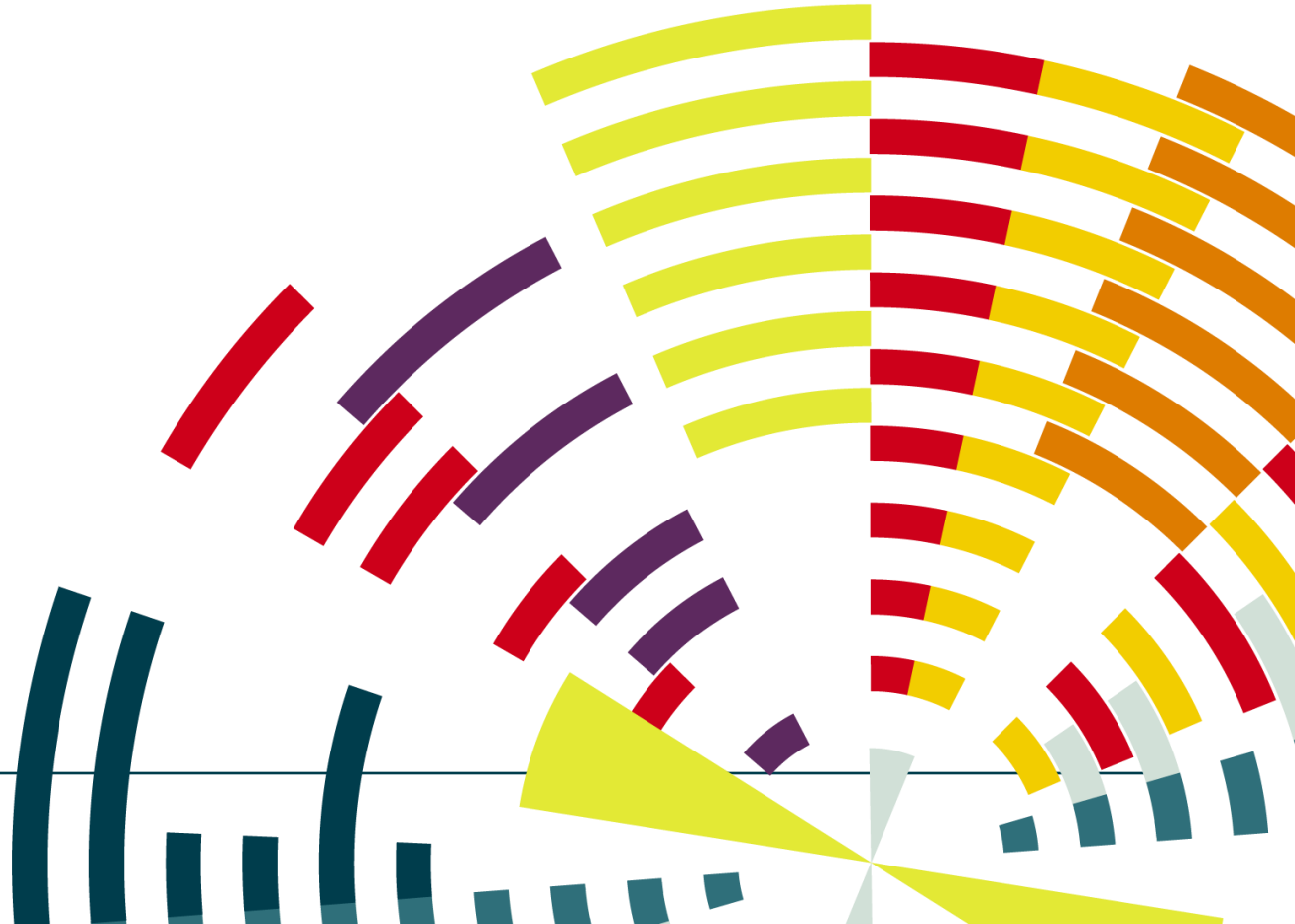
Transformation of Mobility in the Climate-Neutral and Post-Fossil age

Results of the FVV Fuel Study IVb

Presentation to CONCAWE

Dr. David Bothe

16.10.2023



PRESENTED RESULTS ARE BASED ON THE FVV FUEL STUDY IVb

which builds on results of the FVV fuel study IV

Future fuels
FVV Fuel study IV

Analysis of 42 different single fuel / powertrain combinations regarding GHG emissions and costs

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https://www.fvv-net.de/fileadmin/Downloads/Publikationen/FVV__Future_Fuels__StudyIV_The_Transformation_of_Mobility__H1269_2021-10__EN.pdf

Transformation of mobility to the GHG neutral post fossil age
FVV Fuel study IVb

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https://www.fvv-net.de/en/science/how-long-does-it-take-to-get-there

KEY OBJECTIVE: DETERMINING THE OPTIMAL TECHNOLOGY MIX TO BRING CO2 EMISSION IN EUROPEAN (EU27+UK) **ROAD** TRANSPORT TO ZERO

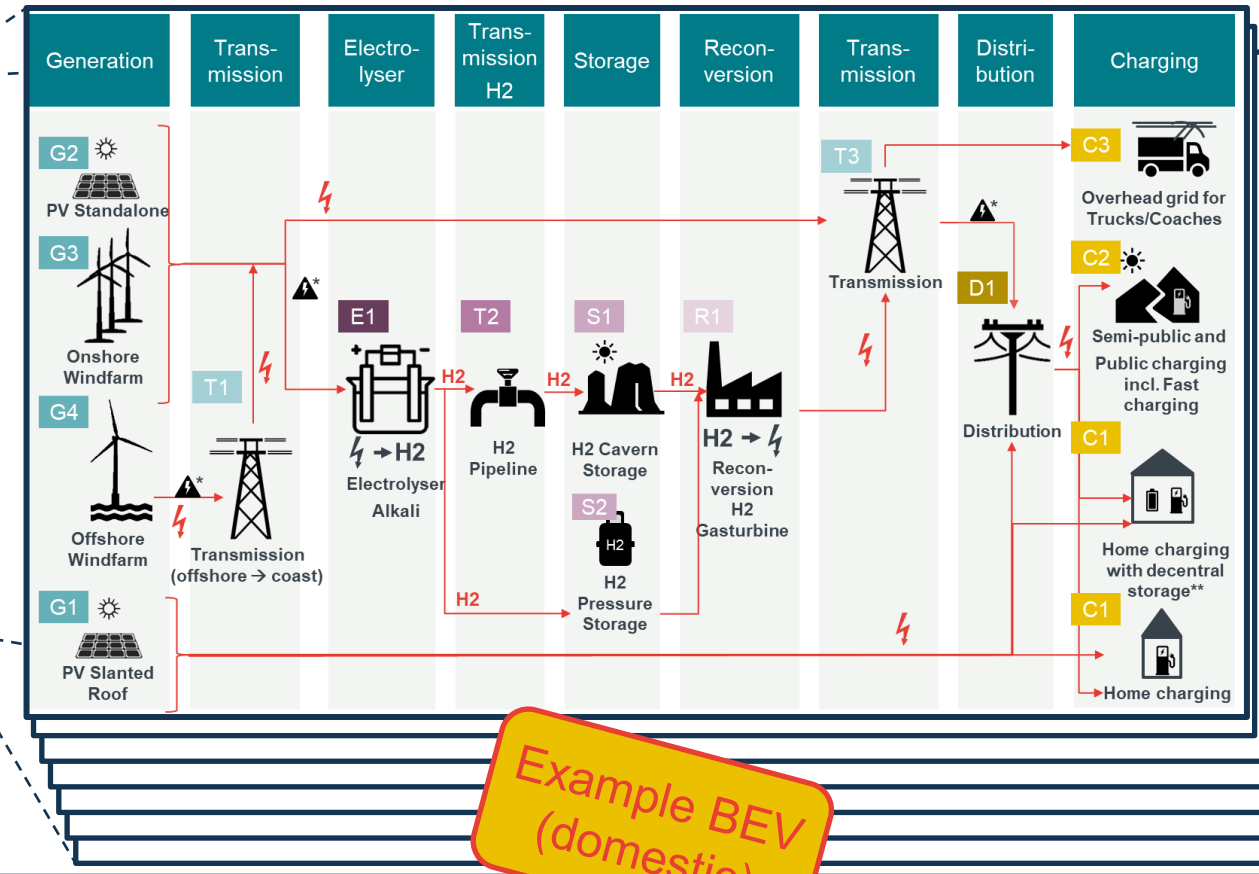
5+1 Fuel Pathways
7 Powertrains

LCA for full energy supply chain and vehicles

19 scenarios

- Electric (BEV) >7.5t catenary line
- e-H_2 (ICEV, FCEV)
- e-FT (ICEV)
- e-CH_4 (ICEV)
- e-MtG (ICEV)
- e-MtG/FT (PHEV)

11 vehicle types
(4 pass.car, LCV, 4 HDV, Public Transp, Coaches)



11 Single-Technology Scenarios

Optimised Technology-Mix (minimising CO2 emissions)

7 sensitivities (relaxed bottlenecks, subset of technologies)

BACKGROUND: FRONTIER'S MOVEID MODEL

Parallel simulation of vehicles and energy infrastructure

Inputs

Vehicle fleet

- Mobility demand per year
- Vehicle stock and lifespan

Infrastructure requirements

- Per powertrain technology, vehicle segment and year
- Liefetime of infrastructure

GHG emissions and raw materials

- Per powertrain, vehicle segment and year
- Initial, running and disposal emissions

CAPEX and OPEX

- Specific investment and operating costs per year

Technical bottlenecks

- Infrastructure and raw marerial availability per year

Model

Linear optimisation model, solved in GAMS

MOVEID Model Optimised Vehicle and Energy Infrastructure Defossilisation

Optimisation objective:

Minimisation of cumulated GHG emissions of the EU27+UK road sector until 2050

…under **constrains:**

- **Technical bottlenecks restricting the use of (GHG-neutral) powertrains**: Restrictions in infrastructure and raw material availability
- **The (GHG-neutral) powertrain(s) available in the modelling setup** : Restrictions to a certain number of powertrains available

Outputs

Optimised pathway

- Share of powertrain trechnology (per vehicle segment and year)
- Ramp-up speed
- Binding technical bottleneck constraints per year

Additional information

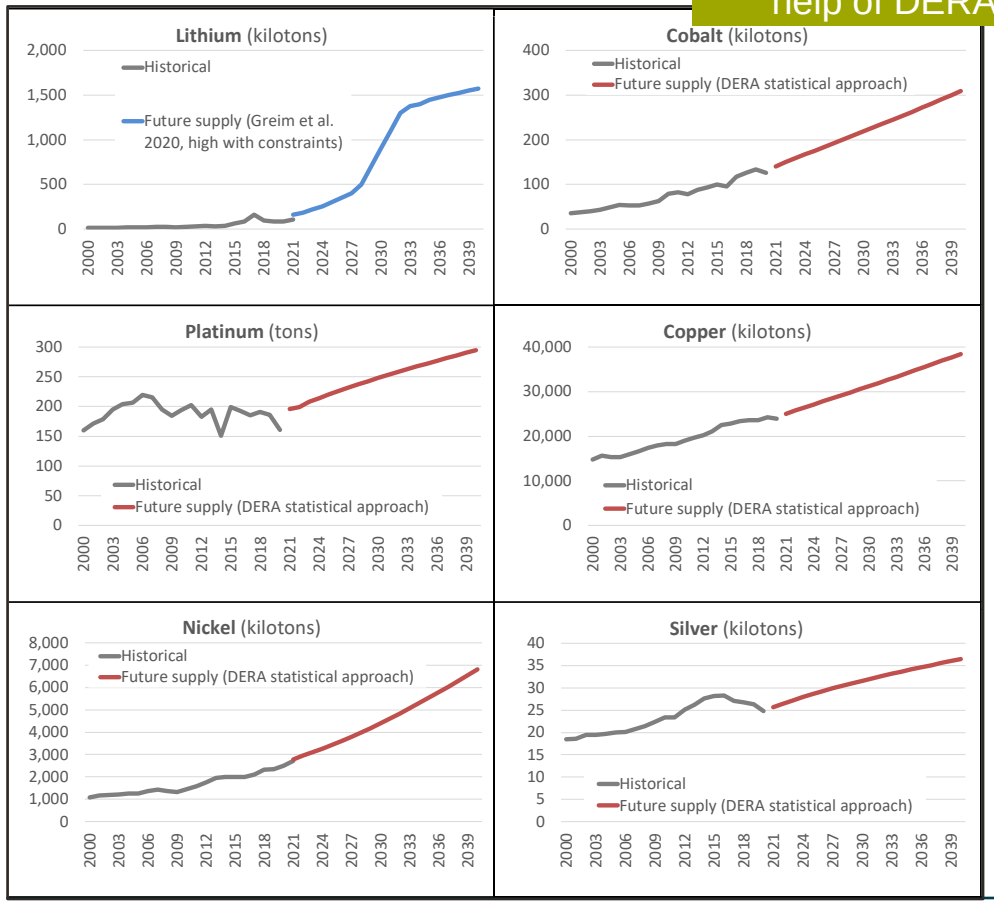
- Infractructure and raw metarial requirements (per powertrain technology, vehicle segment and year)
- Specific investment and operating costs (per powertrain technology, vehicle segment and year)
- GHG emissions (per powertrain technology, vehicle segment and year)
- Tank-to-wheel and well-to-wheel energy demand (per powertrain technology, vehicle segment and year)

DEFOSSILISATION AS SOON AS POSSIBLE – CONSIDERING BOTTLENECKS

*Focus solely on "**technical bottlenecks**", assuming **ideal regulatory and financial ramp-up conditions** ("COVID 19 vaccine development" scenario)

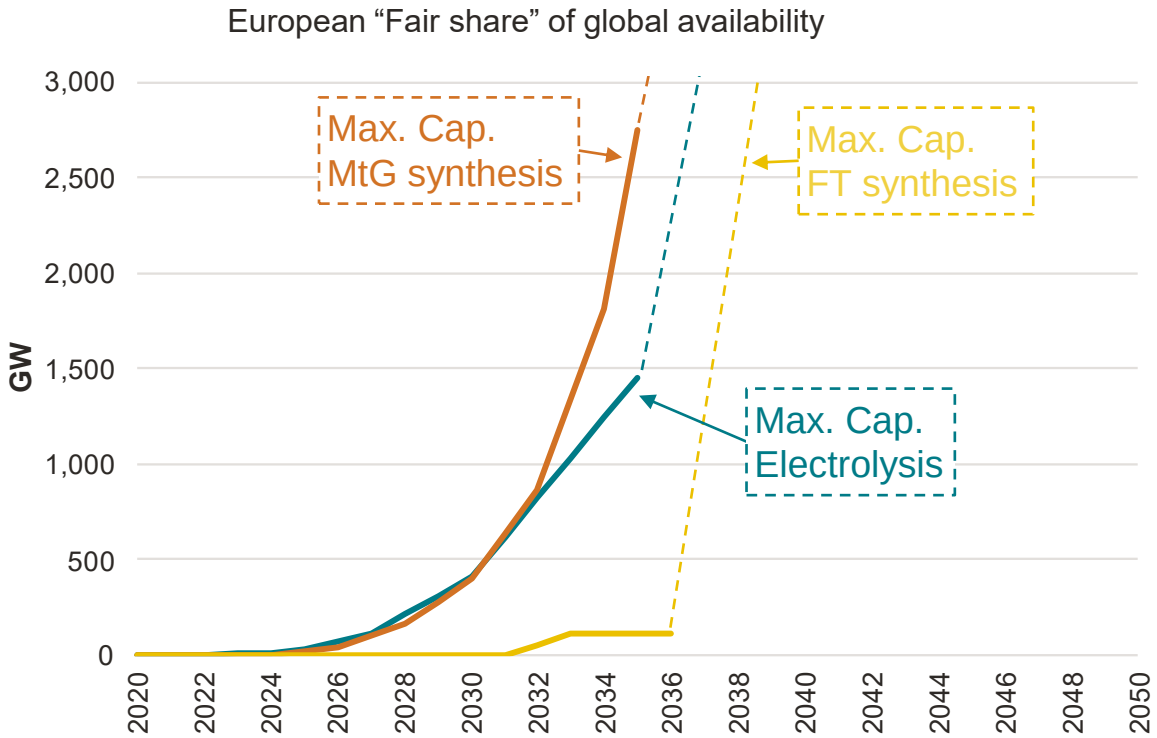
… e.g. for primary material supply

Max. material supply determined with the help of DERA



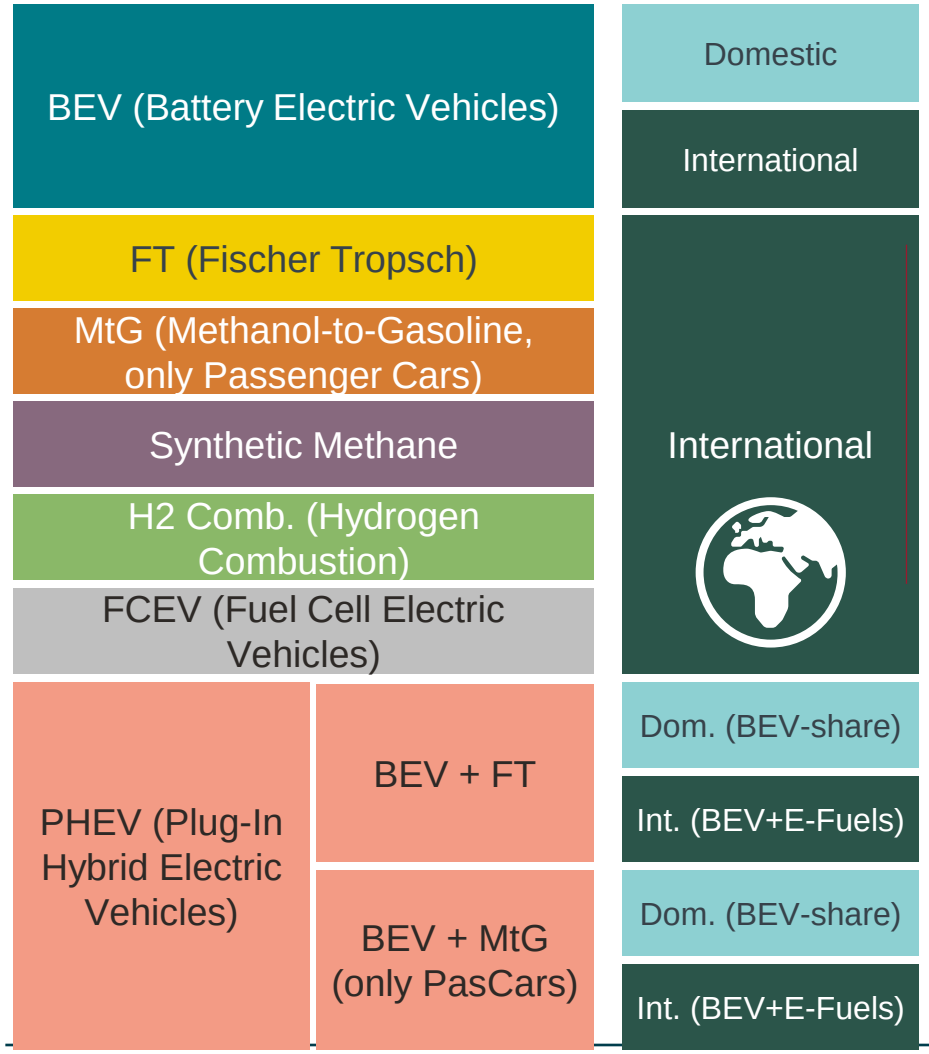
… e.g. for ramp-up of capacities

Determined in 7 Working Groups (>50 Experts from >40 organisations)



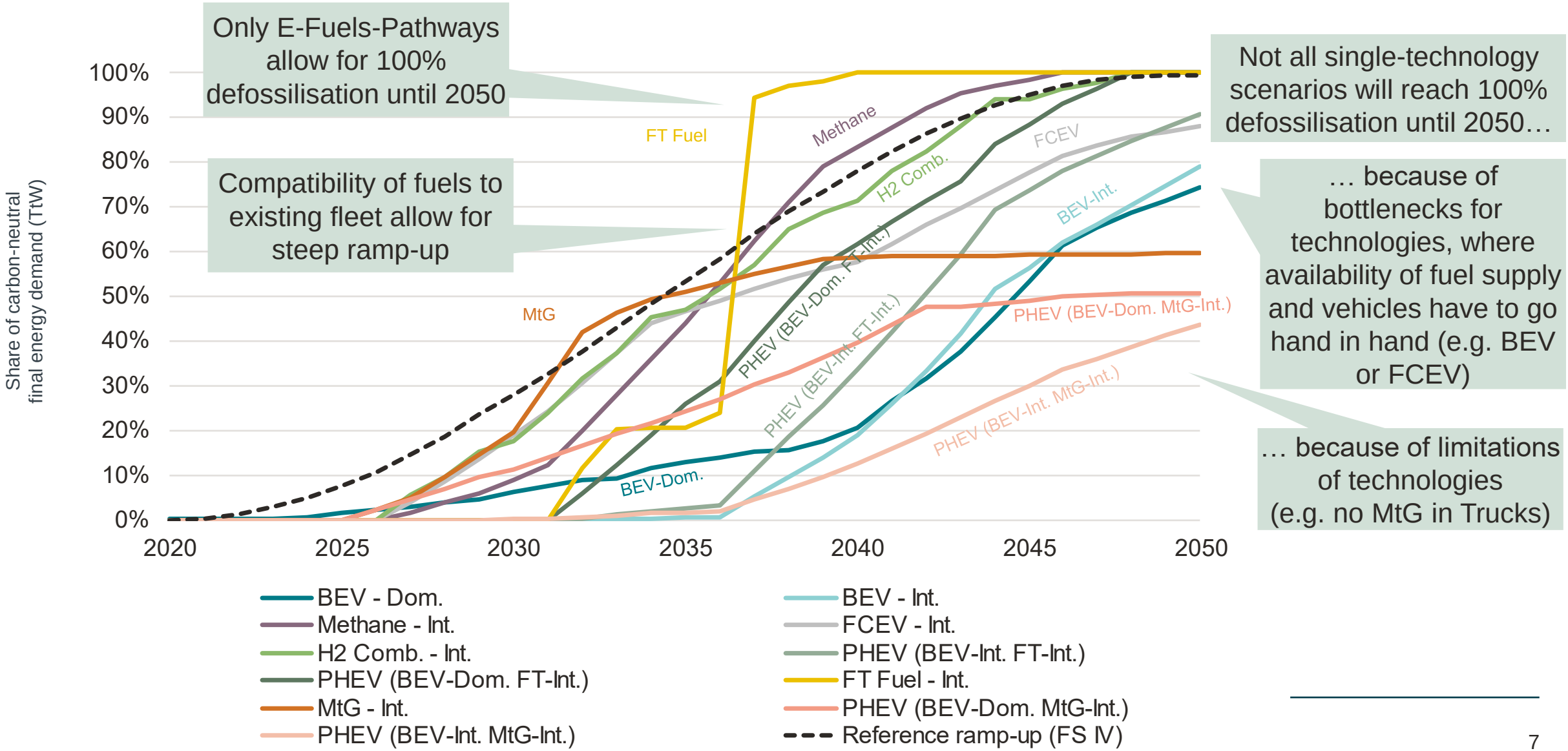
Sources: DERA (Deutsche Rohstoff Agentur), Greim et al. 2020

ALL SINGLE-TECHNOLOGY SCENARIOS RUN INTO BOTTLENECKS …

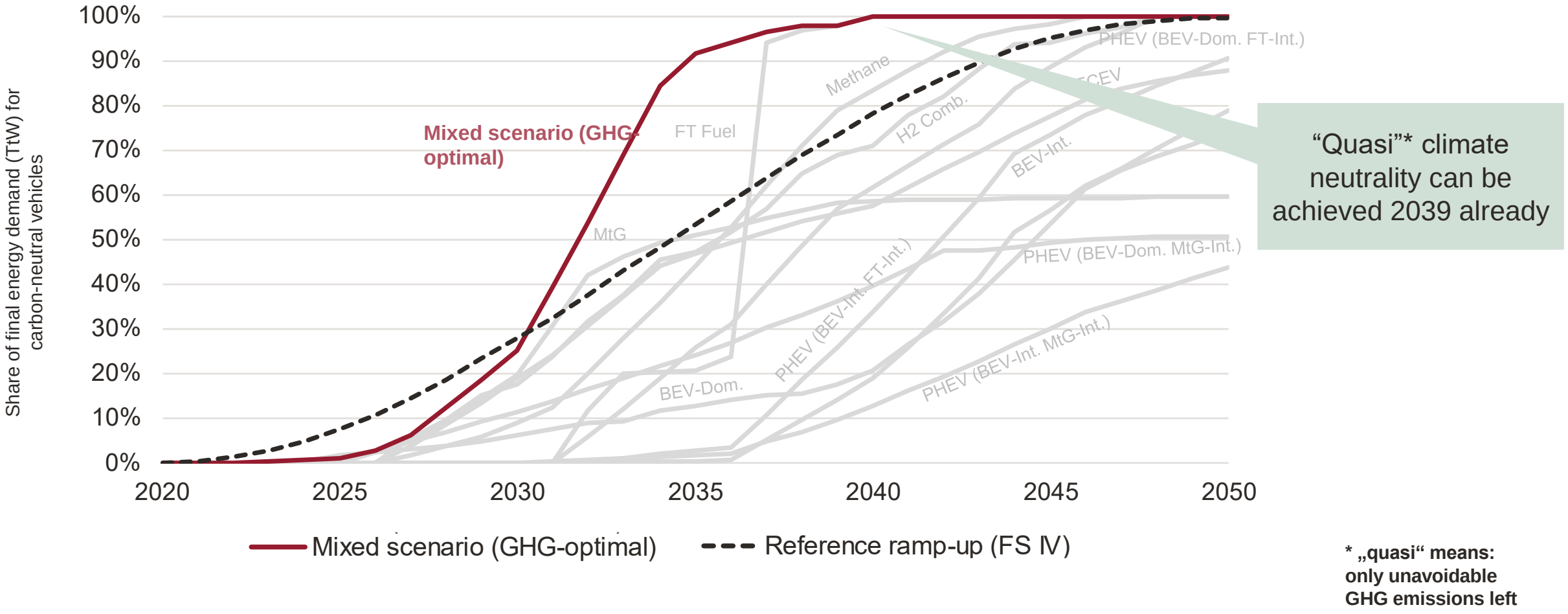


	2020-2029	2030-2039	2040-2049
BEV (Battery Electric Vehicles)	Power transmission grid, catenary lines, cobalt, battery production, wallboxes	Power transmission grid, catenary lines, cobalt, battery production, wallboxes	Power transmission grid, cobalt
International	Sea power cable, catenary lines, cobalt, power transmission grid	Sea power cable, catenary lines, cobalt, power transmission grid	Transmissio grid, cobalt
FT (Fischer Tropsch)	FT synthesis, nickel, electrolysis	FT synthesis, nickel, electrolysis	
MtG (Methanol-to-Gasoline, only Passenger Cars)	Electrolysis, renewable electr. generation, MtG synthesis	Electrolysis, renewable electricity generation	
Synthetic Methane	Methanation, CH_4 import pipelines, electrolysis	Methanation, electrolysis	
H2 Comb. (Hydrogen Combustion)	H_2 import pipeline, electrolysis	H_2 import pipeline, electrolysis	H_2 import pipeline
FCEV (Fuel Cell Electric Vehicles)	H_2 import pipeline, platinum, battery production,	H_2 import pipeline, platinum	Platinum
PHEV (Plug-In Hybrid Electric Vehicles) – BEV + FT	FT synthesis, battery prod., electrolysis, wallboxes	FT synthesis	
PHEV (Plug-In Hybrid Electric Vehicles) – BEV + FT – International	FT synth., sea powr cable, batt. prod., electrolysis, wallboxes	FT synthesis, sea power cable	
PHEV (Plug-In Hybrid Electric Vehicles) – BEV + MtG (only PasCars)	Wallboxes, public chargers, electrolysis	Wallboxes, public chargers	
PHEV (Plug-In Hybrid Electric Vehicles) – BEV + MtG (only PasCars) – International	Sea power cable, wallboxes, public chargers	Sea power cable, wallboxes, public chargers	

… WHICH CONSTRAIN THE ROLL-OUT OF INDIVIDUAL TECHNOLOGIES



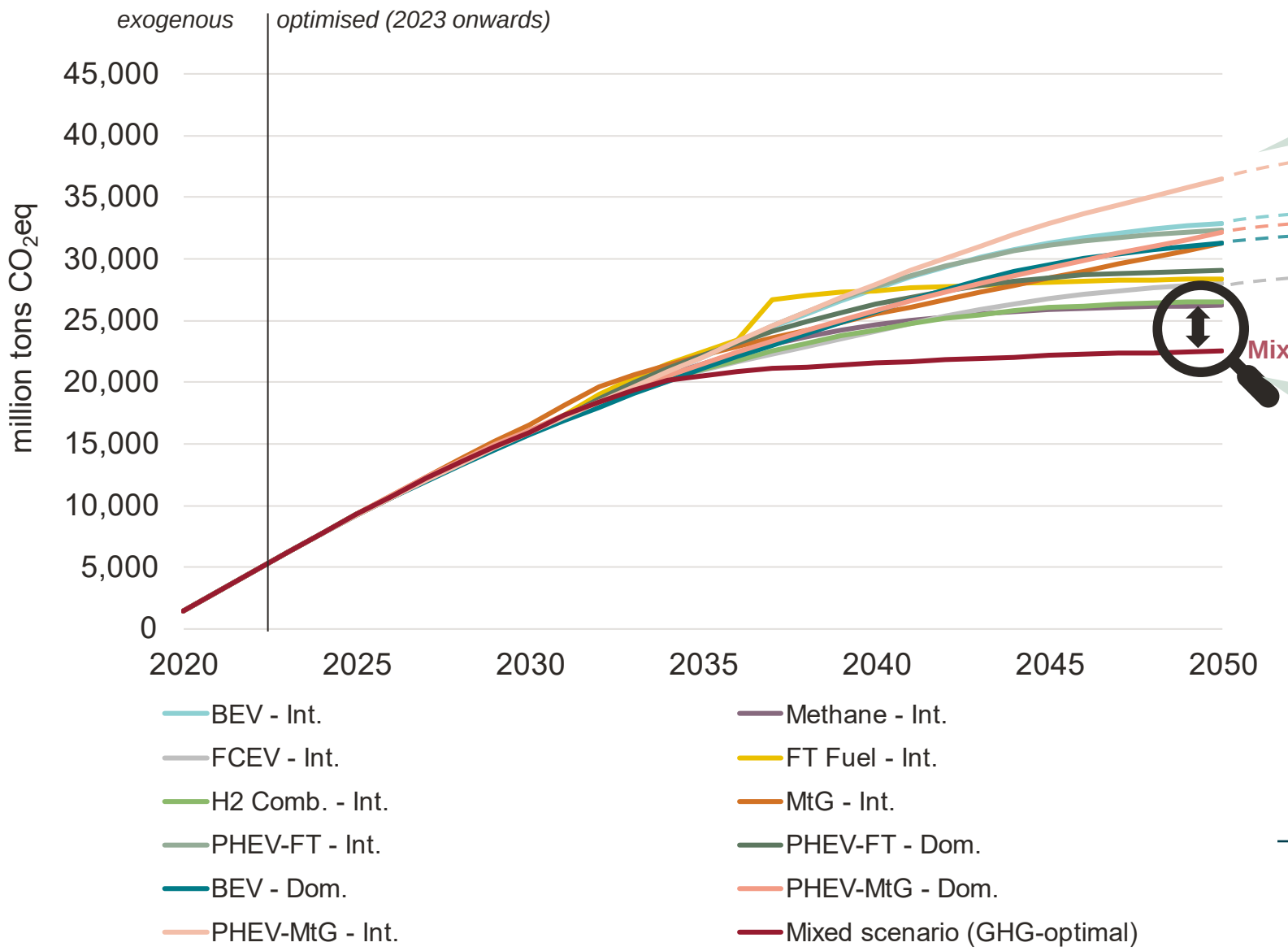
A MIX OF TECHNOLOGIES CAN THEREFORE SIGNIFICANTLY SPEED UP THE DEFOSSILISATION OF EU ROAD TRANSPORT



"Quasi"* climate neutrality can be achieved 2039 already

*** „quasi" means: only unavoidable GHG emissions left**

SPEED IS THE MOST IMPORTANT FACTOR TO REACH CLIMATE OBJECTIVES



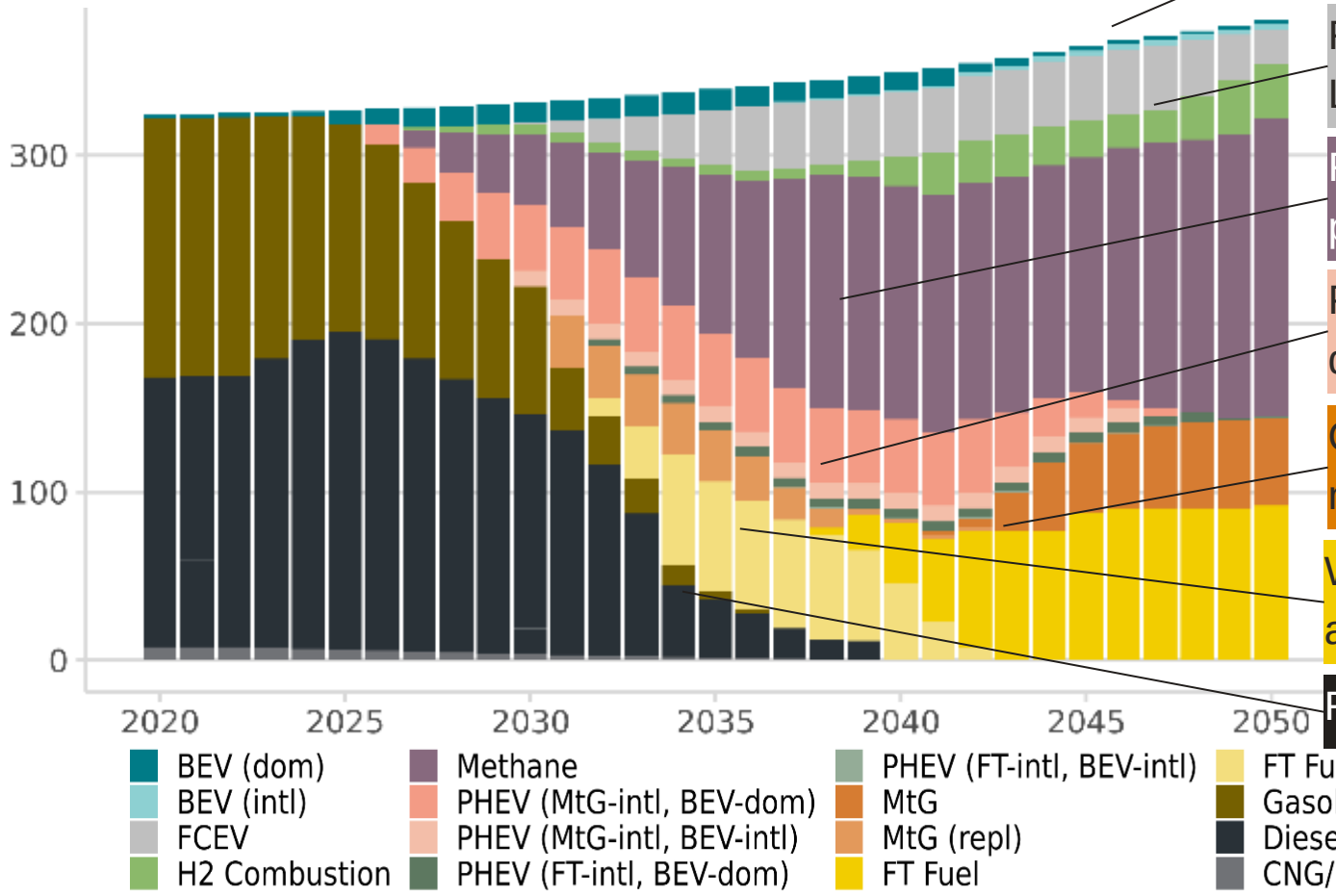
Single technology scenarios

Mixed scenario

Important:
Many single technology scenarios do not reach full defossilisation until 2050!

Cumulated emissions until 2050 3.700MtCO2 lower than best full defossilised single technology scenario (CH4), equivalent to app. 5 years of total German emissions

MINIMUM GHG-MIXED TECHNOLOGY SCENARIO – LDV (PASCAR+N1)



BEV are mainly used in Heavy Duty segment (if Catenary Lines are available – otherwise FCEV/H2)

FCEV and H2 combustions are used both in HDV as well as LDV (2nd best technologies to E-Fuels)

For new vehicles, methane is strongly used (but only slightly preferred over liquid E-fuels)

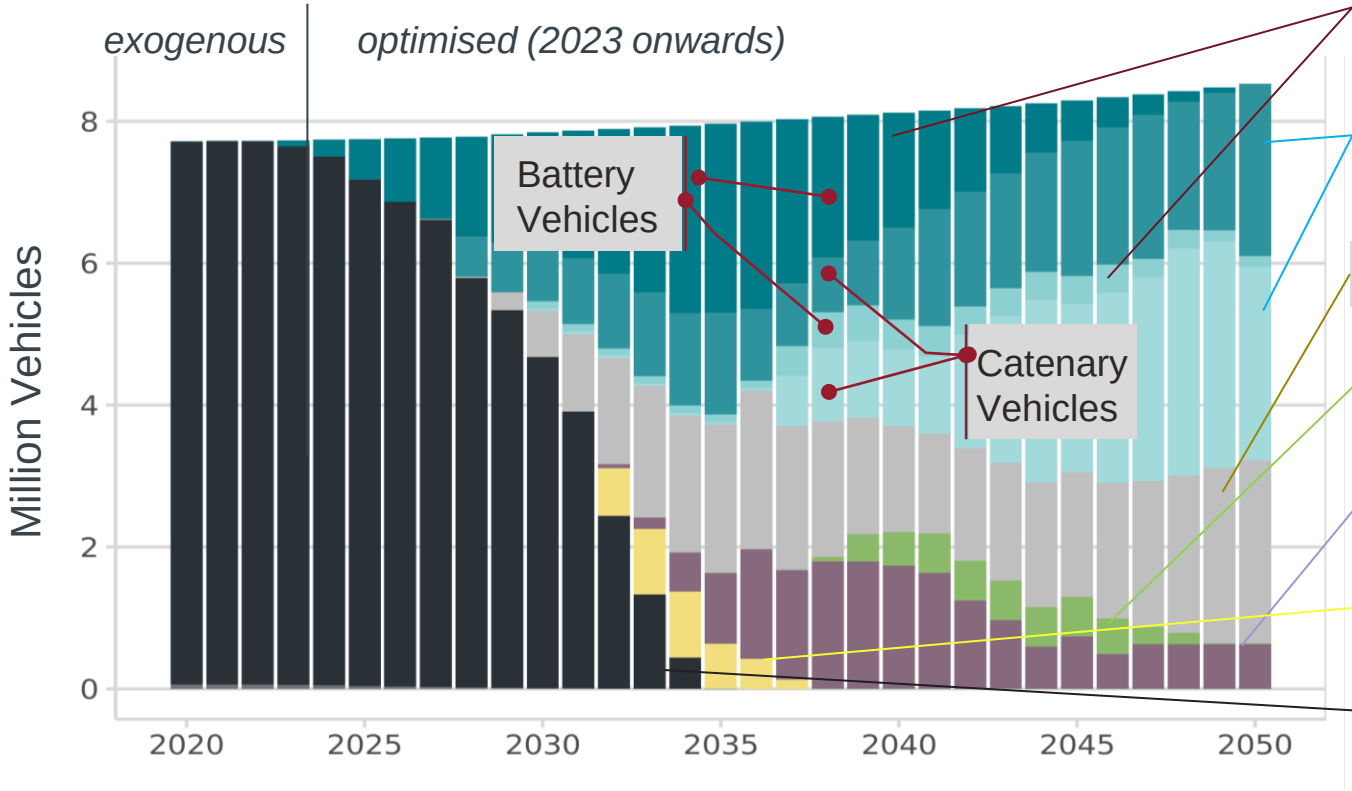
PHEVs (with E-Fuels) are used as an interim-technology during periods when renewable energy is scarce

Once E-fuel supply infrastructure is in place, it is used for new ICE-vehicles

When E-Fuels become available in significant volumes, they are immediately used in the existing fleet

Fossil gasoline phase out 2036, fossil diesel 2039

MINIMUM GHG-MIXED TECHNOLOGY SCENARIO – HEAVY DUTY



Pure BEV (for < 12t HD) phasing out in 2050

Catenary BEV (for > 12t HD) > 50% share in 2050 (rising)

H2-FCEV introduced in 2028, share in 2050 ≈ 35% (rising)

H2-ICEV 2038 … 2048

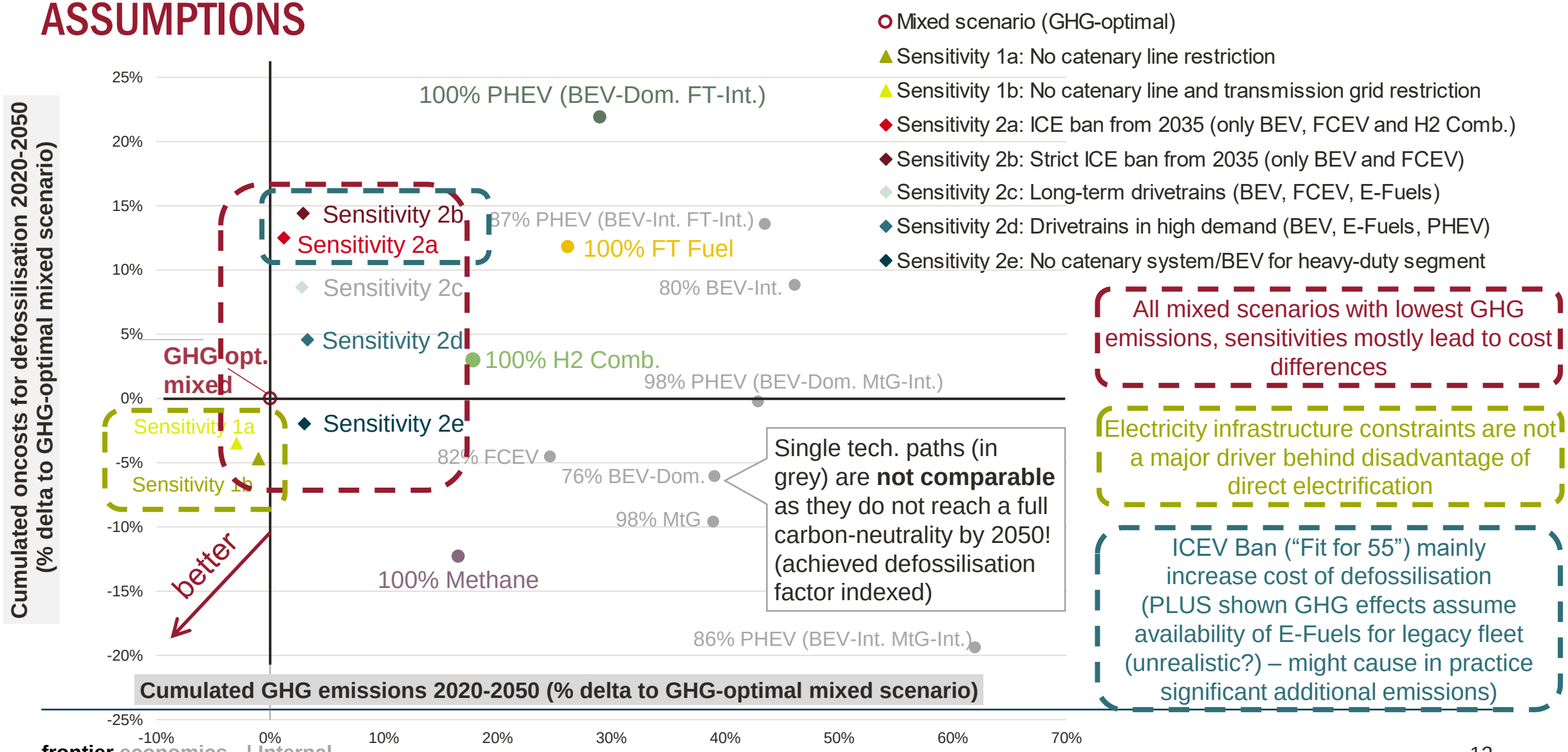
Methane introduced in 2024, share in 2050 ≈ 5% (declining)

FT in ICEV (existing fleet) 2032 … 2037

Fossil diesel phase out 2034

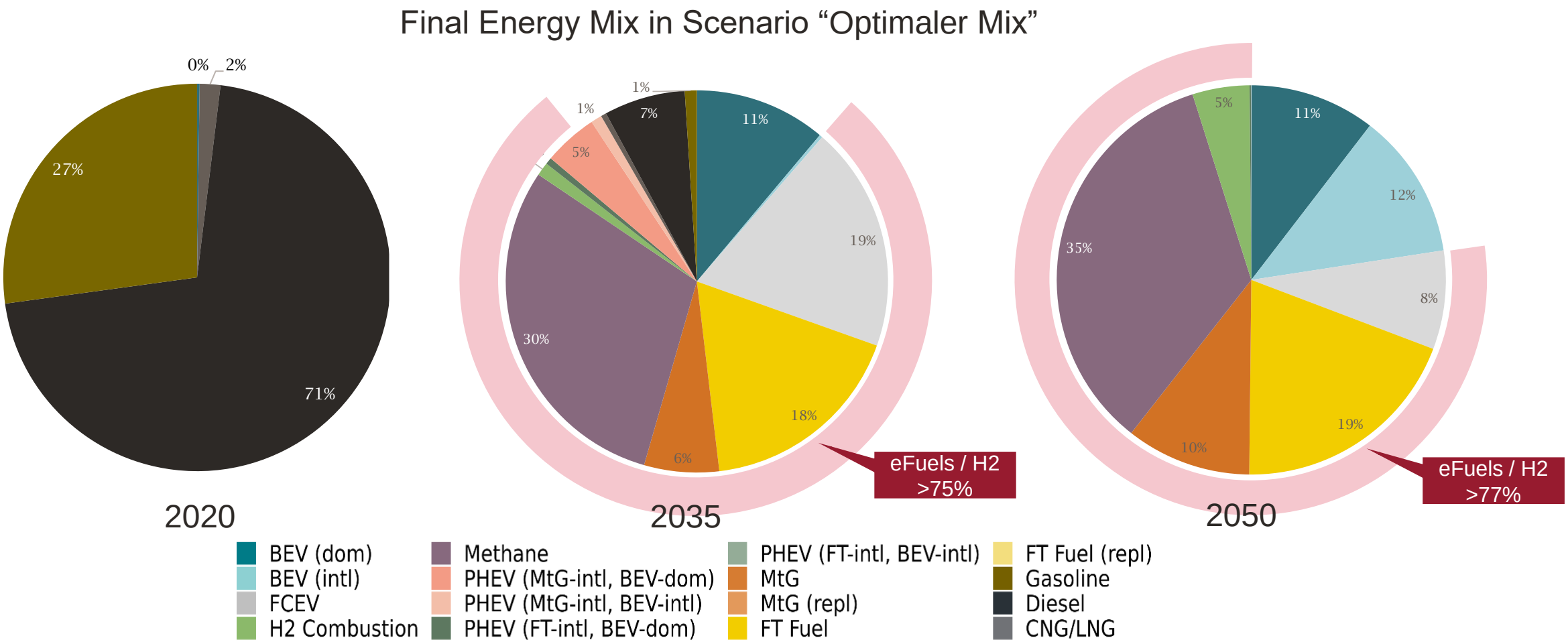
BEV (dom)
BEV (intl)
FCEV
H2 Combustion
Methane
PHEV (MtG-intl, BEV-dom)
PHEV (MtG-intl, BEV-intl)
PHEV (FT-intl, BEV-dom)
PHEV (FT-intl, BEV-intl)
MtG
MtG (repl)
FT Fuel
FT Fuel (repl)
Gasoline
Diesel
CNG/LNG

THE OVERALL FINDINGS ARE ROBUST AGAINST CHANGES TO INDIVIDUAL ASSUMPTIONS



OPTIMAL TECHNOLOGY MIX SHOWS GREAT DIVERSITY - INCLUDING E-FUELS

*Focus solely on **"technical bottlenecks"**, assuming **ideal regulatory and financial ramp-up conditions** ("COVID 19 vaccine development" scenario)



Quelle: https://www.fvv-net.de/science/wie-schnell-geht-nachhaltig

SUMMARY AND CONCLUSIONS

The decisive factor to minimise GHG emissions is the **fastest possible departure** from fossil fuels – **infrastructure and material bottlenecks** need to be addressed quickly

Non-E-Fuel technology scenarios cannot achieve GHG neutrality* by 2050 and yield **significant additional emissions** (e.g. BEV only -> +39%)

A **mix of carbon-neutral energy carrier/powertrain pathways** can speed up the transition to GHG neutrality for road sector compared to single-tech approaches

Drop-in E-fuels (as e.g., MtG/ FT gasoline/diesel) provide a **unique technology option** to carbon-neutrally operate the existing fleet

Under (unrealistically) **ideal regulatory and financial conditions, a mixed scenario can reach GHG neutrality* even by 2039**

Build-up of **significant E-Fuel infrastructure** is crucial, industrialisation of production has to be reached over the next 10-15 years – is the policy framework in EU sufficient?

Banning ICE vehicles from 2035 would lead to **higher GHG emissions and costs** than necessary

EXPRESSION OF GRATITUDE TO AUTHORS OF FVV FUELS STUDY IVb

We would especially like to thank the many colleagues from Frontier Economics, ifeu and the FVV working group "Fuels" who supported this study.

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