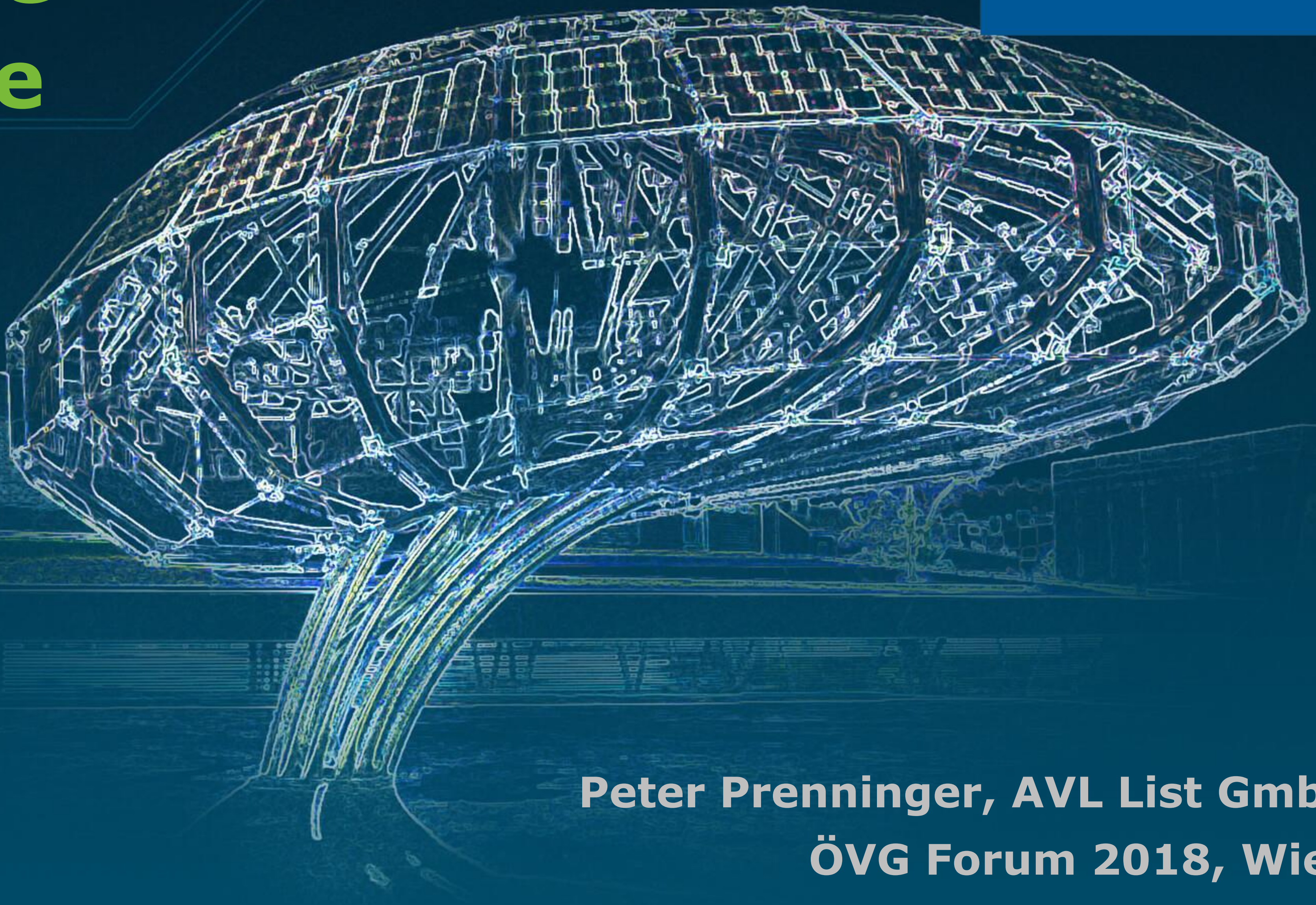
Alternative Treibstoffe und Motoren



Peter Prenninger, AVL List GmbH

ÖVG Forum 2018, Wien

Solutions for all Customer Segments


Passenger Cars


2-Wheelers


Racing


Construction


Agriculture


Commercial Vehicle

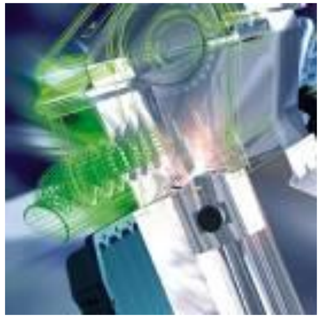

Locomotive


Marine


Power Plants

Powertrain Engineering

Development Platform



Simulation & Testing

AVL Powertrain – a Network of Technical Centers



HQ Graz, **AUT**


Steyr, **AUT**

Graz, **AUT**


Neuenstadt, **GER**


Regensburg, **GER**


Remscheid, **GER**


Munich, **GER**


Ingolstadt, **GER**


Stuttgart, **GER**


Basildon, **UK**


Coventry, **UK**


Paris, **FRA**


Gotenborg, **SWE**


Södertälje,**SWE**


Haninge, **SWE**


Reggio Emilia**, ITA**


Budapest, **HUN**


Istanbul, **TUR**

Europe

Austria*
France
Germany
Great Britain
Italy

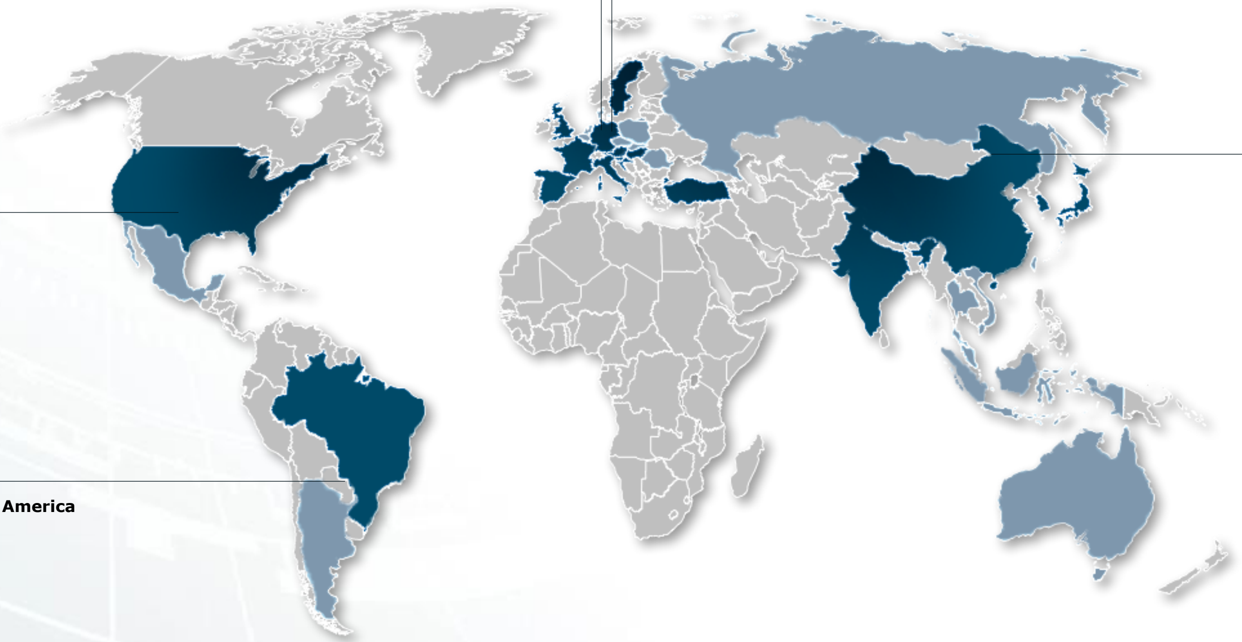
Hungary
Sweden
Turkey


Plymouth, **USA**

Lake Forest, **USA**


Ann Arbor, **USA**


Sao Paulo, **BRA**



North America
USA

South America
Brazil

Asia
China
India
Japan
Korea


Shanghai, **CHN**


Tianjin, **CHN**


Delhi-Gurgaon, **IND**


Tokyo, **JPN**


Seoul, **KOR**

+ another
13 Engineering
Offices

*Headquarters in Graz

Enterprise Development Automotive

RESEARCH 10%
of turnover in-house R&D

INNOVATION 1500
granted patents

STAFF

9.400 employees

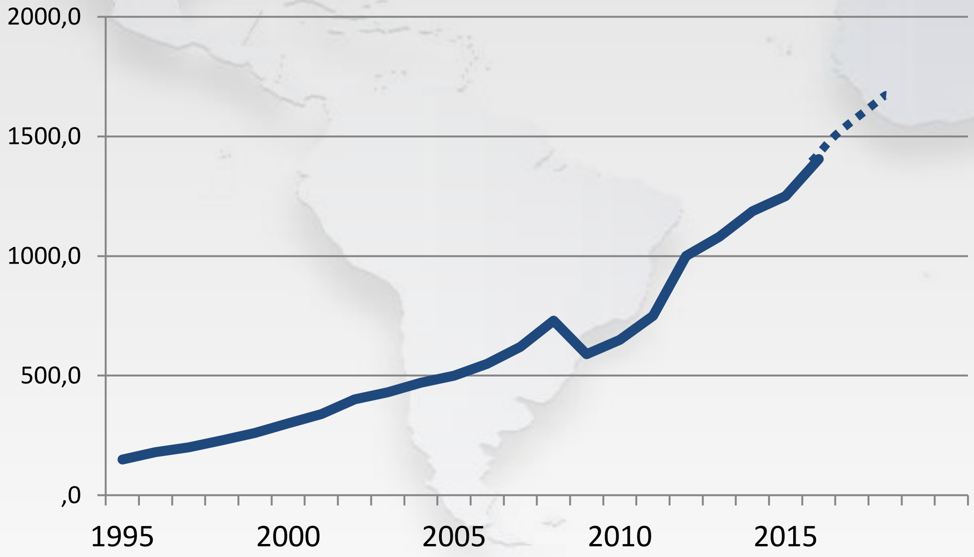
65% engineers and scientists

GLOBAL FOOTPRINT

40 engineering locations
21 of them with own test fields

- **>220** testbeds
- Global customer support network

GROWTH



SALES

1995:
0.15 billion €

2017*:
1.55 billion €

Plan 2018:
1.71 billion €

*Preliminary

EXPERIENCE
70 years !

POWERTRAIN
and its Integration in the Vehicle

ONE

PARTNER

CONTENT

- Boundary Conditions and CO_2 Emissions Targets
- Improvement Potentials of Vehicle Powertrain Technology – View of EU Technology Platform ERTRAC
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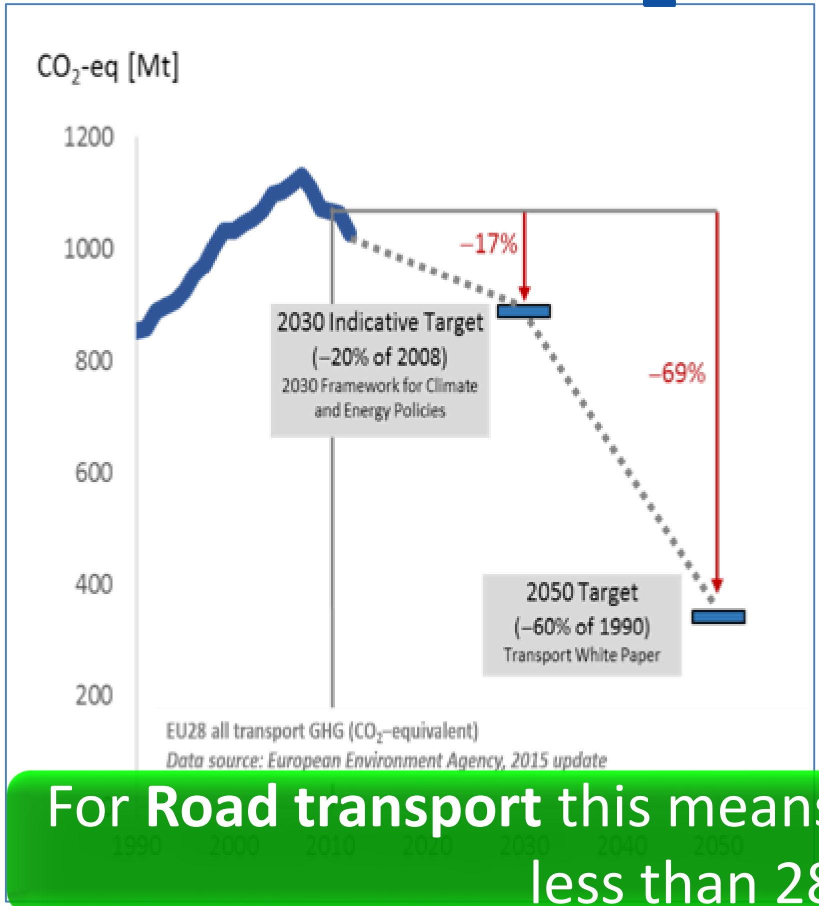
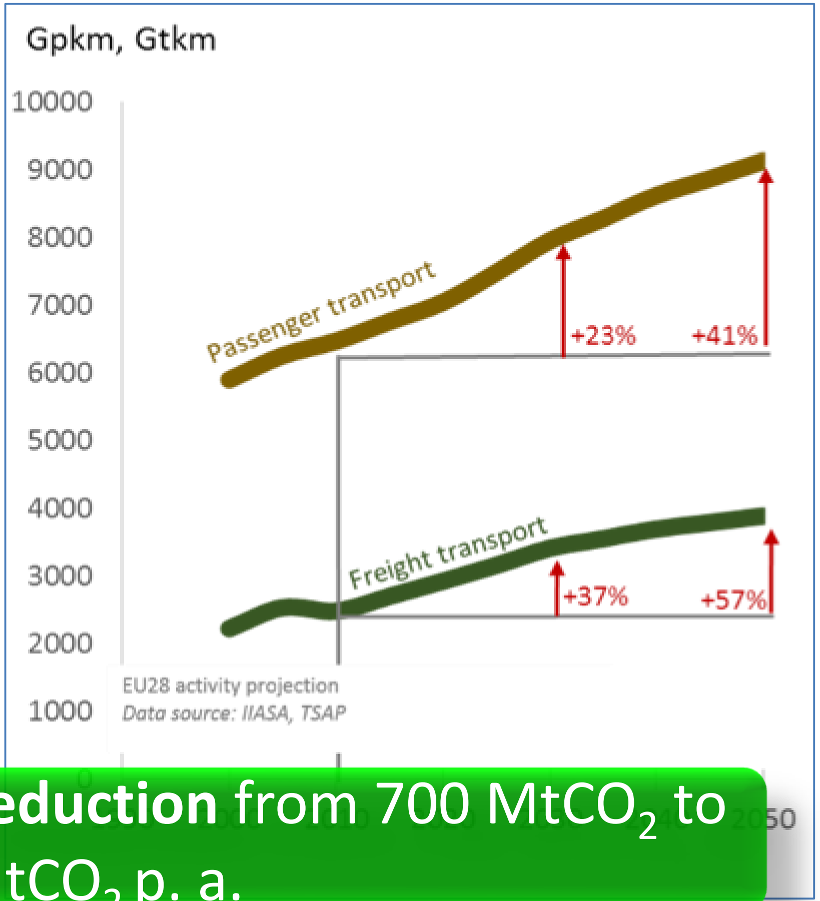
European CO_2 targets for transport





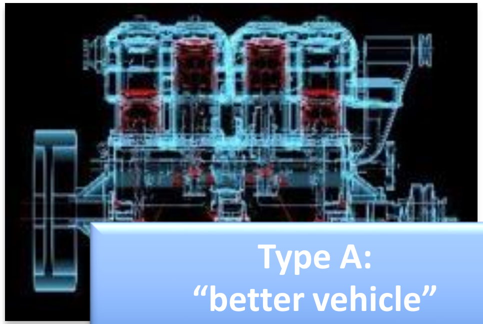
For **Road transport** this means a **reduction** from 700 $MtCO_2$ to less than 280 $MtCO_2$ p. a.

There is a need to significantly reduce transport $\mathbf{CO_2}$ whilst demand is projected to increase

To reach the overall European $\mathbf{CO_2}$ **targets for tra**nsport, a **system approach** is needed

Agreements ERTRAC CO_2 Evaluation Group

- **Only technical measures** are addressed
- **Fleet calculation** is done by simulation tool "**DIONE**" by **JRC**
- **Effects** are based on **reduction factors** (WLTP, RDE etc.)
- **Ranges** (optimistic and pessimistic approach)
- **3 main types of measures**:

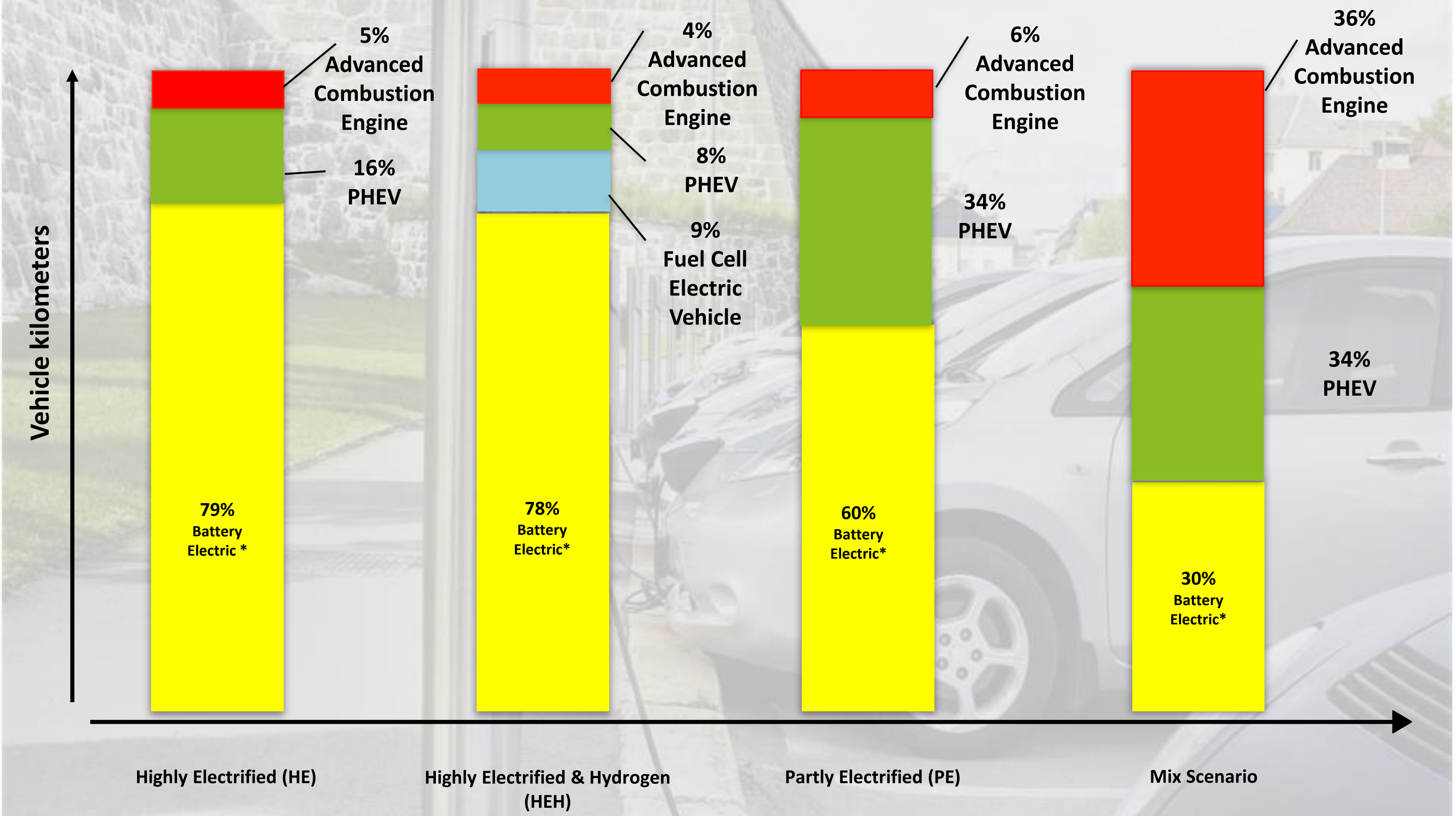


Type A:
"better vehicle"
(powertrain, aerodynamics, weight,…)

Type B:
"better traffic conditions"
("green traffic light,…)

Type C:
"traffic reduction technologies"
(load optimization,…)

2050 Fleet Activity by Powertrain

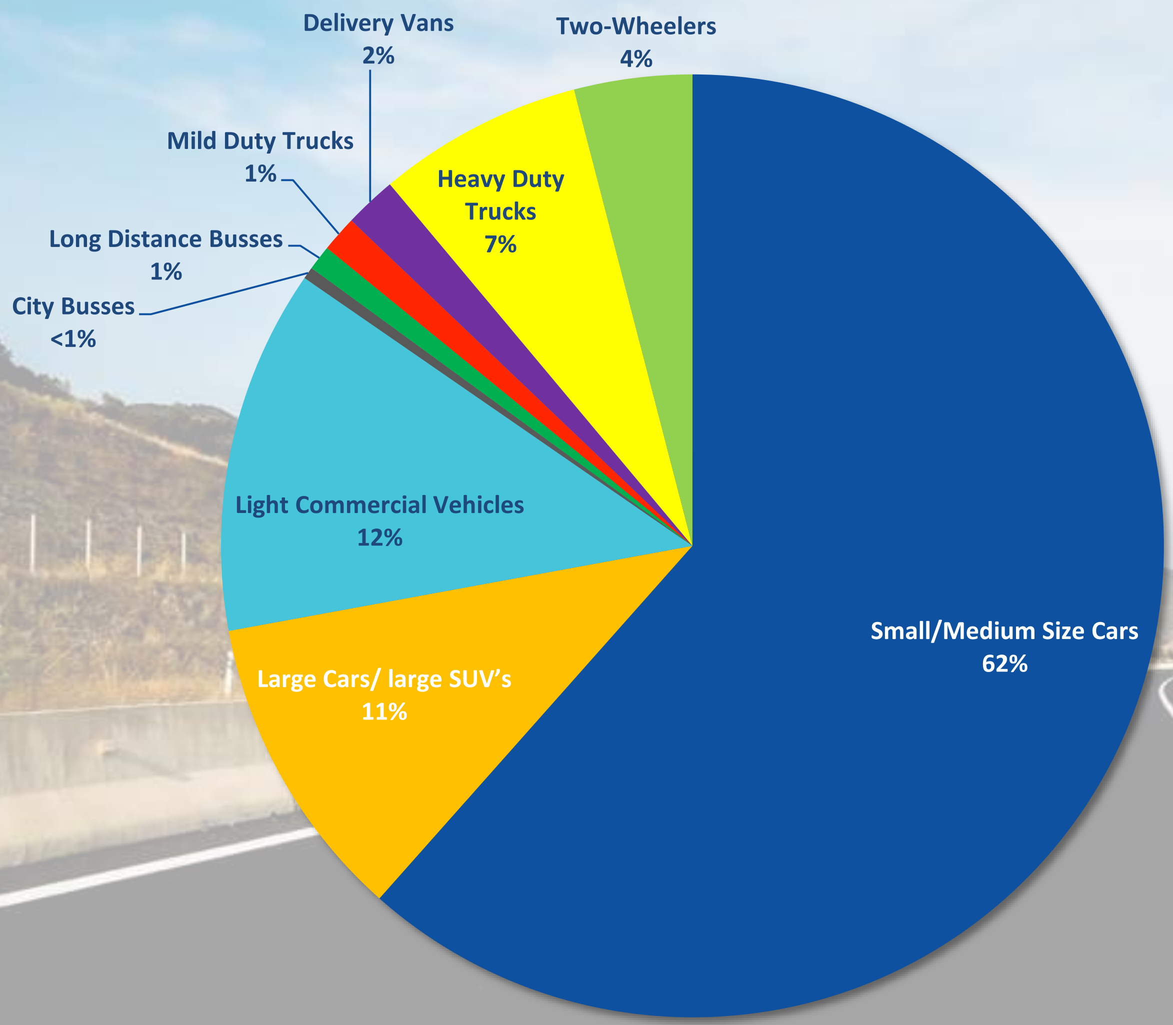


* Remark PHEV: First 50 km of driving-cycle always in electric mode

ERTRAC

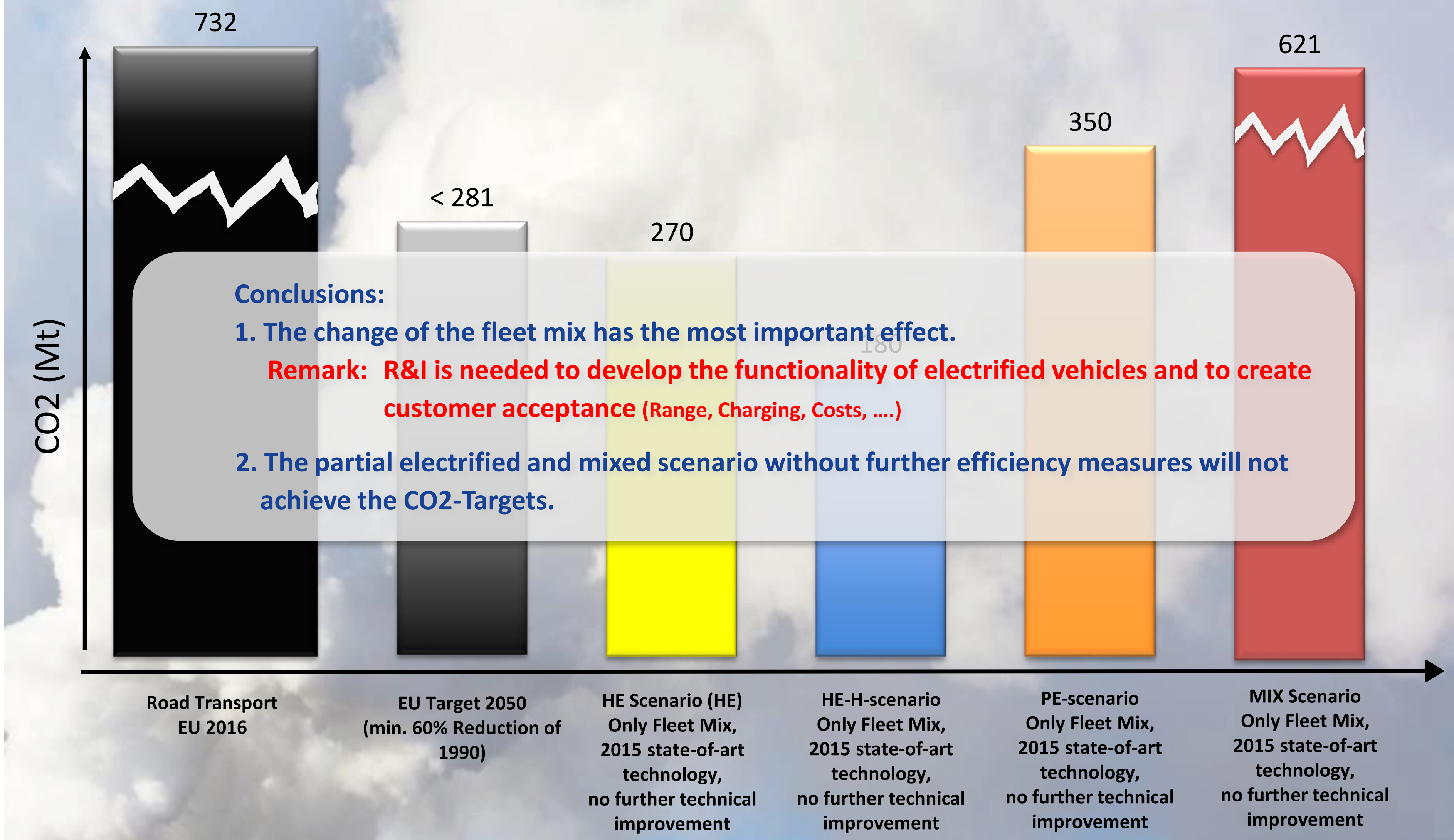
Projected Fleet Activity by Vehicles 2050

(Vehicle km, DIONE Baseline)



Rising activity
with
rising vehicle size

2050 Total CO2 Emissions Road Transport EU
Potential of Fleet Mix Change only (TTW)



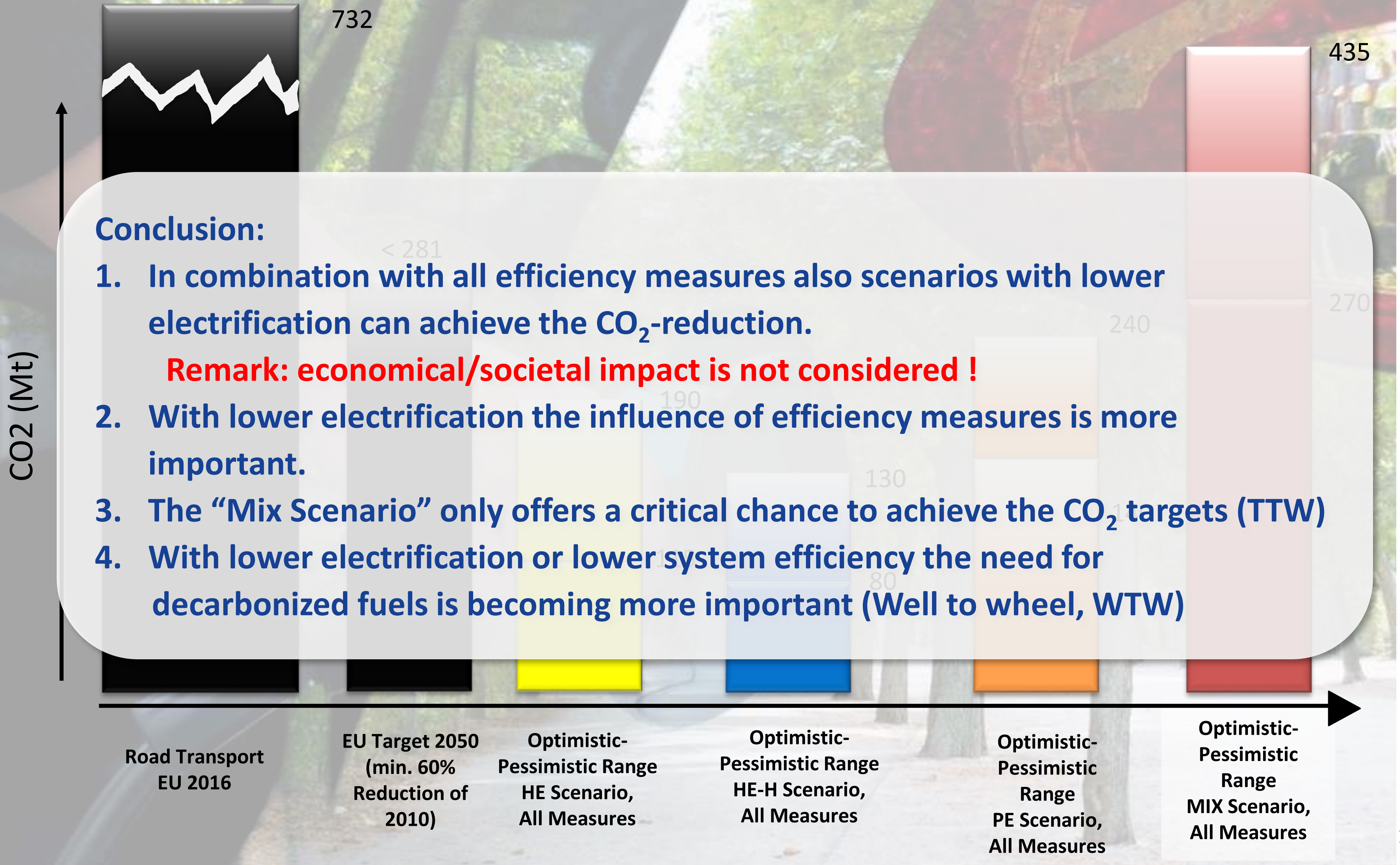
Conclusions:

1. **The change of the fleet mix has the most important effect.**

   Remark: R&I is needed to develop the functionality of electrified vehicles and to create customer acceptance (Range, Charging, Costs, ….)

2. **The partial electrified and mixed scenario without further efficiency measures will not achieve the CO2-Targets.**

2050 Total CO2 Emissions Road Transport EU Fleet Mix scenarios + all efficiency measures

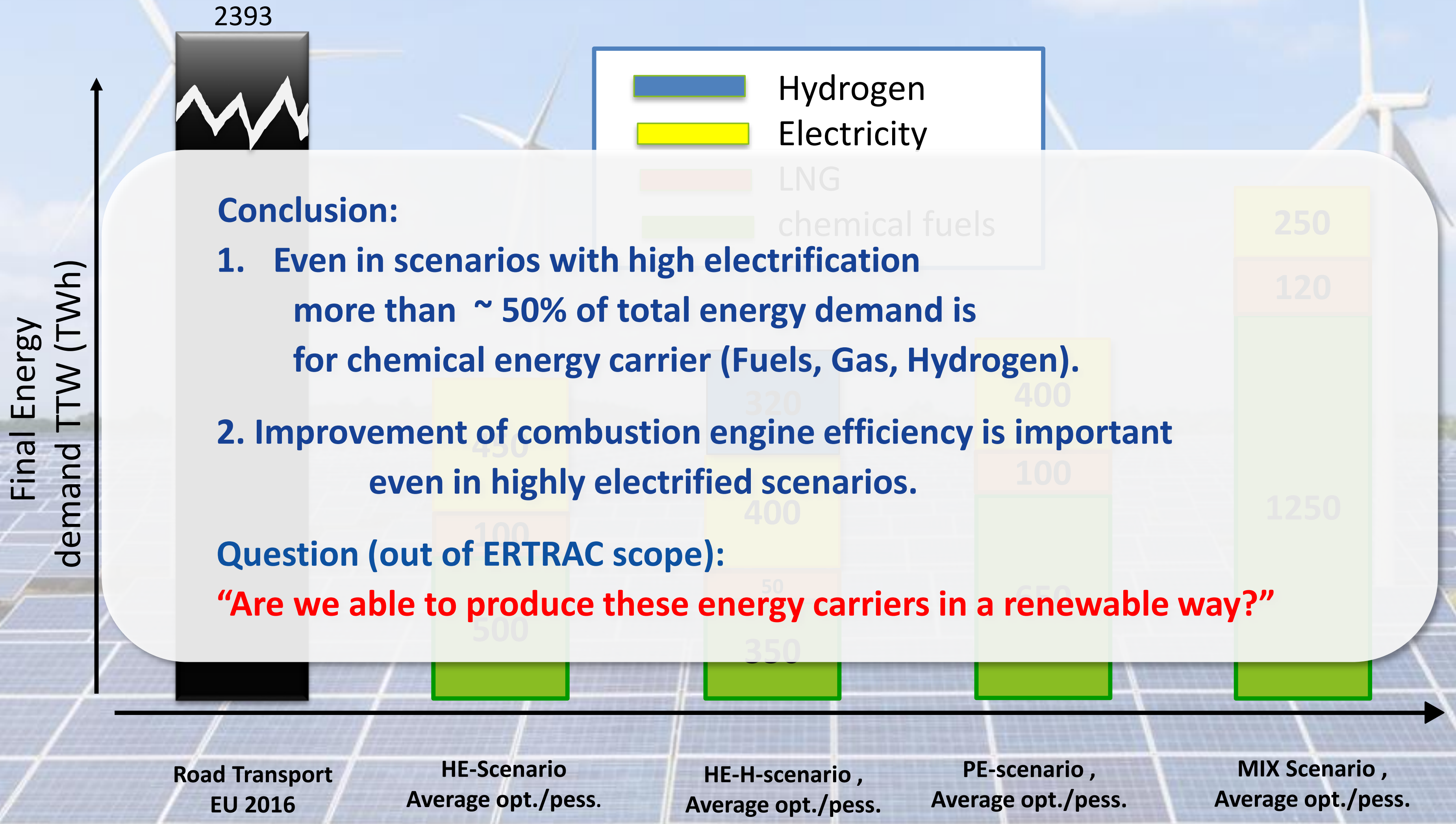


Conclusion:

1. In combination with all efficiency measures also scenarios with lower electrification can achieve the CO_2-reduction.
   Remark: economical/societal impact is not considered !
2. With lower electrification the influence of efficiency measures is more important.
3. The "Mix Scenario" only offers a critical chance to achieve the CO_2 targets (TTW)
4. With lower electrification or lower system efficiency the need for decarbonized fuels is becoming more important (Well to wheel, WTW)

ERTRAC

2050 Total Energy Road Transport EU (TTW)
4 Scenarios, Average of opt./pess



Conclusion:

1. **Even in scenarios with high electrification more than ~ 50% of total energy demand is for chemical energy carrier (Fuels, Gas, Hydrogen).**
2. **Improvement of combustion engine efficiency is important even in highly electrified scenarios.**

Question (out of ERTRAC scope):

"Are we able to produce these energy carriers in a renewable way?"

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OPTIONS FOR ALTERNATIVE FUELS

Natural Gas CNG/LNG

Use of clean burning fossil or bio gas

Biofuels

Conventional & advanced biofuels

Synthetic Fuels

PtX: Fuel produced from Renewable Energy

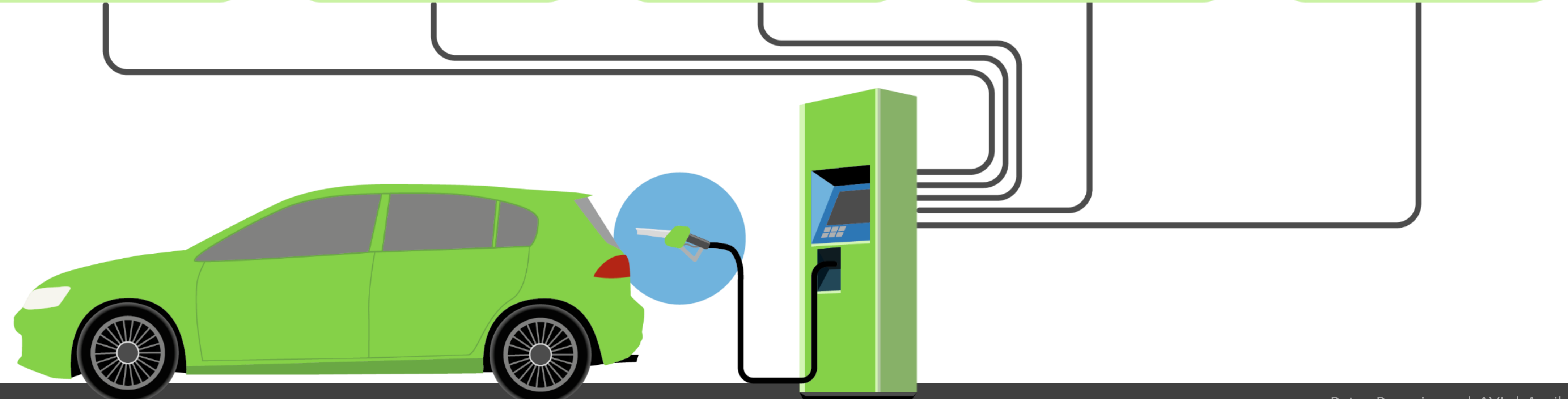
GTL: Liquid fuel from Natural Gas

Hydrogen

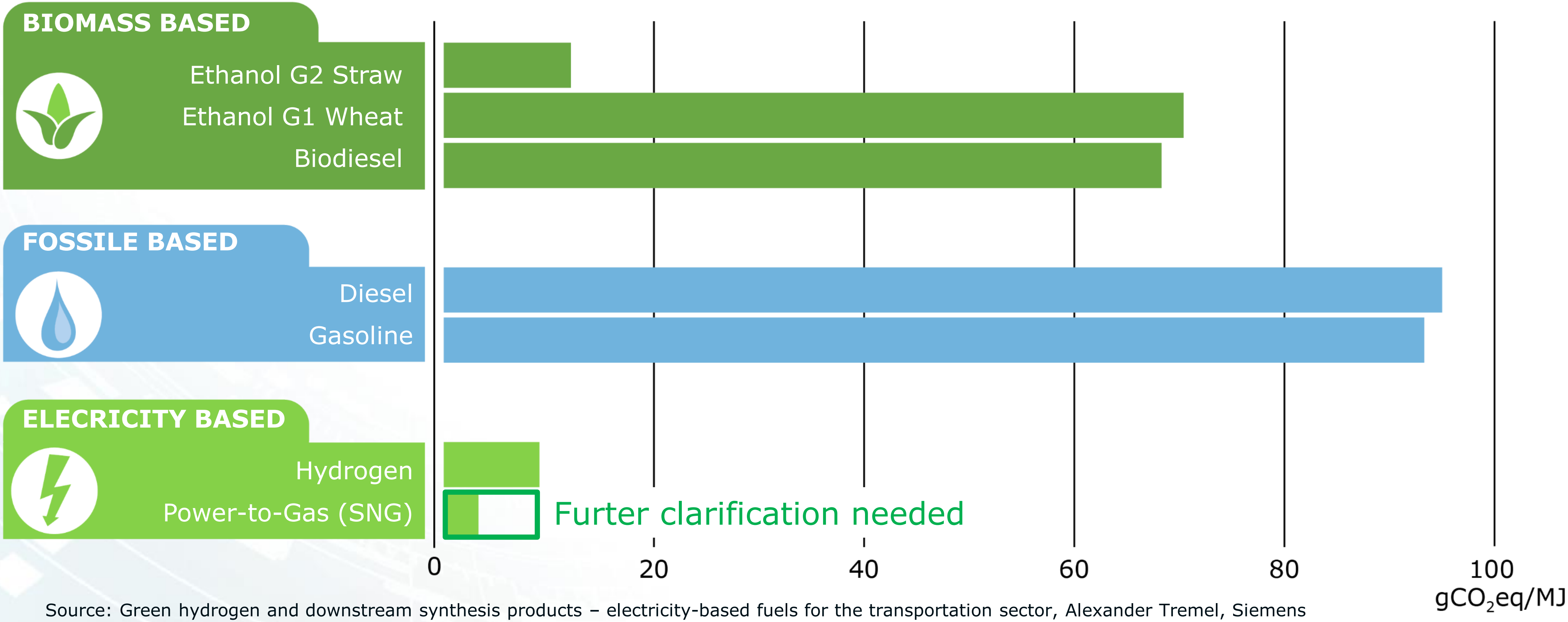
Steam methane reforming or Electrolysis for H_2 production – Fossil or Renewables

Electricity

Providing fossil or ren. Electrons to charge EVs



LIFECYCLE GREENHOUSE GAS EMISSIONS (CO_2 EQUIVALENTS) FOR FUELS

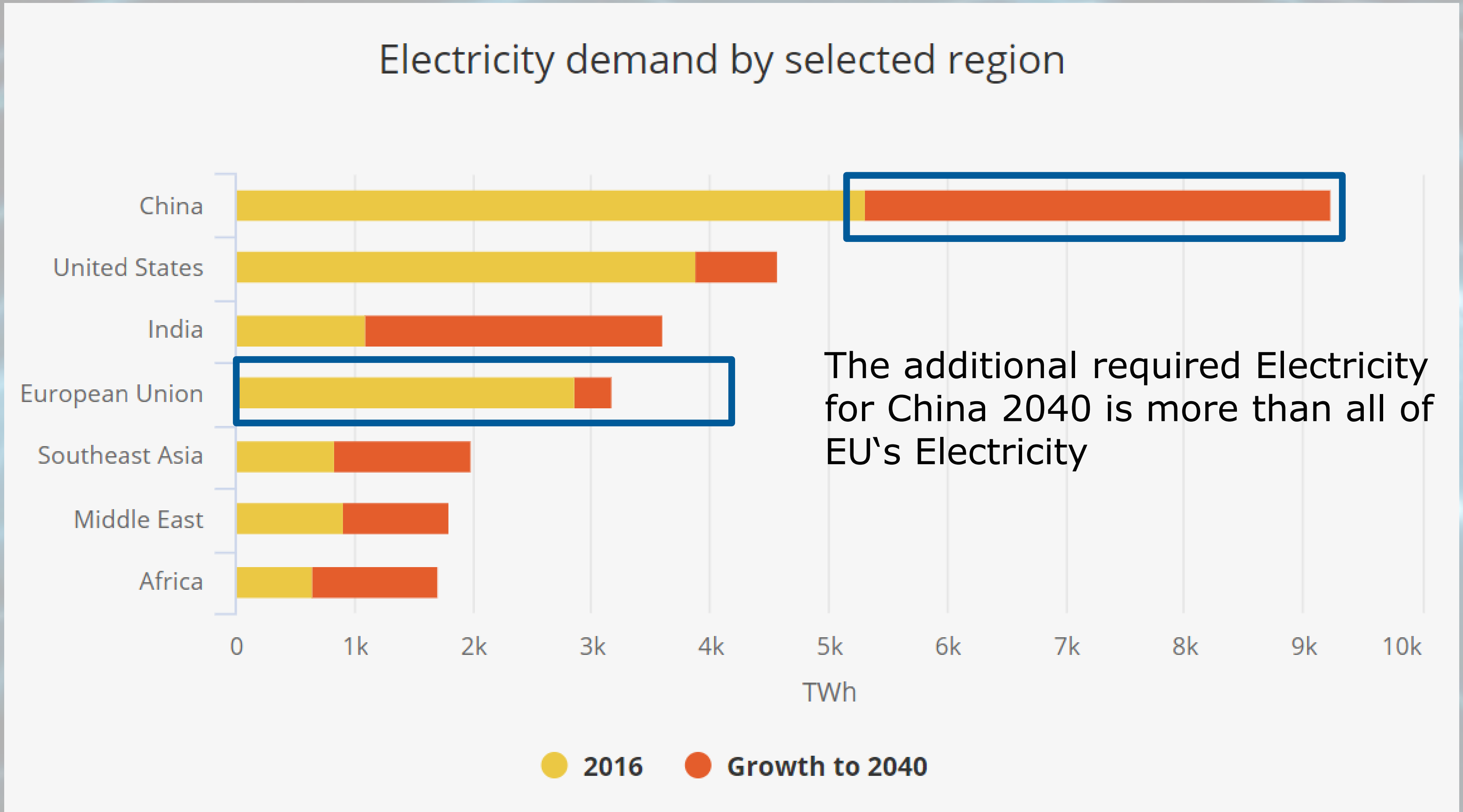


Source: Green hydrogen and downstream synthesis products – electricity-based fuels for the transportation sector, Alexander Tremel, Siemens

Electricity-based fuels are expected to outperform second generation biofuels in green house gas emissions.

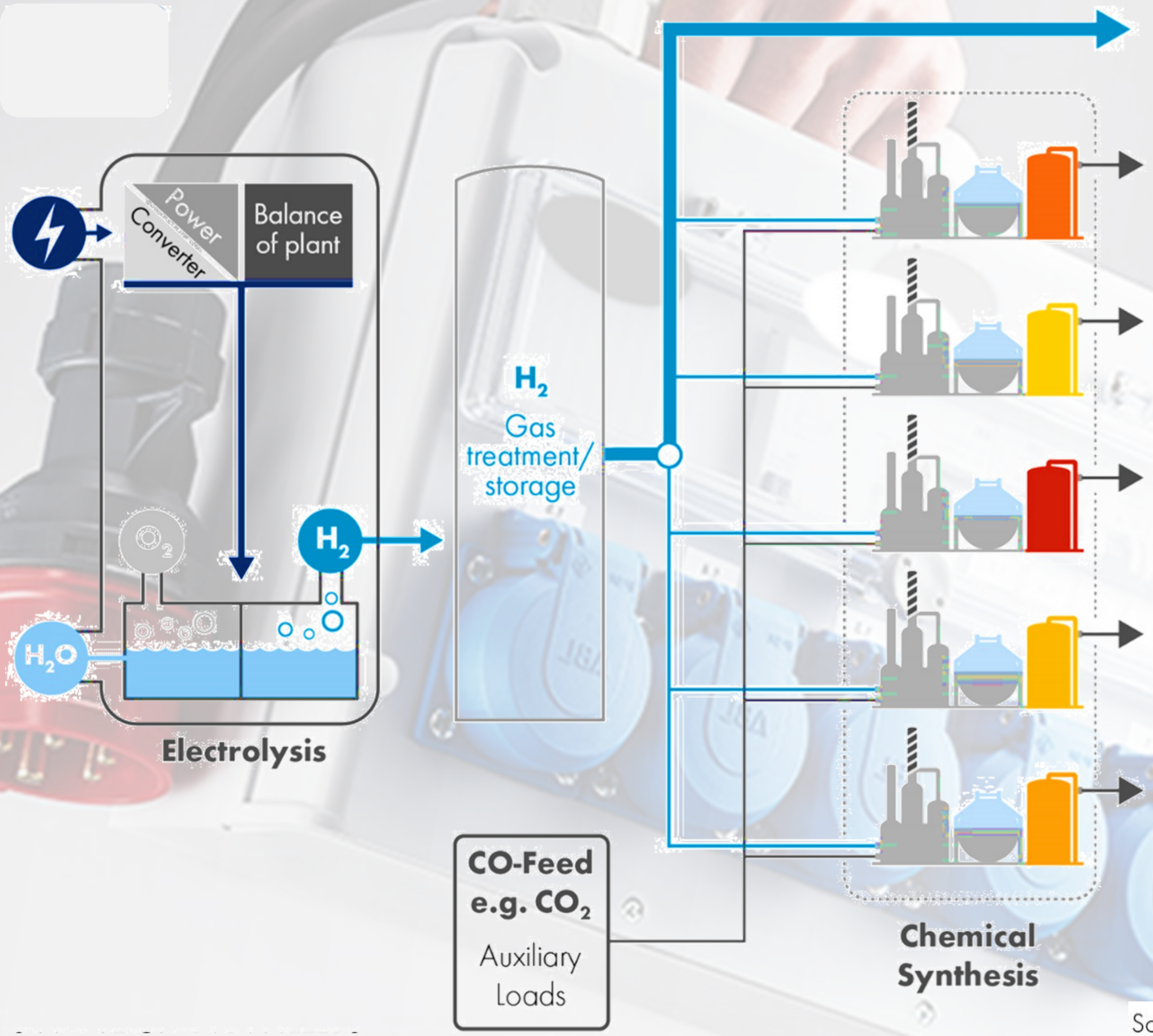
WORLD ENERGY OUTLOOK 2040
THE FUTURE IS ELECTRIFYING

AVL



Source: IEA Report Nov.2017 https://www.iea.org/weo2017/

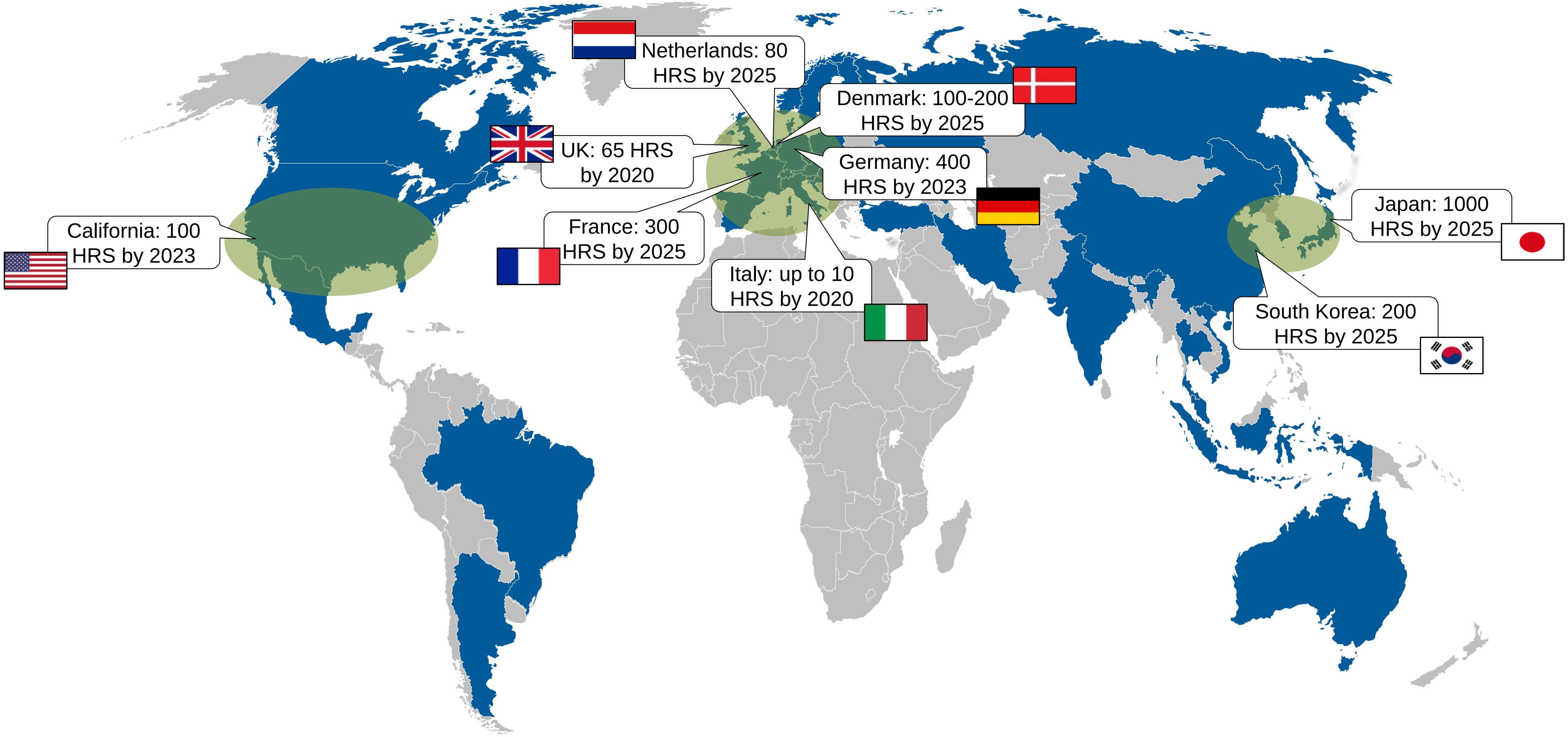
EFFICIENCY CHAIN : FROM PLUG TO FUEL



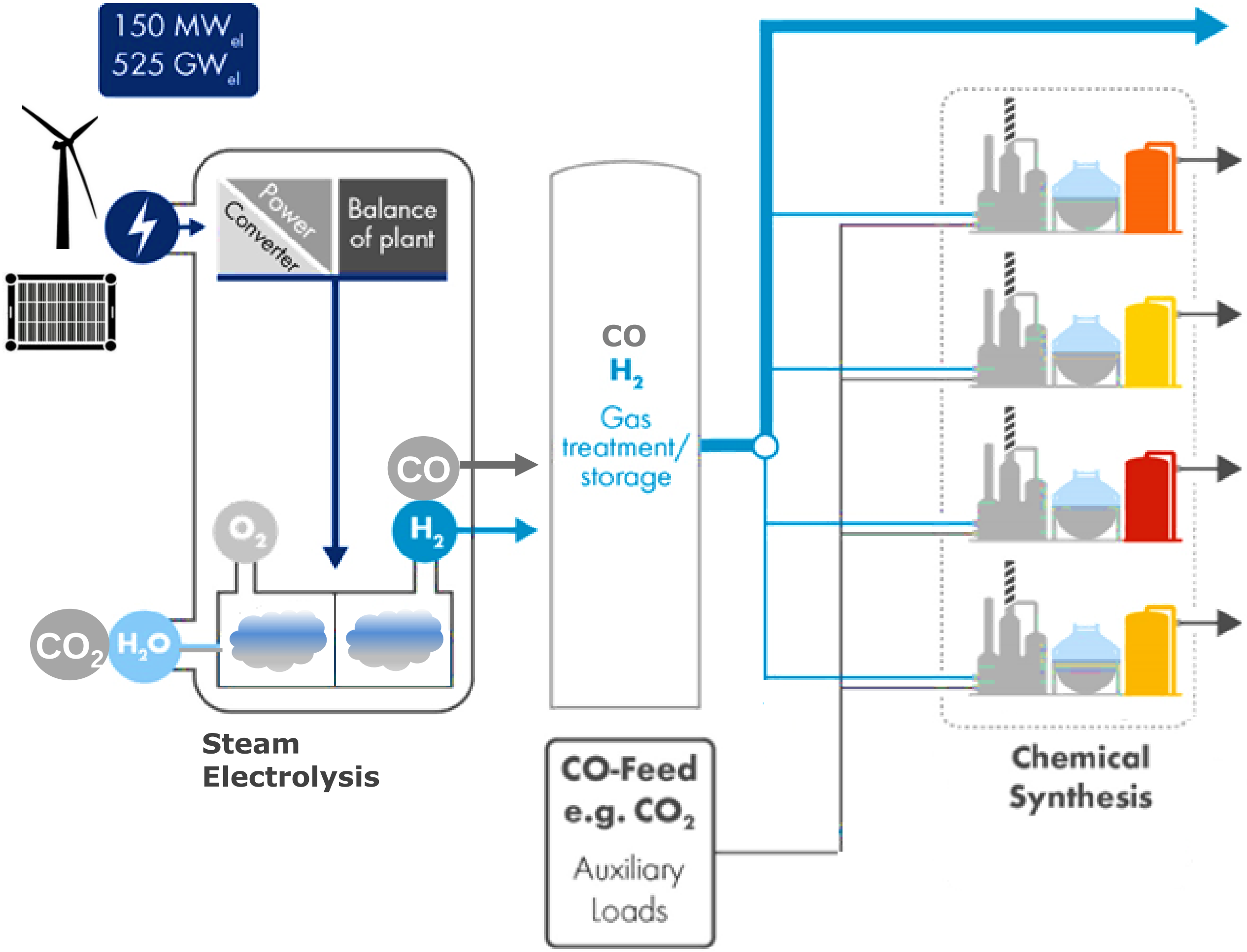
Hydrogen	η = 67%	
Syn. Natural Gas	η = 48,7%	η = 44%
FT Diesel	η = 45,3%	η = 40%
Methanol	η = 45,3%	η = 40%
DME	η = 53,3%	η = 48%
Ammonia	η = 45,3%	

Source:Siemens Corporate Technology, Alexander Tremel: ATZ Automotive Konferenz, Baden Baden Feb. 2017.

H_2 INFRASTRUCTURE



POWER TO X WITH SOLID OXIDE CO-ELECTROLYSIS



	SOEC	Conventional
Hydrogen	η ~ 80%*	η = 67%
Syn. Natural Gas	η ~ 85%*	η = 48,7%
FT Diesel		
Methanol		
DME		

*** Based on AVL project results**

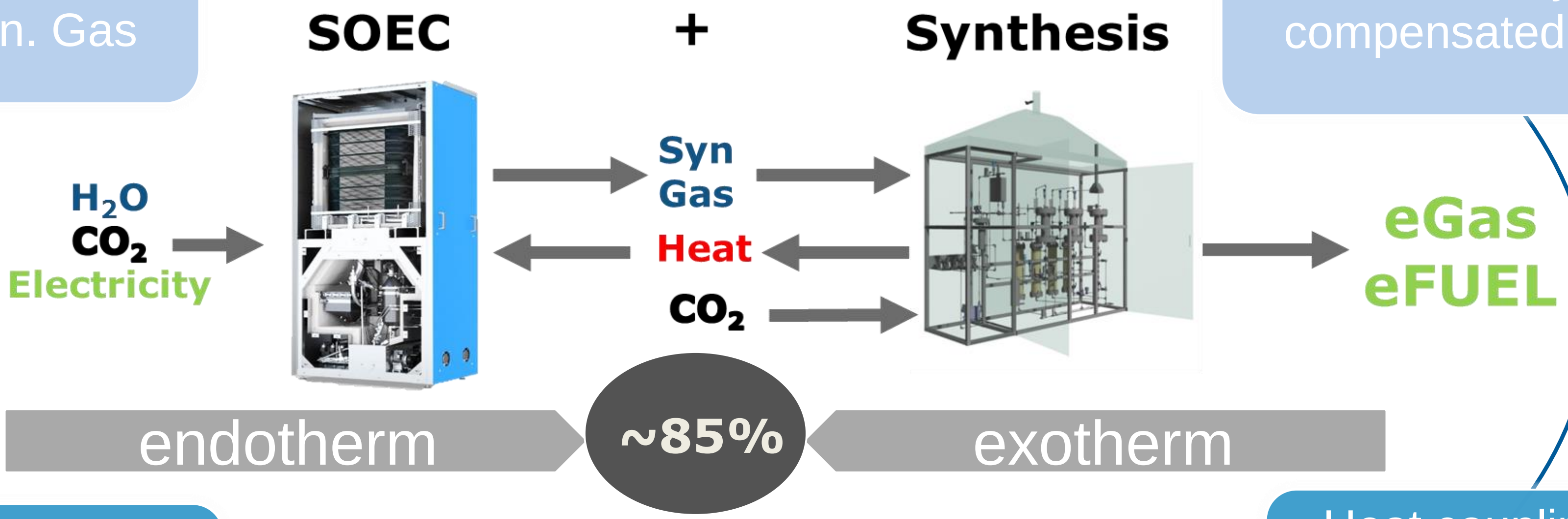
Source:Siemens Corporate Technology, Alexander Tremel: ATZ Automotive Konference, Baden Baden Feb. 2017.

E-GAS – PERFECT FUEL FOR SOFC EVS

Higher efficiency compared to Alkaline and PEM

Direct utilization of CO_2 to syn. Gas

Less electricity needed – compensated with heat

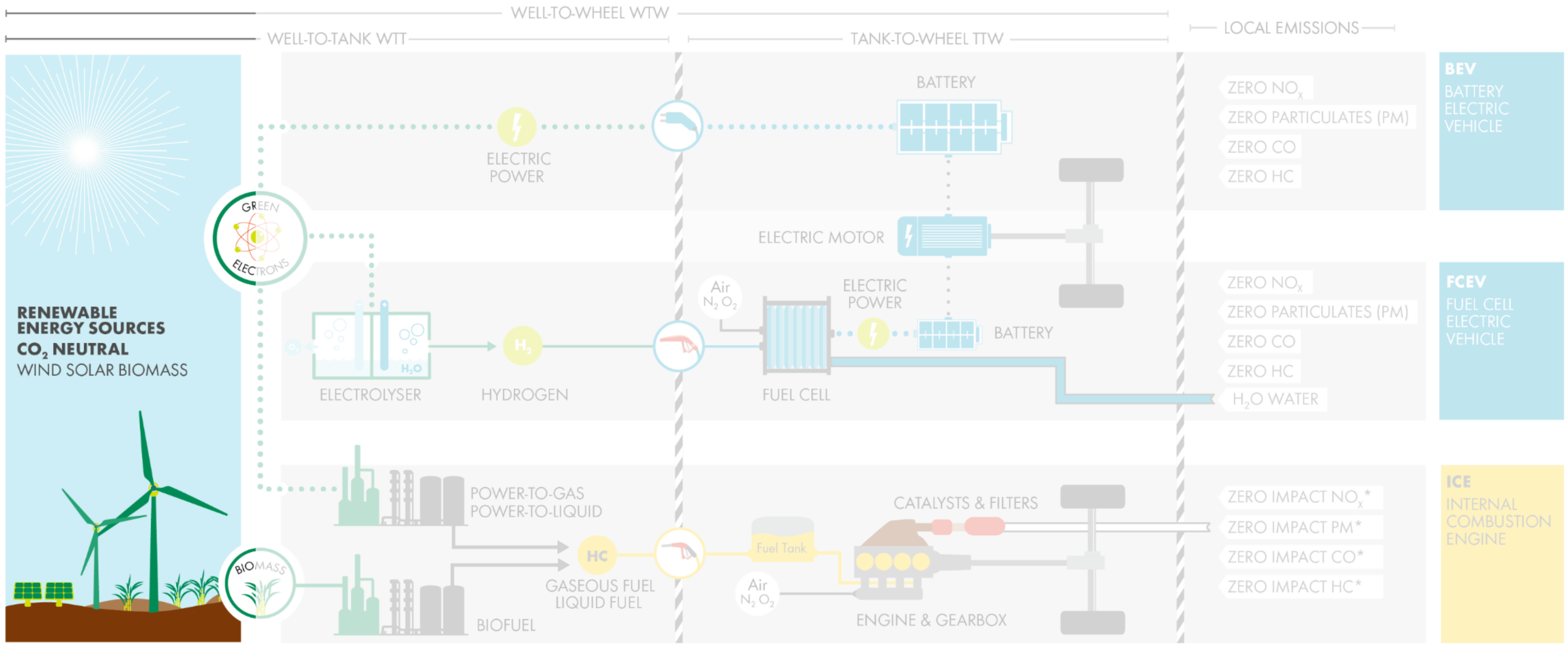


Heat coupling with exothermic synthesis

Heat coupling with waste heat from industry

Separation of electrochemistry and vaporization

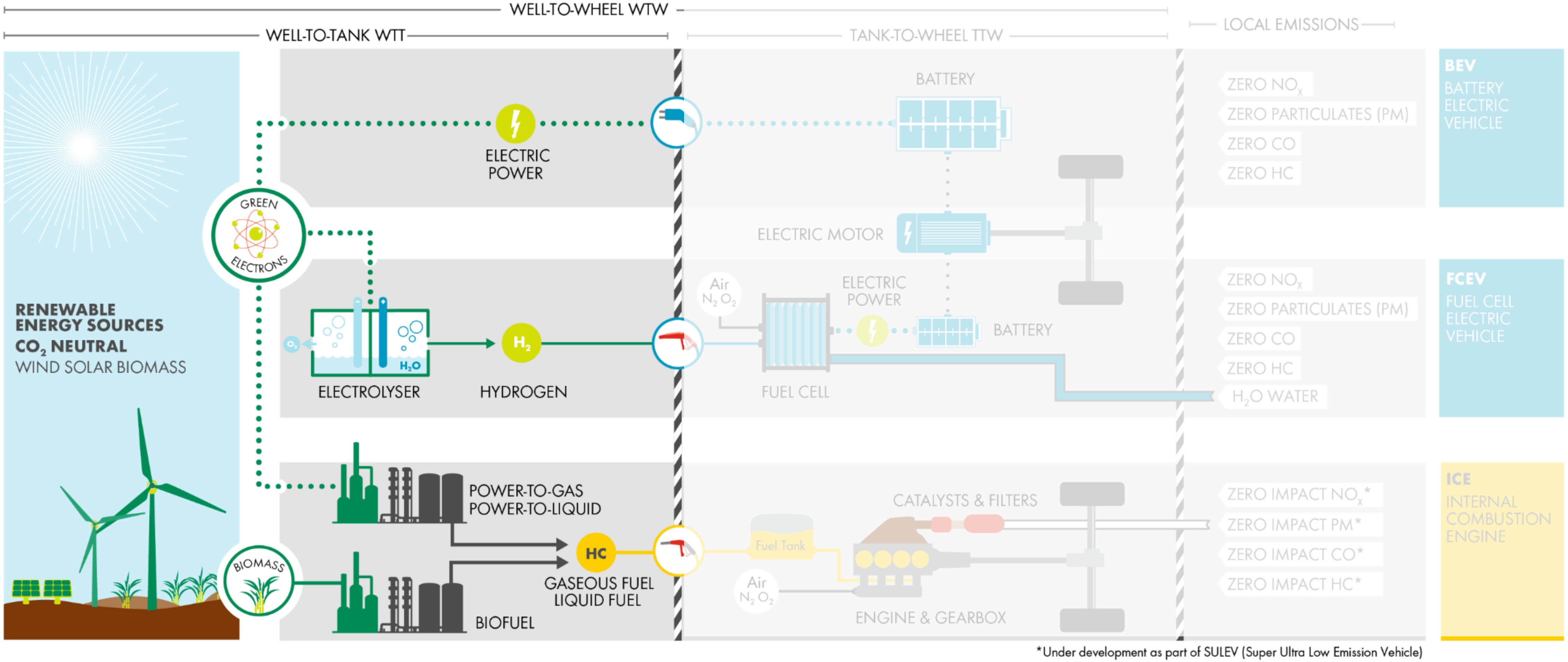
PATHWAYS TO ULTIMATELY CLEAN VEHICLE DRIVETRAINS



*Under development as part of SULEV (Super Ultra Low Emission Vehicle)

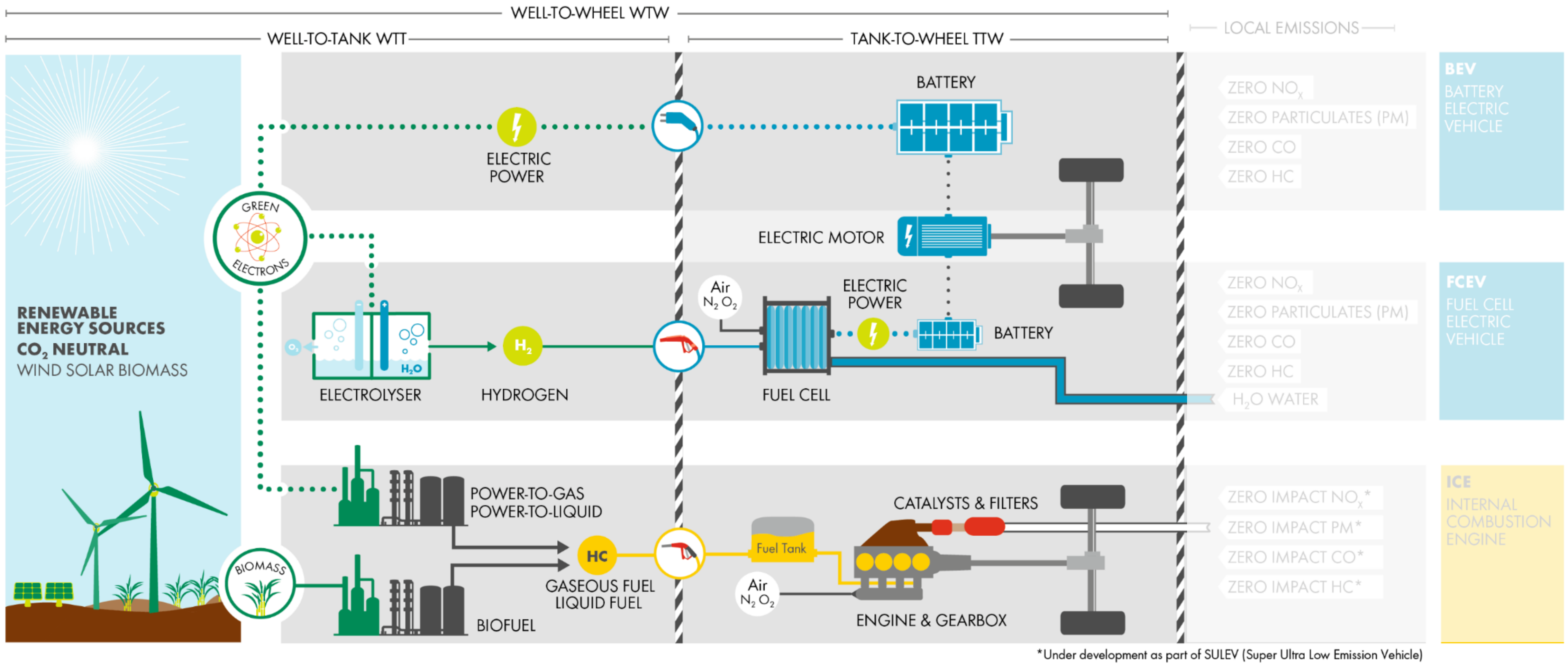
Harvesting

PATHWAYS TO ULTIMATELY CLEAN VEHICLE DRIVETRAINS



Harvesting → Generation

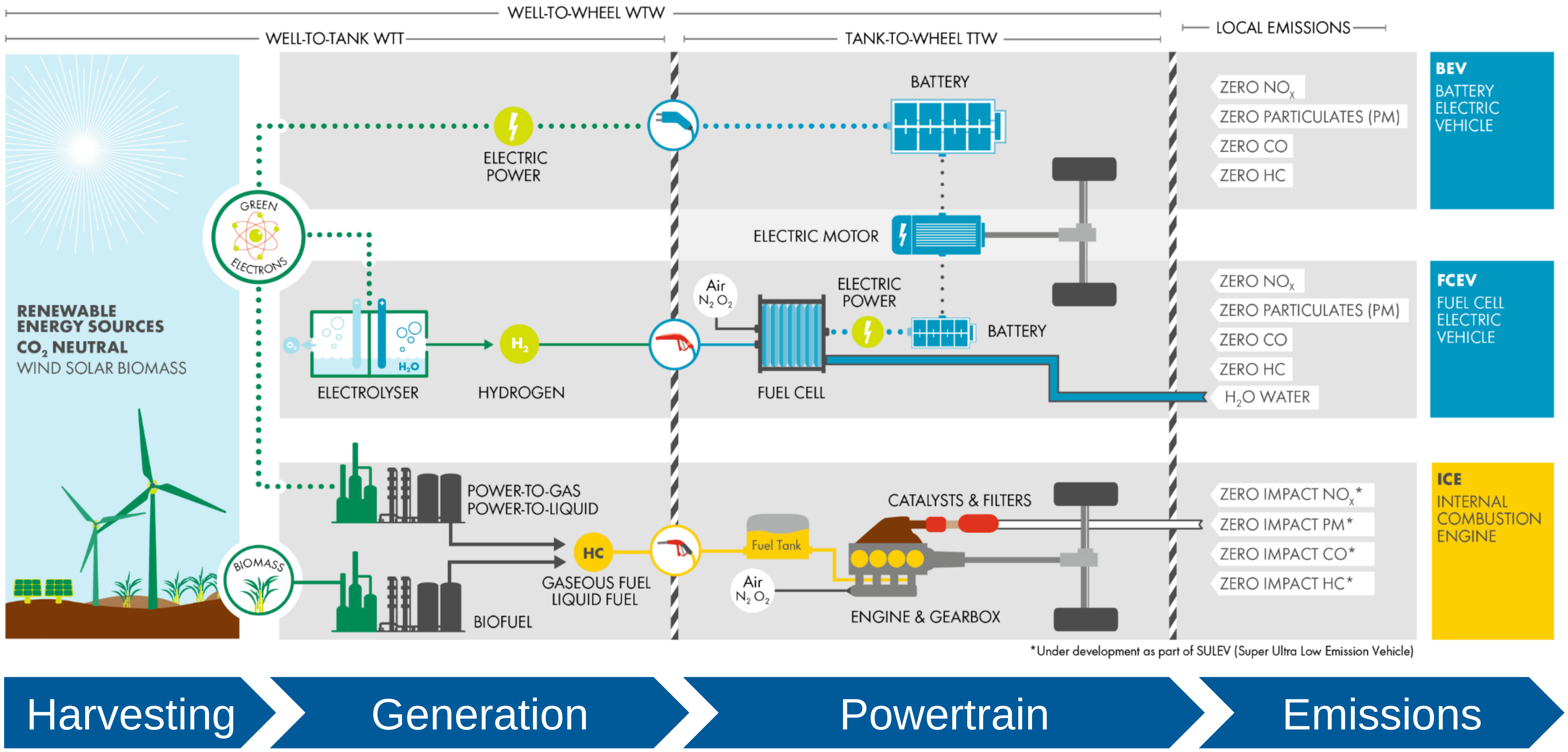
PATHWAYS TO ULTIMATELY CLEAN VEHICLE DRIVETRAINS



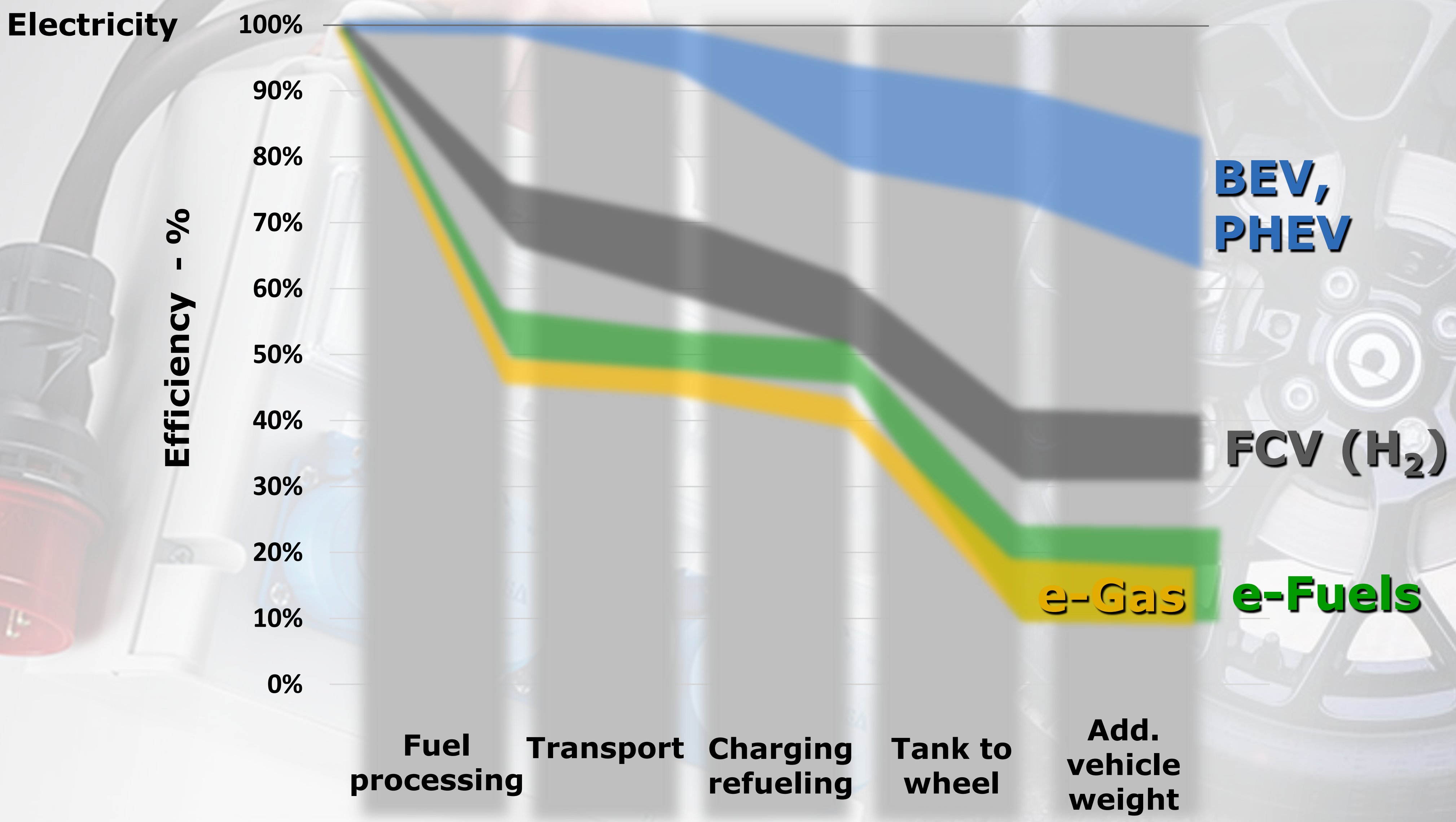
*Under development as part of SULEV (Super Ultra Low Emission Vehicle)

Harvesting → Generation → Powertrain

PATHWAYS TO ULTIMATELY CLEAN VEHICLE DRIVETRAINS



EFFICIENCY CHAIN : FROM PLUG TO WHEEL



Source: Siemens, Alexander Tremel and AVL

RESULT OF EC EXPERT WORKING GROUP

		Road/passengers			Road/freight			Rail	Water			Air
		short	med	long	short	med	long		inland	short-sea shipping	maritime	
Electric	BEV	■			■			■				
	HFC	■	■		■			■	■			
	Grid	■			■			■				
Biofuels (liquid)		■	■	■	■	■	■	■	■	■	■	■
Synthetic fuels		■	■	■	■	■	■	■	■	■	■	■
Methane	CNG	■	■	■	■	■						
	CBG	■	■	■	■	■						
	LNG	■	■	■	■	■	■	■	■	■	■	
LPG		■	■	■	■	■	■		■	■		

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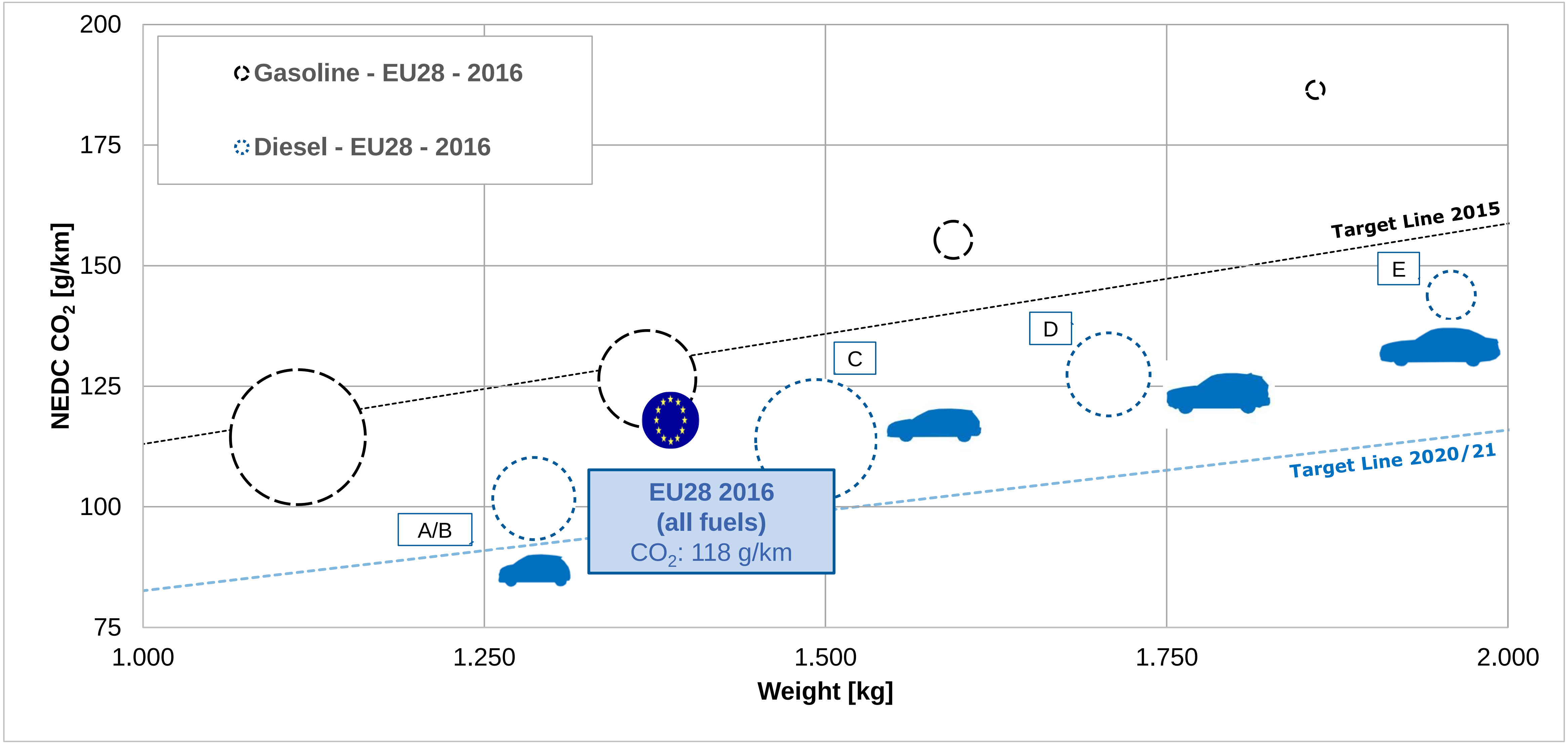
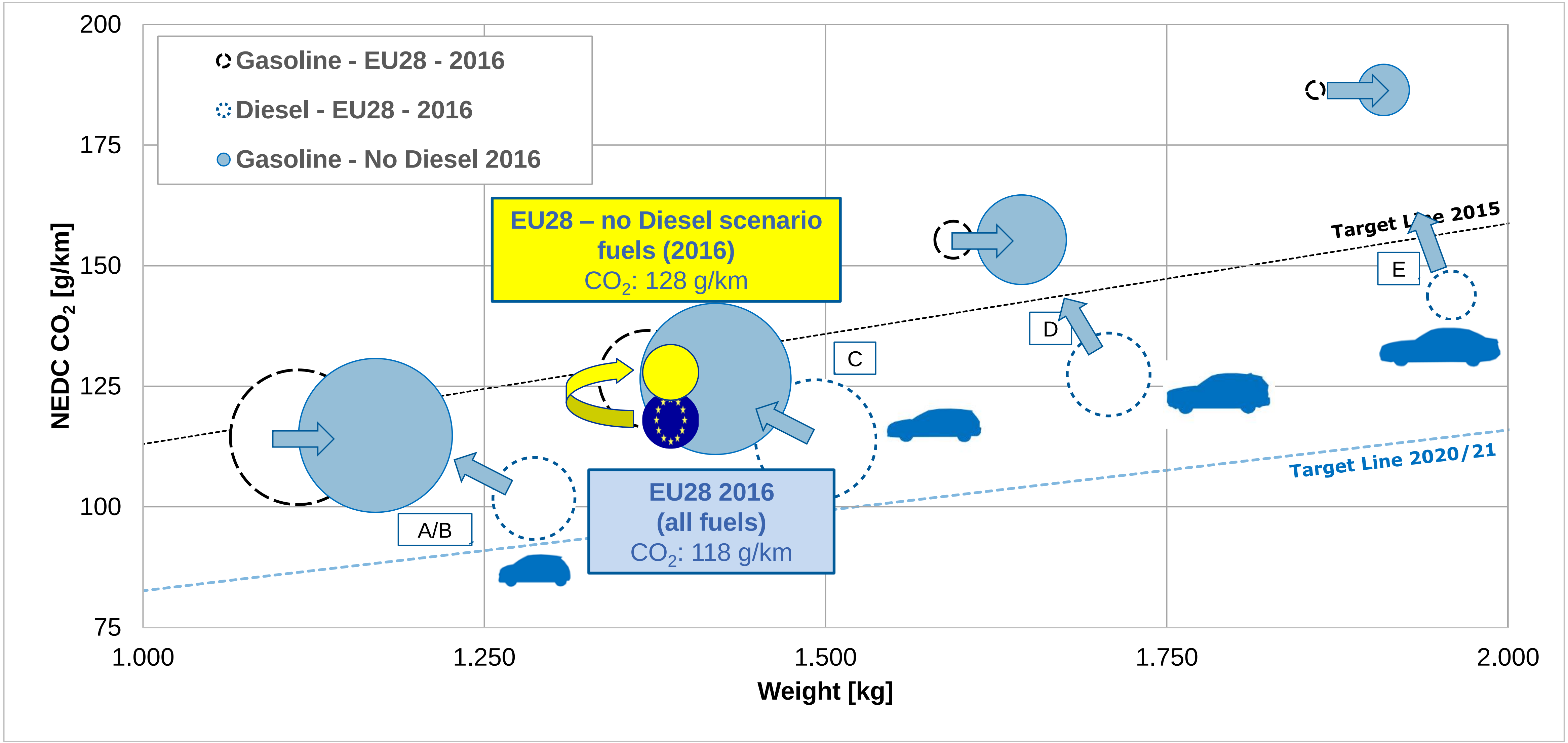
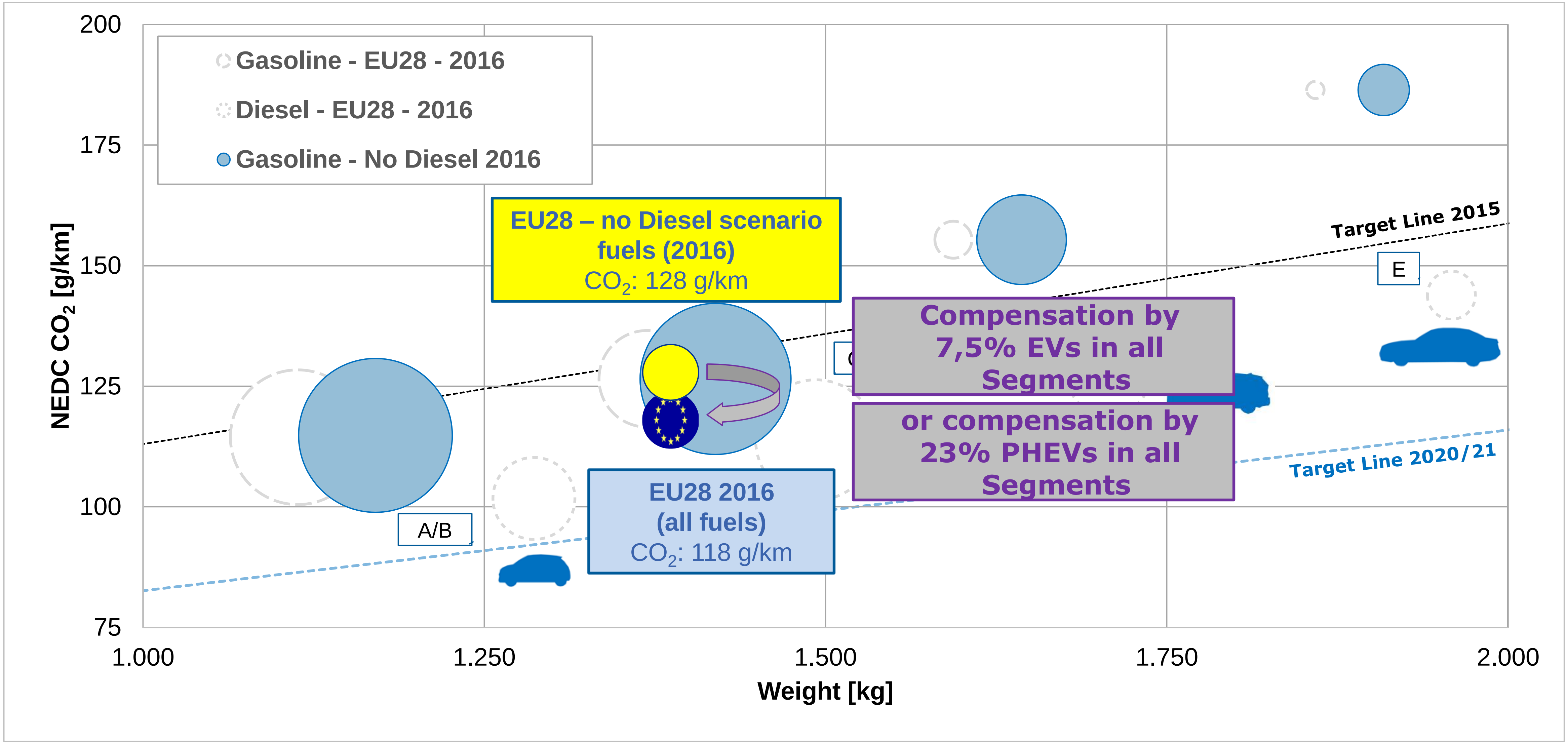
CO_2 PERFORMANCE OVER SEGMENTS STATUS 2016



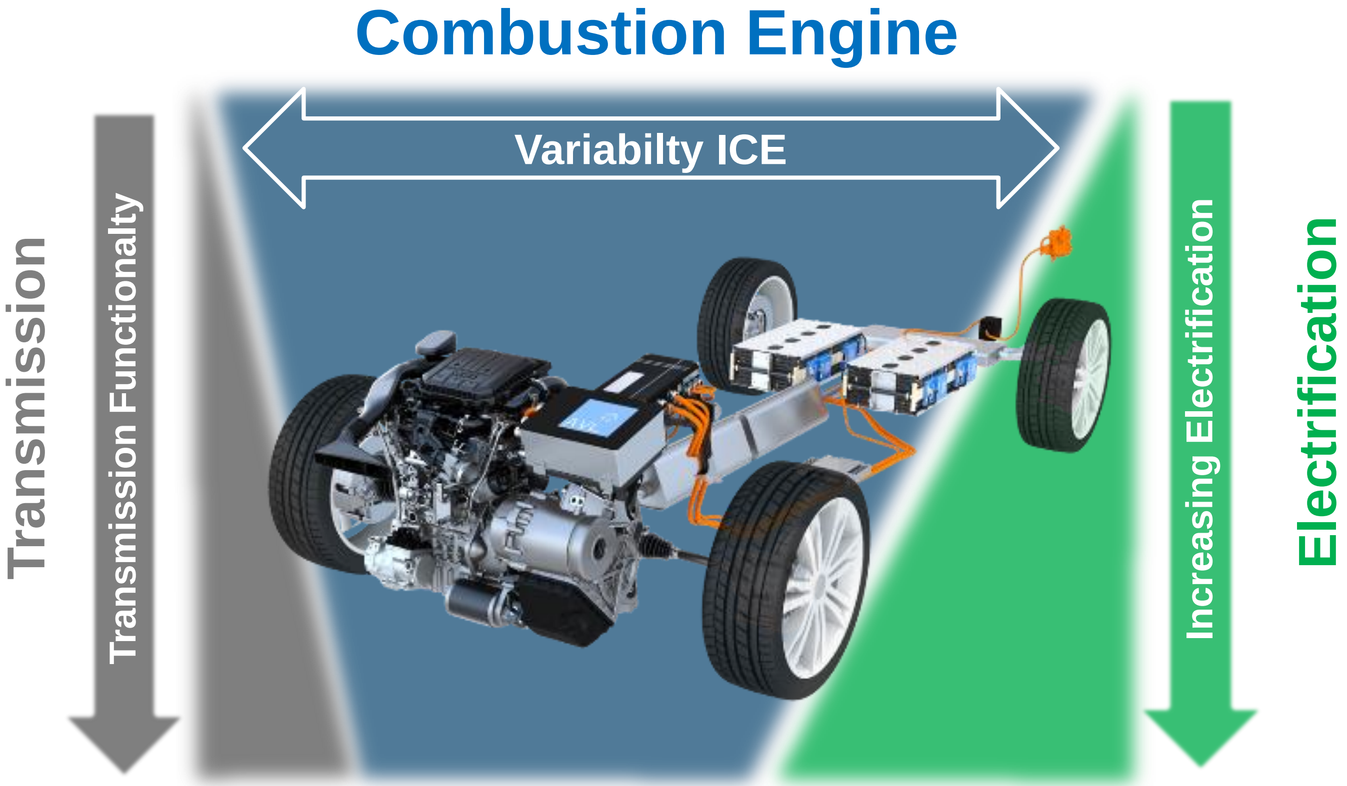
CO_2 PERFORMANCE OVER SEGMENTS NO DIESEL IN 2016



CO_2 PERFORMANCE OVER SEGMENTS NO DIESEL IN 2016

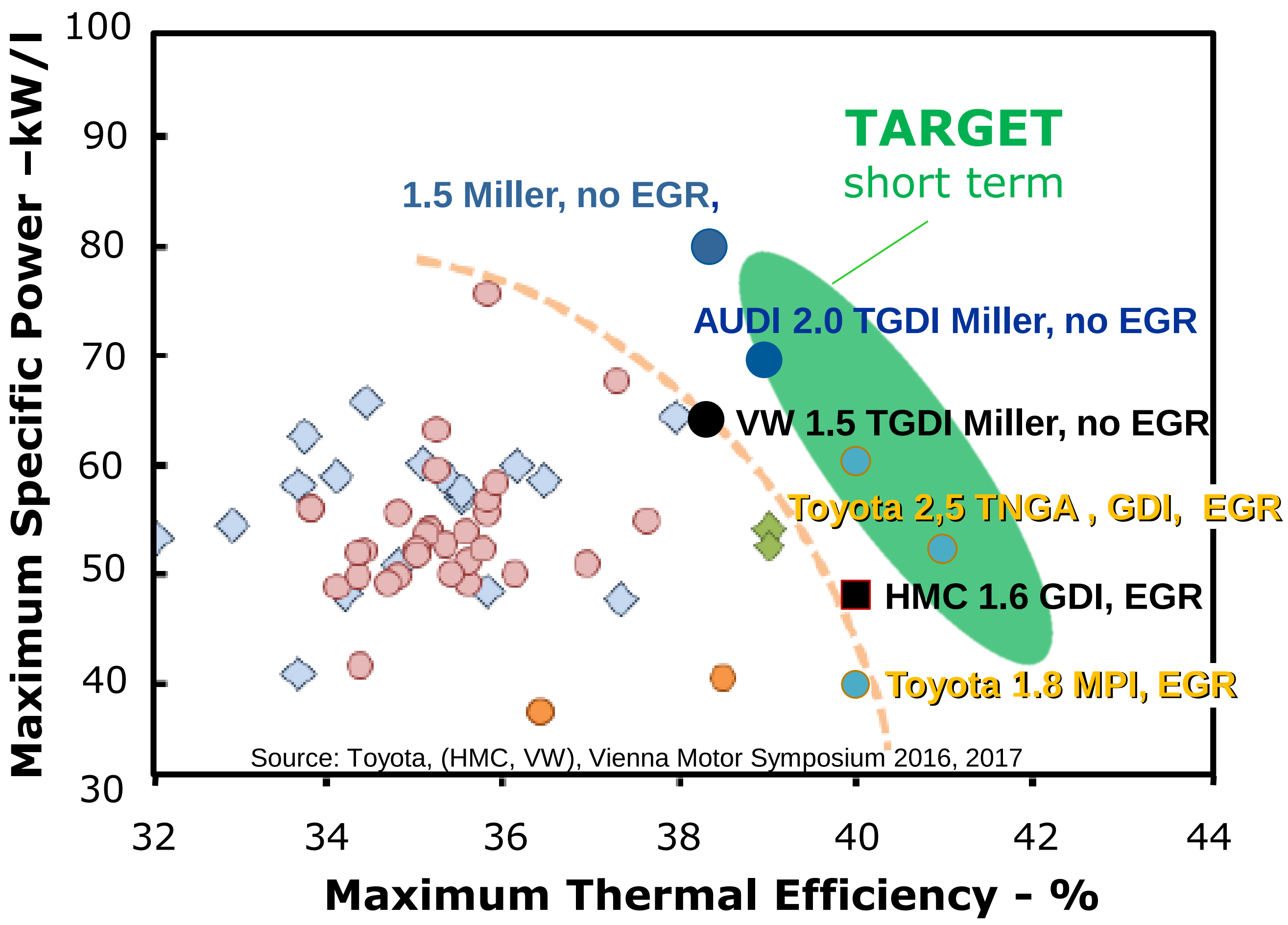


GASOLINE ENGINE TECHNOLOGY TRENDS - TODAY



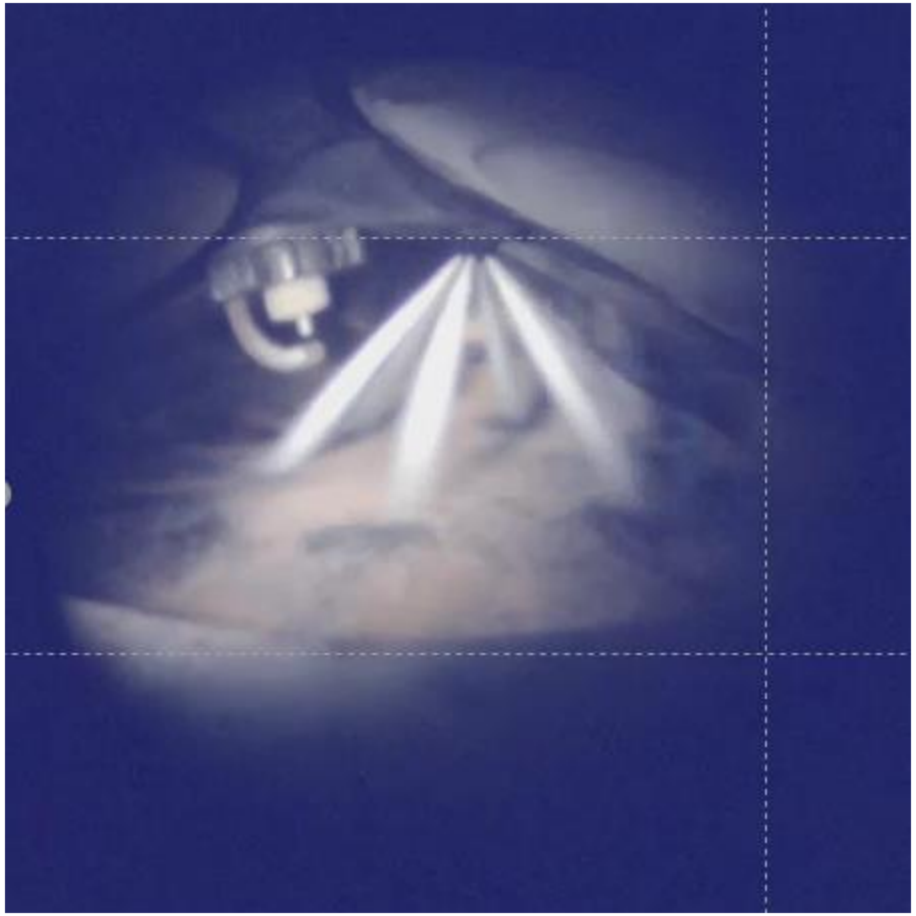
- **Hybridization enables shift towards higher loads ➔ high load area and max. efficiency gaining importance.**
- **Trade-off between maximum efficiency and spec. power becomes the key trade-off**

GASOLINE ENGINE TECHNOLOGY TRENDS - TODAY



- **Hybridization enables shift towards higher loads ➔ high load area and max. efficiency gaining importance.**
- **Trade-off between maximum efficiency and spec. power becomes the key trade-off**
- **Miller / Atkinson Cycle con-firmed as most cost effective CO_2 solutions (e.g. Toyota, Audi, VW, HMC, etc.)**

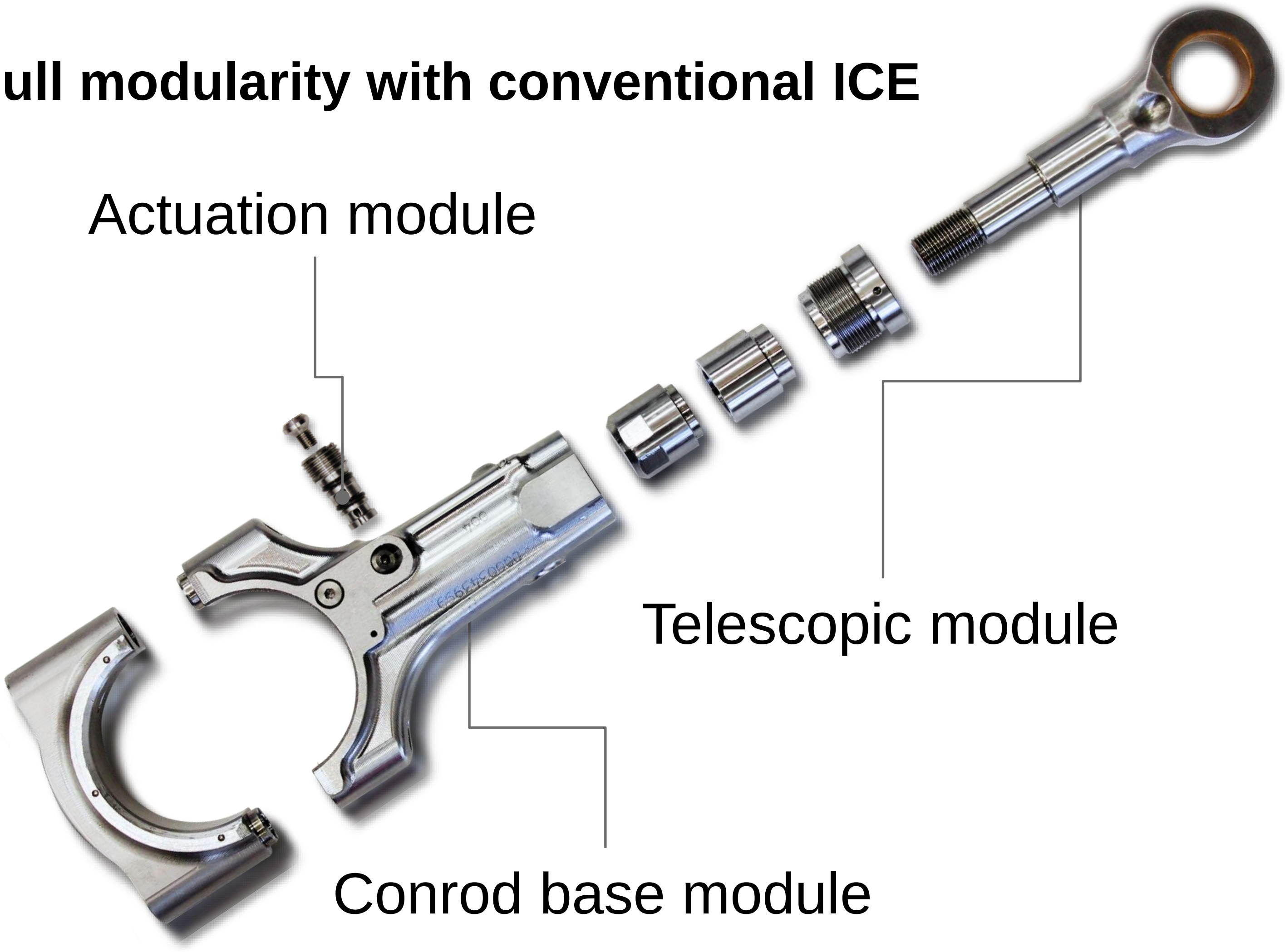
THE "KNOCK FREE SI ENGINE"
1000 BAR FUEL PRESSURE



- **Very late injection.**
- **Optimized start of combustion.**
- **Very short combustion duration (approx. 5°CA)**
- **Very low soot emissions.**
- **The flames from the piston top do not contribute to soot emissions.**

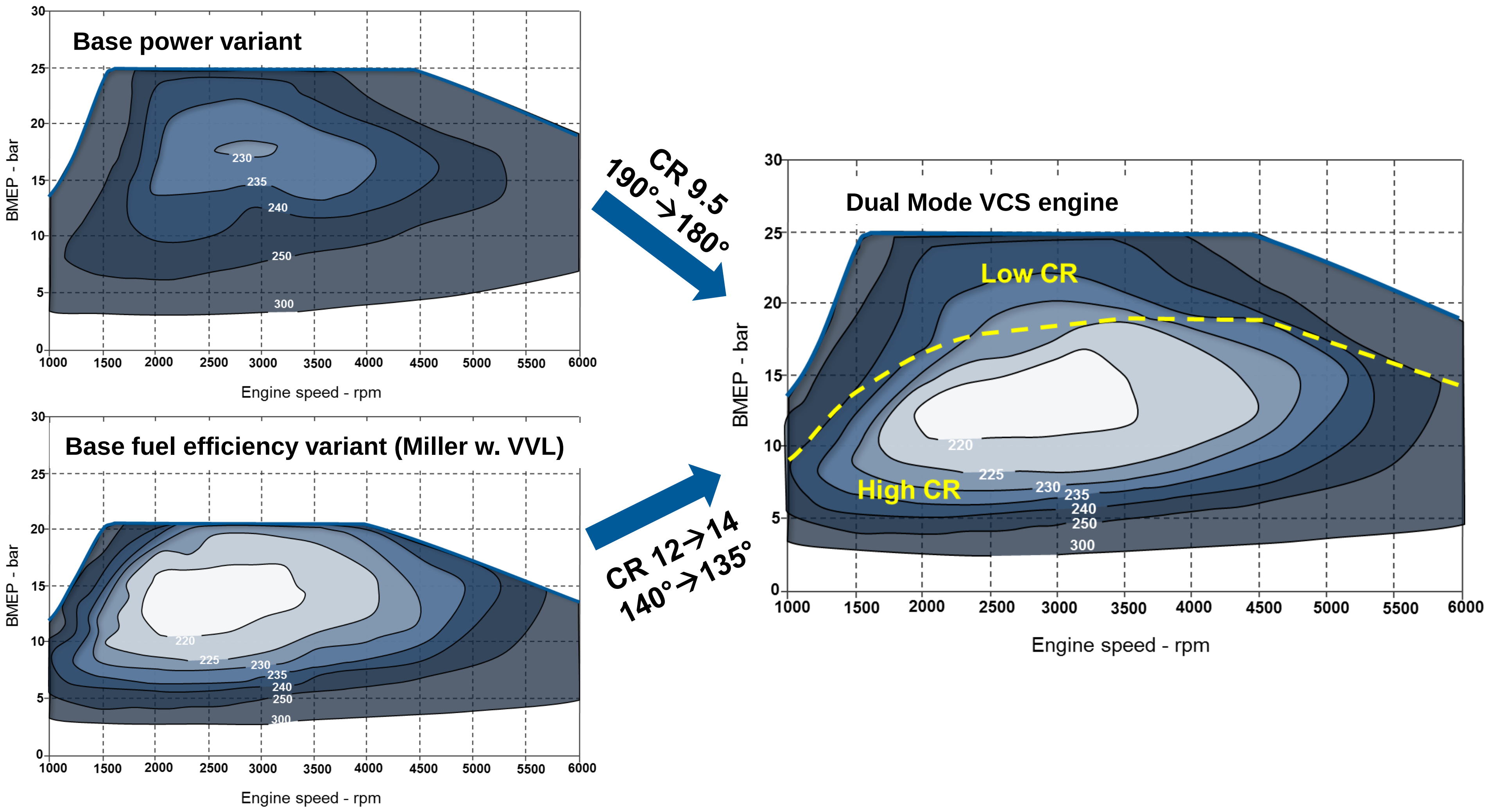
COMBINED HIGH EFFICIENCY & HIGH PERFORMANCE AVL 2-STEP VARIABLE COMPRESSION RATIO VCS

Full modularity with conventional ICE

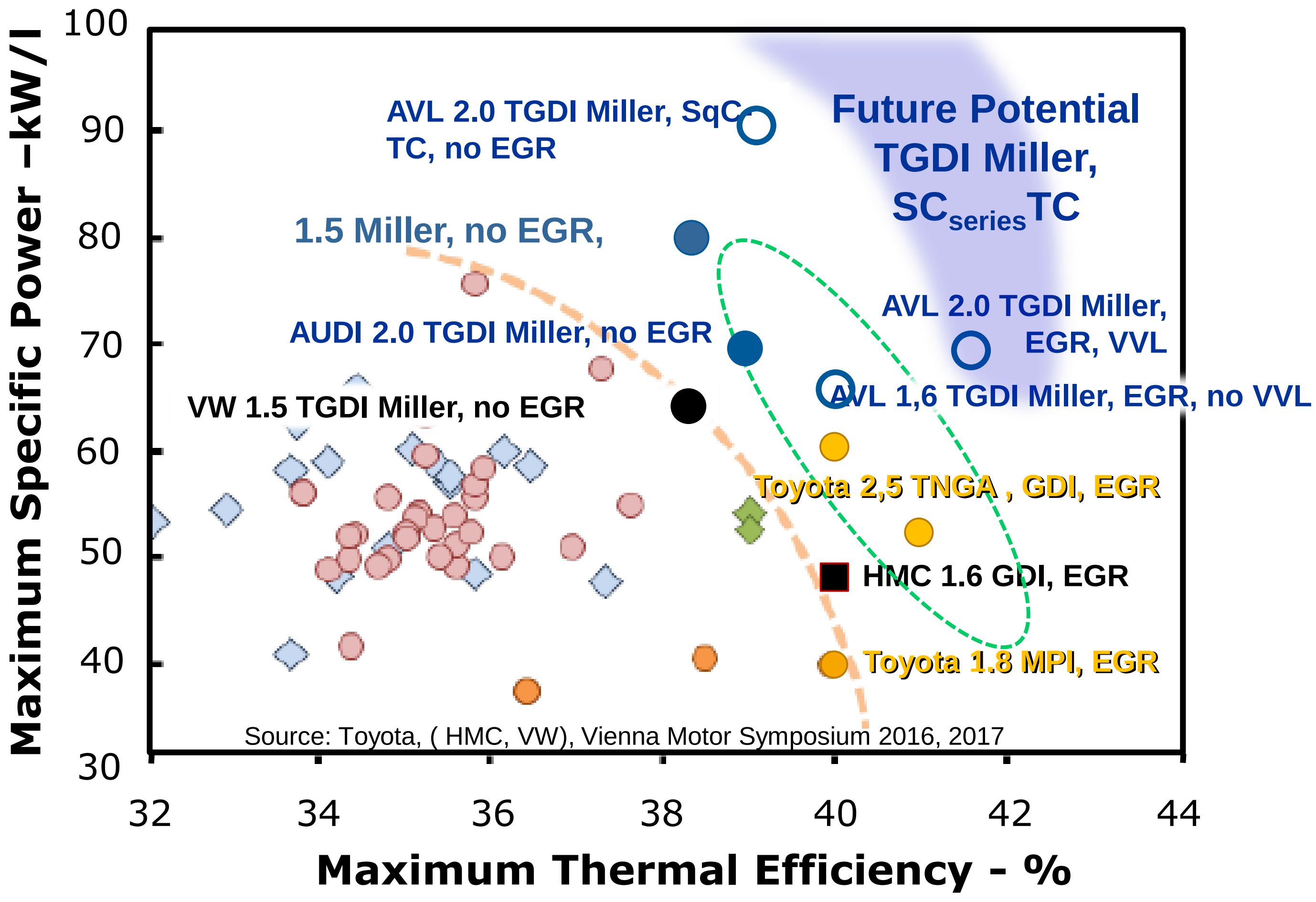


- **Telescope principle & advanced actuation enables easy integration in most existing engines**
- **Full modularity with conventional ICE**
- **Bore pitch, block height, packaging dimensions, same production line kept**

DUAL MODE VCS™
BSFC MAP – 2-STEP VCR, CR 9.5/14

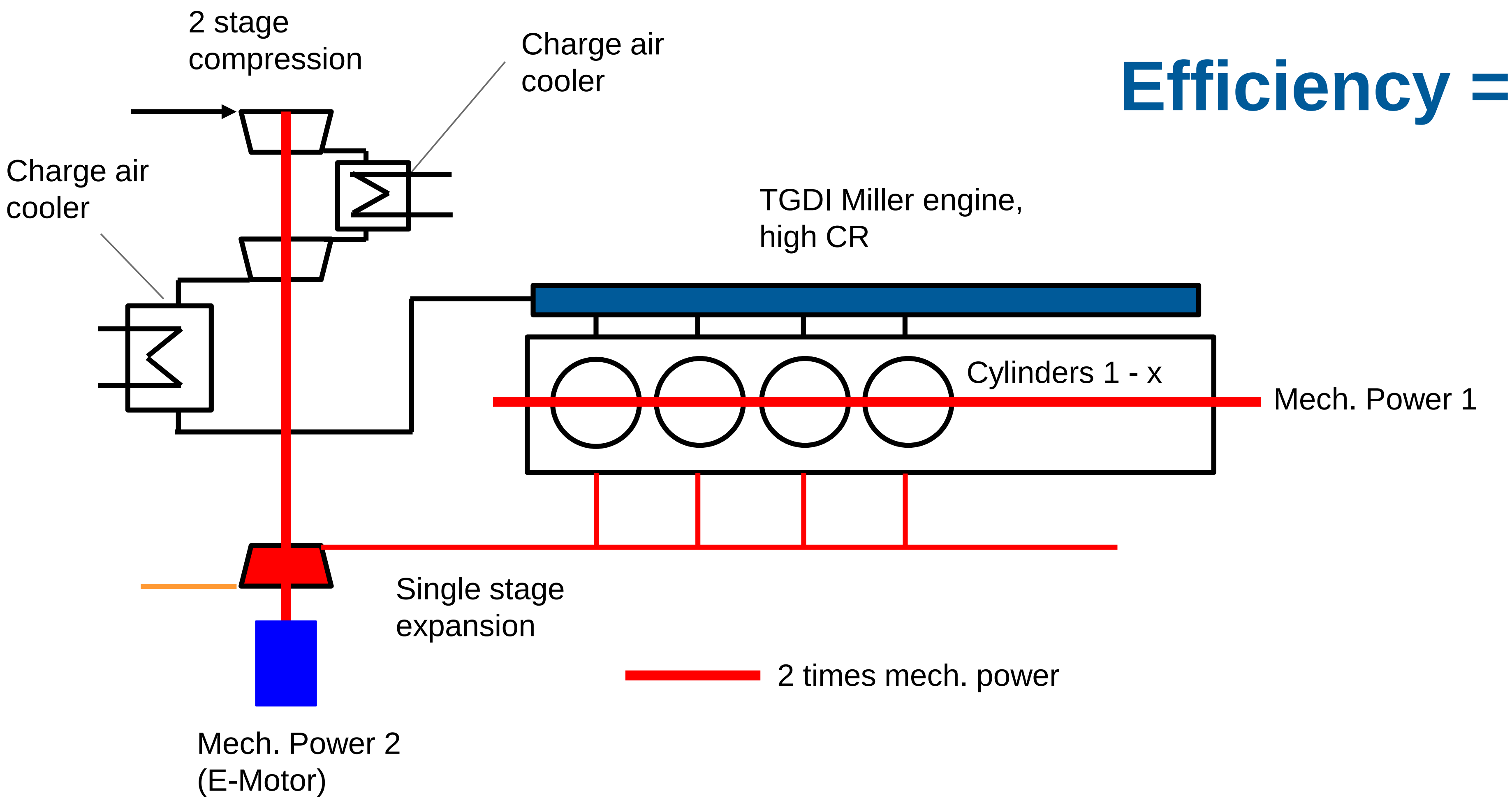


GASOLINE ENGINE
TECHNOLOGY TRENDS – TOMORROW



- **Some RDE requirements (e.g. stoichiometric full load, no scavenging, GPF with higher backpressure) are in contra-diction to high CR, compro-mising thermal efficiency**
- **Refined combustion systems + improved turbomachinery (2-step charging with intercooling- "Series Compressor Turbo-charger- $SC_{series}TC$) as enabler for further efficiency improve-ments**

TWO SHAFT MACHINE



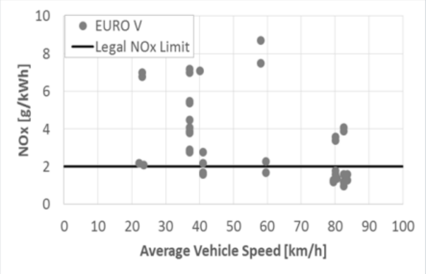
Efficiency = 43 %

CHALLENGES FOR CV POWERTRAINS

Lowest Emissions MUST be fulfilled:

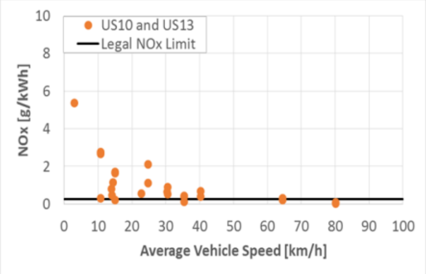
- In real driving operation in the vehicle (RDE, ISC)
- Under standard and non standard ambient conditions (NTE)
- Until End of useful life (Aged Conditions)
- Considering Component Tolerances
- Monitored in vehicle operation (OBD, IUPR)

EURO V



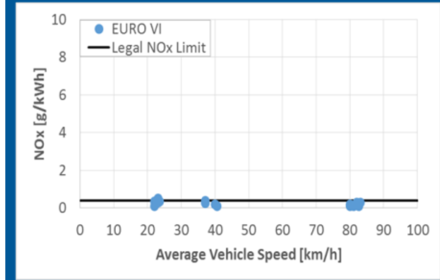
Only certification at standard ambient conditions

US 10/13



Strict engine certification limit and NTE area, but NTE limits do not apply when EAS outlet temperature is < 250°C

EURO VI

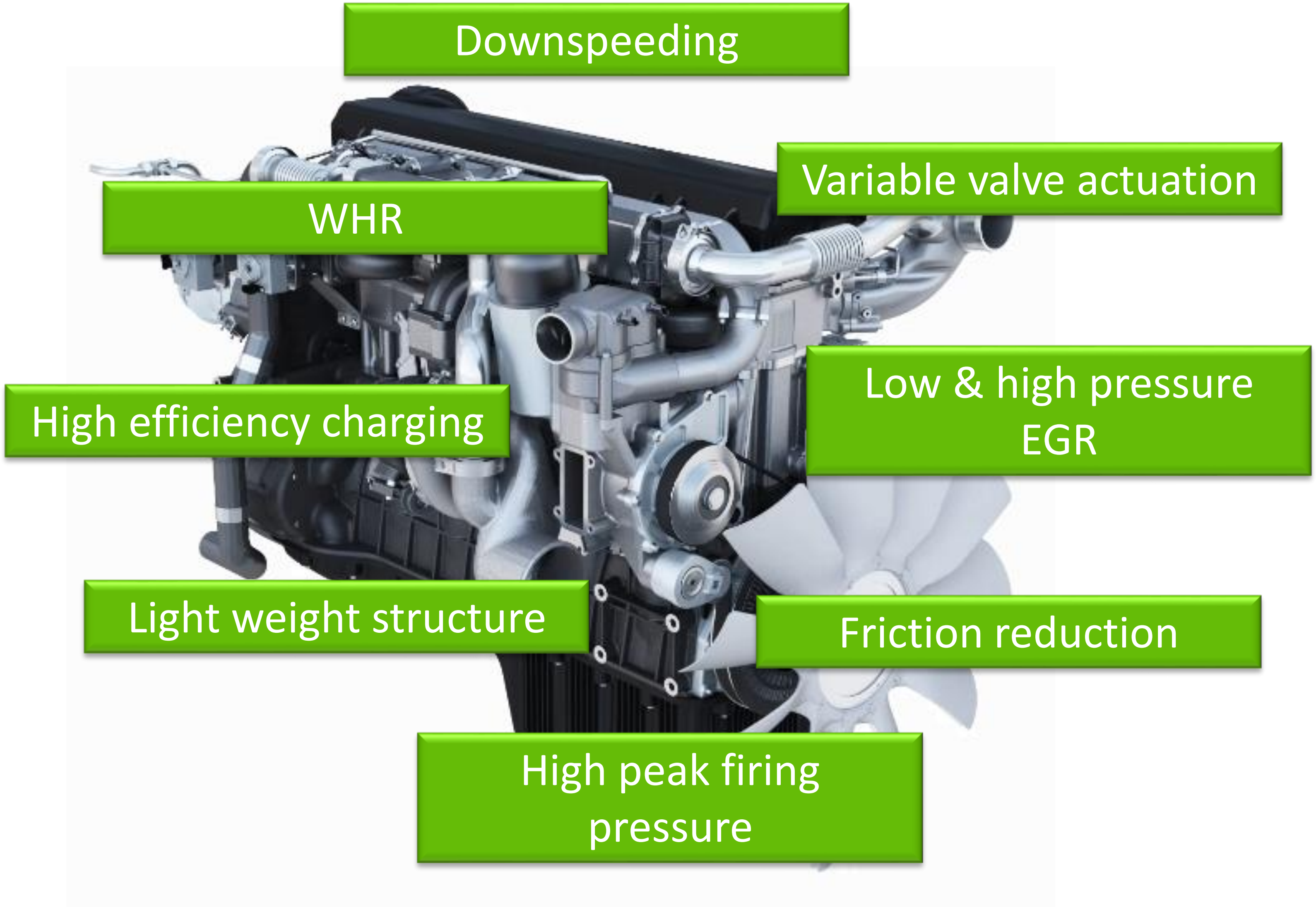


In Service Conformity requirements ensure that low NO_x certification value can be maintained under real field usage

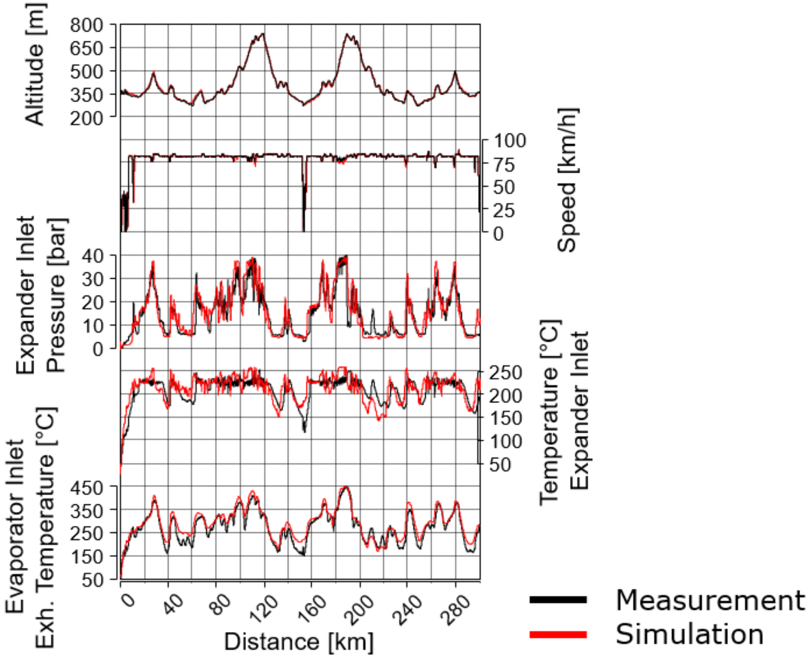
EFFECTS OF CO2 & ULTRA LOW NOX
COMMERCIAL BASE ENGINE

Implementation of advanced technologies

Requiring significant upgrades and new engines



FUTURE ENGINE TECHNOLOGY
WASTE HEAT RECOVERY



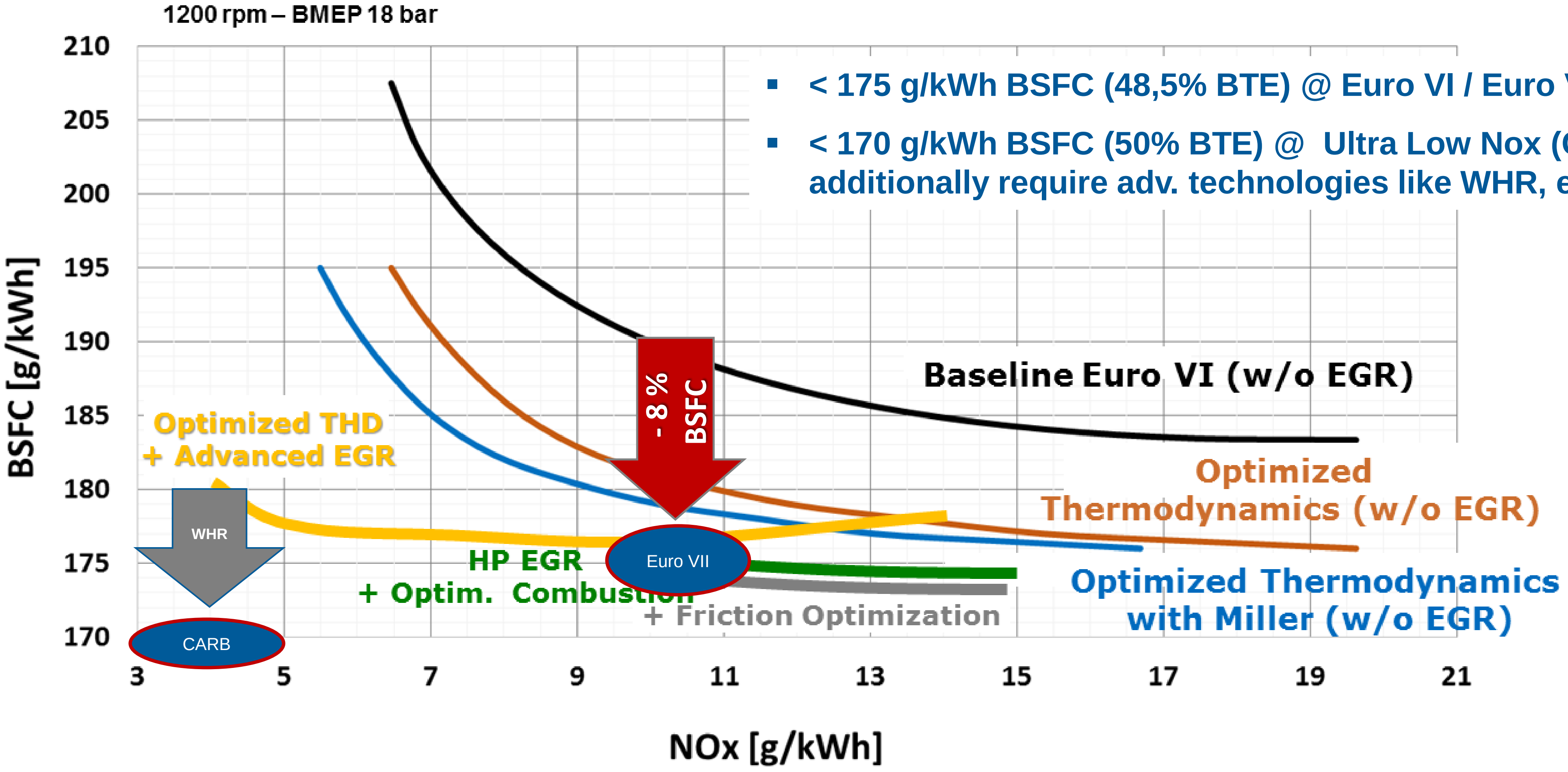
The WHR system developed by AVL has proven following fuel savings:

- 2.5% in EU real world cycle
- 3.1% in US real world cycle
- 3.4% in RMC

R&D Partner FPT POWERTRAIN TECHNOLOGIES IVECO

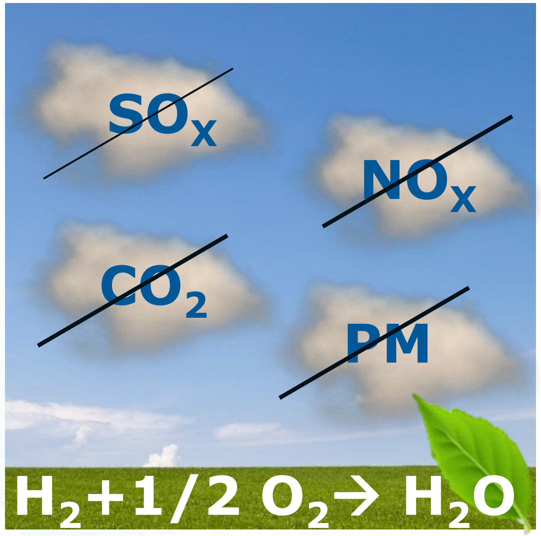
FUTURE ENGINE TECHNOLOGY
GHG & NOX CHALLENGES

TECHNOLOGY ASSESSMENT AVL:
50% BREAK THERMAL EFFICIENCY IS FEASIBLE WITH LOWEST FUTURE EMISSION NORMS



- < 175 g/kWh BSFC (48,5% BTE) @ Euro VI / Euro VII similar
- < 170 g/kWh BSFC (50% BTE) @ Ultra Low Nox (CARB) will additionally require adv. technologies like WHR, etc.

MOTIVATION FOR FUEL CELL

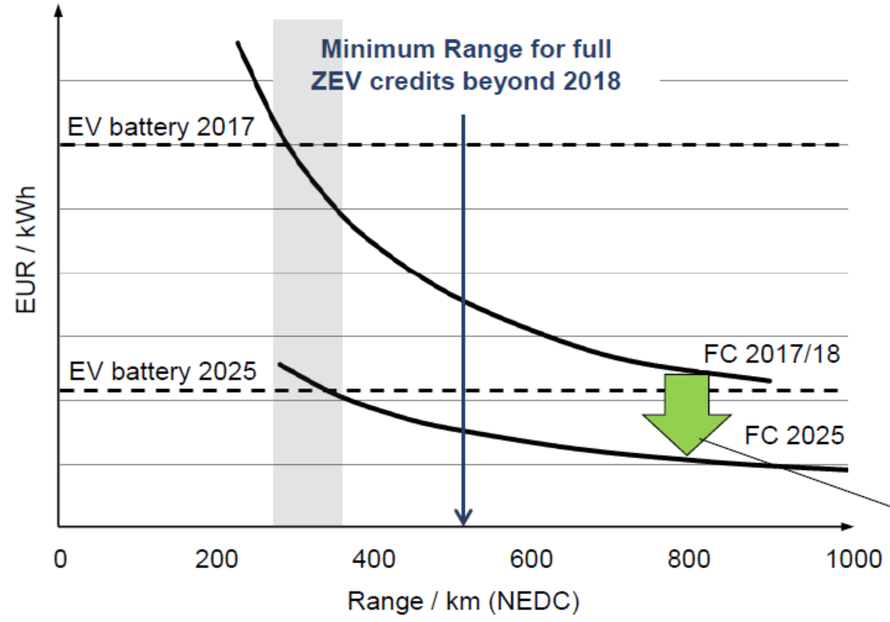


Zero emissions vehicles

~3 minutes to refuel

DAIMLER

FCEV and BEV
Comparison of cost per kWh electrical energy source



Cost for Fuel Cell propulsion: Include FC-stack plus FC-system, HV-battery and hydrogen storage system similar to function of EV-battery for comparison.

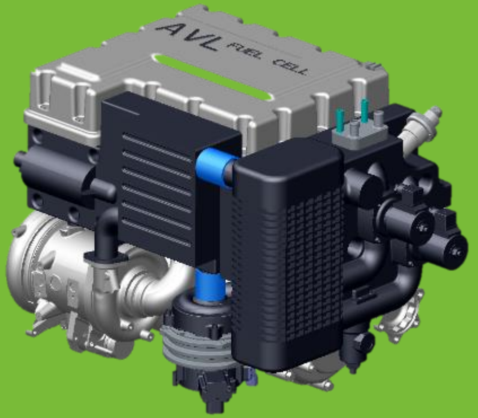
- Higher volume
- More mature supplier market
- Technology improvements

- At approx. 350 km Fuel Cell propulsion is less expensive than EV-battery propulsion

For larger & long range vehicles, FCVs will be lower cost than BEVs

FUEL CELL OPTIONS

PEM
(Emission free)

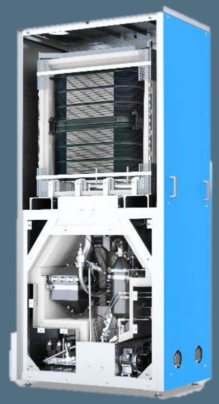


PEM Fuel Cell Engine 20-150 kW

H_2

SOFC
(Almost emission free, only CO_2 emission)

SOFC APU/Range Extender 3-30 kW



SOFC Stationary Power Generator kW-MW

DIESEL | GASOLINE | CNG | e-Gas | LPG | H_2 | Ethanol | Methanol

NISSAN e-Bio Fuel Cell

APU Development

Vehicle Integration

Testing

The first solid oxide fuel cell vehicle in the world
(The first generation of the vehicle was directly presented by Nissan's CEO in 2016 at Rio Olympic in Brazil)

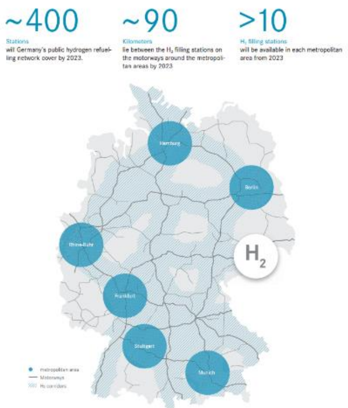
Extension of the range of BEV from 150 to 600+ km by Ethanol Fuel Cell.

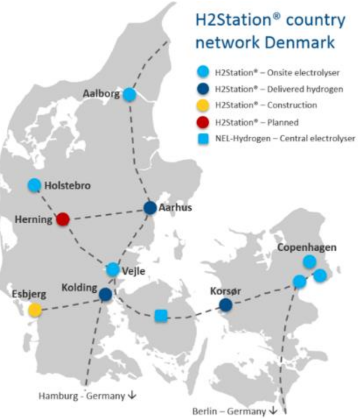
BEV TECHNOLOGY CHALLENGE

Vehicle

- Cost
- Range
- Weight

Infrastructure





AVL 800 V PIONEER

eCarTec
AWARD WINNER

Winner in the category "Drive Technology, System Electrics, Testing Systems": Coup-e 800 – AVL Software and Functions GmbH in 2012

Followers

BOSCH

IONITY

350kW / 400 Stations / 18 Countries

PORSCHE®

ABB

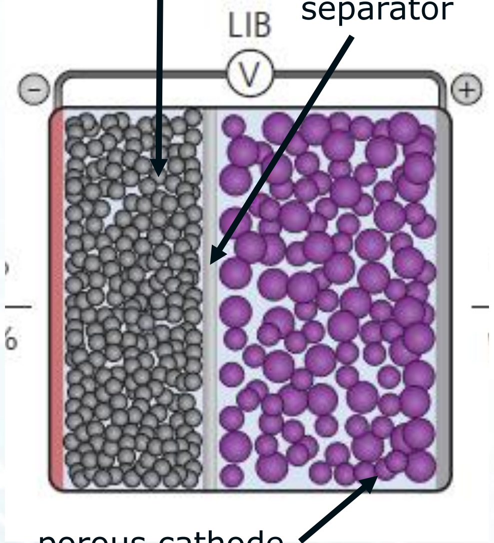
Mercedes-Benz

COMPARISON:CONVENTIONAL LITHIUM-ION CELL VS. ALL-SOLID-STATE CELL

J. Janek, W.G. Zeier, Nature Energy, 1 (2016) 16141.

porous anode
(graphite grey circles)

separator

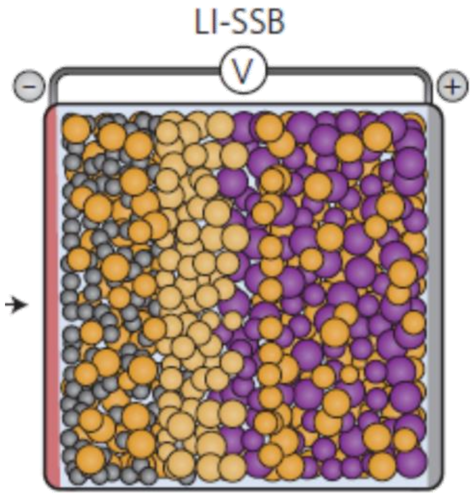


porous cathode
(metal oxide, e.g. NMC
violet circles)

Conventional Li-ion cell

Liquid electrolyte in pores of electrodes and separator

2023



All-solid-state cell with conventional C/Si anode

Liquid electrolyte in porous electrodes replaced by solid (orange cycles)

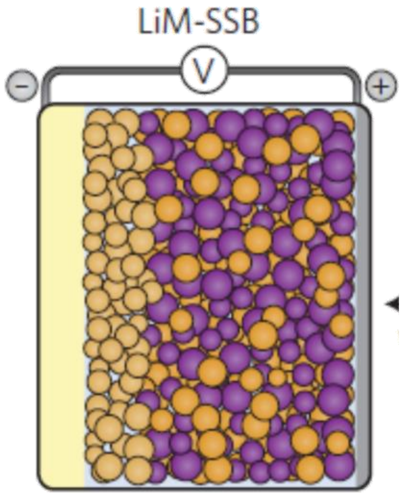
Electrolyte soaked separator is completely replaced by solid (orange cycles)

Possible increase in volumetric energy density by using silicon anodes

No significant change in energy density

No flammable liquids, reduced ageing

???



All solid-state with Li-metal anode

Li metal anode instead of graphite/silicon intercalation electrode
→ Durability & safety issues to be solved

70 % increase of volumetric energy density

40 % increase of gravimetric energy density

SUMMARY

- CO_2 neutral transport needs CO_2 neutral/ CO_2 free energy carriers (syn-fuels incl. H_2 and electricity)
- Very slow „natural“ market penetration of zero-emission vehicles (BEV and FCV) ➔ fast penetration needs EU- or global legislation (zero-emission zones)
- All powertrain technologies including ICE can provide environmentally sustainable solutions – depending on legislative boundary conditions
- Ultimately, massive efficiency improvements are needed to safeguard global mobility requirements

Thank You

www.avl.com