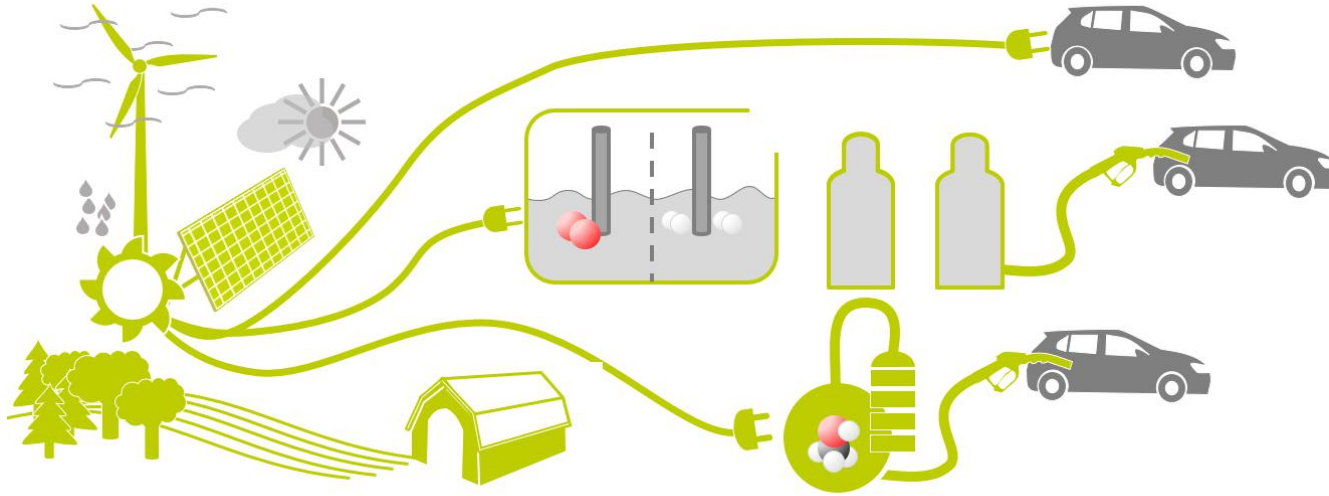
PaREGEn + PEMs4Nano

Final Event

LOOKING INTO THE FUTURE

ELECTRIFICATION, NET-ZERO-CO_2 FUELS, CAV MOBILITY



JOINT FINAL EVENT
12 & 13TH NOVEMBER 2019, SANTA OLIVA, SPAIN (near Barcelona)
PaREGEn + PEMs 4Nano

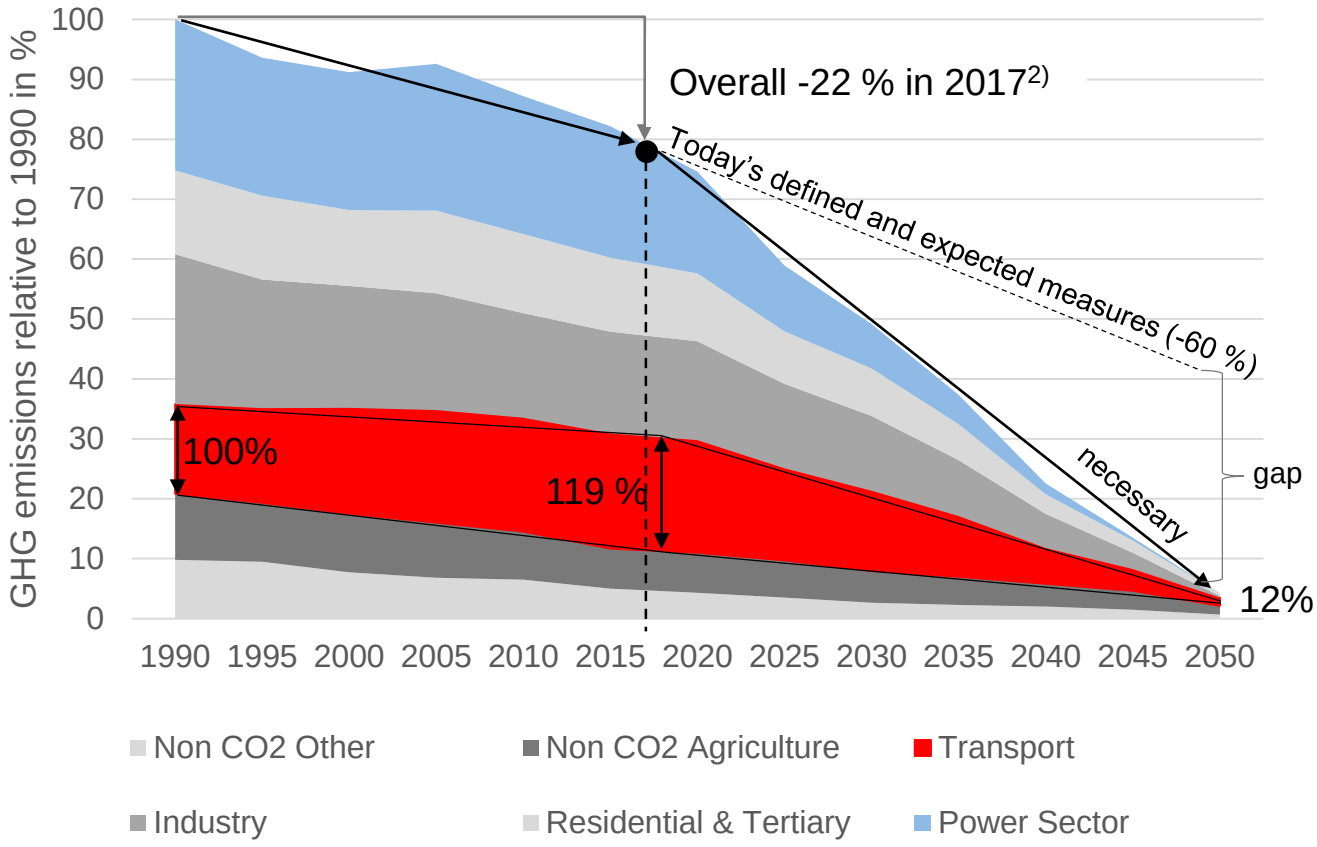
Santa Oliva
12-13 November 2019, Christof Schernus

Many Thanks to:
Benedikt Heuser, Dr.-Ing. Thorsten Schnorbus, Dr.-Ing. Martin Müther, Bernd Lindemann, FEV Europe GmbH
Dr.-Ing. Michael Wittler, Philipp Wienen, FEV Consulting GmbH

FEV

Preventing rapid climate change requires dramatic reduction of GHG emissions in **all sectors**: transport, power, industry, household, farming

95% CUT IN GHG EMISSIONS IN THE EU (100 % = 1990) TO COMPLY WITH 1.5 DEGREES WARMING



Targets

Total GHG emission reduction[1)]

- 95 % until 2050
- 50 % until 2030
- 25 % until 2020

→ linear trend from today necessary

Sector Targets 2050

- almost all electrical energy from regenerative sources (97 %)
- Transport: GHG up to -88 % from 1990 (-91 % from 2017)[3)]

1) Target European Commission. 2050 low-carbon economy. Climate Action
2) Eurostat
3) European Commission, A Clean Planet for all, Nov. 2018

CO_2-neutral mobility
A roadmap of CO_2 emission reduction measures until 2050

Optimization of usage

Connectivity | Shared Vehicles | Advanced logistics | Automated driving

Electrification of powertrains

Hybrid | Battery electric | Fuel cell | Further deployment | Fuel cell

Efficiency increase of vehicles

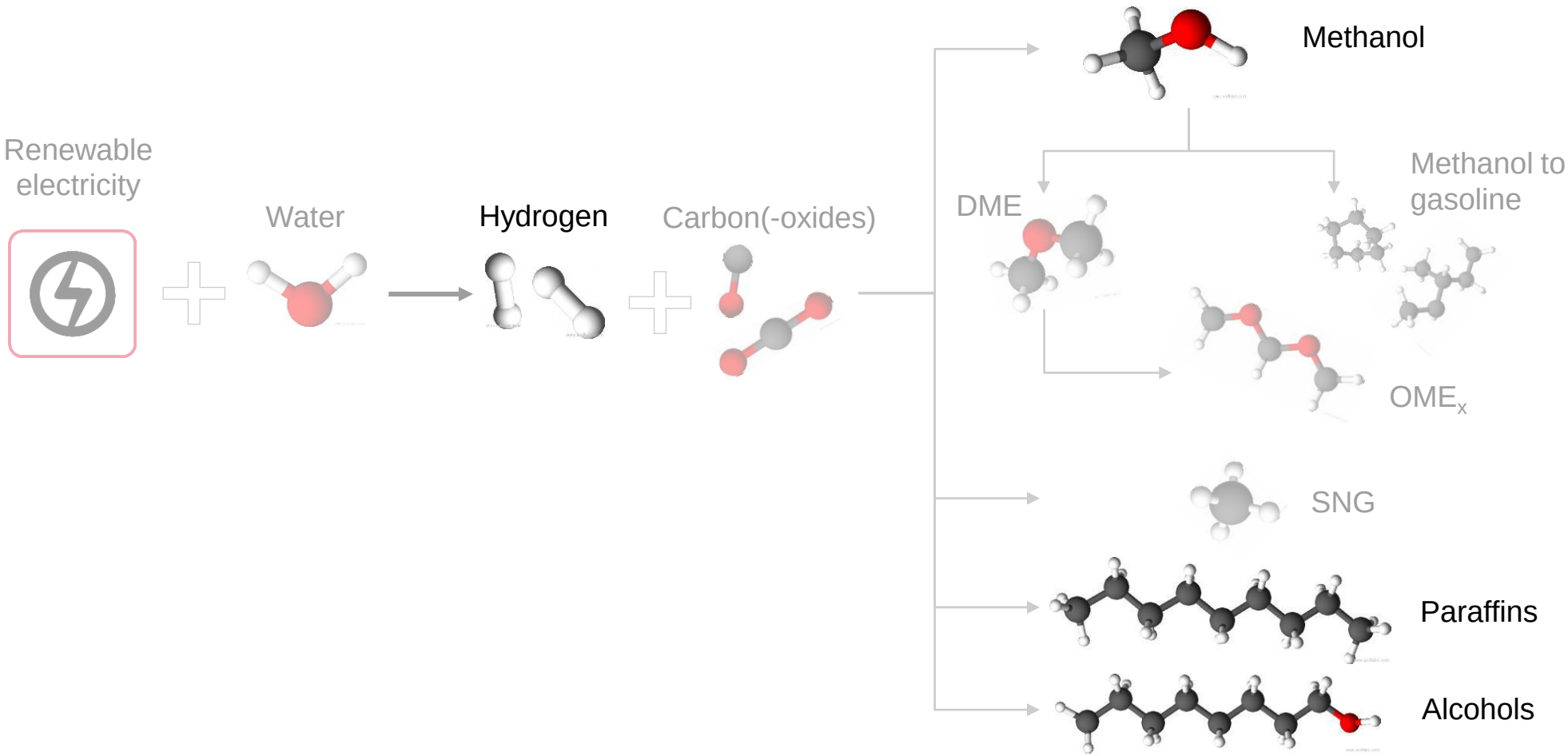
Engine efficiency | Rolling resistance | Lightweight | Aerodynamics | Waste heat recovery

Adaptation of energy carriers

Biomass | Approx. constant | Power-to-X

Electricity based chemical energy carriers show a huge variety

RENEWABLE HYDROGEN IS REQUIRED FOR ALL E-FUELS



Dedicated e-Fuel Shows High Efficiency Improvement Potential

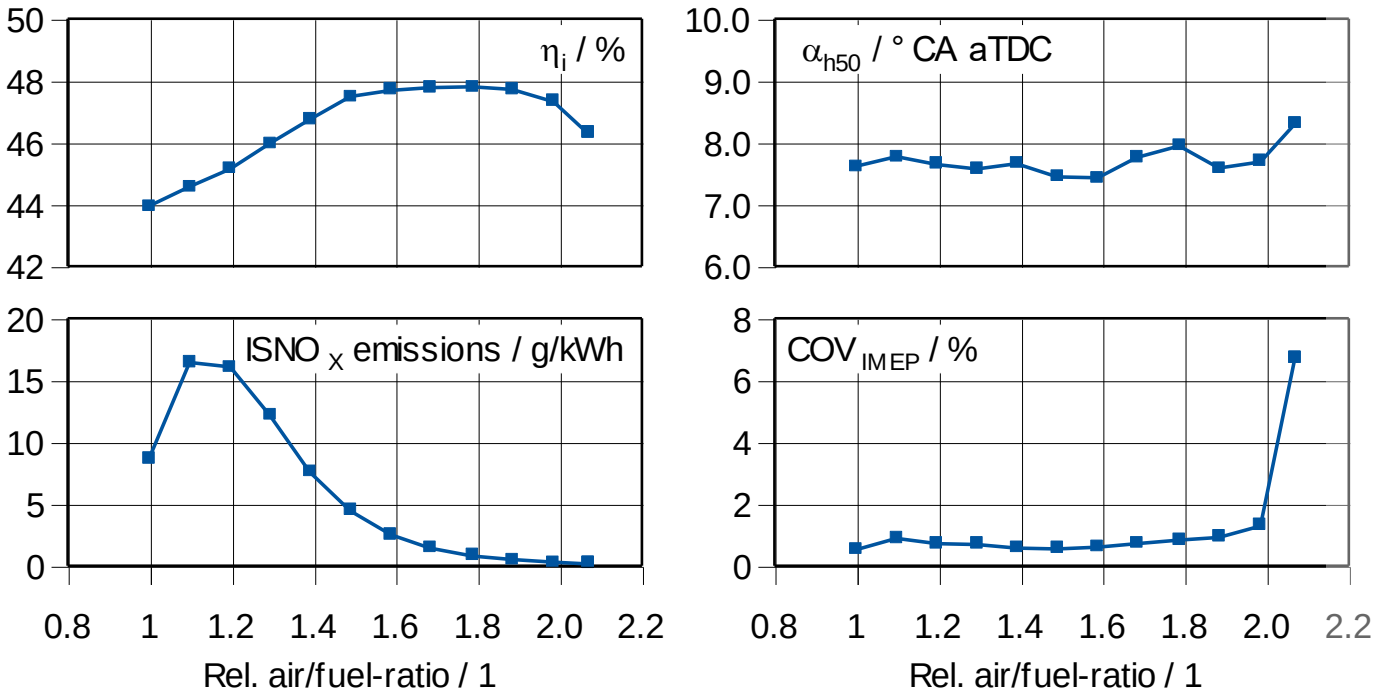
MAXIMUM INDICATED EFFICIENCY OF 47.7% ACHIEVED WITH METHANOL

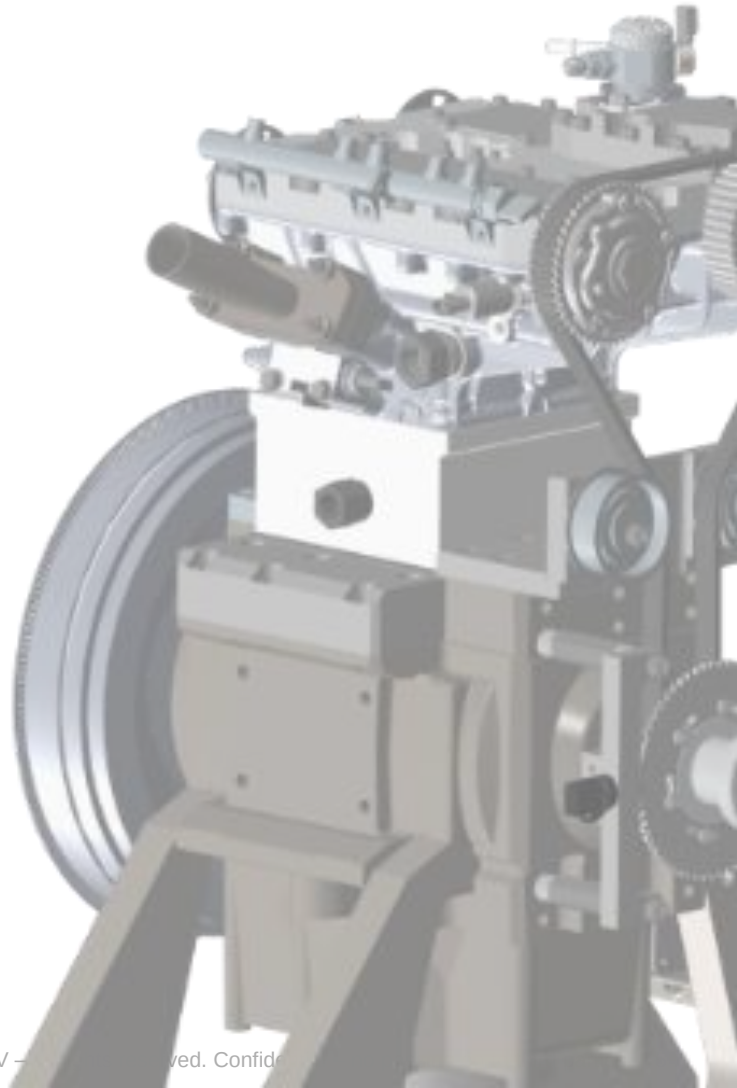
Lean burn combustion with e-Fuel Methanol

Methanol Lambda Variation

n = 2000 min $^{-1}$; IMEP = 18 bar

CR = 14.7; S/B = 1.2; p_{rail} = 200 bar; SOI = 320° CA bTDC





Alternative energy carriers can be applied in various modes of transport
E-Fuels & BIO-Fuels Center of Excellence in EU @ RWTH AC since 2007

APPLICABILITY OF SELECTED ENERGY CARRIERS

Powertrain type	Energy carrier	Application in
Battery electric	Electricity	
Combustion based	Hydrogen	
	Methanol	
	Methane	
	Paraffins	

For the rating we considered four factors: fuel production cost, availability, energy density and compatibility with the vehicle stock

Application fully restricted Application unrestricted

Will Connected and Automated Driving save CO_2?

LIKELIHOOD OF REBOUND EFFECTS DEPENDS ON DEGREE OF AUTOMATION

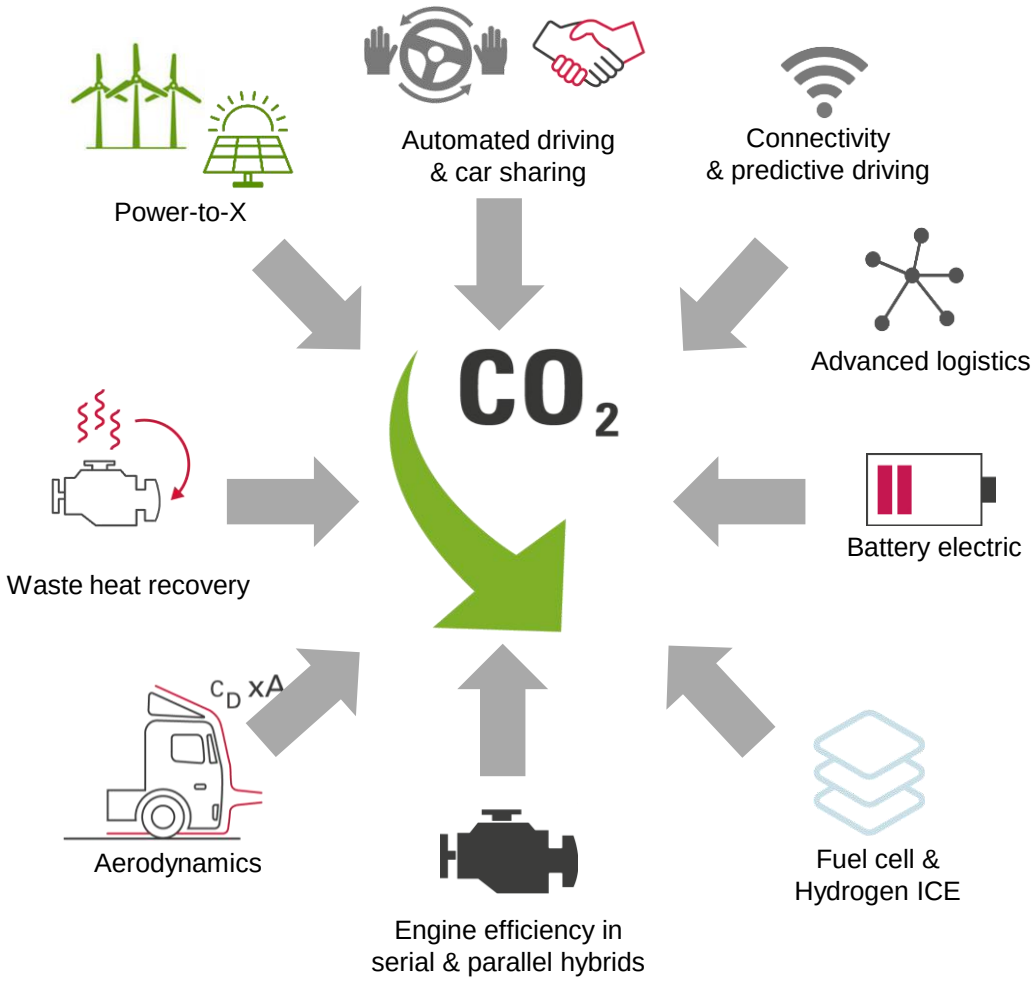
Up to SAE level 2-3:

- Smoother driving profile can save energy
  - Predictive driving
  - Less torque reserve needed
- Connected eco-routing can help improving traffic flow
- Highway pilot with better compliance to speed limits reduces speed level and fuel consumption
- Potential rebound from ^sensor and IT power consumption on-board and ICT

SAE level 4 & 5

- Facilitates public transport with smaller vehicles operating at higher frequency
  - More attractive suburban and rural public transport & better mass ratio of persons/vehicle
  - Risk of more rides with low or no occupancy
- Possible rebound effects from personal cars
  - Potential cannibalization of public transport by individual used AV
  - Unmanned driving ability abuse, e.g. not parking
- New business models (pay with your data, ad-financed “free” riding) promoting careless use
- Potential rebound from on-board sensor and IT power consumption, entertainment, ICT, and in HPC centers

CO_2-neutral Mobility requires combined efforts and can only be achieved by implementation of a wide range of technologies



USAGE:
Optimization of Usage can contribute its share, especially through connectivity and predictive driving

ELECTRIFICATION
of Powertrains is on its way, further developments of batteries and e-machines with higher efficiency ongoing

EFFICIENCY:
Engine efficiency > 50% & serial hybrids with P2hybrid efficiency under development

ENERGY CARRIERS:
Fuels from renewables are necessary to reach the CO_2 emission reduction ambitions – yet until now there is too few political support and industry investment

Let the fossils rest in peace! (cit.: Tobias Block, VDA)
Establish a circular economy for carbon dioxide!

THERE WILL BE NO ENERGY REVOLUTION WITHOUT P2X!

The fastest pathway to CO_2 neutral mobility:

- Powertrain electrification with modest battery sizes
- Renewable Drop-in fuels (bio-waste and CCU)
- Ramp-up hydrogen as domestic energy buffer
- Methanol from Spain and MENA states

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