



High Efficiency Range Extender (REX) and Dedicated Hybrid Engine (DHE) Solutions for Passenger Cars and Heavy Duty Vehicles

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High Efficiency REX and DHE Solutions for Passenger Cars and Heavy Duty Vehicles



Introduction and Motivation



Passenger Car DHE to HER



Heavy duty applications Different Scenarios



Summary & key takeaways Conclusions & outlook



Why DHE and REX Matter Across Vehicle Classes

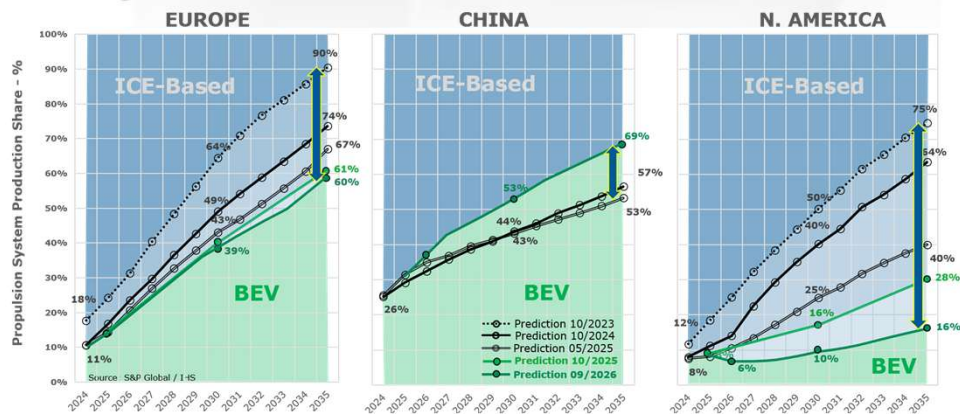
1/2 – Legislative Boundary

Passenger Car

Volatile market situation requires additional Hybrid variants to maximize CO₂ fleet robustness

REX to maximize benefits from utility factor (Europe) and to increase Utilization on **BEV production** lines

Industrial leverage. Mature engine/e-drive modules and smaller batteries can shorten launch timing.



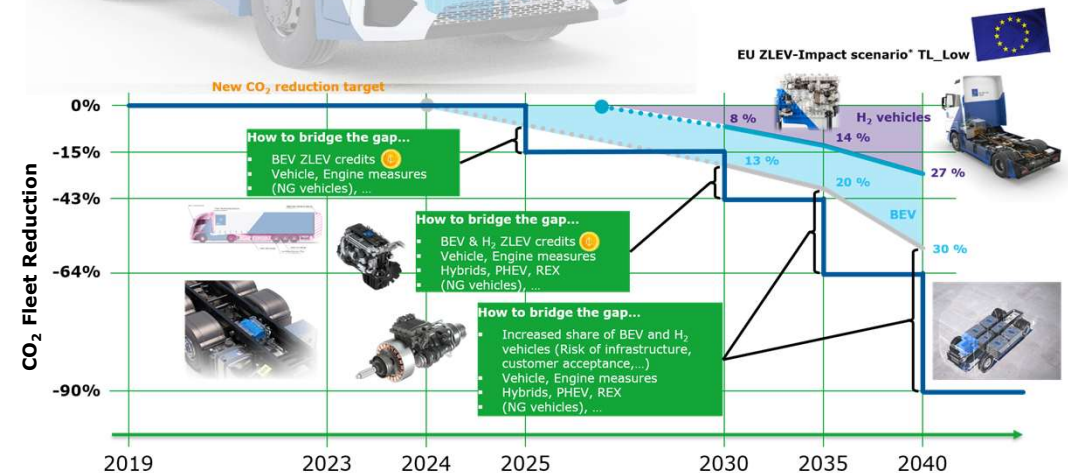
Source: S&P Global / IHS: Car production forecast: 2023 vs. 2026

Commercial Vehicle

Steep targets. -45% (2030), -65% (2035), -90% (2040) CO₂ fleet reduction.

Infrastructure hedge. Contribution of H₂ vehicles uncertain, Truck charging infrastructure remains limited

Operational bridge. REX, ensuring uptime and reliability may accelerate electrification.



* Commission staff working document (2023) 89 final: Impact scenario

Why DHE and REX Matter Across Vehicle Classes

2/2 – Customer Use Cases and Motivation

REX extends the viable electric mission. DHE converts fuel energy efficiently in a dedicated operating window.

BATTERY-ELECTRIC TRACTION AS THE COMMON BASE

PASSENGER CAR

Range confidence

- Smaller battery for daily electric use
- Long-distance capability without charging dependency
- Compact, quiet and highly efficient dedicated hybrid engines (DHE)

LCV

Payload & uptime

- Avoid battery sizing for the worst operating day
- Route flexibility under variable payload and distance
- Robust DHE balancing efficiency, cost and serviceability

HEAVY DUTY

Mission reliability

- Sustained energy for demanding transport missions
- Reduced battery mass and charging-infrastructure dependency
- Durable DHE for efficient continuous REX operation

SYSTEM VALUE

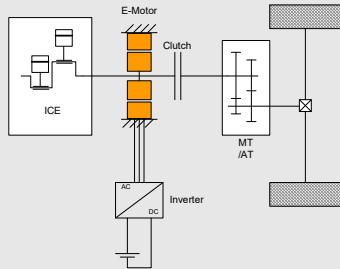
Maximize electric driving • Avoid battery oversizing • Secure the mission
• Use fuel only where it adds system value

PASSENGER CAR



Hybrid Powertrain Configurations

Parallel



Mainstream in Europe

Baseline is conventional PWT
Using typically multi-speed AT/DCT Transmissions



Mercedes E450 MY21 (P1)



BMW 330e MY21 (P2)



Renault Clio E-TECH MY21
(P1 / P2.5)

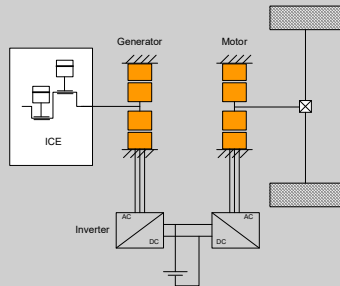


Mercedes E300de MY21 (P2)



BMW X1 25e MY21 (P0 & P4)

Serial



Niche for PC HEVs Renaissance for REX

Baseline is BEV drivetrain

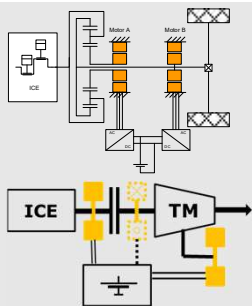


Nissan Note e-Power MY21 (S)



Chinese REX Vehicles

Powersplit
(serial/parallel)



Toyota Hybrid System P/S Configurations

Mainstream in China
Single Speed DHT
Powerful e-Motor as main propulsion



Toyota Prius MY21 (THS)



Honda CR-V e:HEV MY21 (P/S)



Chery Fulwin A8 (P/S)



Ford Kuga (THS)



Mitsubishi Outlander (P/S)



BYD Seal (P/S)

Range Extender Potential Applications (e.g. China)



Limited - Range Extender (limp home functionality)

already known from the past

- Small engines → e.g.: 1.0l 3 or even smaller 2cylinder
- Similar battery size as in the base BEV

- + **packaging** (best integrability in existing BEV platforms)
- **Limited power with empty battery**
- **NVH** (rotary engines - air born noise critical)



Serial Hybrid like Range Extender

- Engines mainly derived from existing engine portfolio
→ e.g.: 1.5l 4cylinder
- ~50% smaller Battery than base BEV

- **Packaging** (more suitable for BEV based multipurpose platform)
- + **minor limitation in drivability** (even with empty battery)
- + **NVH**

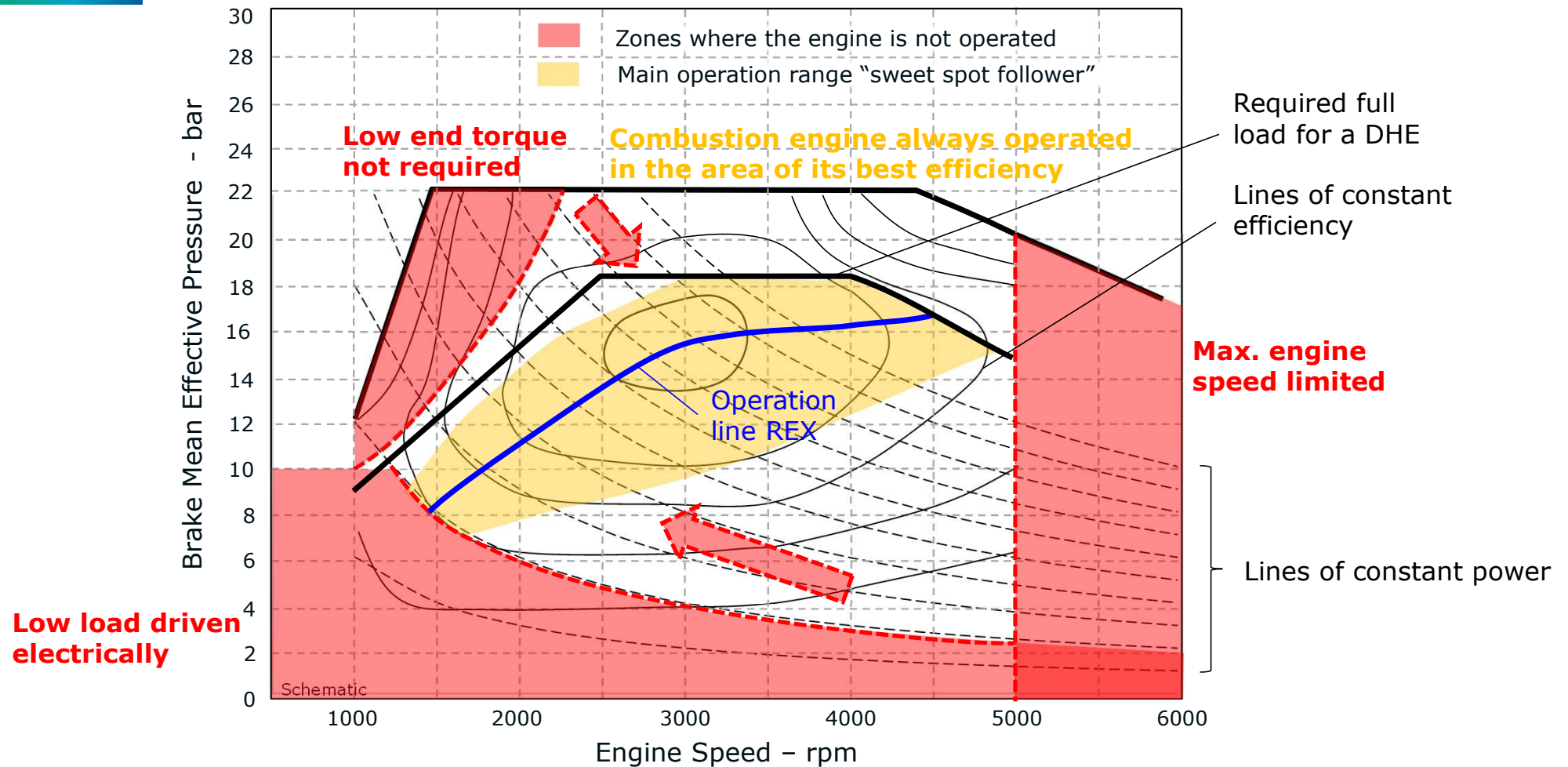
BEV to PHEV transformation (P1/P3+P4)

- Hybridized EV platforms
- Integration of a P1/P3 Hybrid Unit in an existing BEV

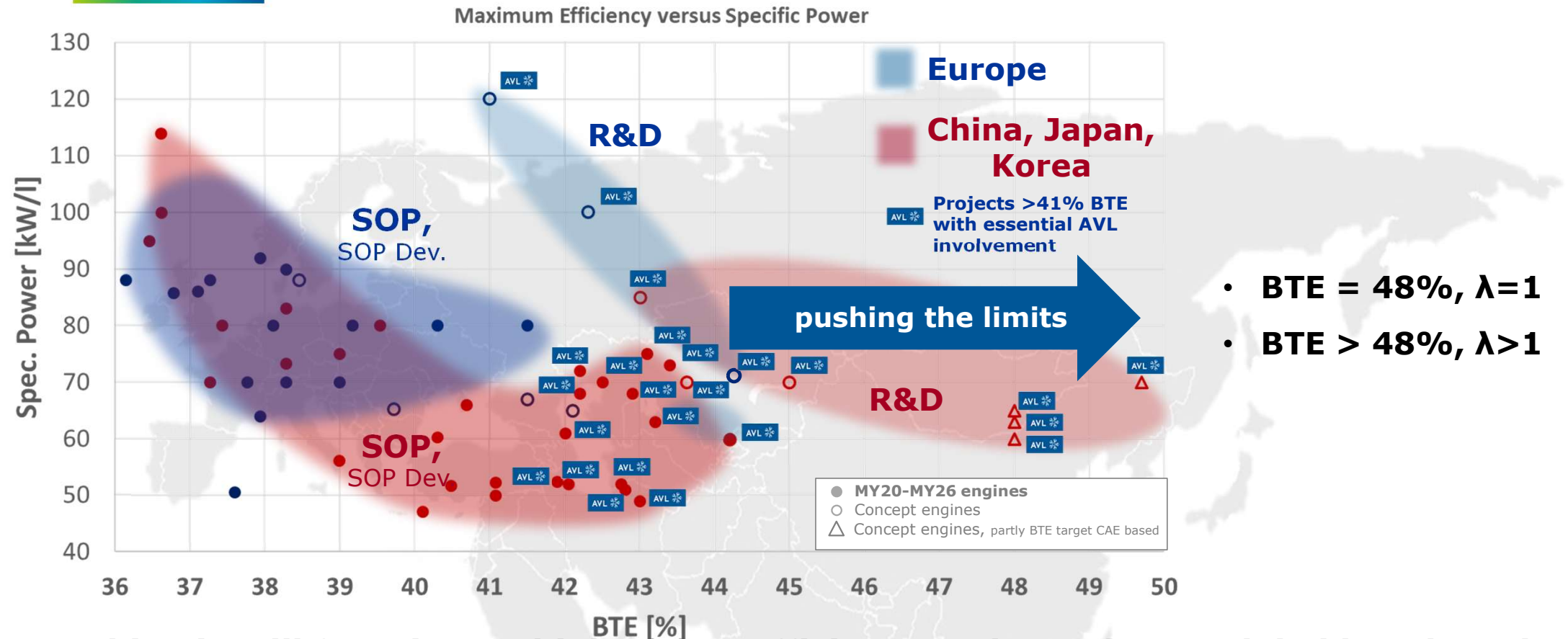
e.g.: Horse 2027



What is a Dedicated Hybrid Engine (DHE)?



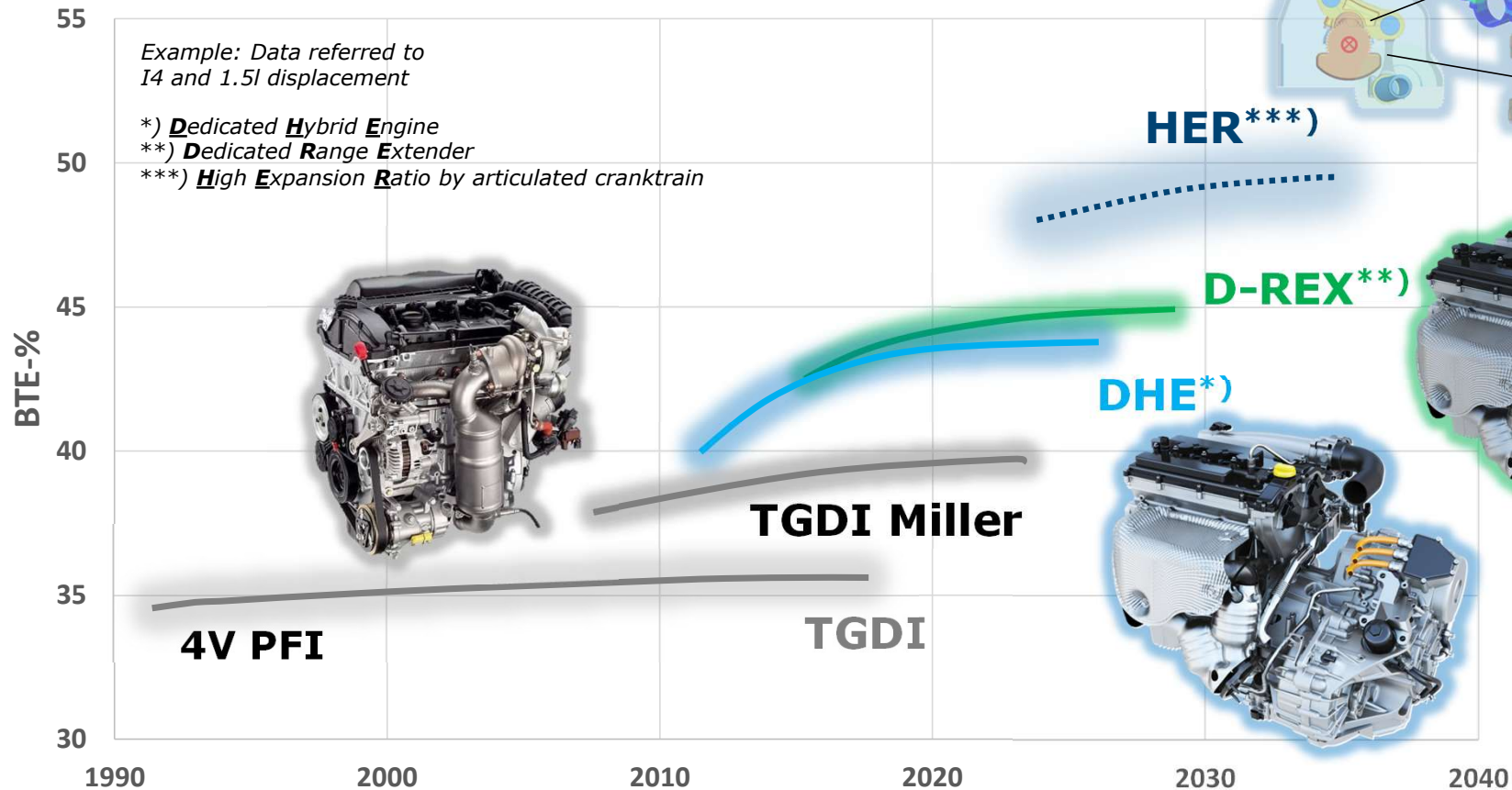
Main PassCar ICE Development Trends EUROPE versus ASIA 2025/2026



- BTE = 48%, $\lambda=1$
- BTE > 48%, $\lambda>1$

***China is still focusing on highest ICE efficiency and remains as global benchmark
Europe is starting to catch up***

The Evolution of ICE Efficiency



New degrees of freedom offer further efficiency potential



Dedicated Hybrid Engine - xHEV Democar-Examples – high BTE

HEV

AVL



Main DHE pathways:

- High compression ratio
- Long stroke
- Cooled LP EGR
- Low friction
- Miller/Atkinson cycle
- ...



44.2% BTE

PHEV

AVL



45% BTE

REEV

AVL



D-REX potential:

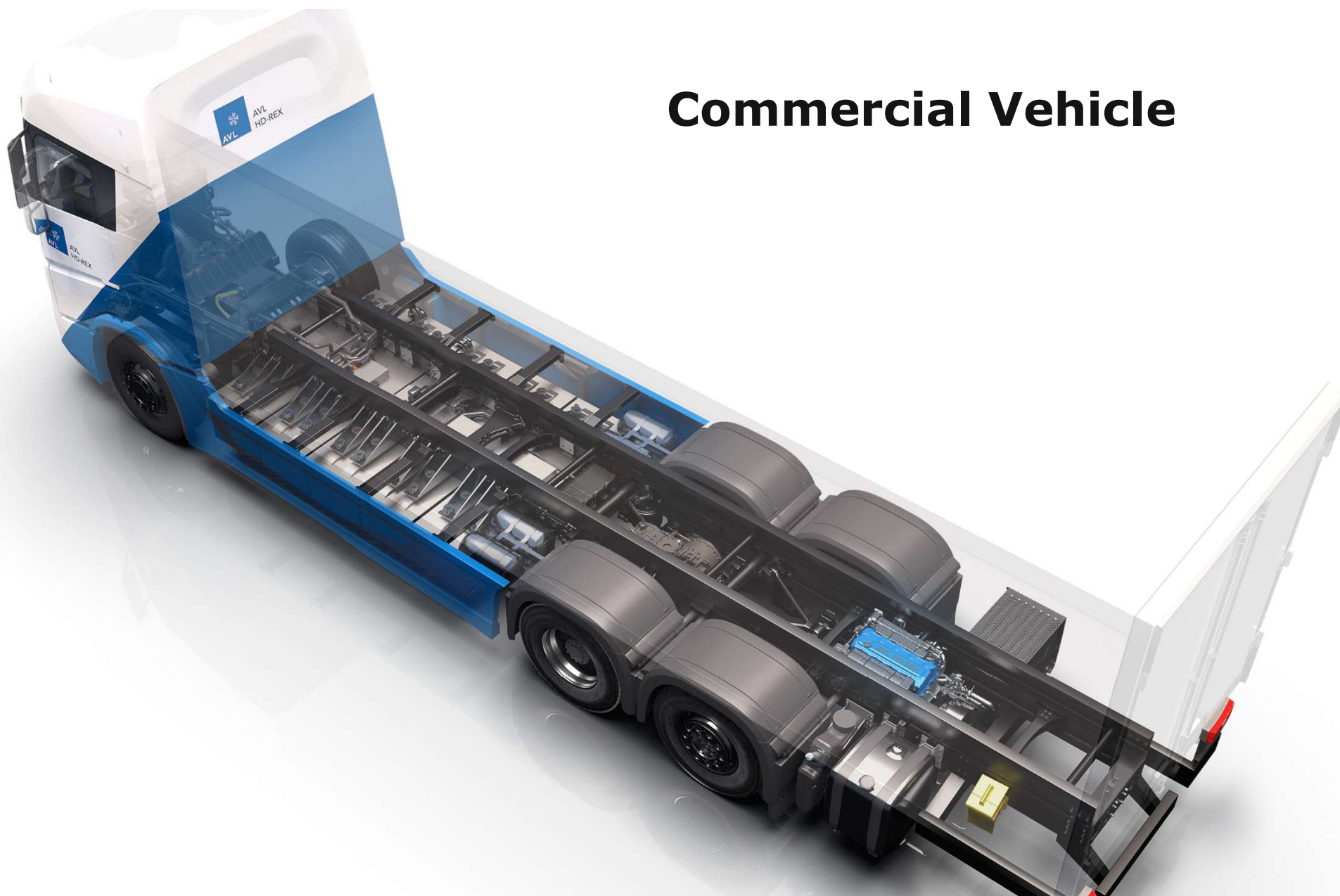
- Further increased CR
- More single point focused operation strategy
- Advanced system for highest BTE values (HER)
- ...



48% BTE

High BTE is achievable in xHEV applications (even with Stoichiometric combustion)

Commercial Vehicle



EU De-Carbonization Trend and Powertrain Options

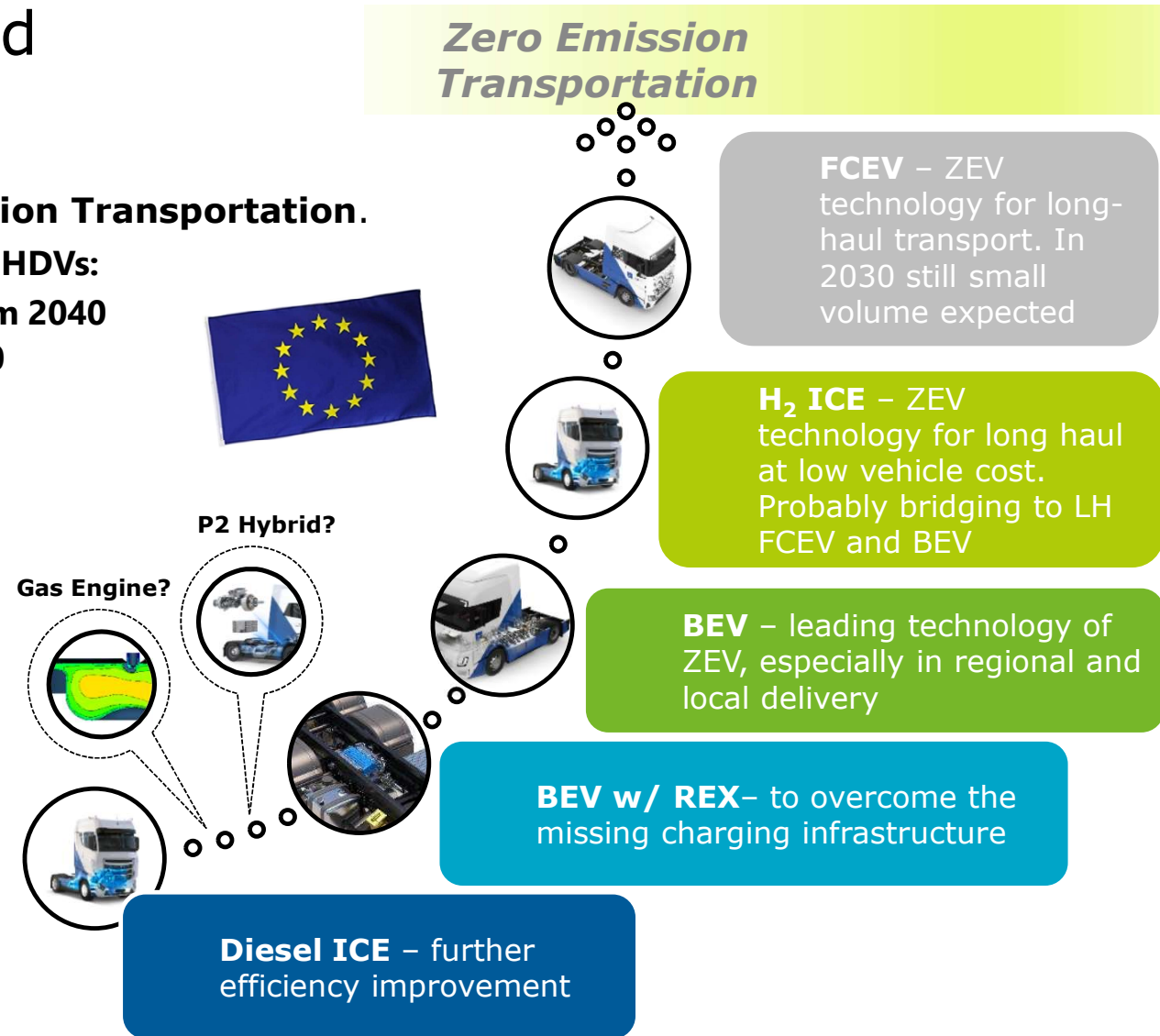
In **Europe**, trend goes towards **Zero Emission Transportation**.

EU fleet-average CO₂ reduction targets for new HDVs:
–45% from 2030 | –65% from 2035 | –90% from 2040
rolling fleet to be decarbonized by 2050

OEMs will have to comply with fleet CO₂ targets of all vehicles being sold within 1 year.

Solutions

- Highly efficient **Diesel ICE**
- **BEV**
- **BEV w/ REX**
- **P2 Hybrid**
- **H₂ICE**
- **FCEV**



Commercial Vehicle Technology

Different Hybrid Architectures in VECTO for Sub-Group **5-LH**

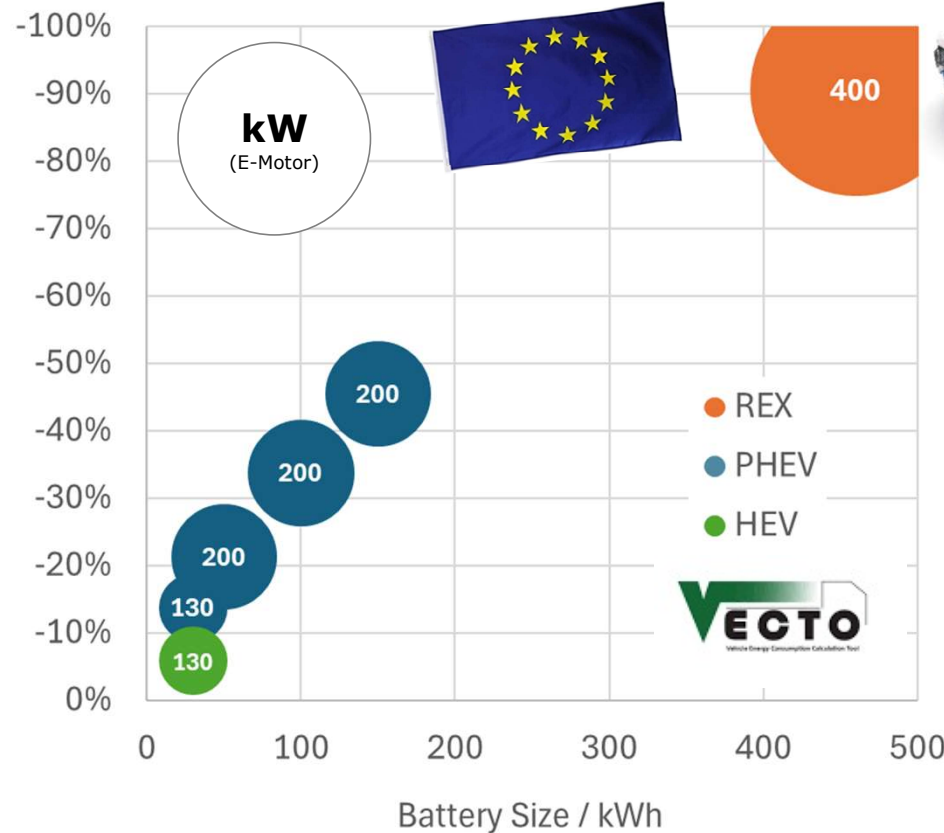


**Vehicle
Efficiency
Calculation
Tool**

ICE Derived Solution



CO2 Reduction in VECTO / %



Dedicated REX



BEV Derived Solution



Real World Benefit / TCO

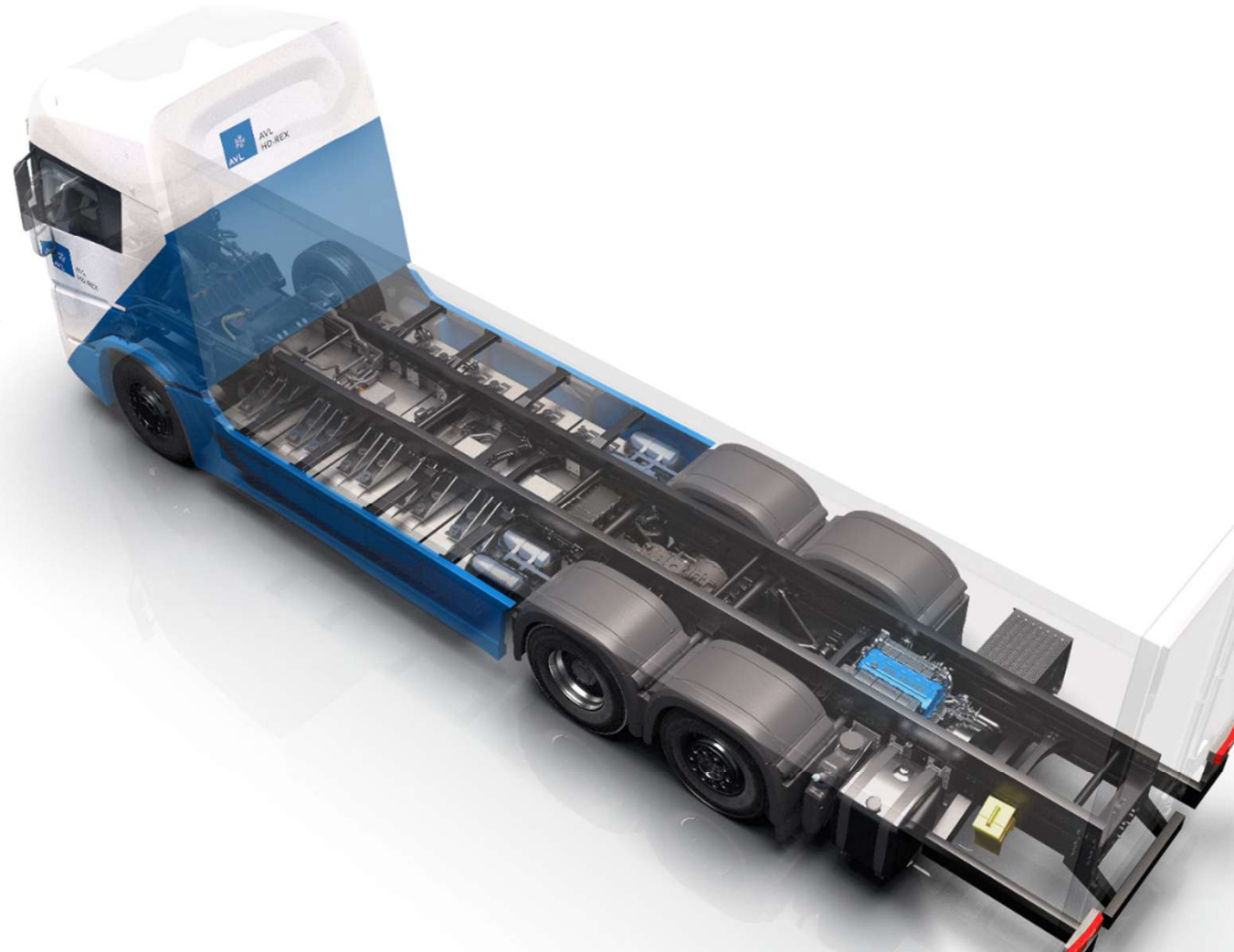


AVL Powertrain System Optimizer

**PHEVs / REEVs provide strong CO₂-saving potential in VECTO;
AVL's PSO allows to balance both, fleet value optimization and real-world benefits vs. cost.**

HD-REX Motivation

- Combines **diesel-like flexibility & long-haul capability** with BEV benefits
 - **Low OPEX via depot charging** + zero-emission driving
- REX bridges infrastructure gaps & **avoids high opportunity charging costs**
- Enables **scale effects for BEV platforms**



HD-REX: Electric Efficiency with Diesel-like Resilience!

Motivation for Range-Extenders in Commercial Applications

HD-REX: Electric Efficiency with Diesel like Resilience!

HD REX ramp-up certainty

Critical Response

- Absolute **mission reliability**
- High auxiliary loads
- Infrastructure independence
- Redundancy



Image Rights: Rosenbauer, AVL, KI, MAN, BYD

Truck

- Cover **long haul missions**
- Avoid mega-batteries
- Improve TCO
- Independence from MCS



Motorhome

- **Off-grid independence**
- Long range
- Onboard power supply
- Smaller battery & weight benefits



Coach

- **Long distance viability**
- Alpine/cross border reliability
- Battery downsizing



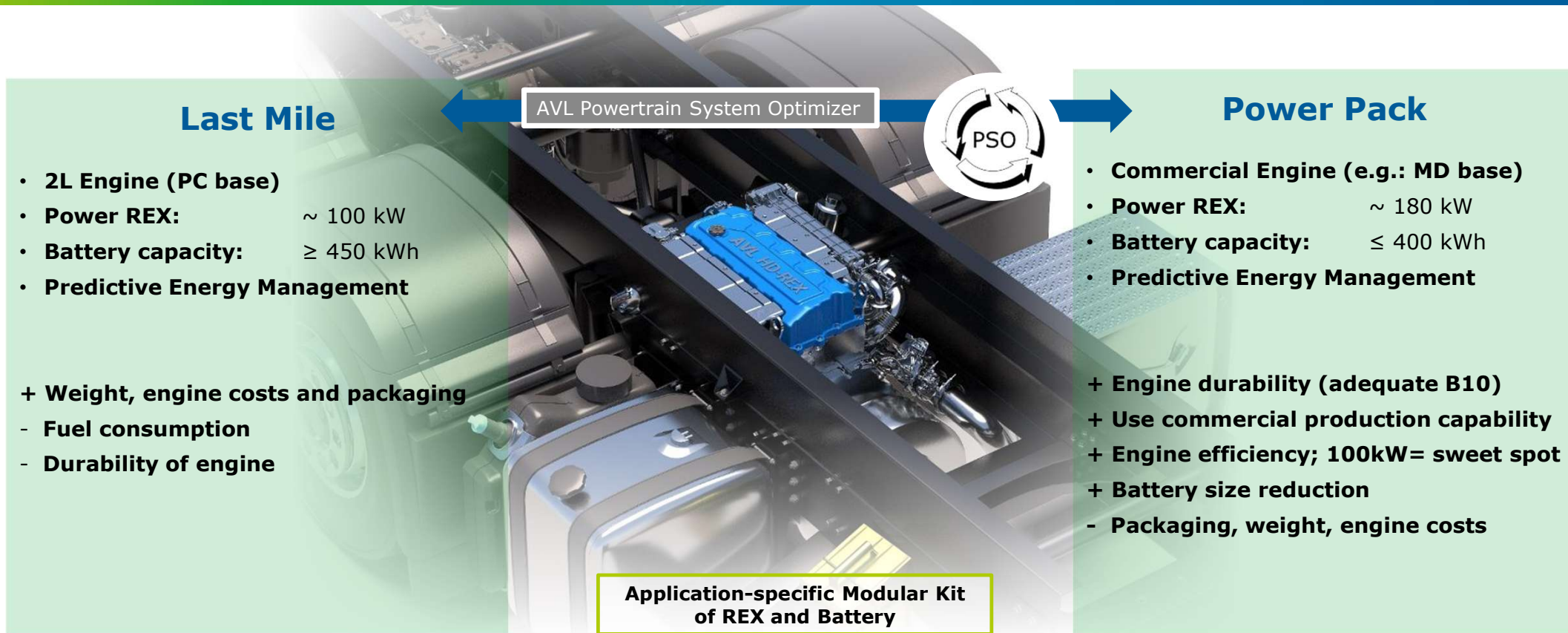
Bus

- Backup energy
- Smaller batteries
- **Route flexibility**
- Limited grid capacity workaround



Mainstream Application HD Transport REX Options

HD-REX-PU: Scenarios from PC base up to Commercial MD



From proven diesel platform to DHE/REX-ready

A focused BTE / BSFC walk captures maximum efficiency where the hybrid system actually operates

1 PROVEN BASE

Existing diesel engine platform



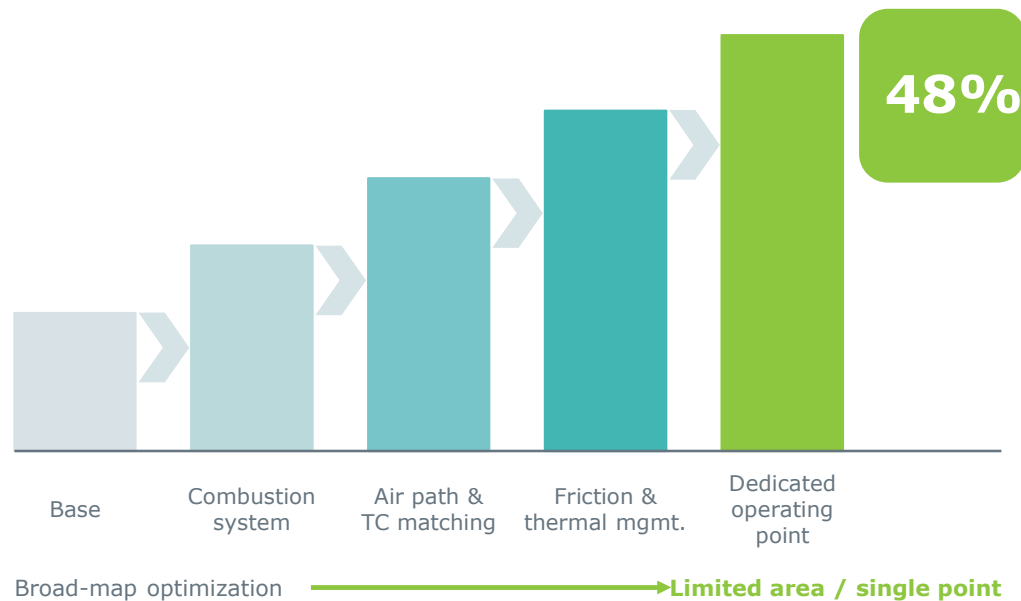
Standard diesel components

- production-oriented hardware
- existing installation package
- proven component base

2 FOCUSED EFFICIENCY WALK

BTE ↑

Optimize only the operating area required by the hybrid strategy



3 UPGRADE PACKAGE

Make the platform DHE / REX-ready

- Combustion & calibration
- High-efficiency TC / air path
- Thermal & friction measures
- Validation at relevant points

Result

Highest efficiency without a clean-sheet engine

Reuse the existing diesel platform and add only the measures needed for the defined hybrid operating window.

AVL's Truck Technology Portfolio

FCEV

- City Delivery
- Regional Delivery
- Long Haul



BEV

- City Delivery
- Regional Delivery
- Long Haul with MWC



REX

BEV derived PHEV

- Last Mile Delivery
- Long Haul



H₂-ICE

SI and HPDI

- Traction
- Long Haul



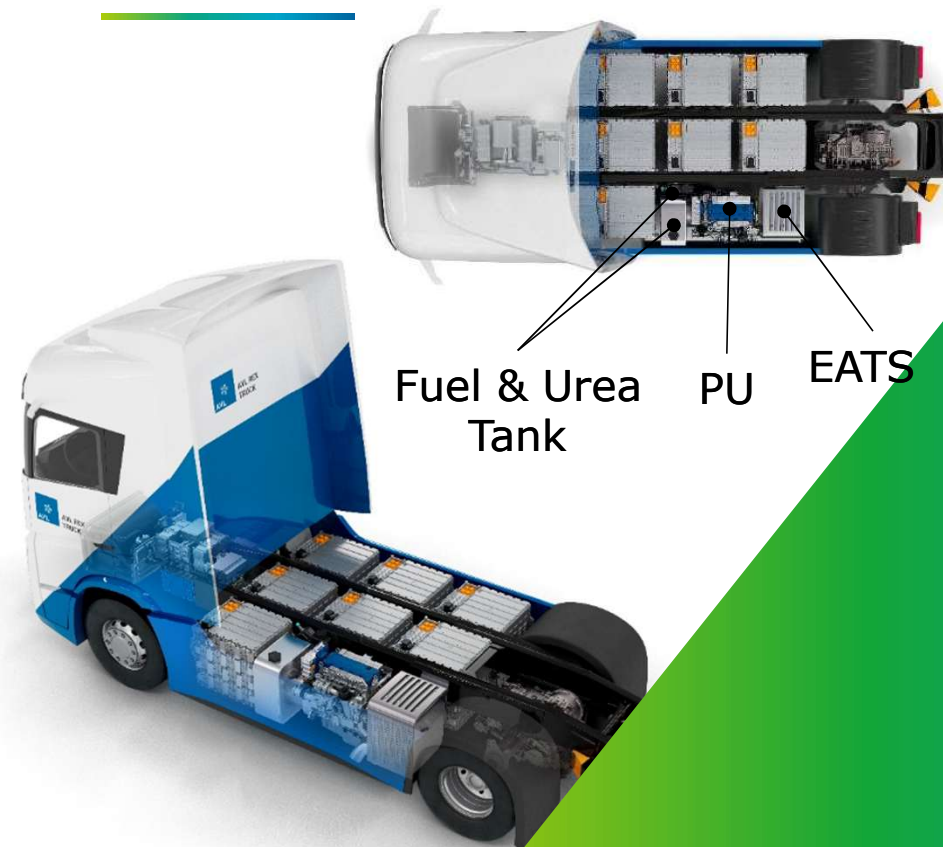
BTE 50% ICE

P2 Hybrid PHEV

- Traction
- Long Haul



HD REX – “Last Mile”



European 4x2 Tractor

- Range-Extender Arrangement
- Installed battery capacity: 460 kWh
- 100-140 kW electrical PU-power
- Fuel Capacity: 90 l
- Urea Capacity: 35 l

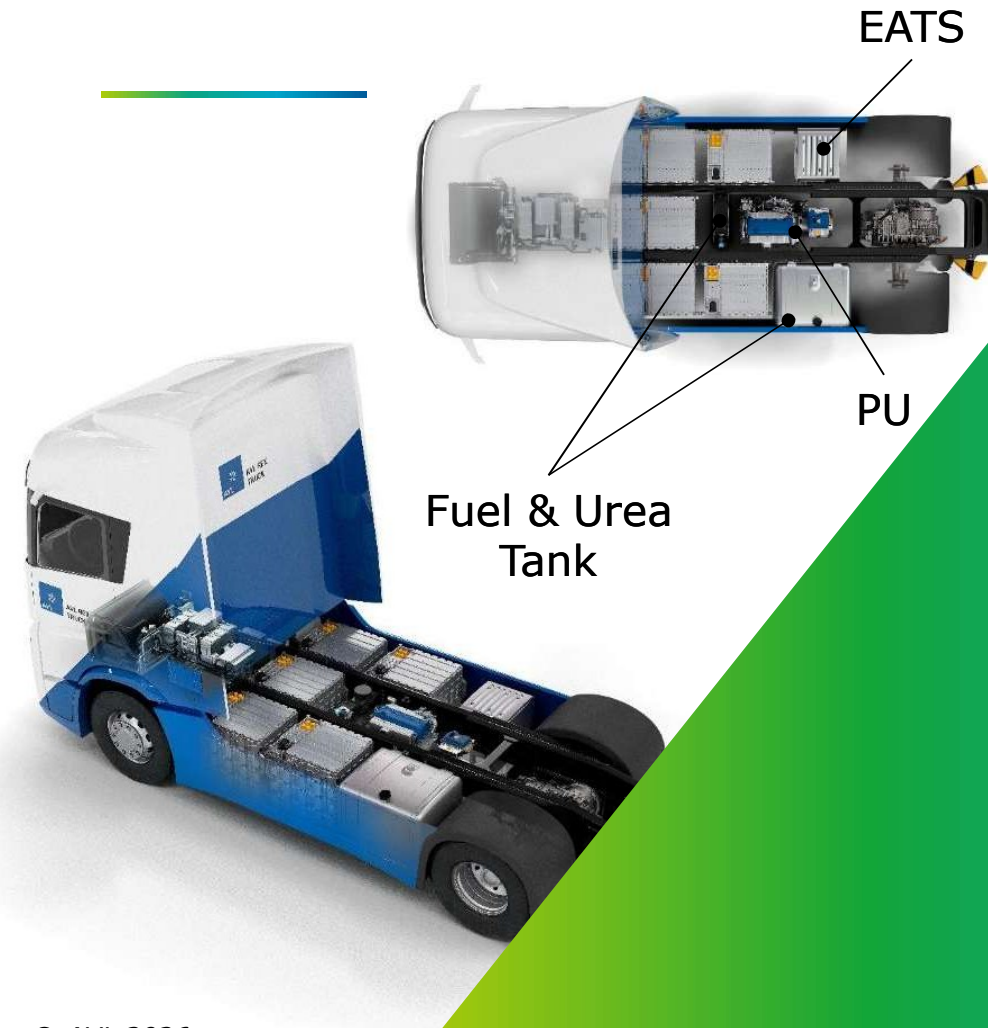
Electrical Range: 400 km

Extended-REX Range: 320 km

Total Range 720 km

Weight Benefit: ~ 180 kg

HD REX – “Power Pack”



European 4x2 Tractor – Power Pack

- Power-Pack Arrangement
- Installed battery capacity: 330 kWh
- 140 kW electrical PU-power
- Fuel Capacity: 390 l
- Urea Capacity: 55 l

Electrical Range: 300 km

Extended-REX Range: 1200 km

Total Range 1500 km

Weight Benefit: ~ 840 kg

Source: DHL



Propulsion
Technology

Infrastructure

Energy Carrier

SCANIA, DHL and AVL present REX concept at the Vienna Motor Symposium 2026

Summary and Outlook

One system principle, dedicated solutions for each vehicle mission

PASSENGER CAR

Range confidence

- Right-sized battery for daily electric driving
- Dedicated high-efficiency REX for exceptional missions
- Compactness, NVH and cost remain decisive

HEAVY DUTY

Mission reliability

- Battery and REX sized for transport mission and infrastructure
- Payload, uptime and sustained power drive the architecture
- Dedicated high-efficiency DHE, generator, EATS and thermal system

OUTLOOK: LCV

The next vehicle class

- Combines PC package and NVH constraints with commercial utilization
- Payload, uptime and variable routes create a strong REX use case
- Next task: bring REX live on LCV vehicles

COMMON PRINCIPLE

Maximize electric driving • Avoid battery oversizing • Secure the mission • Use fuel only where it adds system value

The principle is common. The solution must be dedicated to the mission.

High Efficiency Range Extender (REX) Solutions for Passenger Cars and Heavy Duty Vehicles

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