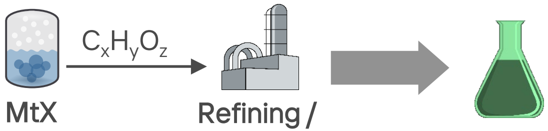
MtG based eFuel

MtG eFuel ~200...300 components

High MtG blending quality influence:



- knock sensitivity / RON
- boiling curve / FBP
- amount C9+ aromatics
- emission behavior



MtX synthesis

Refining / Finishing

Tailor-made eFuel (Next Gen)

Tailor-made eFuel < 10 components

Potentials:

- higher knock sensitivity / RON
- improved evaporation behavior
- aromatics avoidance
- better emission behavior

Source: SAE Capri 2021 “eFuels: a further step towards sustainable mobility”, A. C. Kulzer, keynote speech

Next Gen eFuels definition for maximum emission potentials

POrsche SYNthetic eFuel @single cylinder at Porsche

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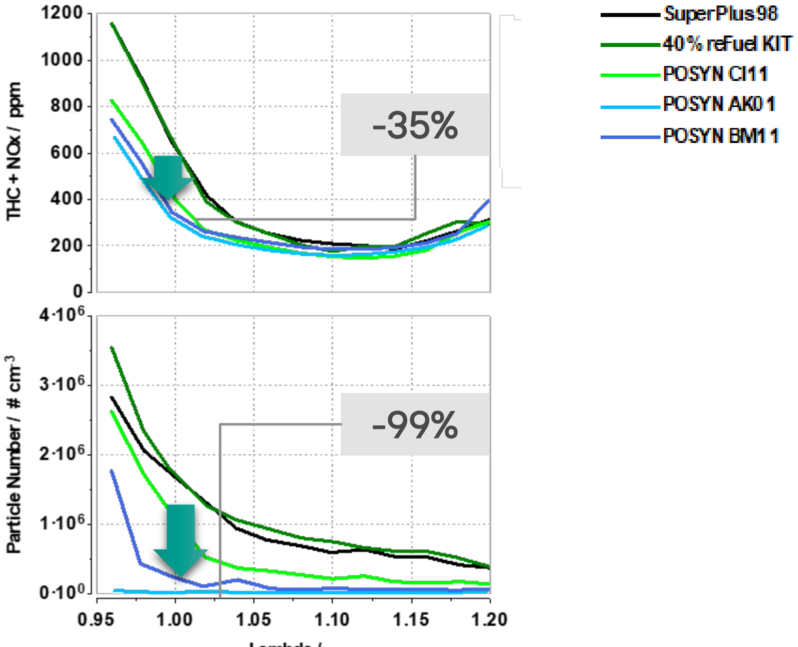
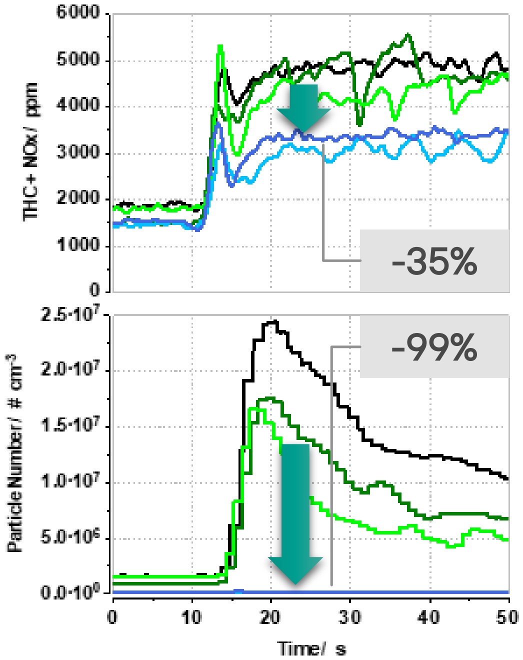
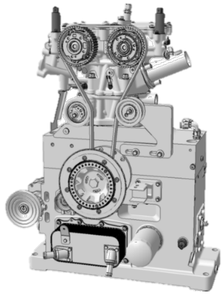
CatHeating 1500/750mbar, TWA 40°C



Cold Load Jump 1500/2bar→WOT, TWA 40°C





Source: SAE Capri 2021 "eFuels: a further step towards sustainable mobility", A. C. Kulzer, keynote speech

Next Gen eFuels definition for maximum performance & emission reduction

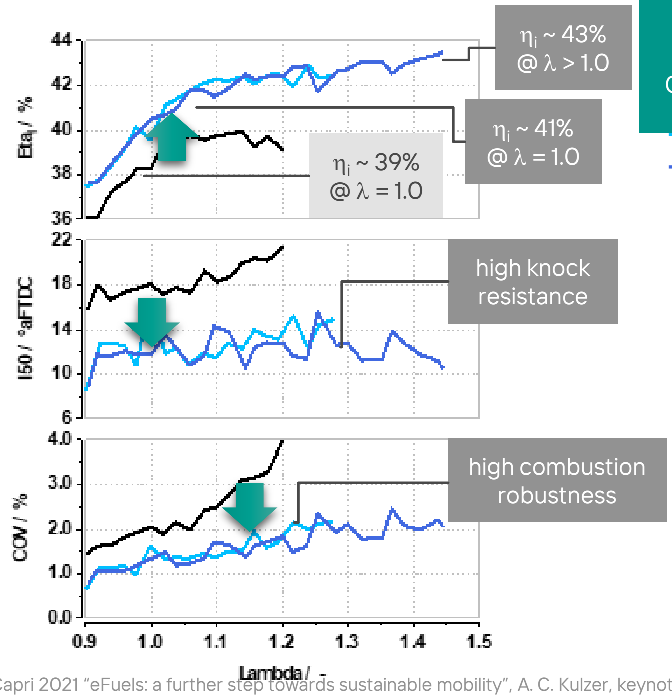
POSYN @single cylinder with high knock resistance & emission potentials

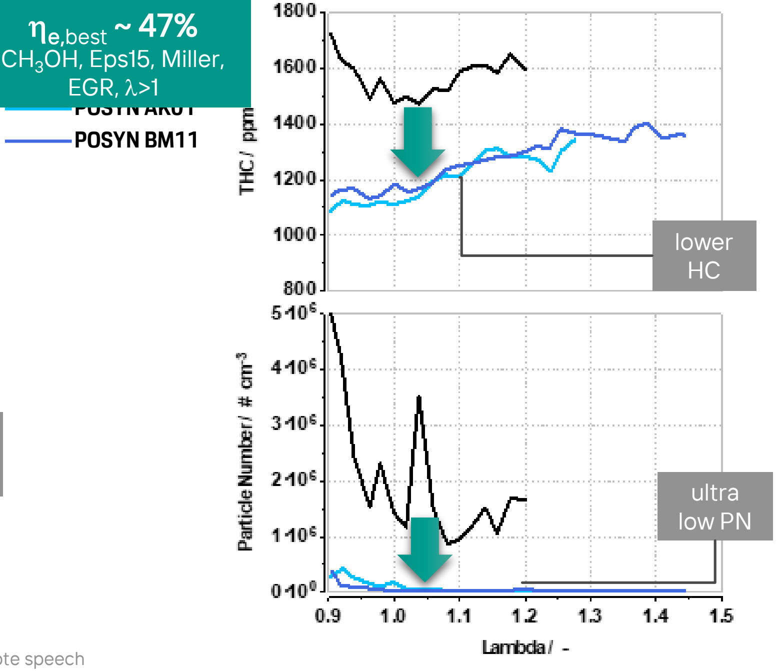
Lambda Sweep @4000/18bar$_{BMEP}$

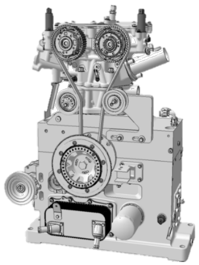
FVV ICE2025+

$\eta_{e,best}$ ~ 47%

CH_3OH, Eps15, Miller, EGR, λ>1







Source: SAE Capri 2021 “eFuels: a further step towards sustainable mobility”, A. C. Kulzer, keynote speech

Summary

eMobility + eFuels → path to sustainable mobility

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- **Renewable eFuels**
  - necessary complement to eMobility
  - production based on green hydrogen and closed CO_2-cycle
- **eFuels production costs**
  - strongly depend on electrolysis step & renewable energy cost
  - cost efficient in regions of the world using wind or solar energy (where surplus of renewables!)
- **Need for an eFuels development method**
  - for best trade-of between fuel properties (clean & efficient combustion) and production feasibility
- **Further potentials**
  - within an adapted EN228 gasoline standard, optimized blending could lead to better quality and further emission reduction within the existing stock fleet
  - Next Gen eFuels offer additional opportunities for further performance and emission potentials, considering a widdened/new prospective fuel standard

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Thank you!

mobility
electric/molecular
energy carriers
CO_2-neutral
powertrain systems

leading sustainable powertrain system innovation

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Automotive Powertrain Systems

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