Technological Diversity

Media Tech Day

July 23rd, 2024

MAHLE

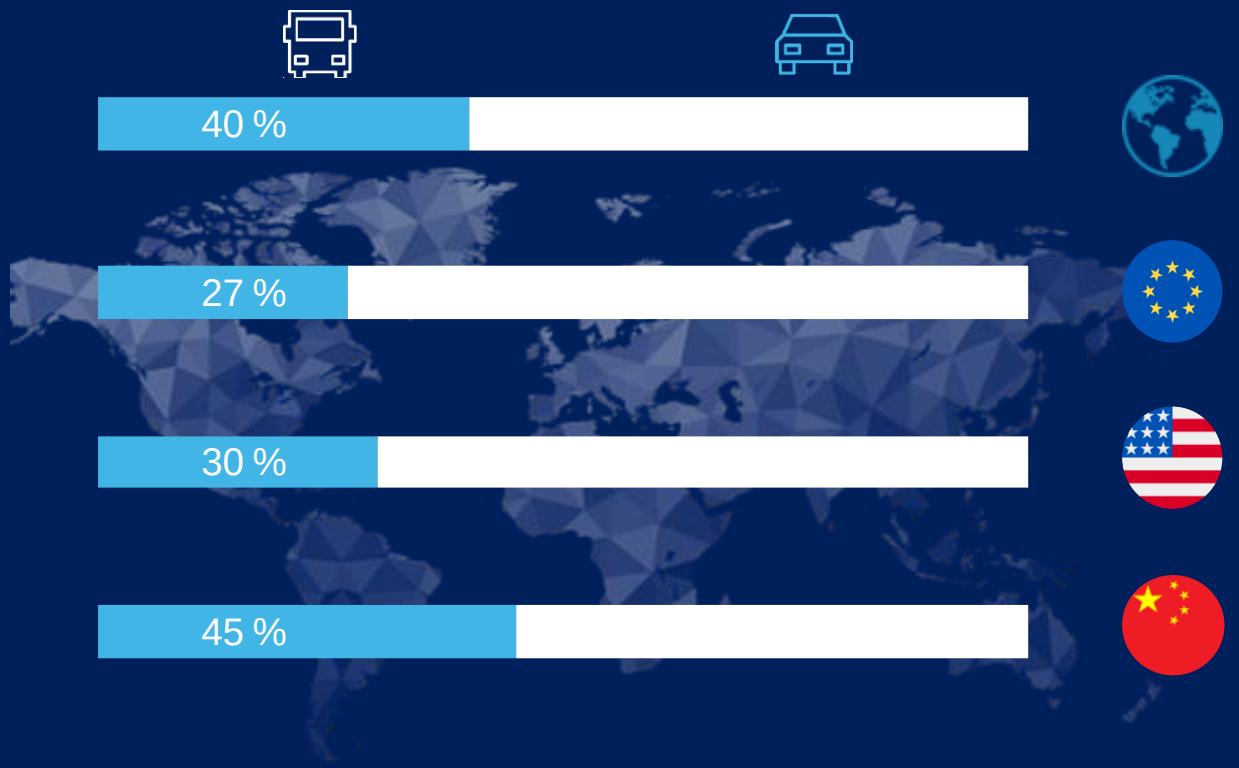
Tension Fields in the Transportation Sector

- Regulatory environment
- Competitive dynamics
- Technology
- Cost
- Consumer behavior

Split of Road Transport CO_2 Emissions
And: Freight Transport will Further Increase …

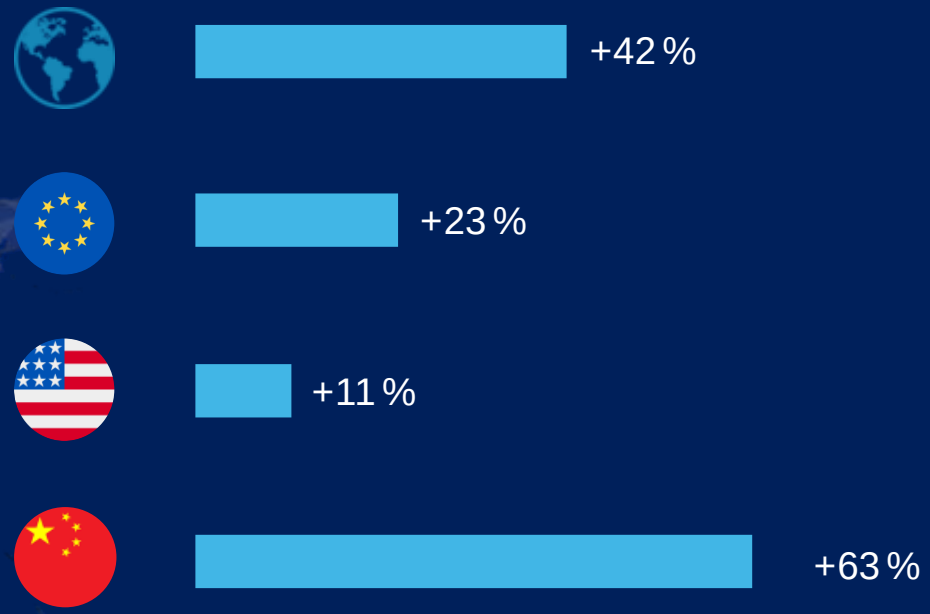
Share of road freight transport emissions

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 Outlookt 2022 | FZ Juelich

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Highest Diversity Around the Globe








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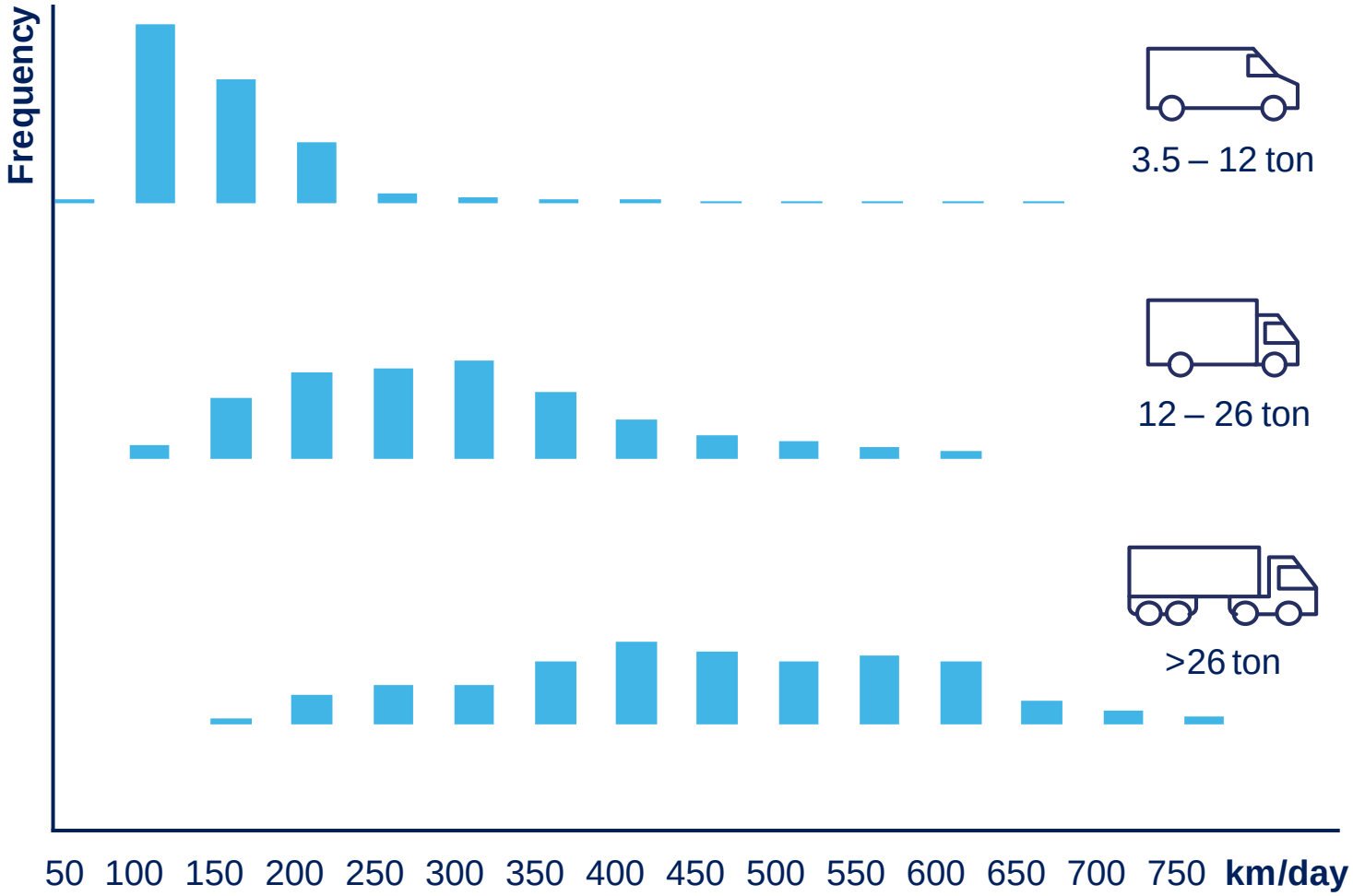
High Variety of Truck Usage Scenarios (by Weight/Volume)



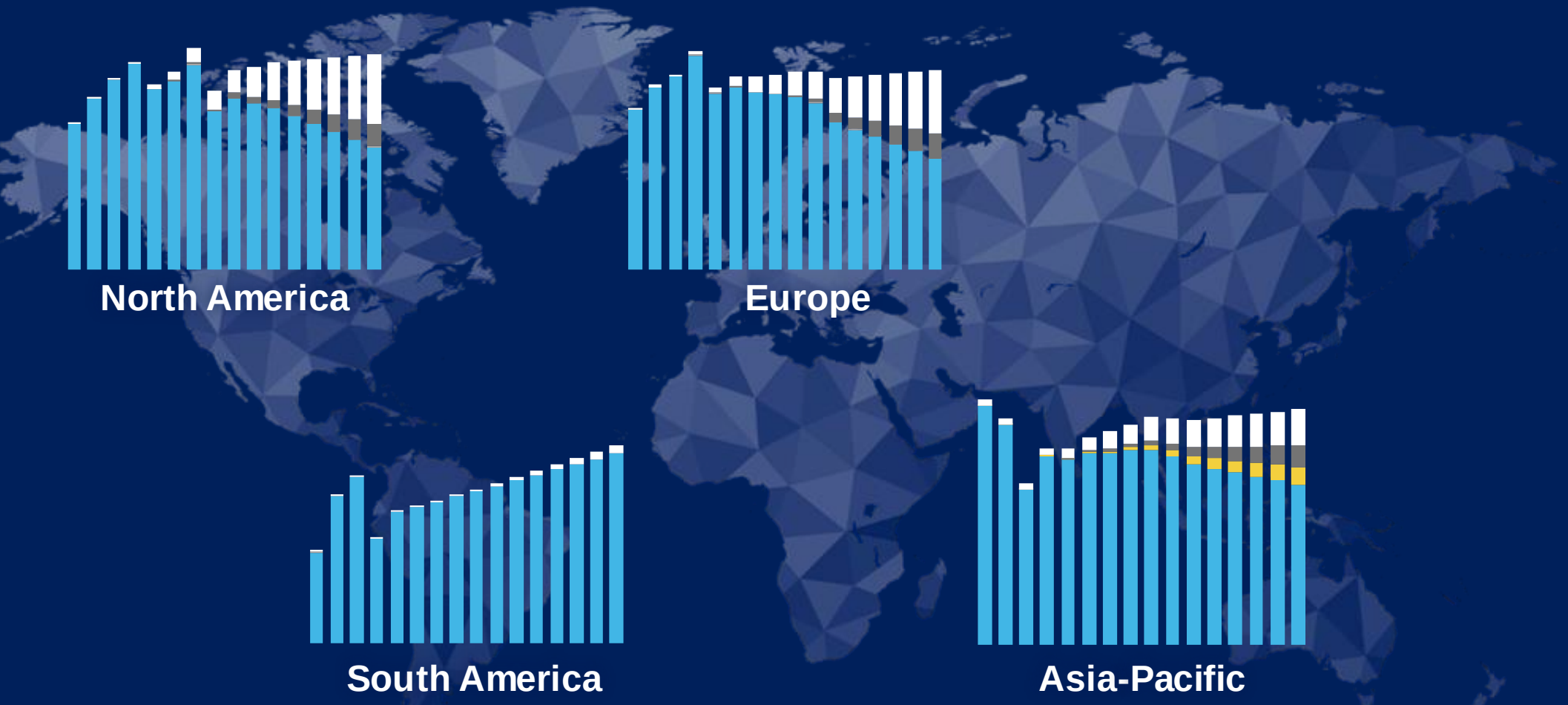







Source: ifeu 2022 "Vergleichende Analyse der Potentiale von Antriebstechnologien für Lkw im Zeithorizont 2030"

We Need a Multi-Path Strategy for Europe and the World



BEV

FCEV

PHEV/FHEV

ICE*

Time range: 2020 – 2035 ***** Incl. Gasoline, Diesel, CNG/LNG/LPG, H_2 ICE

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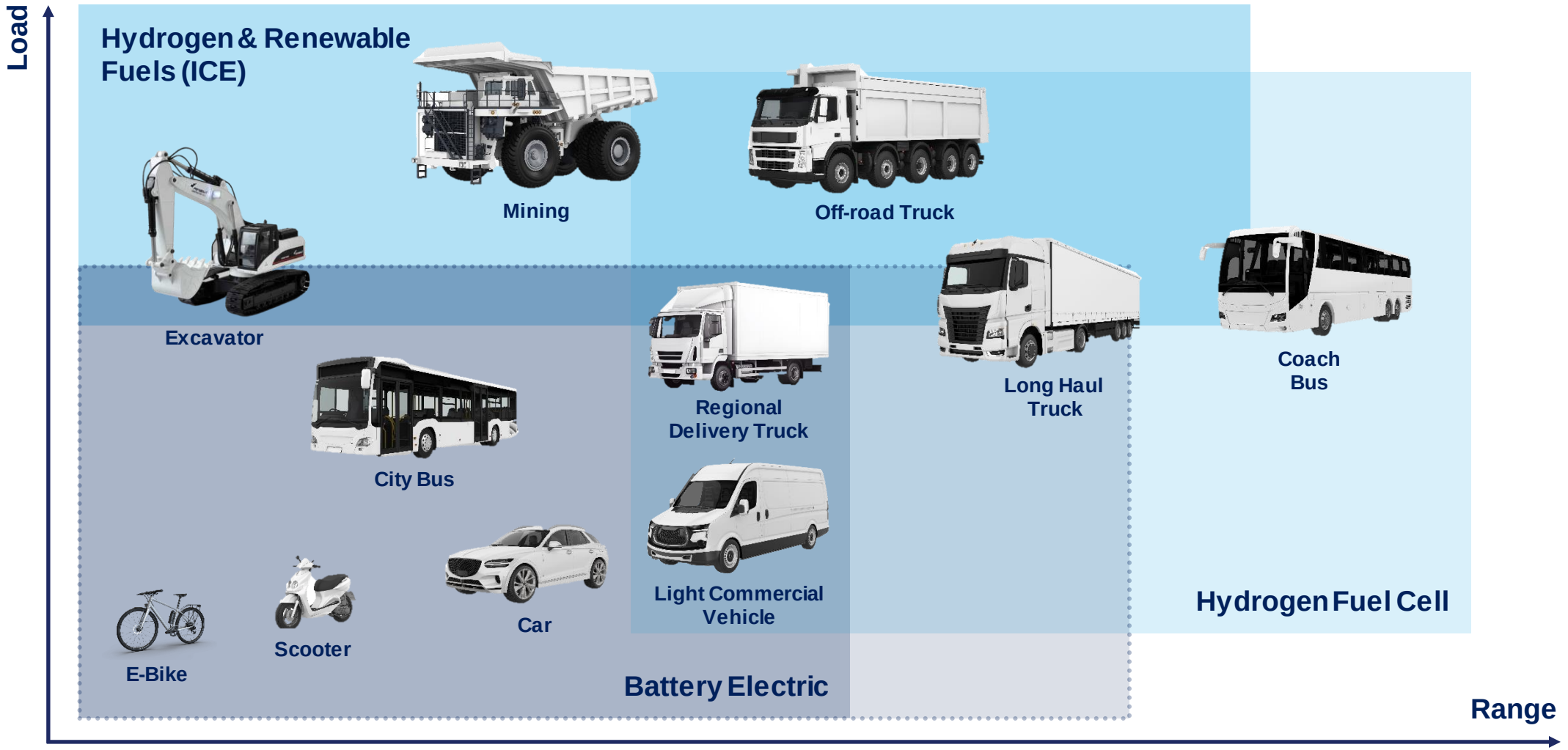
The Future of Mobility Will be More Diverse



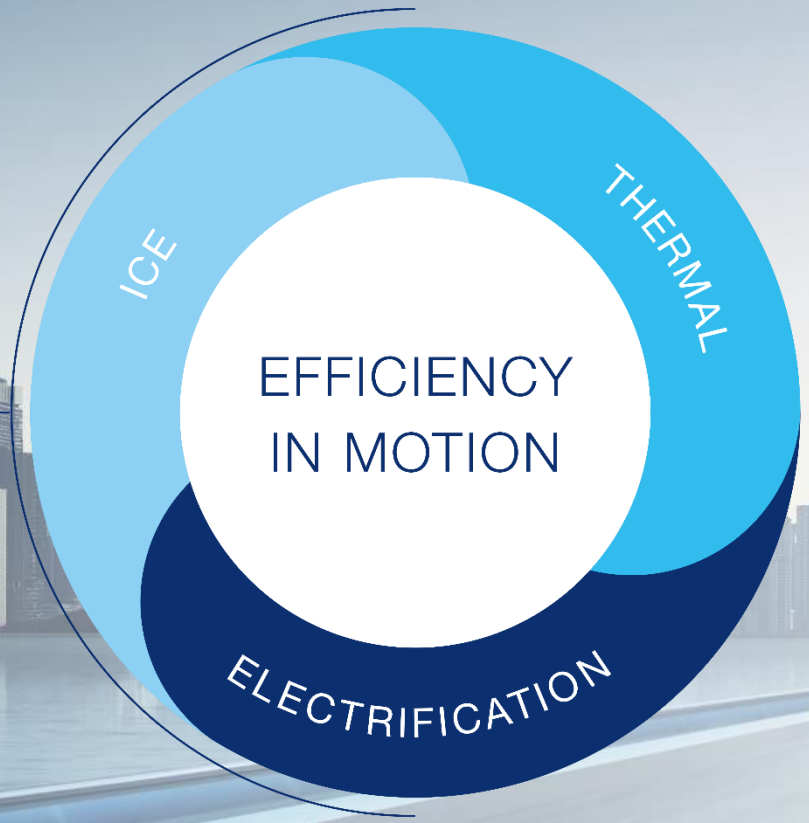
Technological Diversity

MAHLE 2030+
is Successfully Driving Transformation

Cost leadership strategy

Improve efficiency, including H_2 and renewable fuels.

WE SHAPE
FUTURE MOBILITY



System solution strategy

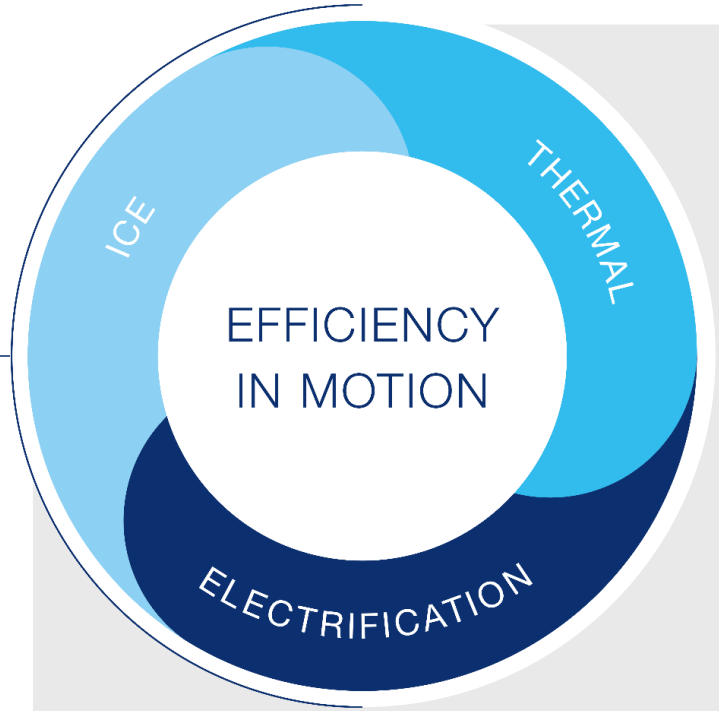
Major supplier of modular and highly efficient thermal management systems with global footprint.

Focus strategy

On electric drives and intelligent charging.

MAHLE Innovations for Medium and Heavy Duty Applications

WE SHAPE
FUTURE MOBILITY



H_2 Filter

Battery Cooling Plate

E-Compressor

Bionic Fan

E-Heater

Fuel Cell Periphery

Liquid Management Module for SCT E-Motor and E-Axle

H_2 Power Cell Unit

Electrical Oil Pump

Technology Kit for E-Motors (SCT + MCT)

Cathode Module

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MAHLE Multi-Path Approach

BEV

Fuel Cell

H_2 ICE

Hybrids/Renewable Fuels

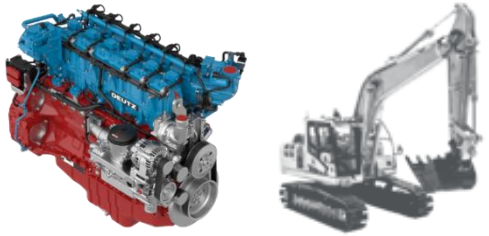
Multi-Path Technologies – A MAHLE Success Story

Opening
MAHLE Hydrogen Test Center

Start
of series developments for fuel cell and H_2 ICE components

World Premiere
MAHLE SCT e-motor specifically for commercial vehicles

SOP
MAHLE H_2 ICE components on the market with multiple OEMs

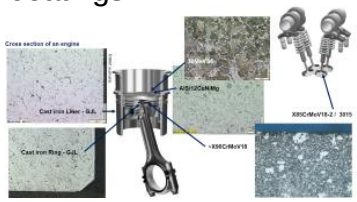


2020 | 2021 | 2022 | 2023 | 2024 | 2025

Pre-Development
Components for hydrogen powered powertrains and of advanced electric traction motors

First System Tests
Operation of both fuel cell system and H_2 ICE at MAHLE

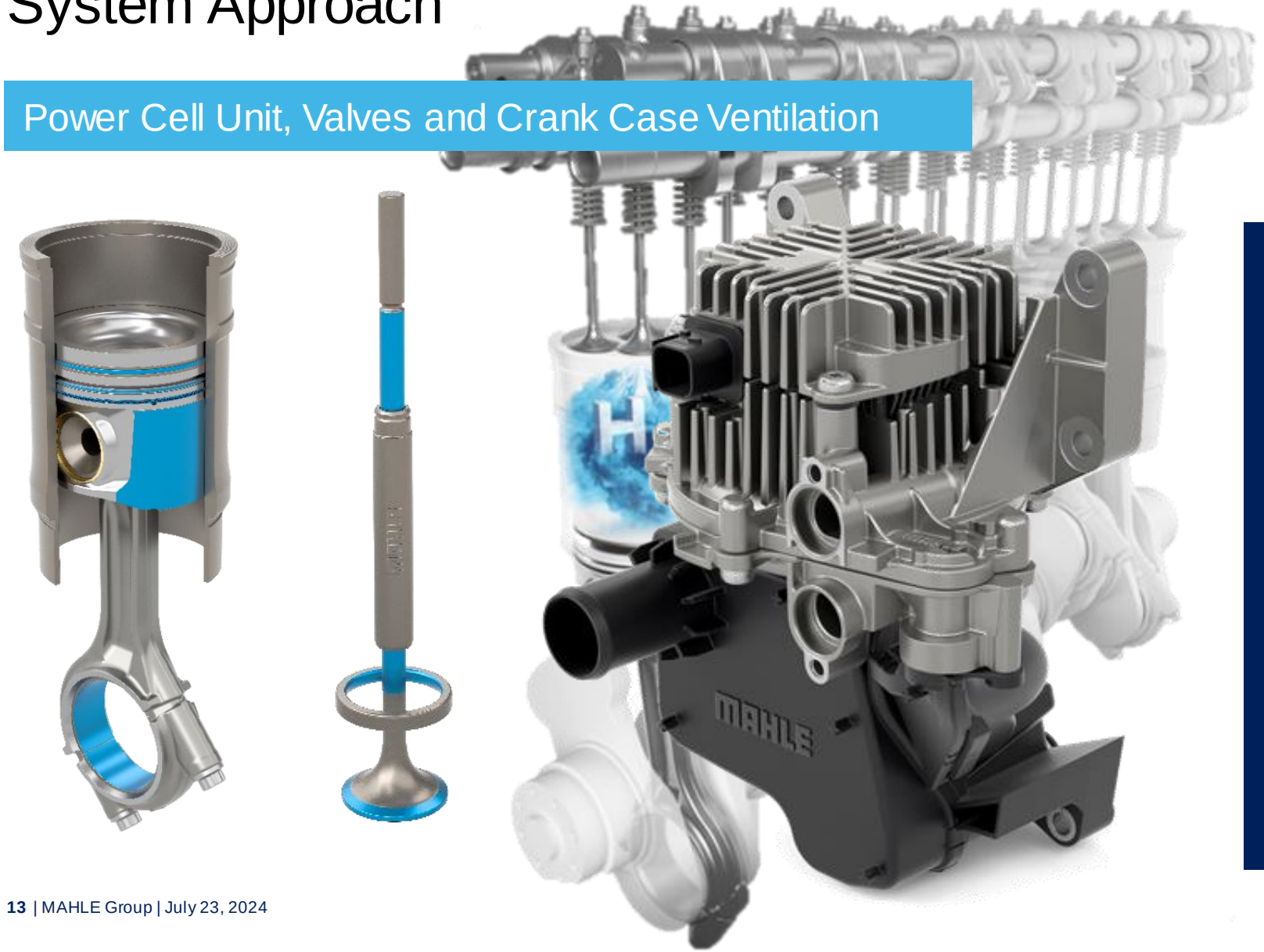
H_2 Influence
Detailed investigation on component materials and coatings



IAA Transportation
MAHLE fuel cell thermal management, humidifier and e-axle

MAHLE Hydrogen Internal Combustion Engine System Approach

Power Cell Unit, Valves and Crank Case Ventilation



System approach
means holistic investigation of H_2 ICE with partners.

Components
for maximum engine performance and safety.

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

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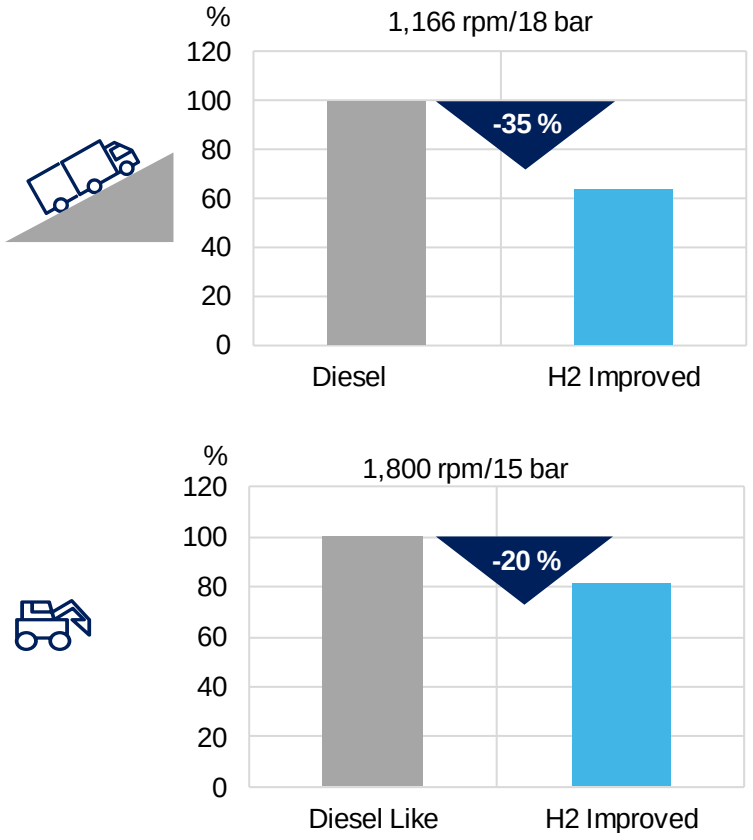
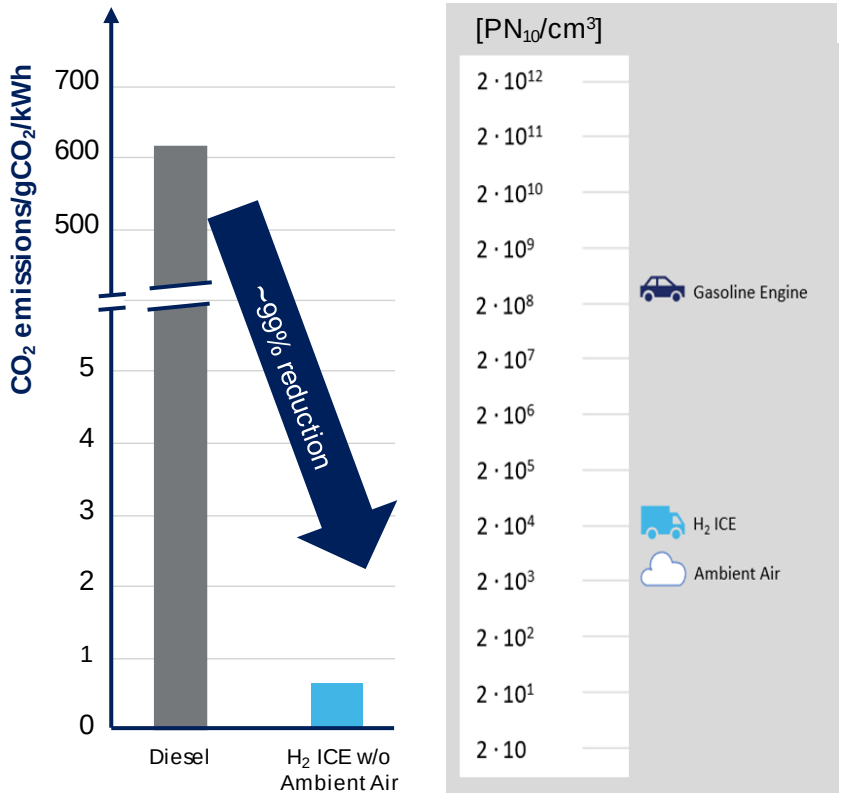
MAHLE Hydrogen Internal Combustion Engine Challenges Solved!

H_2 Dedicated Power Cell Unit Benefits

Blow-by



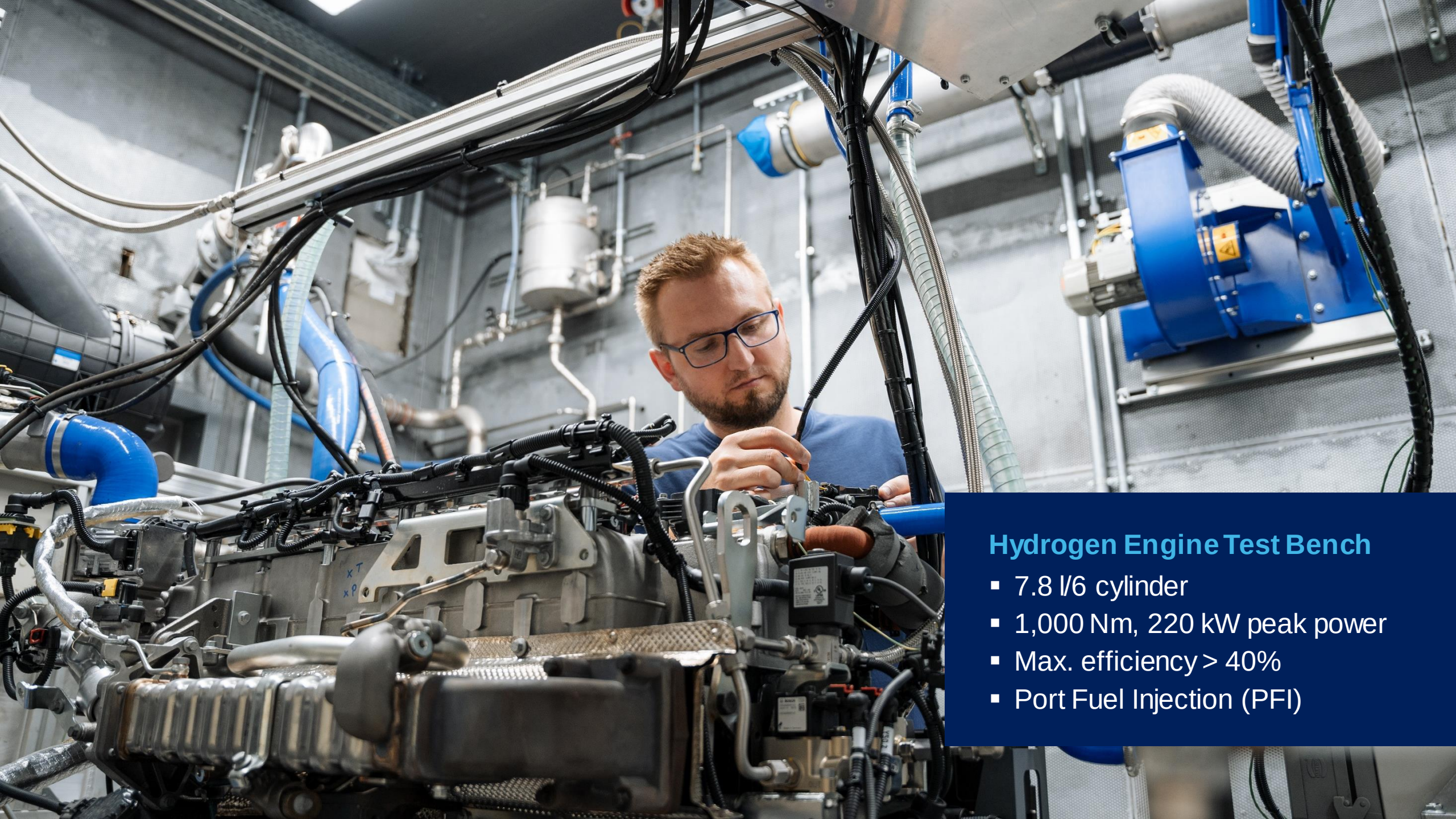
CO_2 and particulate emissions



Functional performance
Reduction of blow-by and oil consumption proven in tests with more than 1,000 hours
→ Safe and durable.

CO_2 impact
Low oil consumption leads to less than 1 gCO_2/kWh
→ "Zero Emission Vehicle".

Emissions
Low particulate emissions
→ EU VII ready.



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


Electric A/C Compressor


Electric Pump


H_2 Heater


Electric Fan

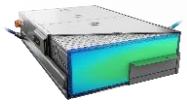

C2C Heat Exchanger*

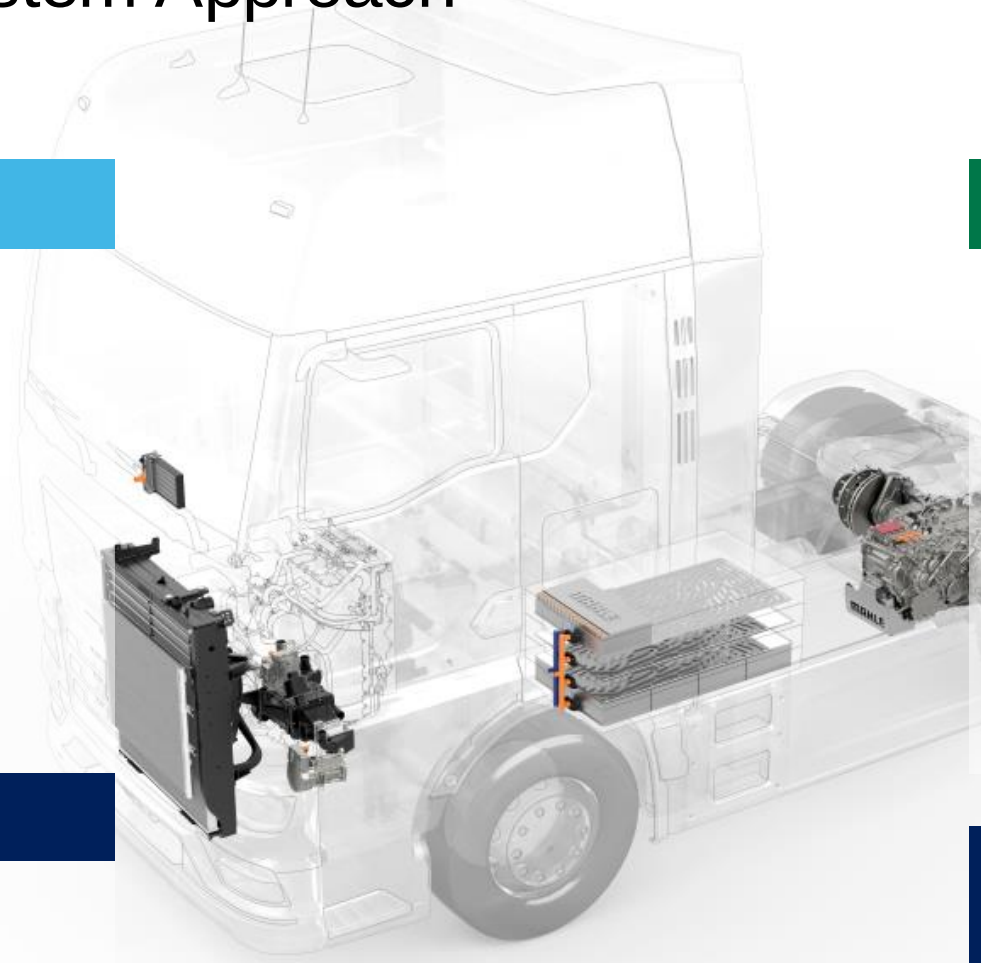

Cooling Module

Electric Powertrain


Electric Motors


Electric Motor Components


Battery Know-How

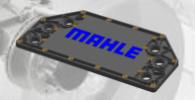


Air Management


Air Filter


Humidifier/Cathode Module


Charge Air Cooler



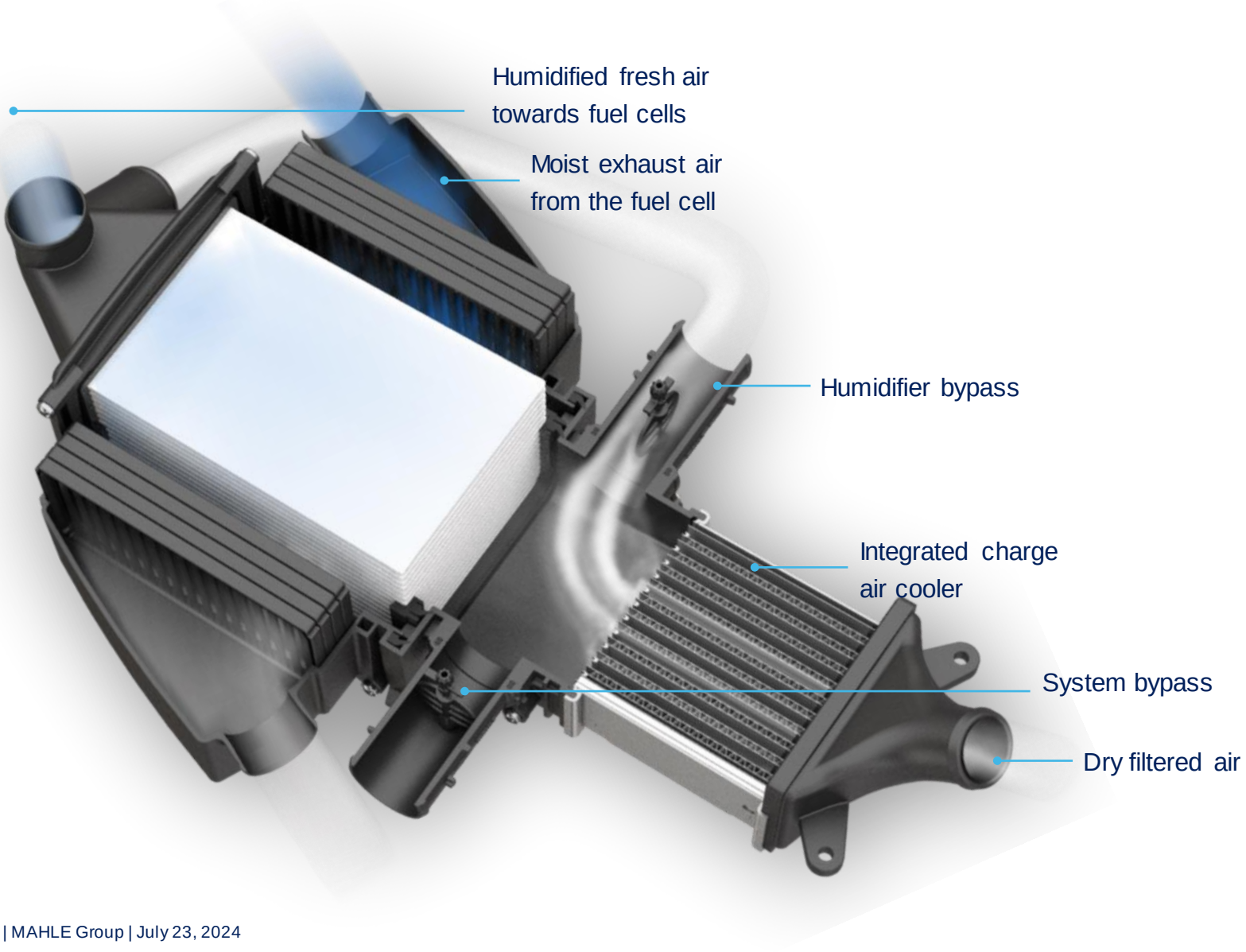
End Plate


Ion Exchanger

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

* Coolant-to-Coolant Heat Exchanger

Cathode Module – Highly Integrated Design

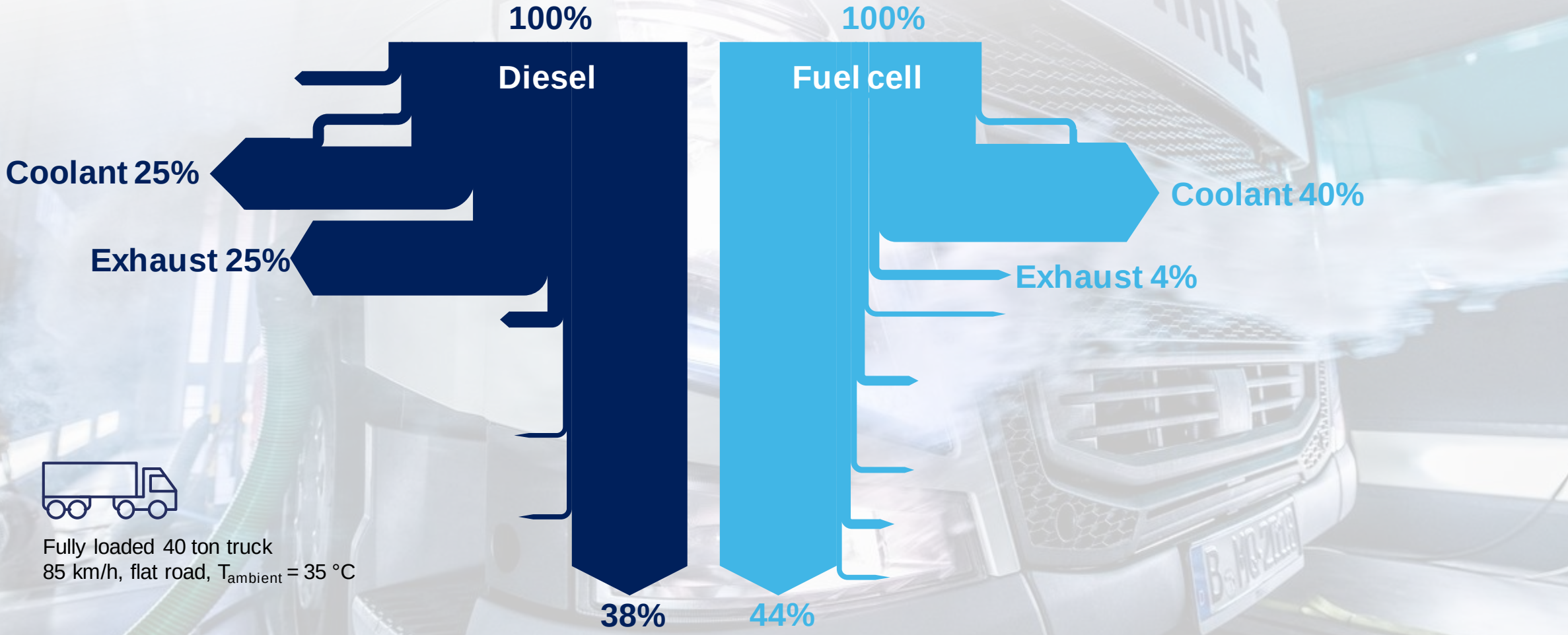


Highly integrated design
incl. charge air cooler, humidifier and water separation.

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.

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



Fully loaded 40 ton truck
85 km/h, flat road, $T_{ambient}$ = 35 °C

Coolant Pump and Battery Cooling for More Efficiency

Performance Coolant Pumps
2.5 kW and 5 kW 800 V
“power on demand” with highest efficiency.

Bionic Battery Cooling Plate
Increases heat transfer by 10% and reduces pressure losses by 20%.

World Premiere: Fuel Cell Cooling Module with Evaporation Cooling for More Performance

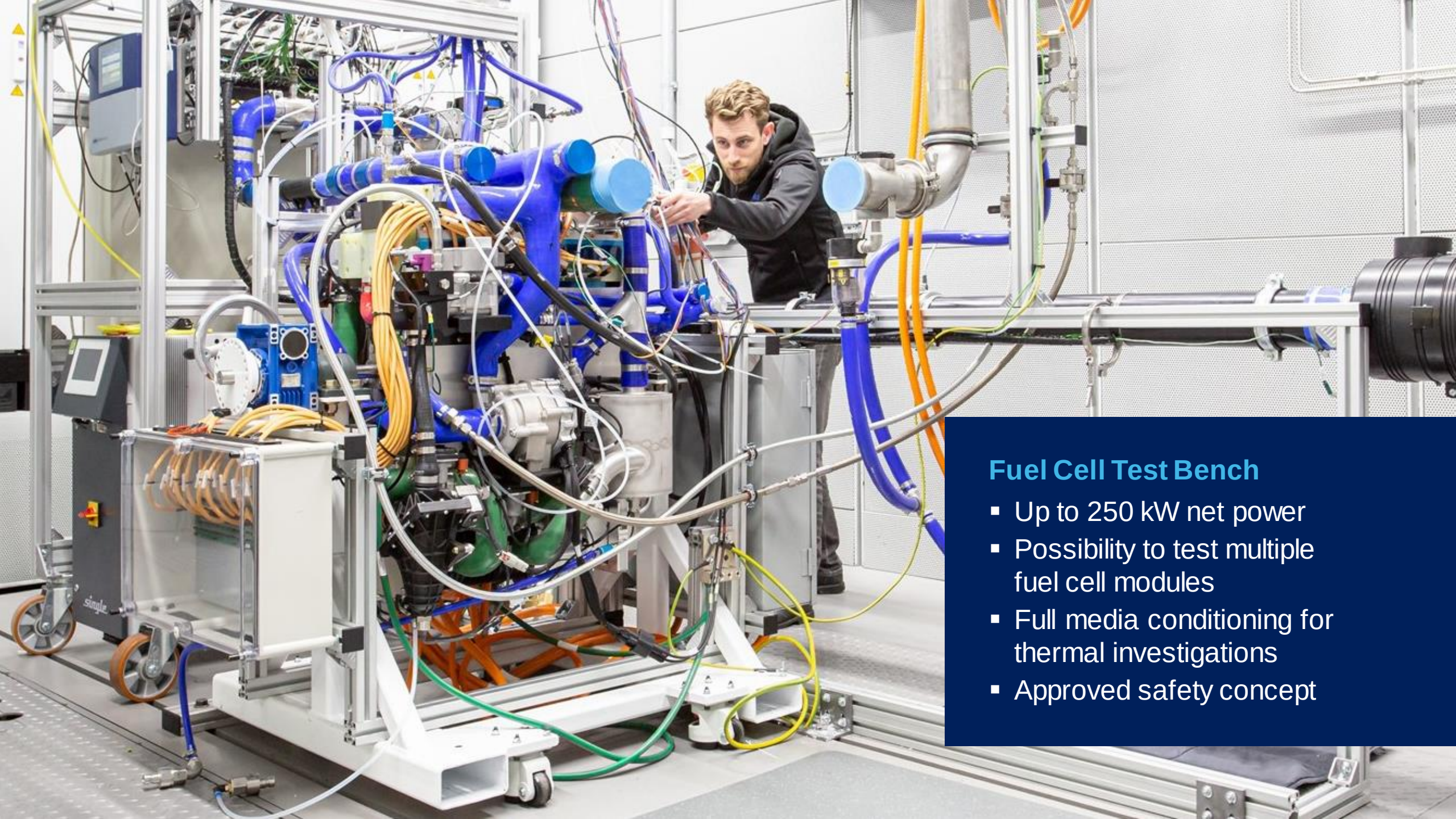
Performance Cooling Module
enabling high power heavy-duty fuel cell applications.

Evaporative Cooling
Optional function to increase cooling performance by up to 50 kW.

World Premiere: AI Generated Bionic Fan for Reduced Noise

AI Generated Bionic Fan

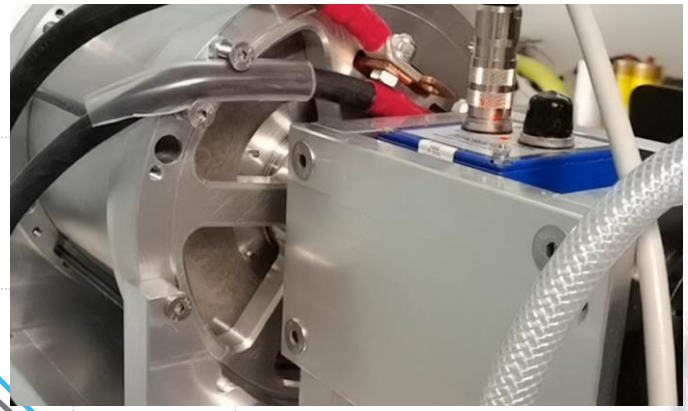
- Increases performance
- Lowers noise by up to -4 dB(A). More than halving of sound power
- Reduces weight by 10%

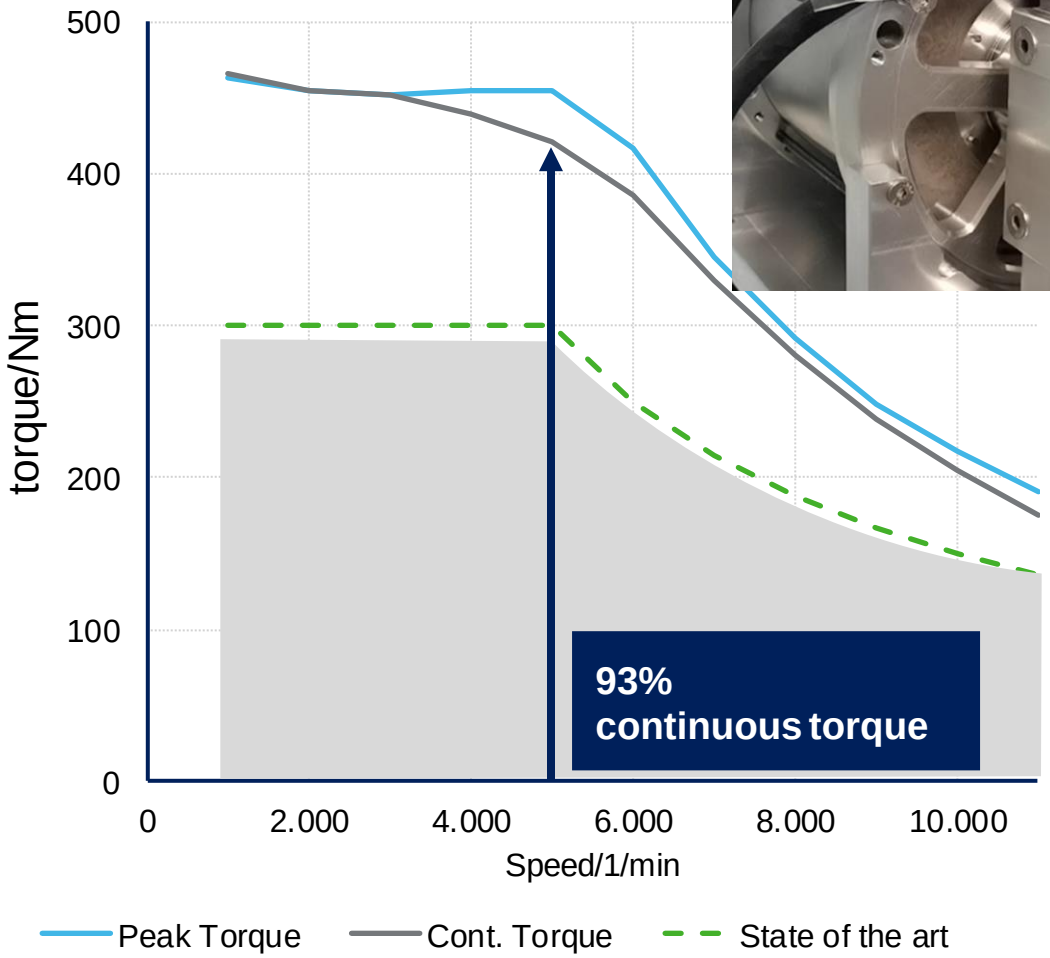


Fuel Cell Test Bench

- Up to 250 kW net power
- Possibility to test multiple fuel cell modules
- Full media conditioning for thermal investigations
- Approved safety concept

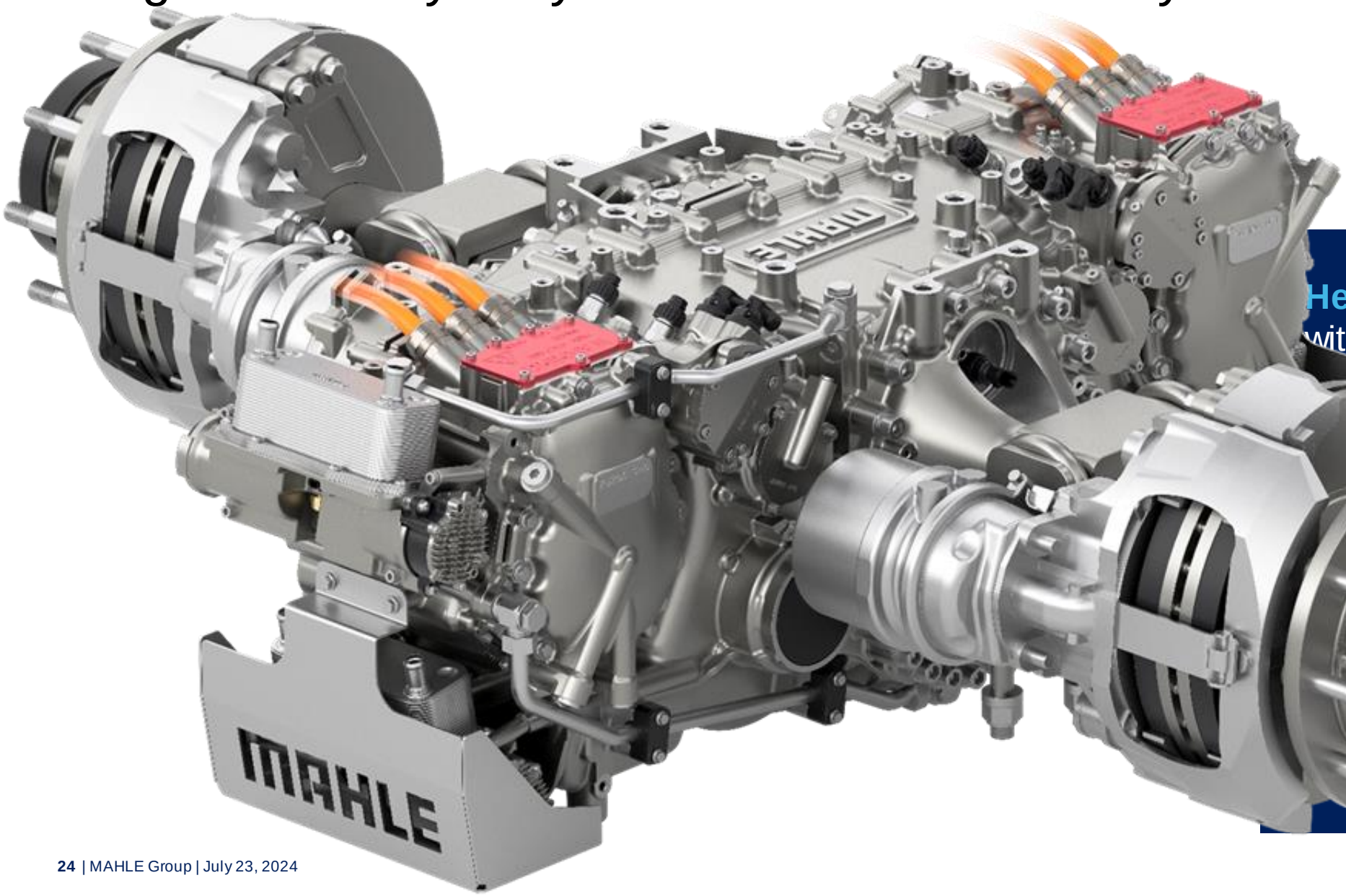
Endurance Champion: MAHLE Superior Continuous Torque E-Motor (SCT)





Performance Cooling Module
enabling high power heavy-duty fuel cell applications.

Integrated Heavy-Duty E-Axle Shows MAHLE System Expertise



Heavy-Duty E-Axle
with two MAHLE SCT e-motors
96.5% motor efficiency.

tinuous Power
us power
W peak power.

nt Module
d routing
r motors
on.

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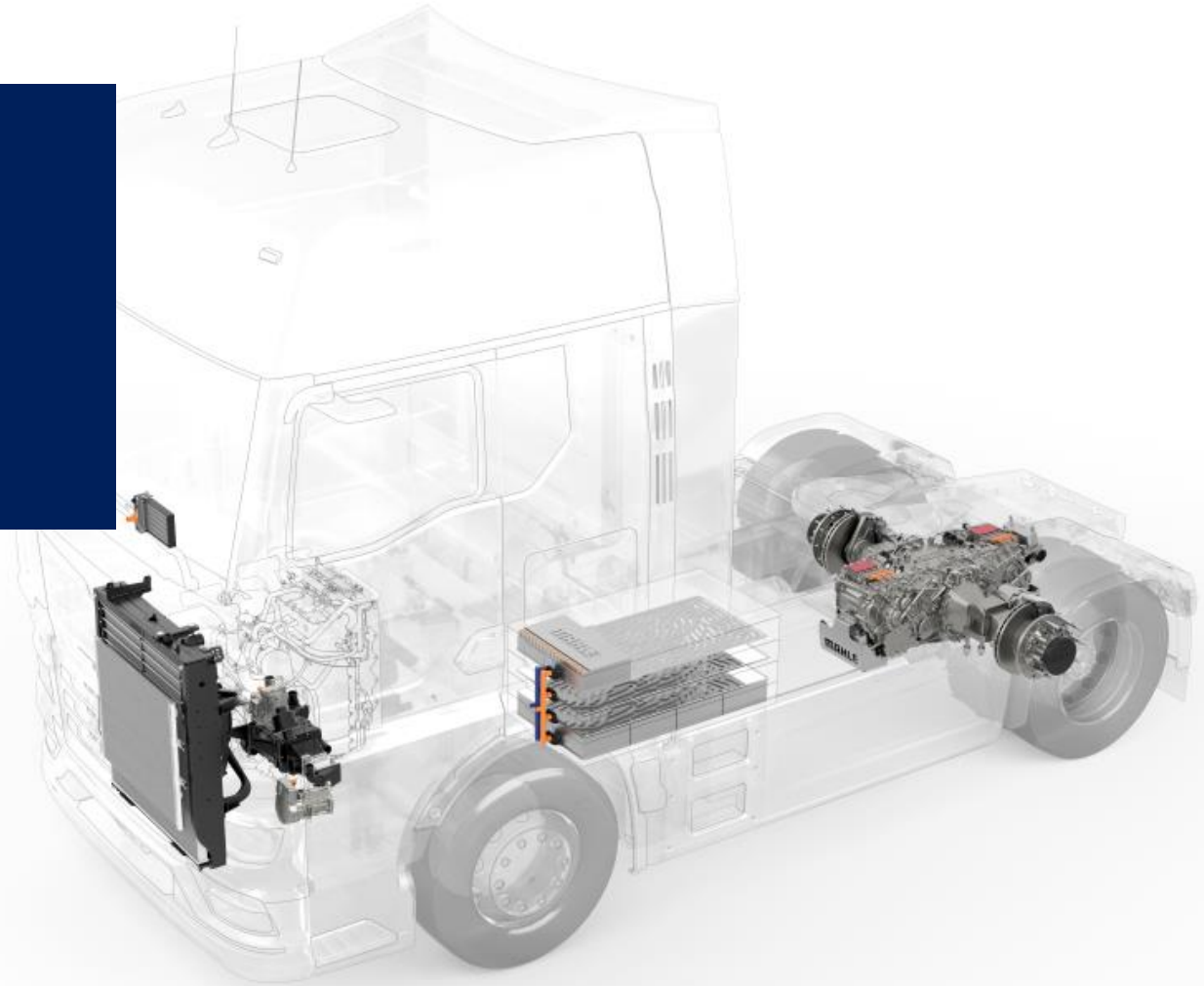
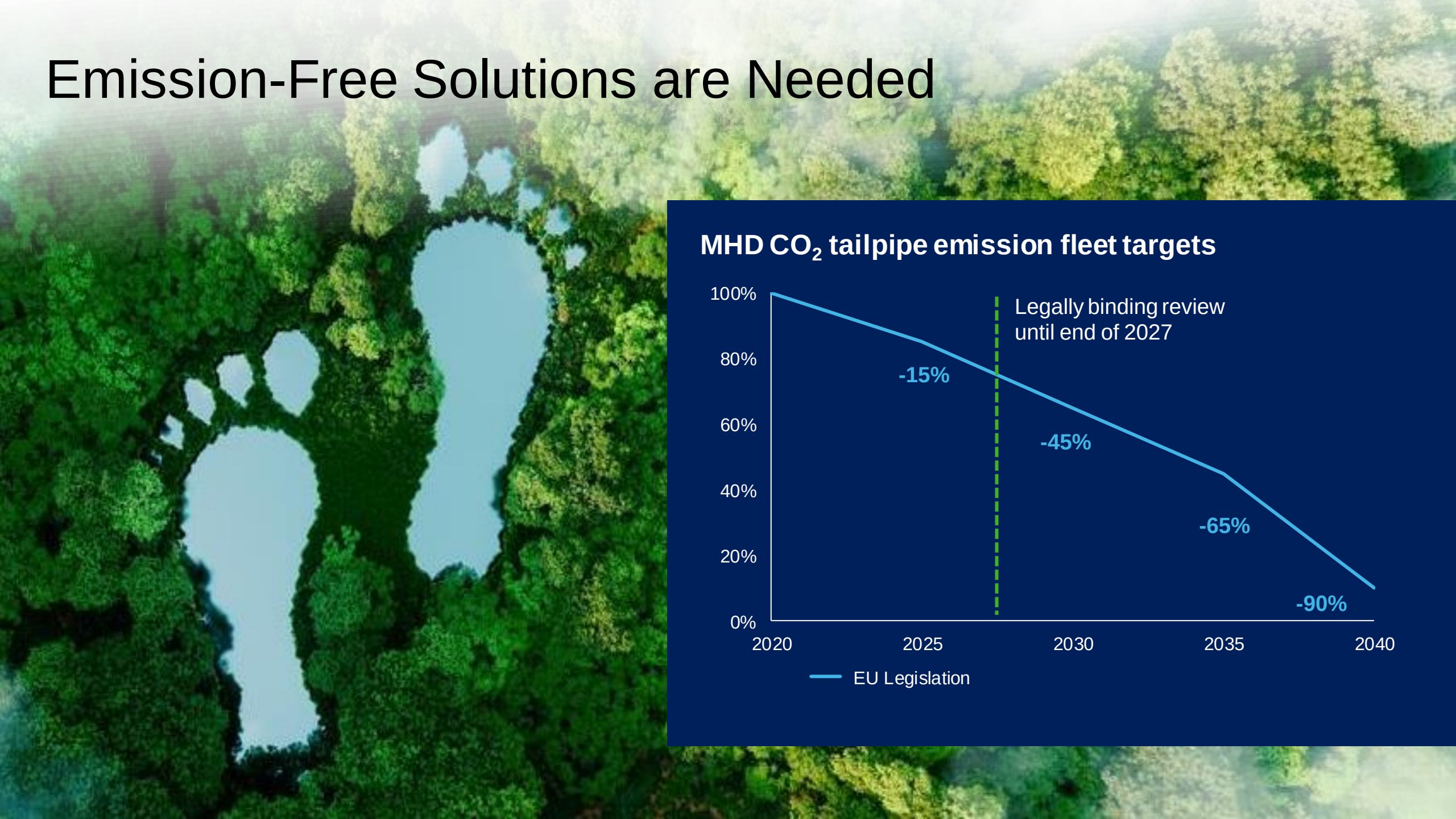
MAHLE System Expertise and Components for Hydrogen Mobility



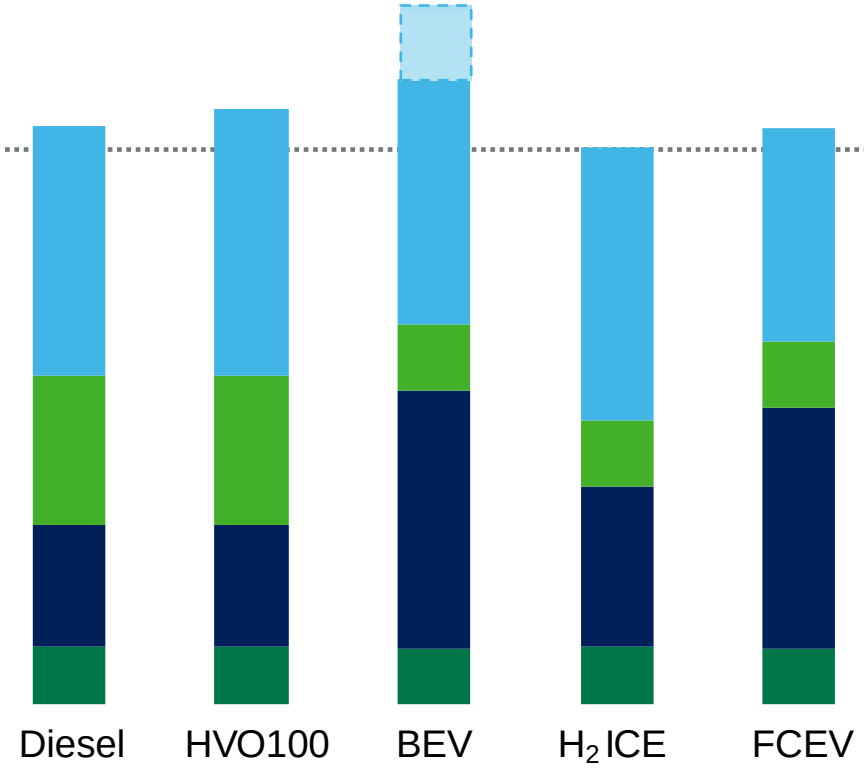
Emission-Free Solutions are Needed



Infrastructure as Challenge for Daily Routine at Service Stations

- H_2 and renewable fuel stations with **less space demand** compared to CCS/MCS charging infrastructure.
- **H_2 and renewable fuel refuelling** with **time benefits** compared to charging.
- **H_2 and renewable fuel trucks** with **higher range,** beneficial for areas with weaker infrastructure, e.g., Eastern Europe.

International Long-Haul Truck 2030



Stuttgart – Almería: ~2,000 km

Best TCO_{100km} for H_2 ICE: **~€89**

95% of total distances on highways, excl. driver

- **Fuel/Energy**
  Production, transport & taxes
- **Administration**
  Toll[1]
- **Vehicle cost incl.**
  Maintenance & financing
- **Insurance & others**
- **Effect of increase of public charging**
  (35% overnight + 50% MCS)

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

FCEV & H_2 ICE with **cost benefit at €5 kg H_2** – subsidies needed to reach target H_2 price. **H_2 infrastructure** needs to be established

Source: MAHLE TCO Calculation Q2-2024 | **1** Highway tolls calculated according to country-specific rates in GER/FRA/ESP

MAHLE Technologies: Enabling Tomorrow's Climate-Friendly Transport Sector

- Technological diversity is key to fast decarbonization
- MAHLE strategy is effective
- MAHLE products are designed, tested and ready for volume production
- A political framework conducive to climate-neutral drives is needed
- MAHLE to unveil innovations for climate-neutral heavy-duty transport at IAA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Let’s Meet at the IAA