

Technological Diversity



Hydrogen in the transport sector – A Tier 1 perspective

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Tension Fields in the Transportation Sector



Regulatory environment



Competitive dynamics



Technology

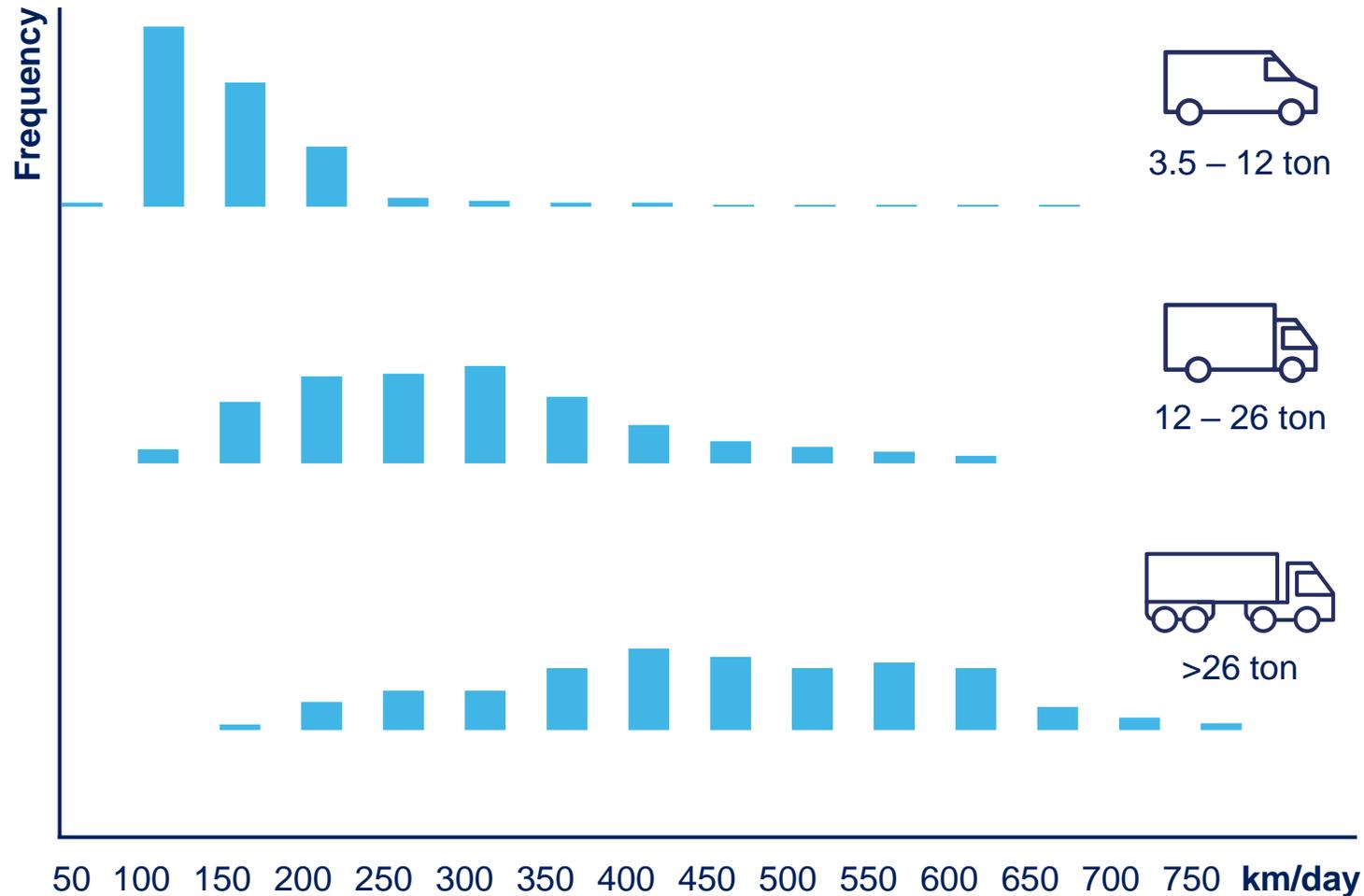


Cost



Consumer behaviour

High Variety of Truck Usage Scenarios (by Weight/Volume)



Split of Road Transport CO₂ Emissions

And: Freight Transport will Further Increase ...

Share of road freight transport emissions

Based on total road emissions



Development of road freight transport volume in 2030

in ton kilometers compared to reference year 2019

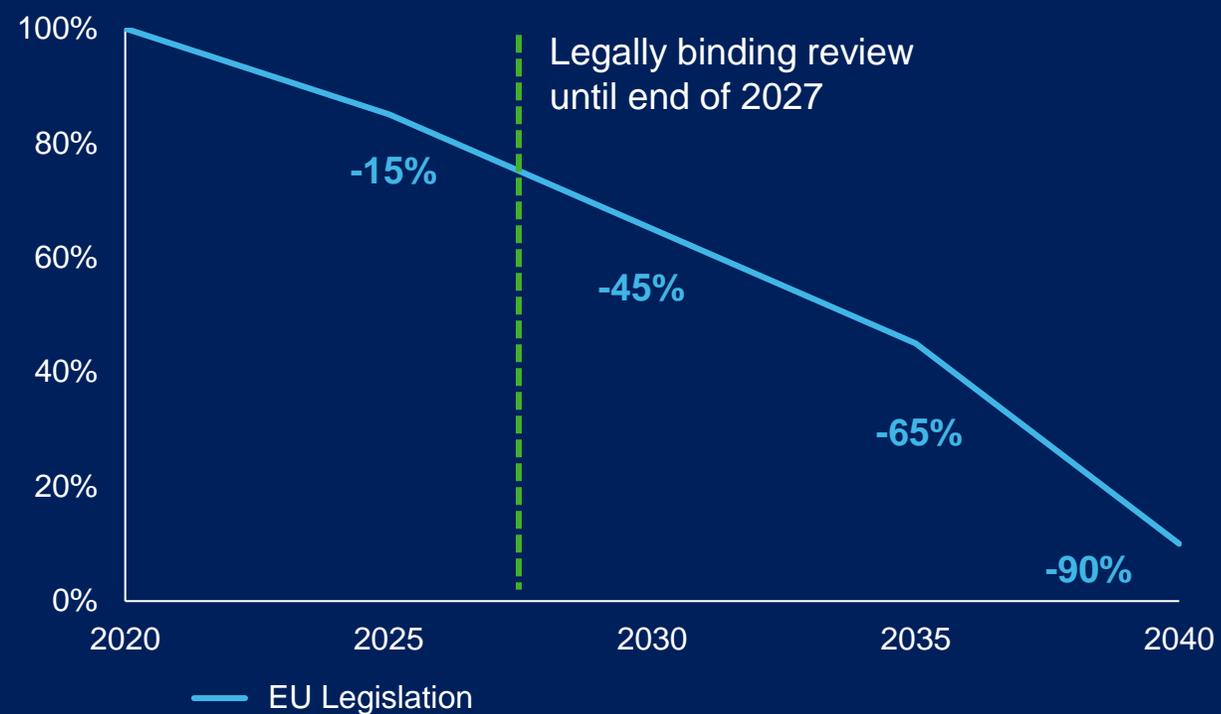


Sources: IEA, Destatis, Nepis.epa.gov, sciencedirect <https://doi.org/10.1016/j.energy.2022.123628>

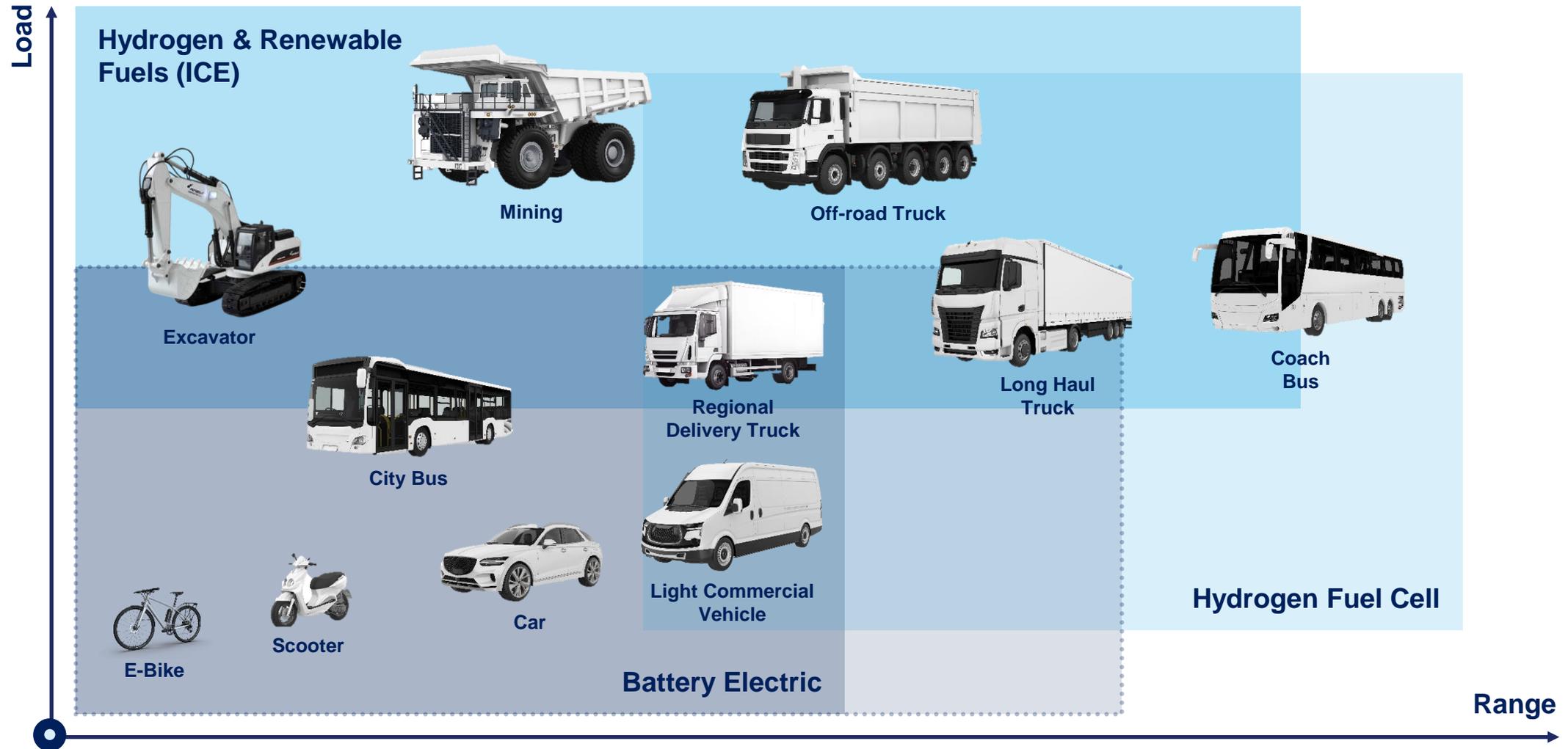
Sources: Eurostat, U.S. Department of Transportation - Freight Analysis Framework | China statistical yearbook | Asian Transport Outlook 2022 | FZ Juelich

Emission-Free Solutions are Needed

MHD CO₂ tailpipe emission fleet targets



The Future of Mobility Will be More Diverse



MAHLE Multi-Path Approach

BEV



Fuel Cell



H₂ ICE



Hybrids/Renewable Fuels



Multi-Path Technologies – A MAHLE Success Story

➤ Opening

MAHLE Hydrogen Test Center



2020

➤ Start

of series developments for fuel cell and H₂ ICE components



2021

➤ World Premiere

MAHLE SCT e-motor specifically for commercial vehicles



2023

➤ SOP

MAHLE H₂ ICE components on the market with multiple OEMs



2025

➤ Pre-Development

Components for hydrogen powered powertrains and of advanced electric traction motors

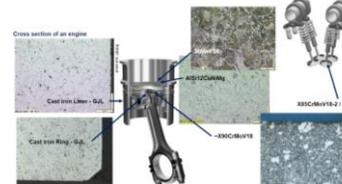
➤ First System Tests

Operation of both fuel cell system and H₂ ICE at MAHLE



➤ H₂ Influence

Detailed investigation on component materials and coatings



➤ IAA Transportation

MAHLE fuel cell demonstrator: thermal management, fuel cell and e-axis



MAHLE Hydrogen Internal Combustion Engine System Approach

Power Cell Unit, Valves and Crank Case Ventilation



System approach

means holistic investigation of H₂ ICE with partners.



Components

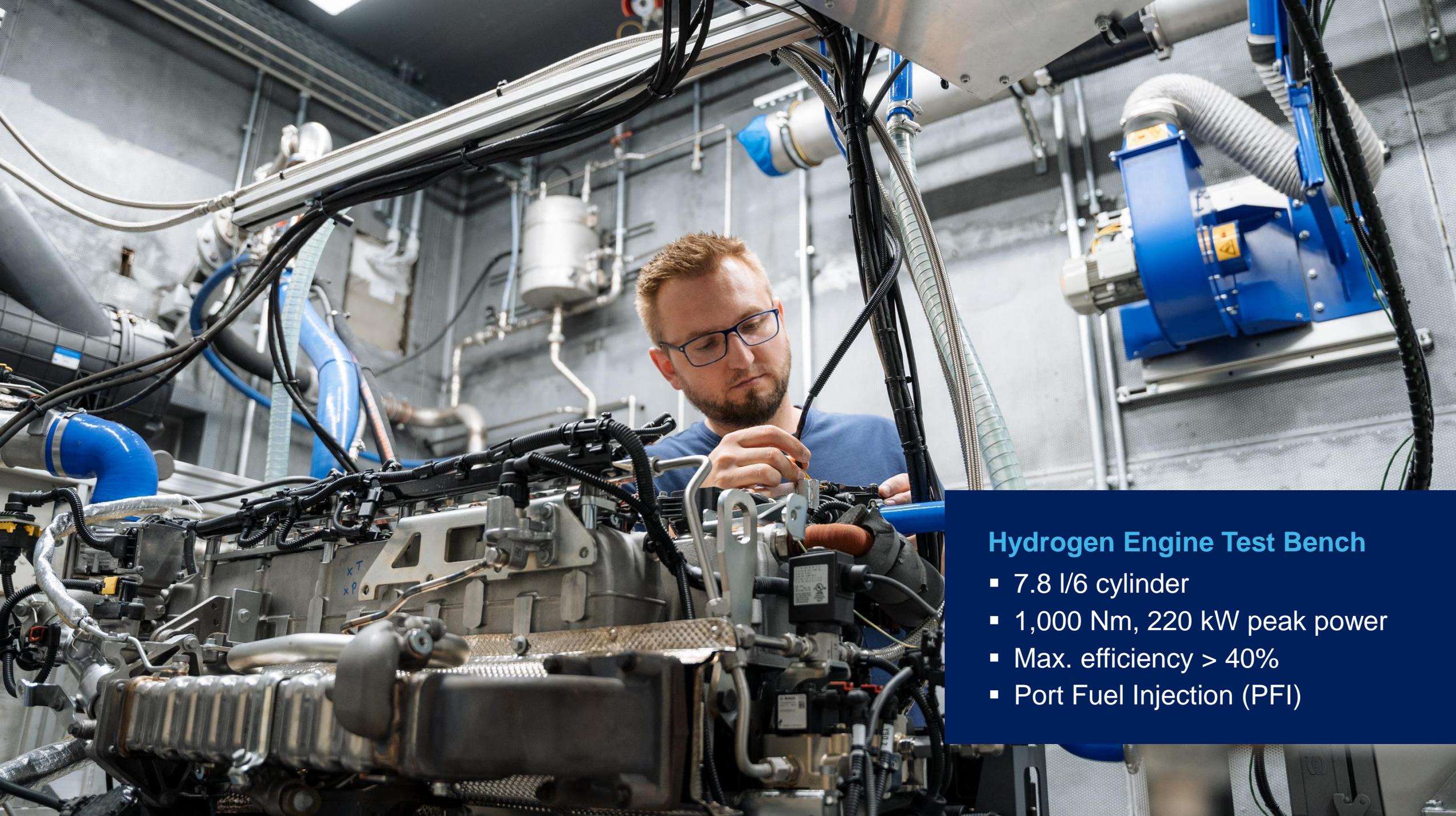
for maximum engine performance and safety.



Full testing capabilities

incl. rig tests, engine testing on bench and demonstrator vehicles.





Hydrogen Engine Test Bench

- 7.8 l/6 cylinder
- 1,000 Nm, 220 kW peak power
- Max. efficiency > 40%
- Port Fuel Injection (PFI)

MAHLE Fuel Cell System Approach

Thermal Management



E-Compressor



E-Pump



E-Heater



Bionic Fan



C2C Heat Exchanger*



Battery Cooling Plate

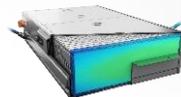
Electric Powertrain



Electric Motors



MAHLE eAxle Demonstrator



Battery Know-How

Air Management



Air Filter



Cathode Module



Charge Air Cooler



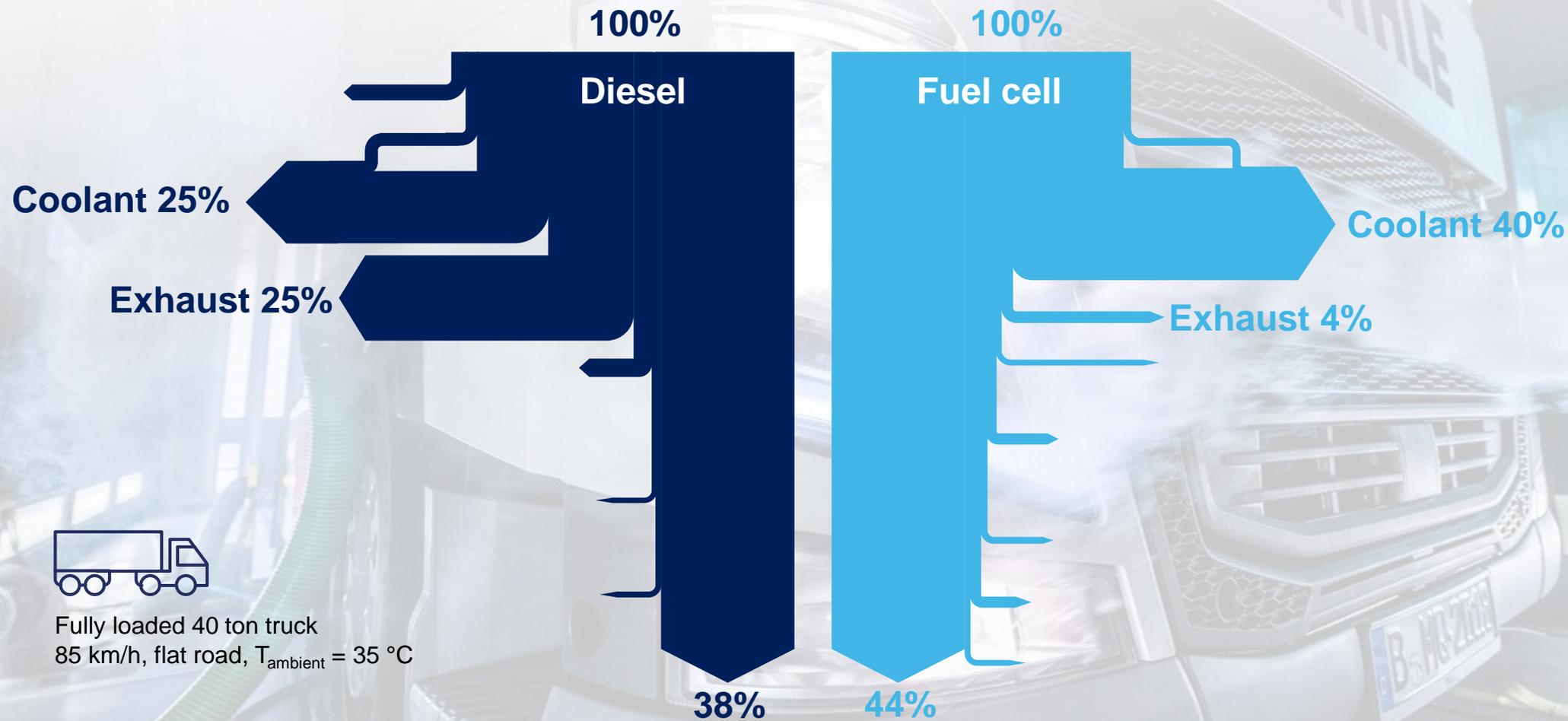
Ion Exchanger

End Plate

➤ **Portfolio System Approach**
MAHLE provides balance of plant components embedded in a strong system approach.

* Coolant-to-Coolant Heat Exchanger

Despite Higher Efficiency, Requirements for the Fuel Cell Cooling System Increase



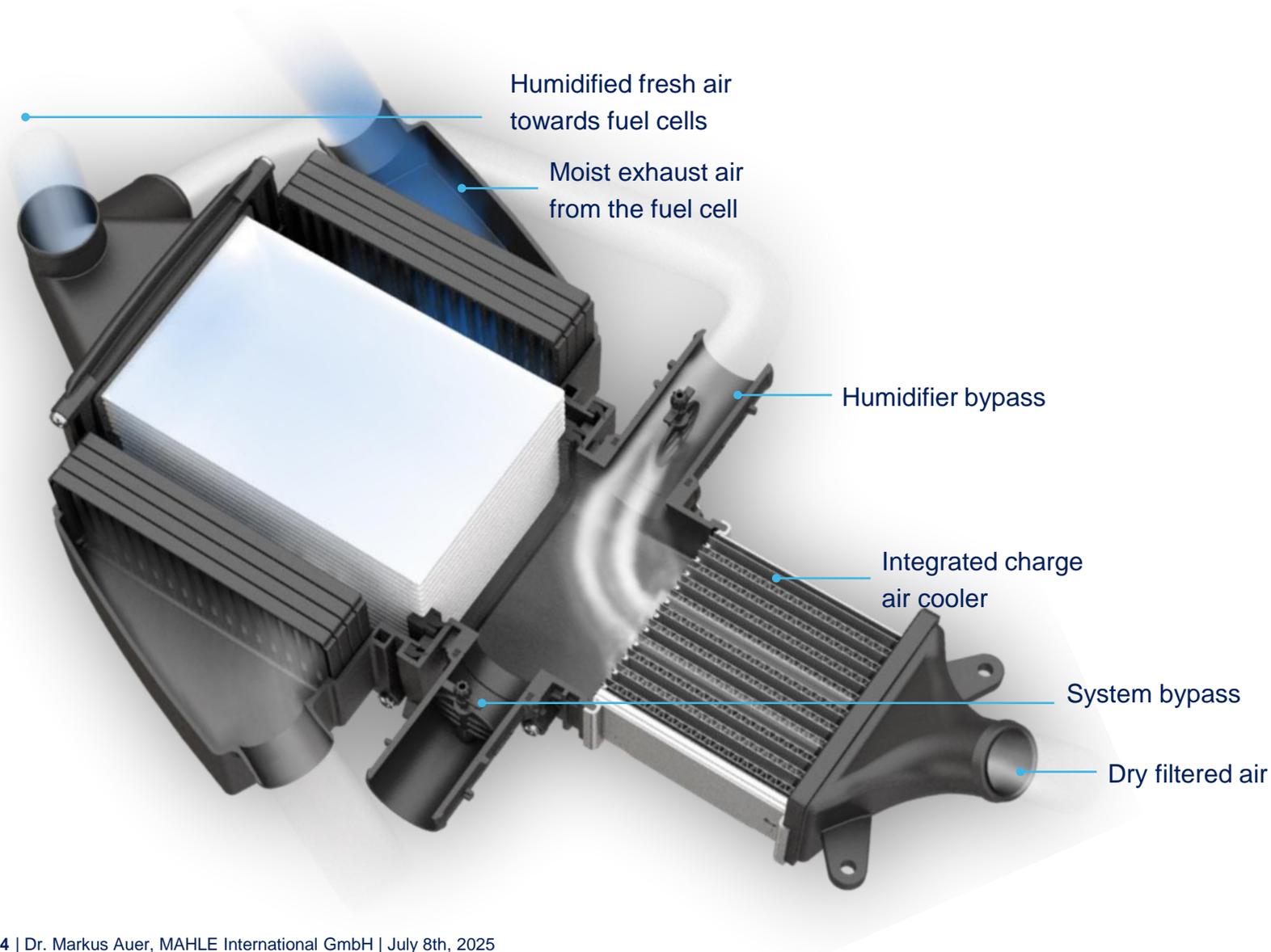
World Premiere: AI Generated Bionic Fan for Reduced Noise



AI Generated Bionic Fan

- Increases performance
- Lowers noise by up to -4 dB(A). More than halving of sound power
- Reduces weight by 10%

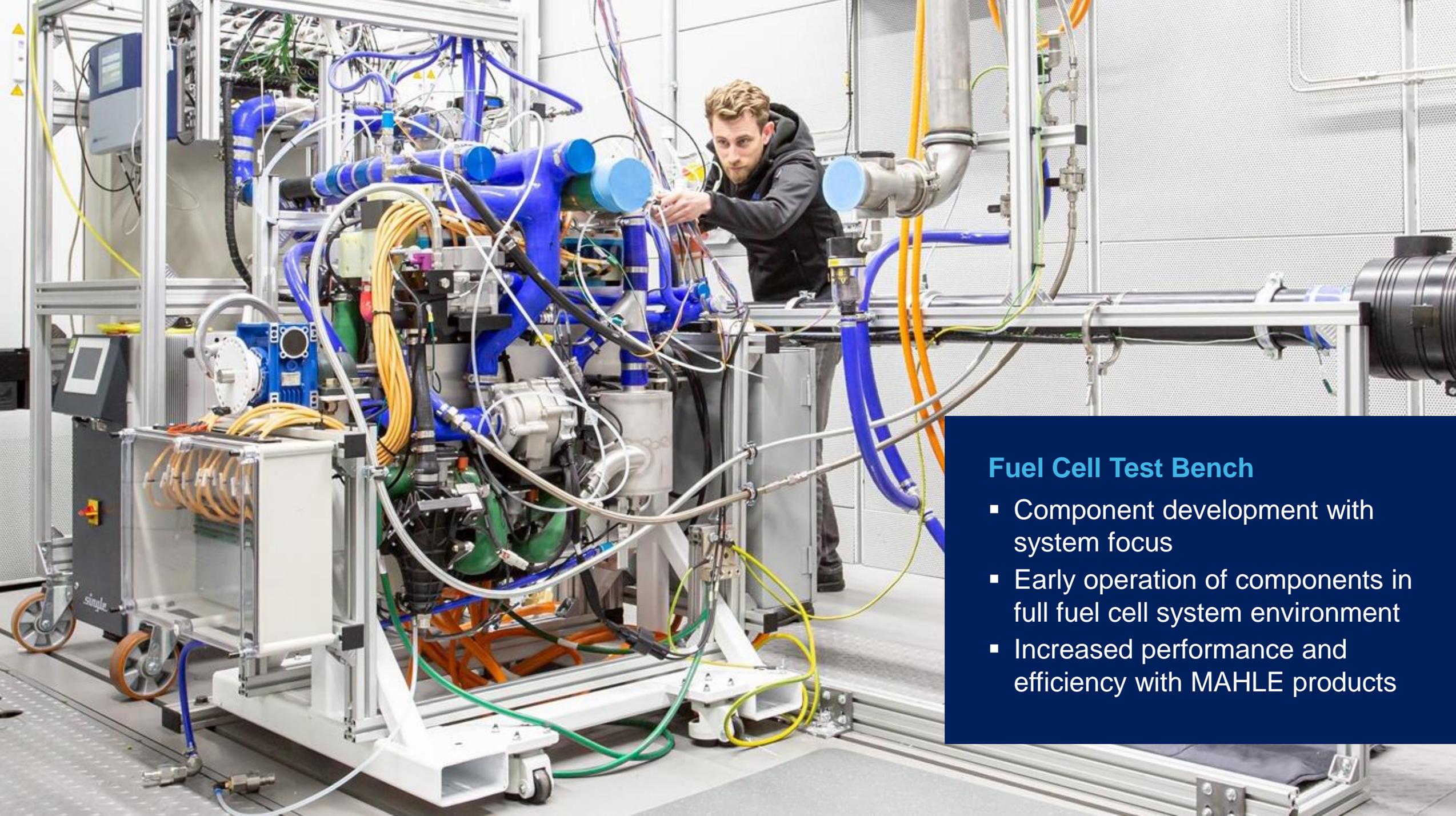
Cathode Module – Highly Integrated Design



Highly integrated design
incl. charge air cooler,
humidifier and water separation.

Up to 50% higher water transfer rate
(compared to best competitor)
enable increased operation
temperature and lower fuel
cell membrane degradation.

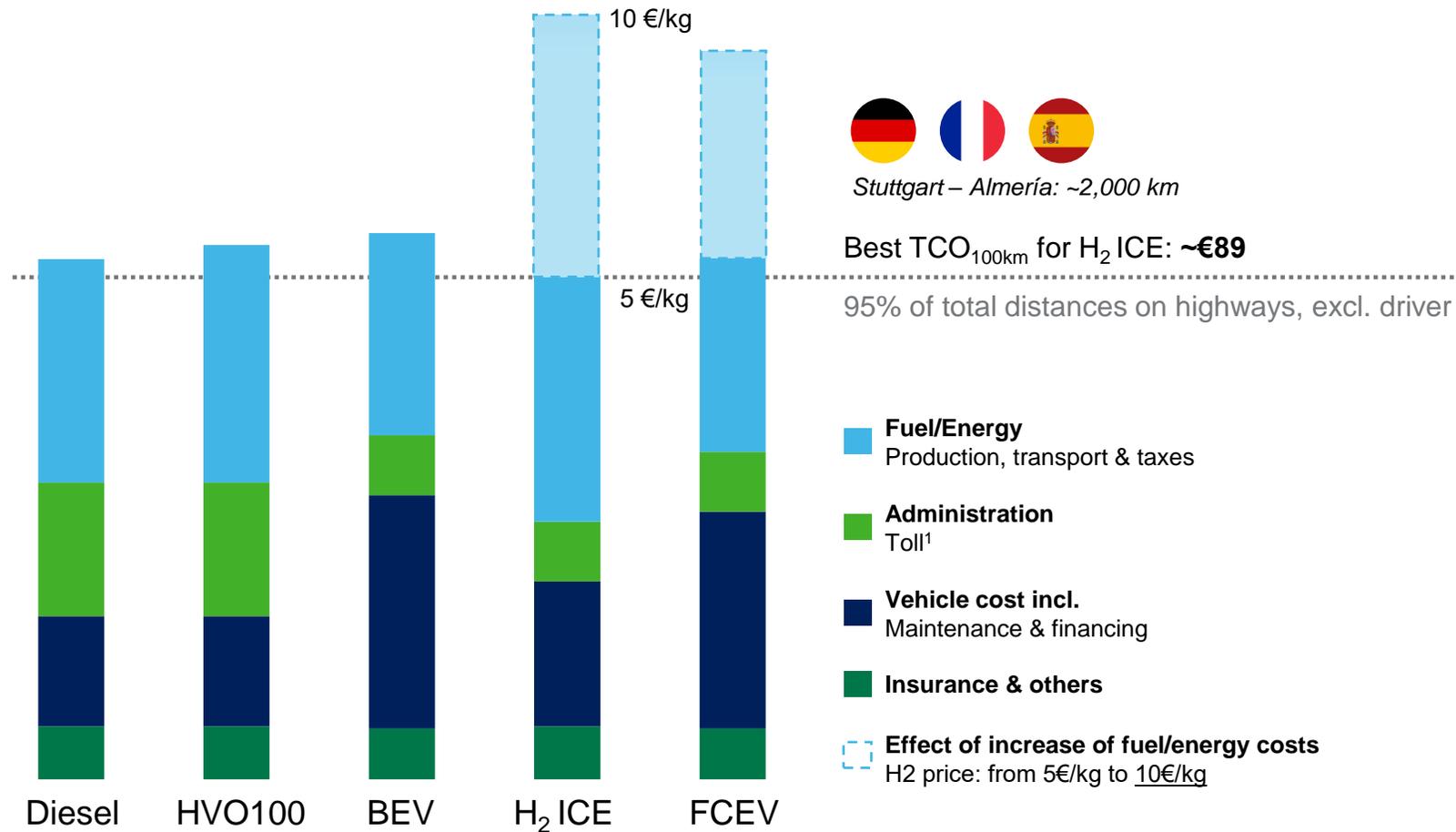
Maximum performance
with 50% lower pressure losses
results in +1% peak power
and efficiency increase.



Fuel Cell Test Bench

- Component development with system focus
- Early operation of components in full fuel cell system environment
- Increased performance and efficiency with MAHLE products

International Long-Haul Truck 2030



- Needed daily range: **810 km**
- Public charging: **75% (overnight)**
- Annual distance: **172,125 km**
- Depreciation period: **4.1 years**

➤ **FCEV & H₂ ICE with cost benefit at €5 kg H₂ – subsidies needed to reach target H₂ price. H₂ infrastructure needs to be established**

Infrastructure as Challenge for Daily Routine at Service Stations



- H₂ and renewable fuel stations with **less space demand** compared to CCS/MCS charging infrastructure.
- H₂ and renewable fuel refuelling with **time benefits** compared to charging.
- H₂ and renewable fuel trucks with **higher range**, beneficial for areas with weaker infrastructure, e.g., Eastern Europe.

AFIR – A first step in the right direction

VEHICLE FLEET FORECAST



~ 465k

Long-haul trucks (>16to)

[MAHLE CO₂ Conformity 2030 Scenario]



~46k

Long-haul trucks (>16to)

[MAHLE CO₂ Conformity 2030 Scenario]

INFRASTRUCTURE FORECAST



~2,800

Charging Hubs

[according to AFIR]

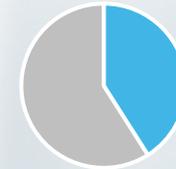


~650

H₂ stations

[according to AFIR]

COVERAGE



~35%

Infrastructure coverage

[Assumption 60% public charging, Ø2,6 MW/Hub]



38%

Infrastructure coverage

[Assumption 1 ton/day per station]

How do we make Hydrogen based mobility a success story?

Fast & colorful H₂
production

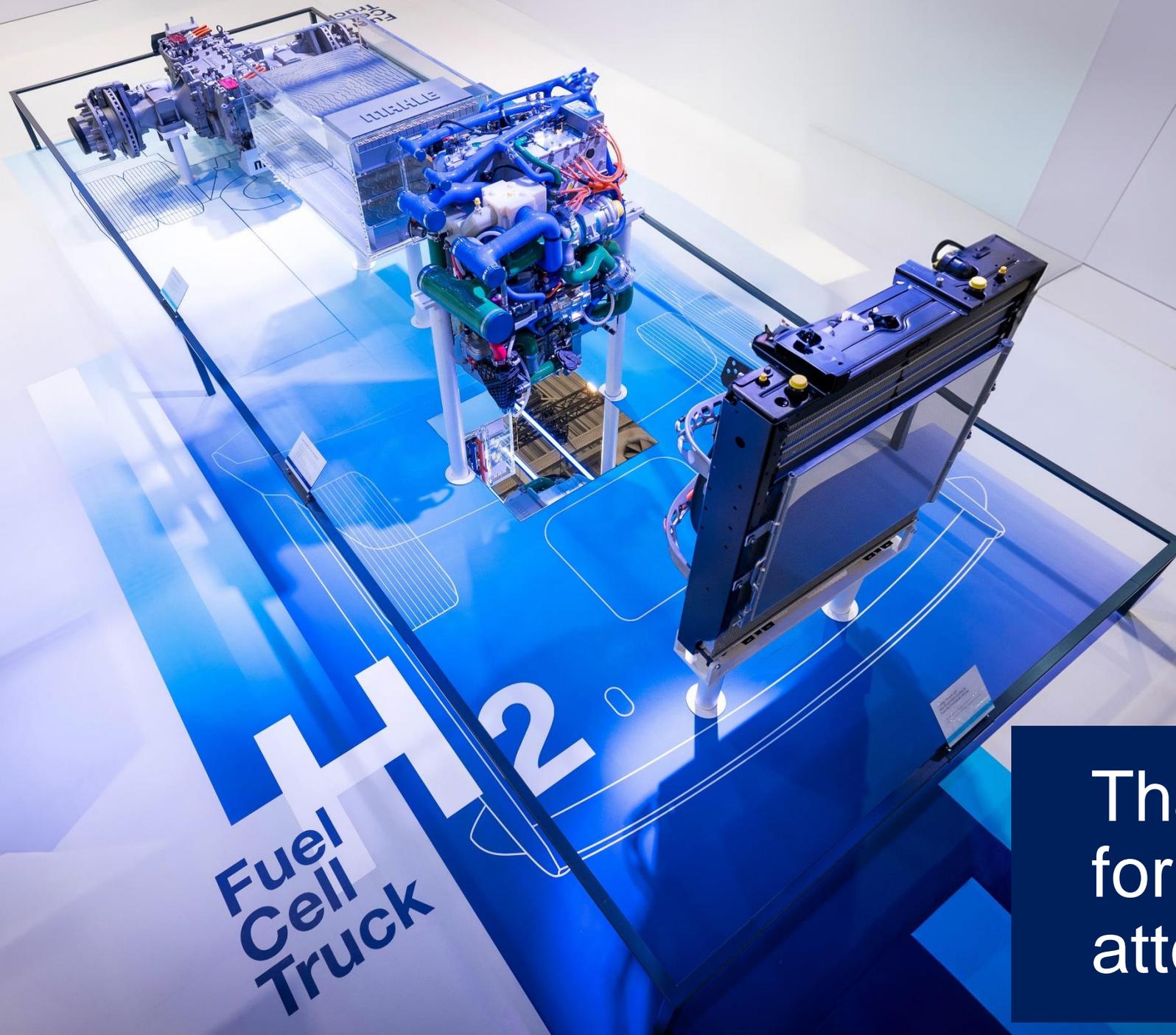
Infrastructure scale-up

Simplify green H₂
legislation

Global technology usage

Equality for all climate
neutral powertrains

➤ Let's make Hydrogen a viable solution for sustainable transportation



Fuel Cell Truck

Thank you
for your kind
attention