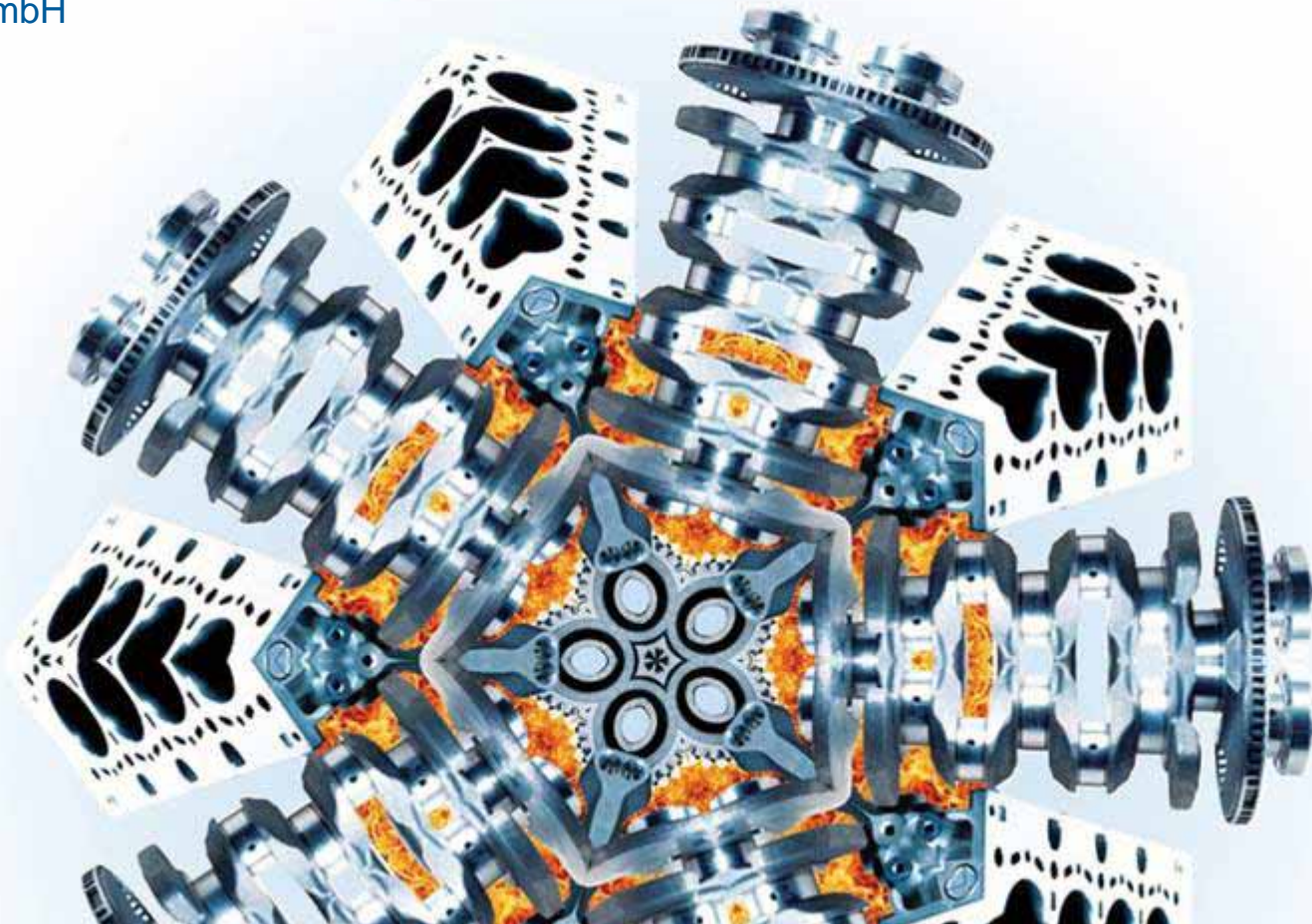


AVL ELECTRIC VEHICLE



ELECTRIFICATION OF VEHICLE DRIVE TRAIN – THE DIVERSITY OF ENGINEERING CHALLENGES

A3PS – Conference, Vienna
Dr. Frank Beste
AVL List GmbH





Global Megatrends:

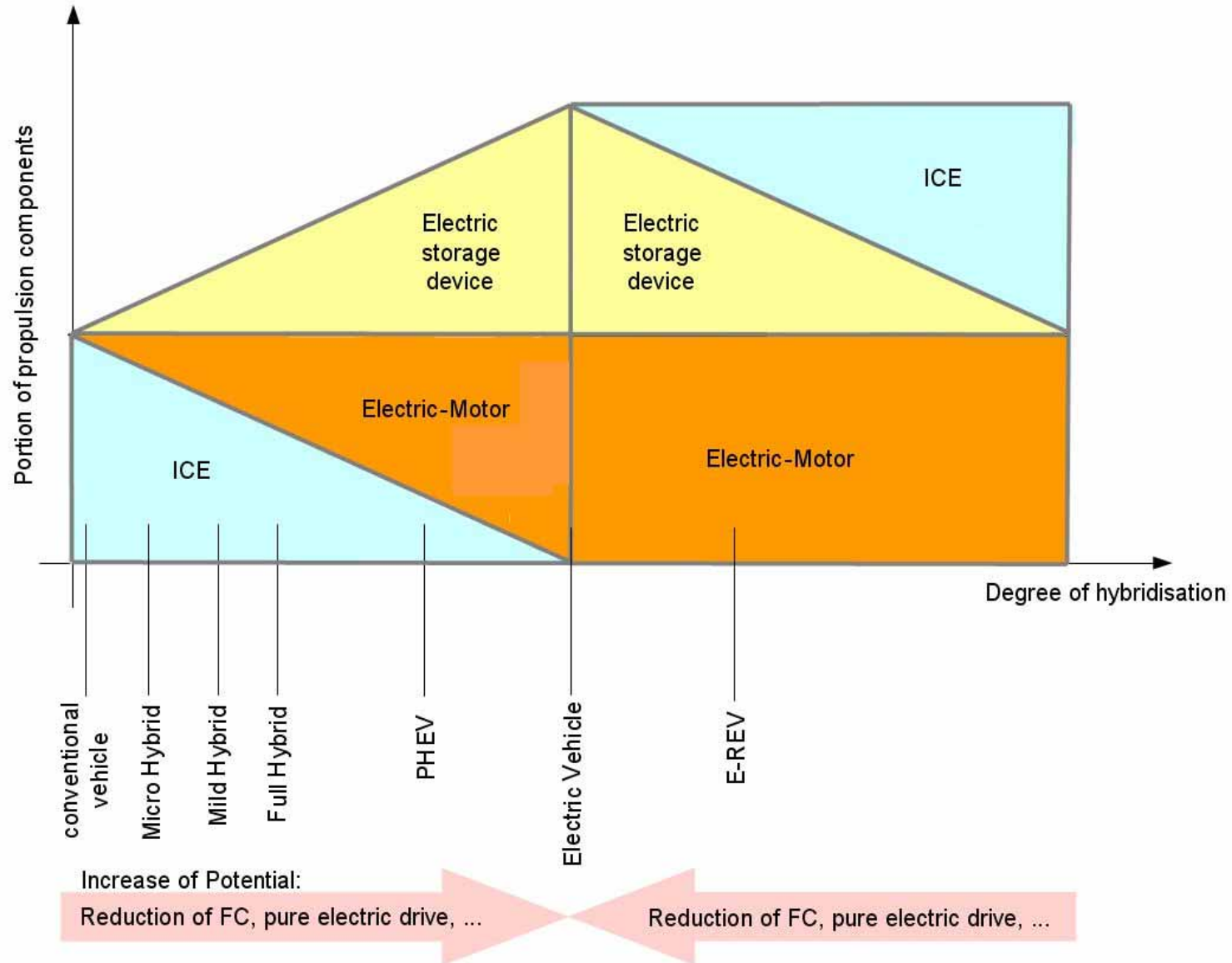
- Urbanization and mobilization
- Environmental Care
- Demographic Challenge

Motivation for Powertrain Electrification:

- Replacement of energy generated by an ICE by regenerative electric energy supplied by the electric network
- Maximising the recovery of braking energy during vehicle deceleration
- Reduction of power consumption of auxiliaries by strictly demand oriented operation
- Shifting of engine operation points towards map areas of best BSFC or lowest specific pollutant emissions
- Customer oriented new vehicle package concepts
- New vehicle functions (automatic parking, turning on the spot, ...)

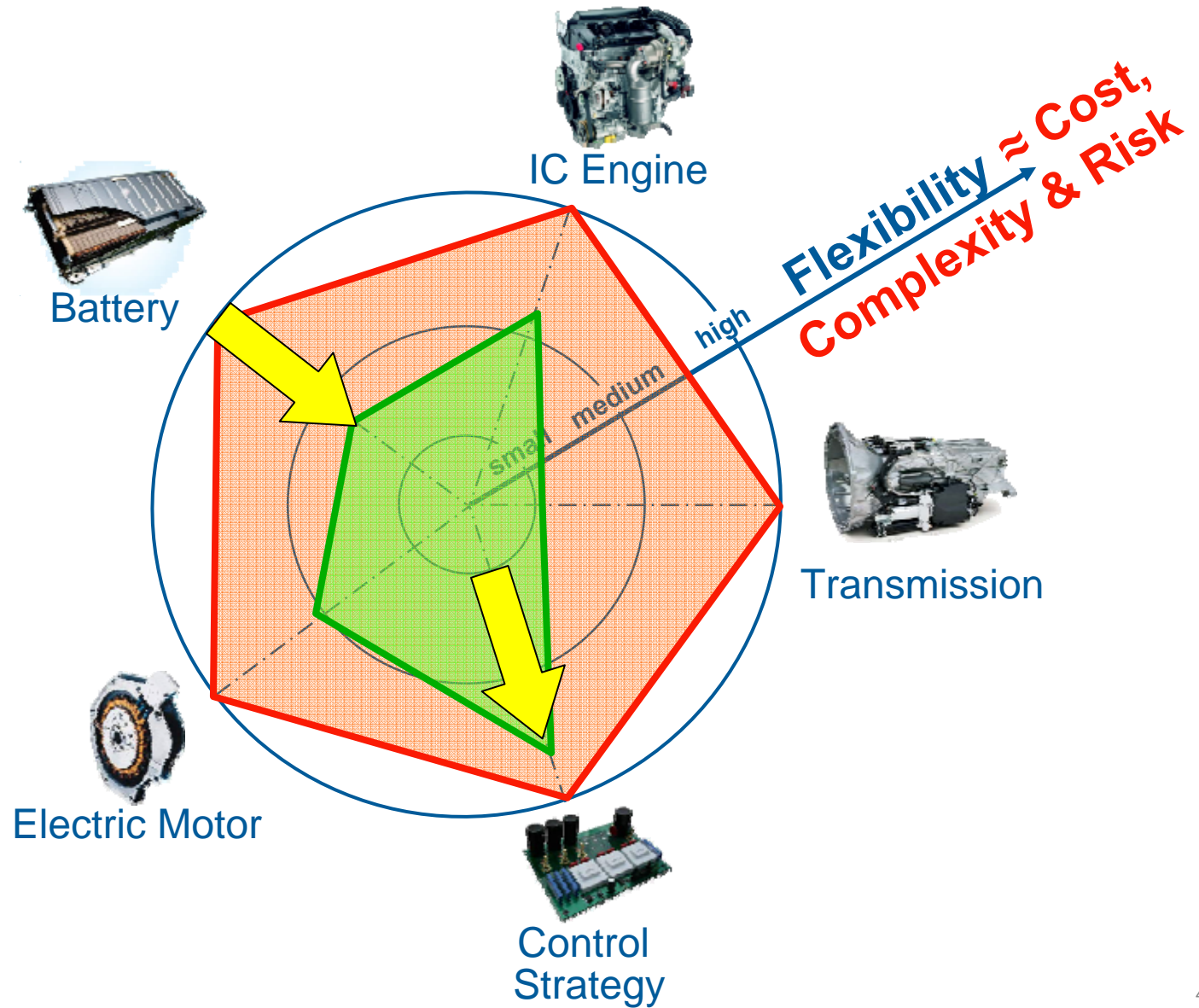
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Hybrid Types and Functionalities



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Base Elements of the Powertrain

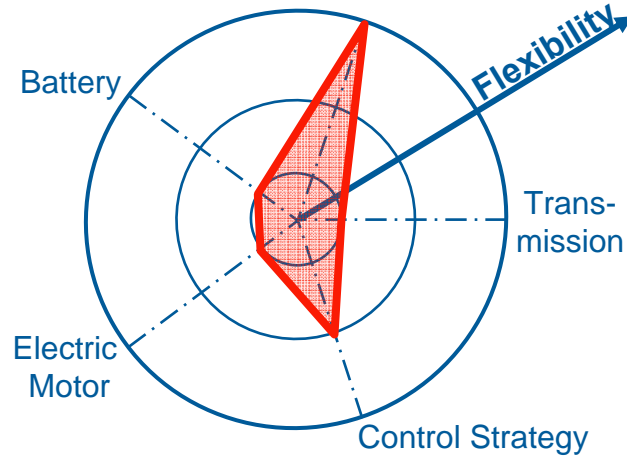


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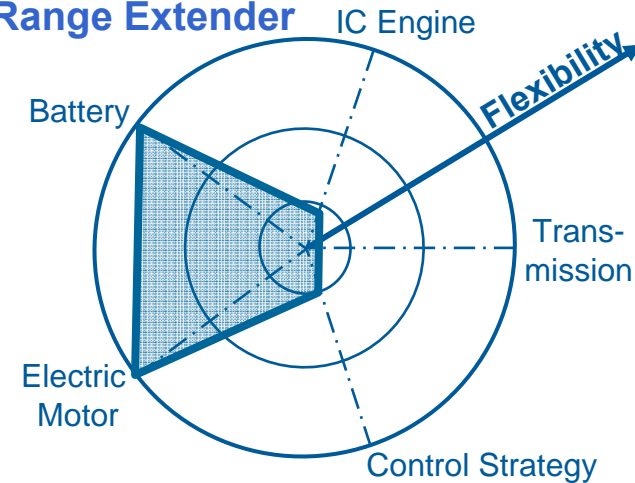
Base Elements of the Powertrain



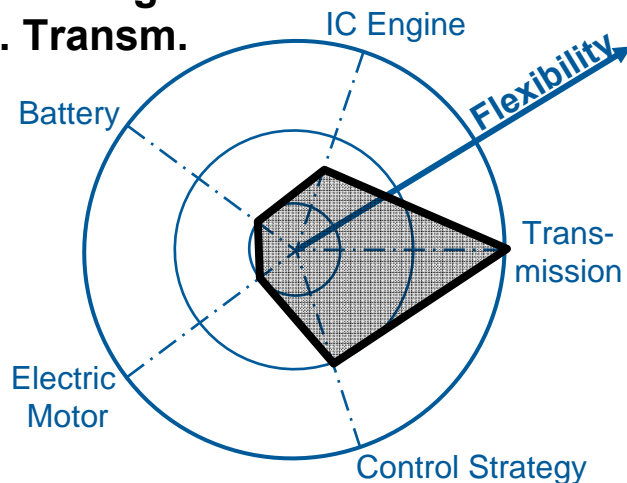
Fully Variable SI Engine + Man. Transmission



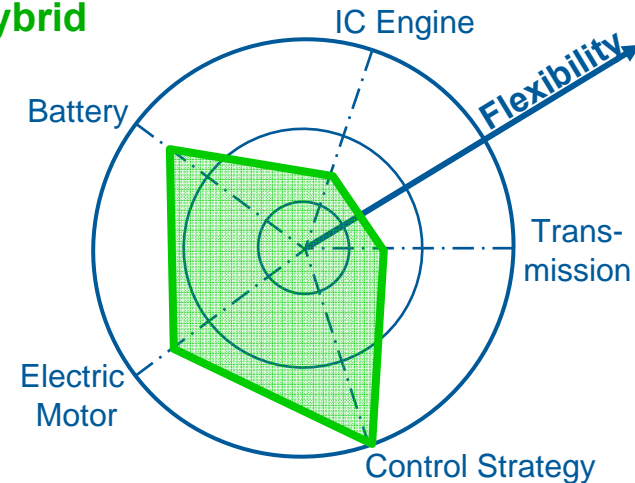
Electric Vehicle + Range Extender



Standard IC Engine + Autom. Transm.

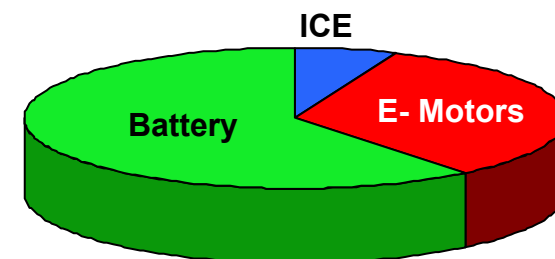
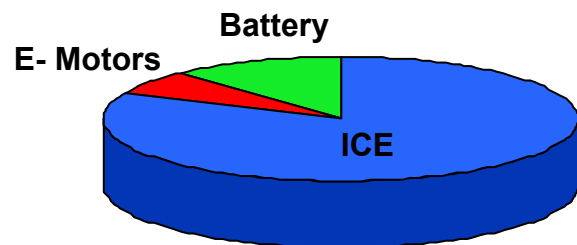
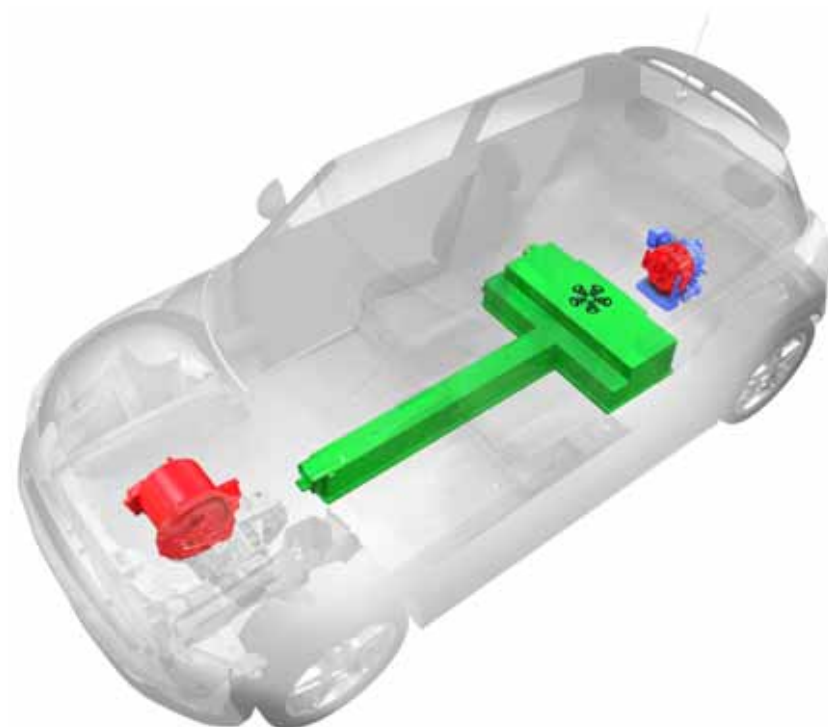
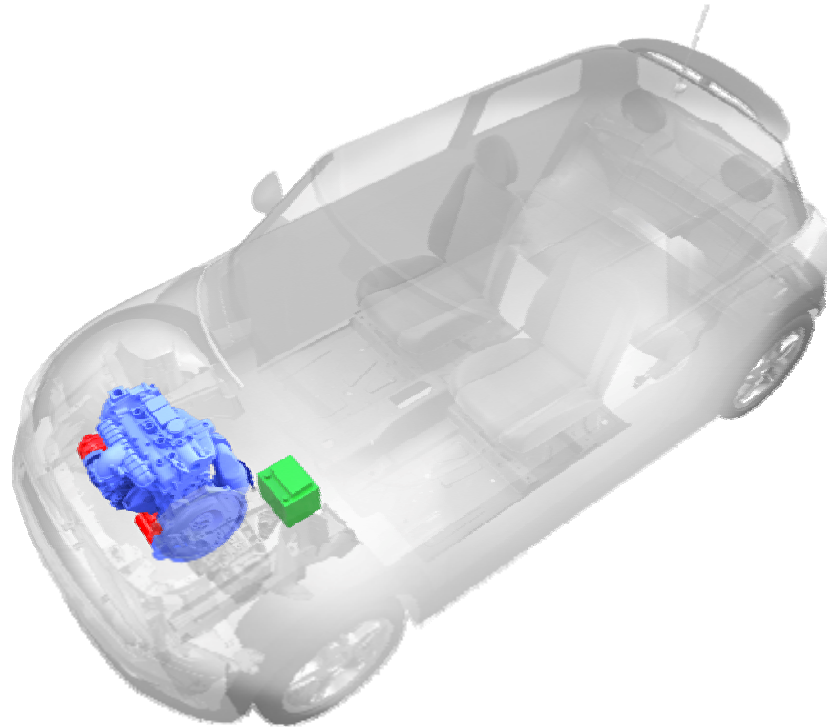


SI Powersplit Hybrid



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Base Elements of the Powertrain



- Battery
- Electric Motor
- Internal Combustion Engine



- Typically non linear optimization task
- Often there is no single optimum
- Optimization methodology, development, production, operation boundaries and recycling bias the technical solutions
- Changing cost structure of electric components will redirect the technical solutions
- Legal requirements might influence the size of energy storage units

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Demonstrator



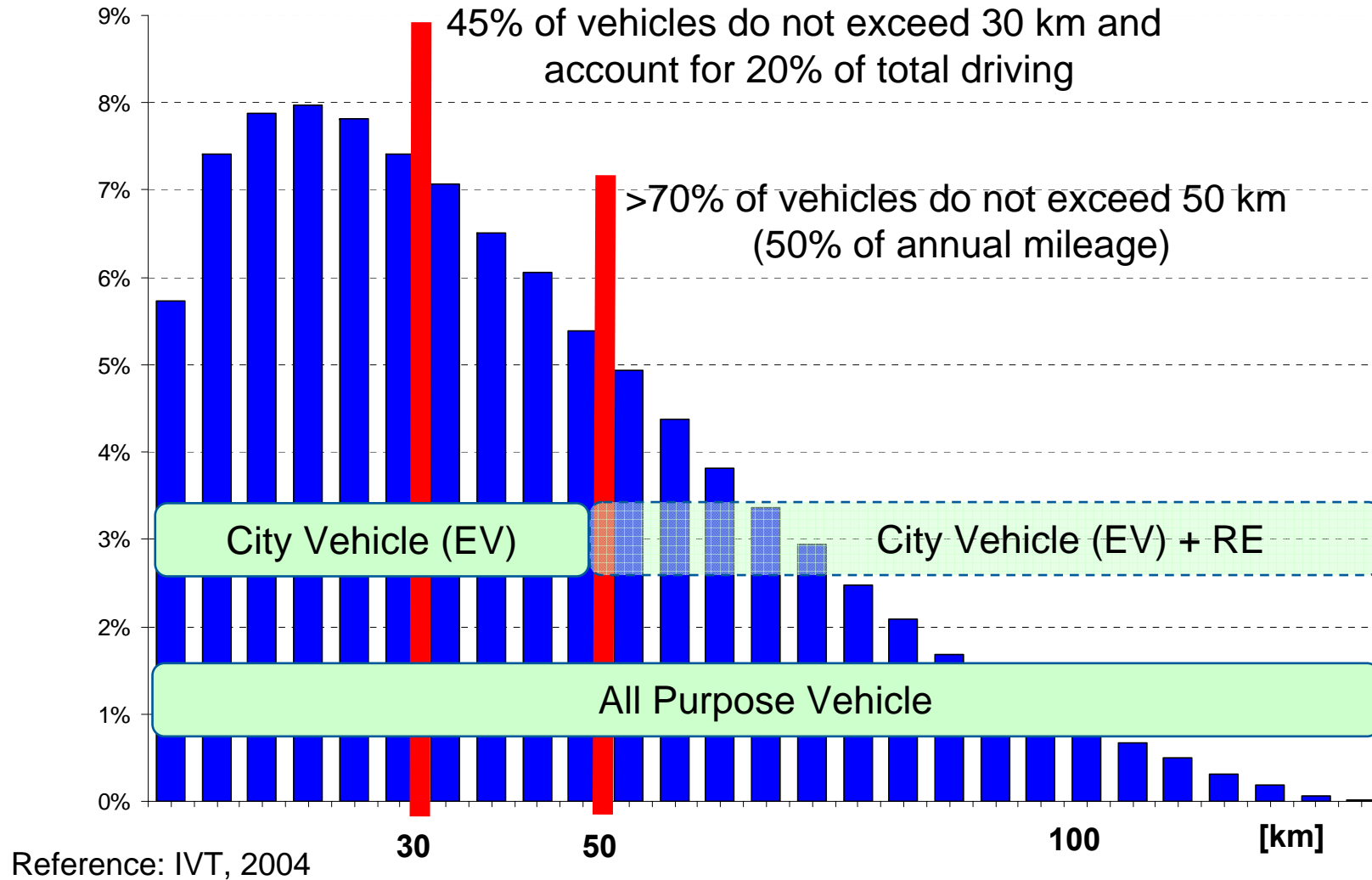
AVL electric vehicle

- Plug-in vehicle demonstrator designed for mega-city driving
 - AVL Range Extender System for at least 250km driving range
-
- ➔ No passenger compartment restrictions
 - ➔ Acceptable cost of energy storage system
 - ➔ Competitive driving performance
 - ➔ No performance restrictions with Range-Extender operation



AVL ELECTRIC VEHICLE

Distribution of Daily Driving Distances in Germany

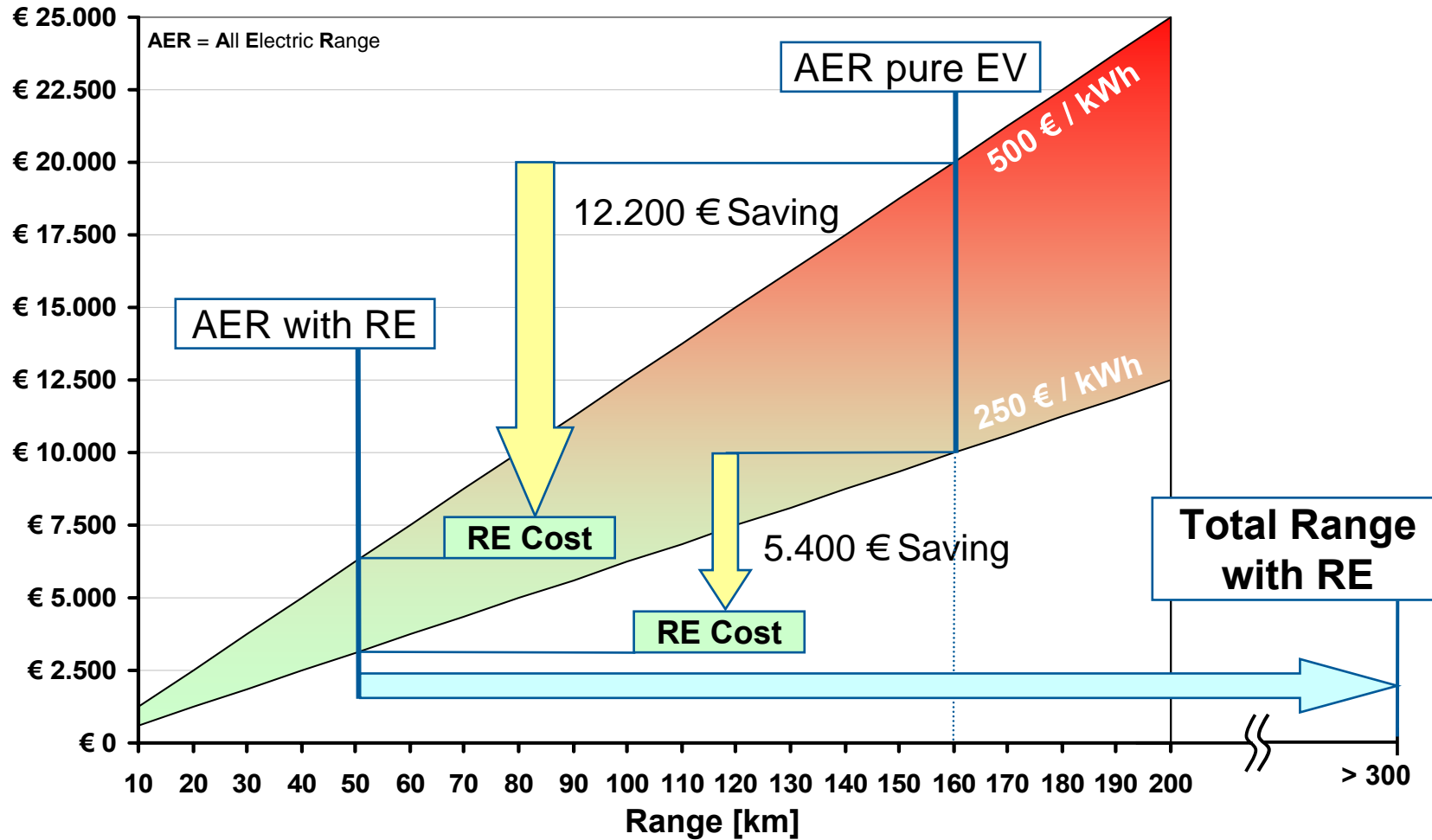


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Battery Cost Comparison

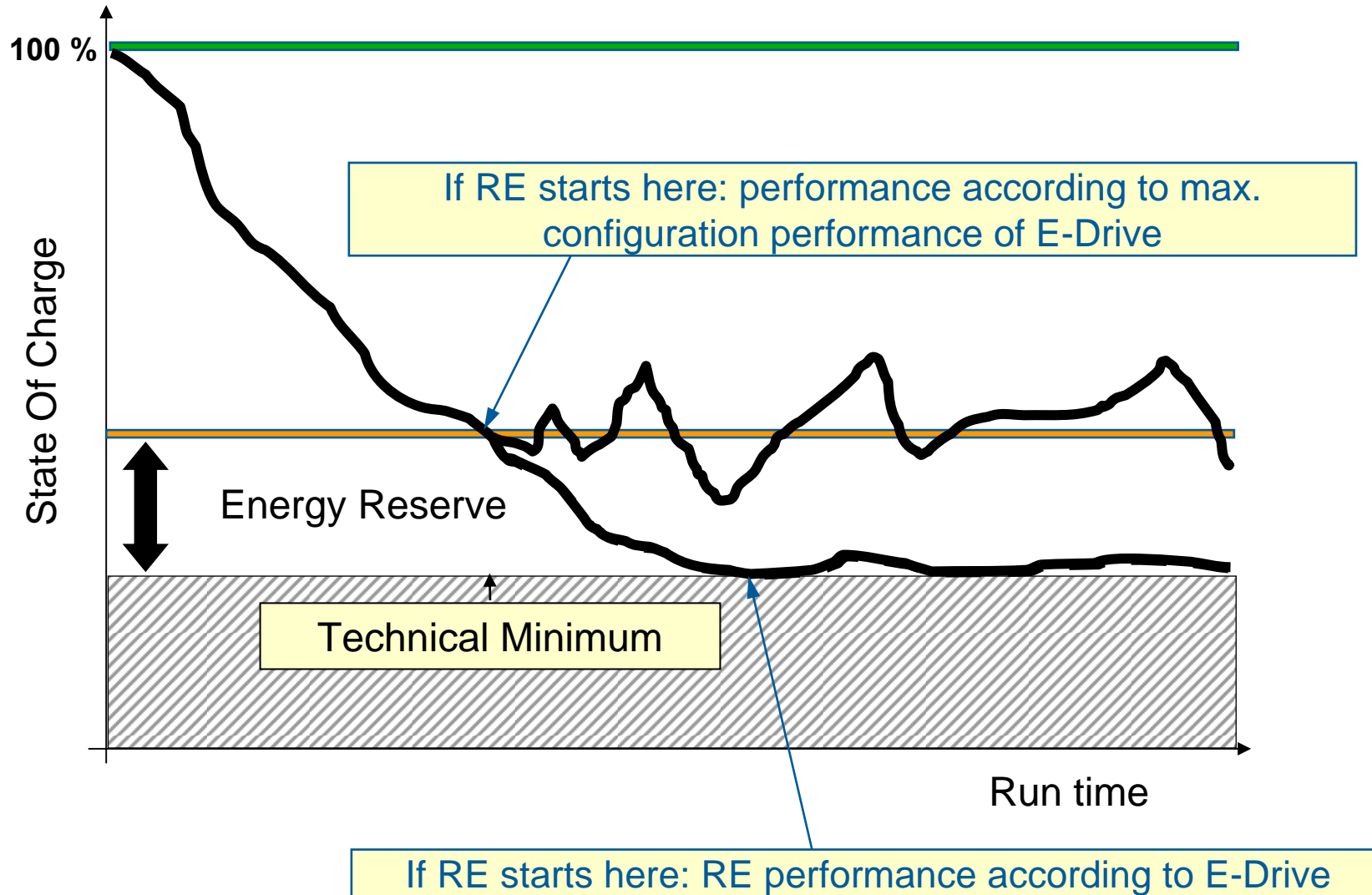


Battery Costs - based on energy consumption of 20 kWh / 100km



AVL PURE RANGE EXTENDER

Energy Reserve - Recharging Strategy



AVL PURE RANGE EXTENDER

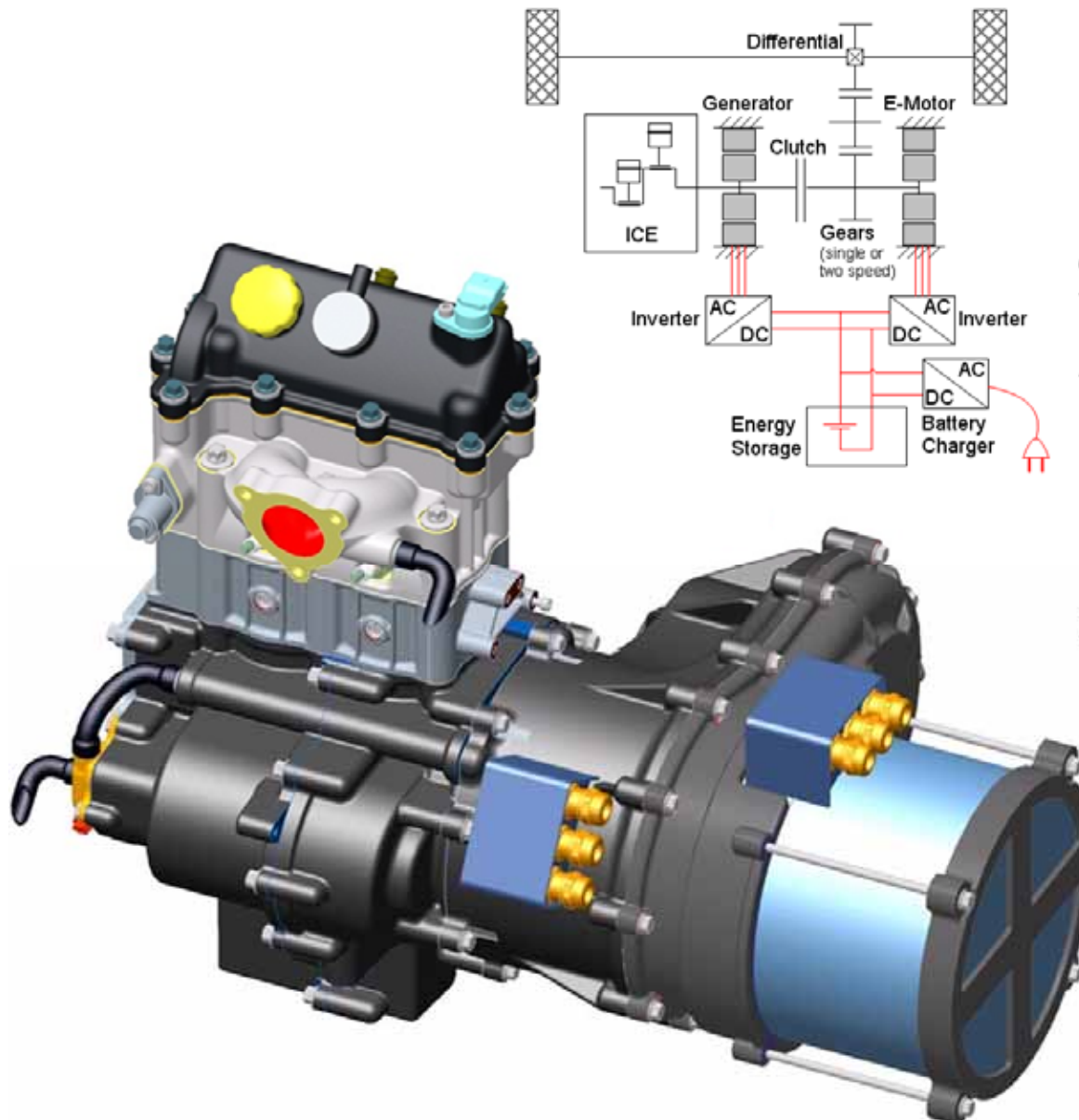
System Targets



1. NVH, Comfort
2. Reliability
3. Package and Weight
4. Costs
5. Performance / Efficiency

AVL ELECTRIC VEHICLE

Concept Study: Direct Drive



Key specifications:

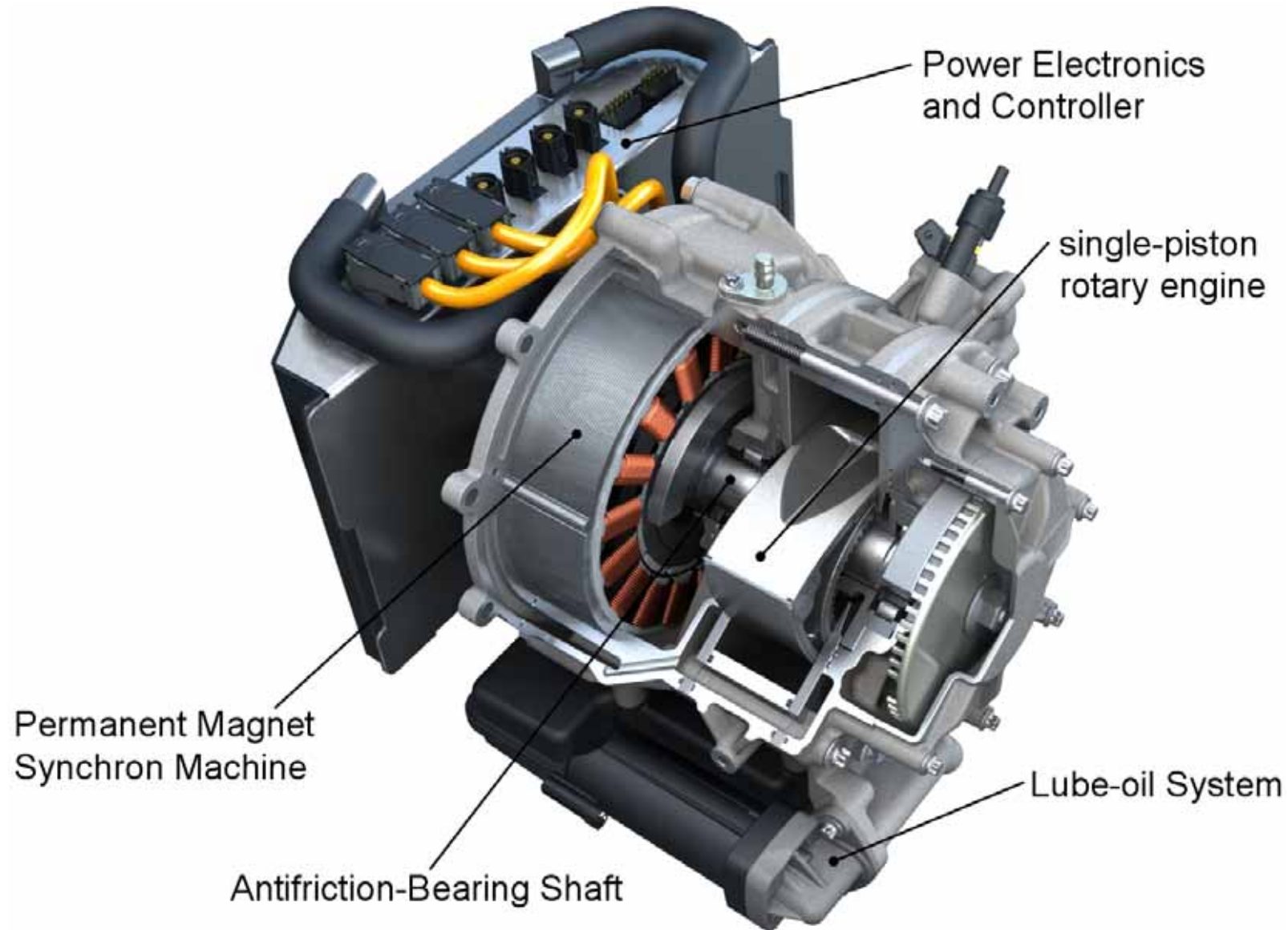
Engine config.: 2-cyl, 4-stroke MPI, NA
 Displacement: 570 cc
 Bore x Stroke: $\varnothing 70$ mm x 74 mm
 ICE Rated Power: 25 kW
 Engine speed range: 1000 – 6000 rpm
 Generator concept: PMSM, 15kW
 Traction E-Motor: PMSM, 60kW

Technical highlights:

NVH: 90° crankpin offset balancer shaft
 Friction: Roller bearings
 No lubrication pump
 2V valve train
 Low product cost: Two bearing crankshaft
 HPDC crankcase,
 direct acting valve train
 Integr. exhaust manifold

AVL PURE RANGE EXTENDER

Core Module with Rotary Engine



AVL PURE RANGE EXTENDER

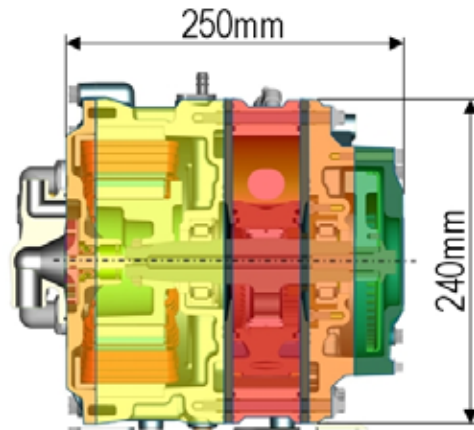
Key Specifications Rotary Engine



Engine configuration:	Single disk rotary engine
Displacement :	254 cc
Power:	18 kW @ 5000 rpm
Fuel consumption:	260 g/kWh
Generator concept:	Permanent magnet synchronous machine
Thermal management:	Single circuit liquid cooling
Controller:	AVL rapid prototyping control unit
Software:	Module embedded SW and CAN interface
Electric output:	15 kW @ 320 – 420 V (12 kW above 250 V)
Max. performance scaling potential:	up to 36 kW electric output (= 240%)
1m averaged sound pressure:	65 dBA
System box dimension (L x H x W):	490 mm x 400 mm x 980 mm
Engine – generator unit weight:	29 kg
Module weight:	65 kg

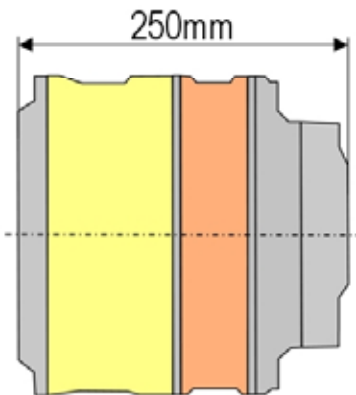
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Performance Scalability of Core Module



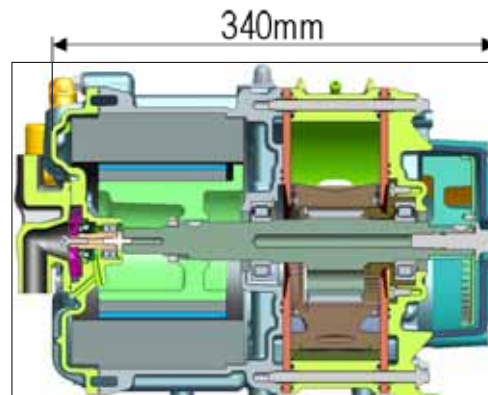
Base Design:
 Single piston rotary engine
 Rotor width 50mm
 Speed 5000min⁻¹
 MEP 8.4bar
 → Electric output 15kW

Variant 1



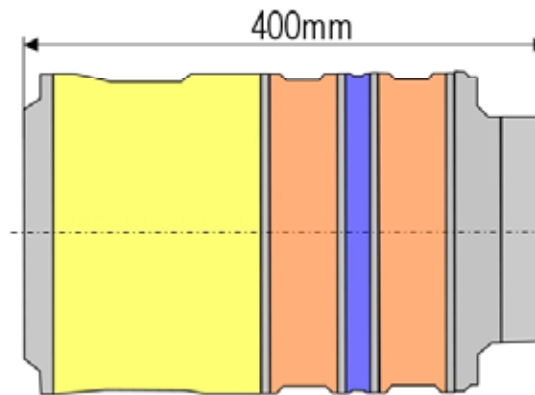
Single piston rotary engine
 Rotor width 50mm
 Speed 7000min⁻¹
 MEP 10.5bar
 → Electric output 25kW

Variant 2



Single piston rotary engine
 Rotor width 70mm
 Speed 7000min⁻¹
 MEP 10.5bar
 → Electric output 36kW

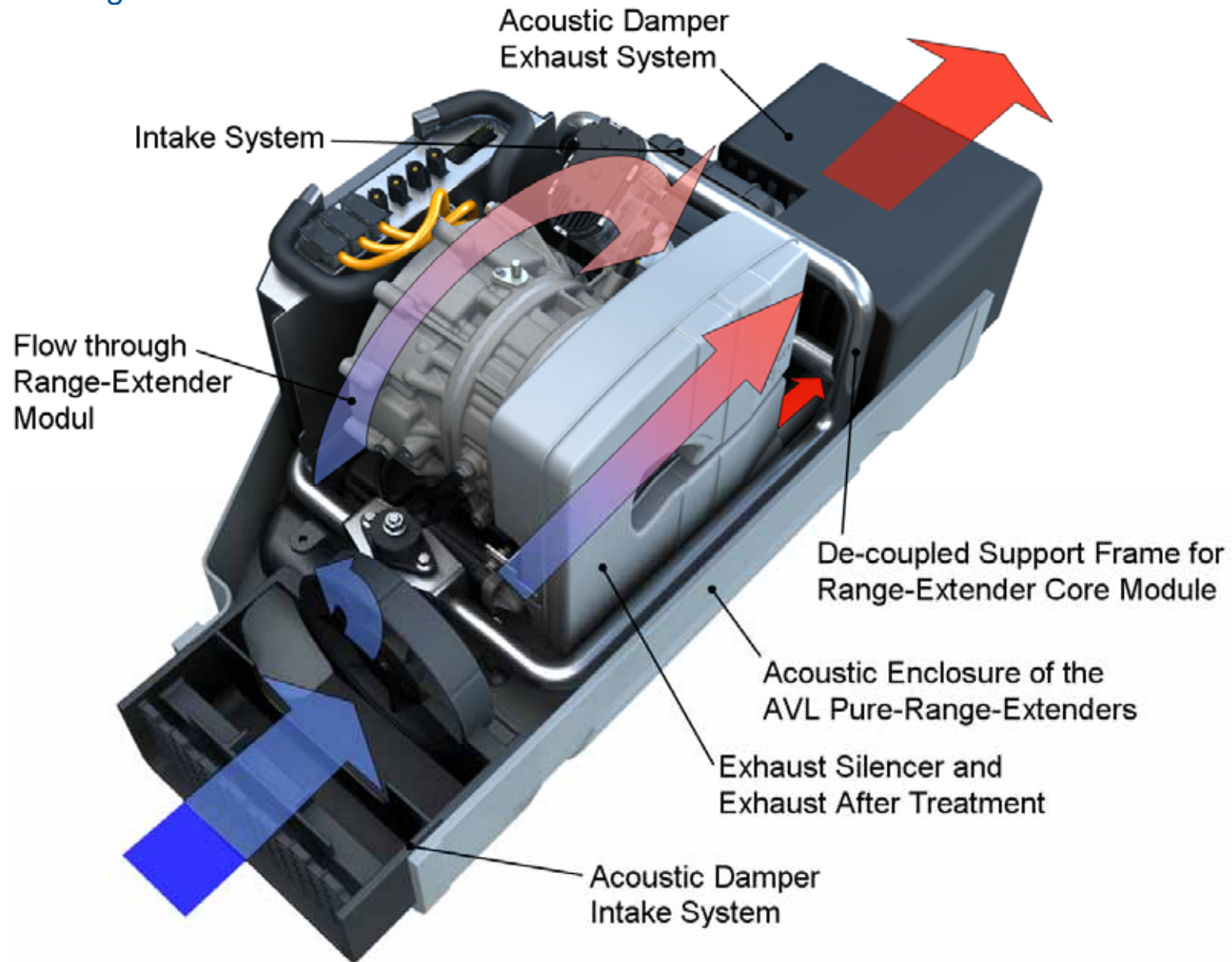
Variant 3



Double piston rotary engine
 Rotor width 50mm
 Speed 7000min⁻¹
 MEP 10.5bar
 → Electric output 50kW

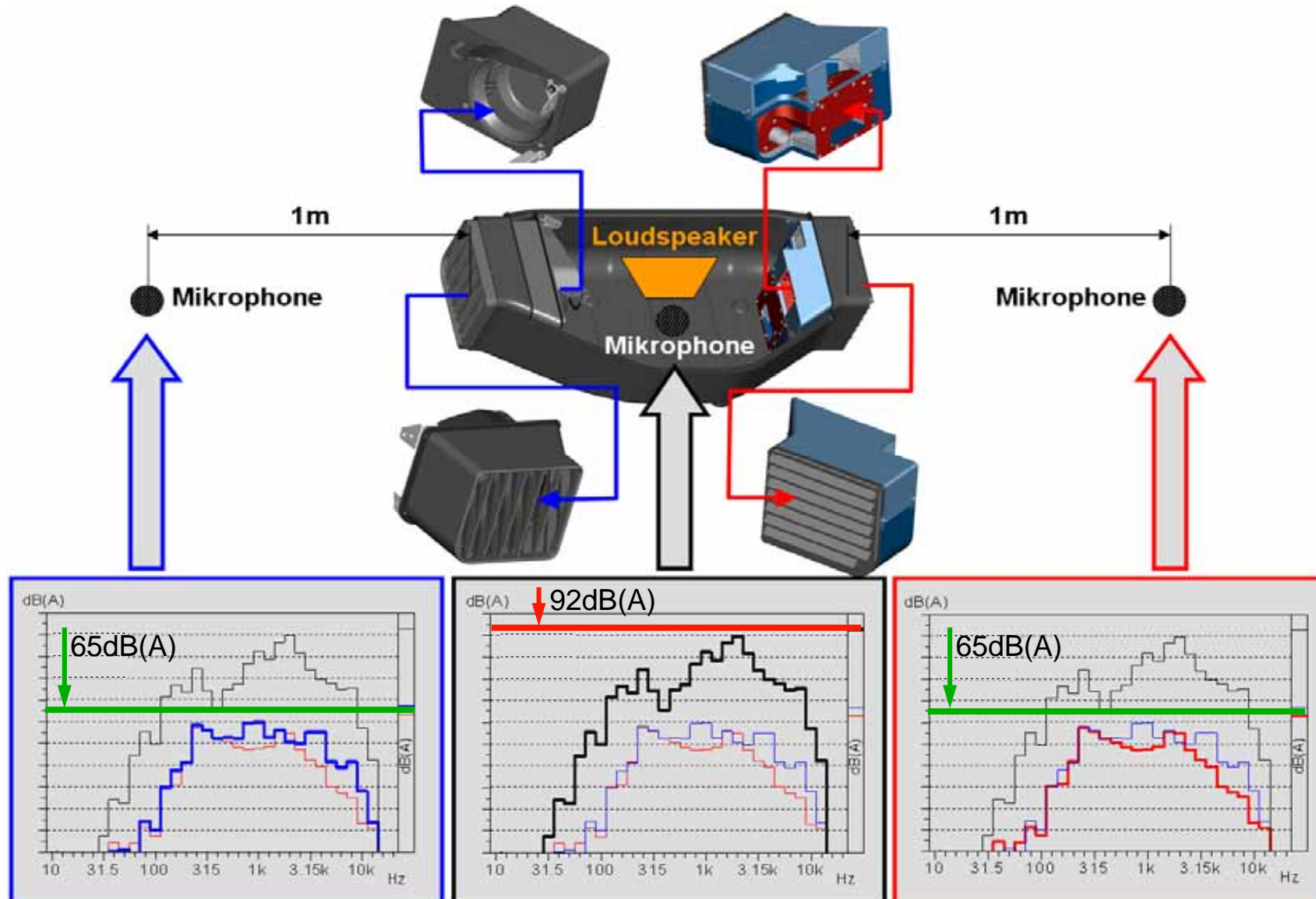
AVL PURE RANGE EXTENDER

System Integration



AVL PURE RANGE EXTENDER

Acoustic Optimization

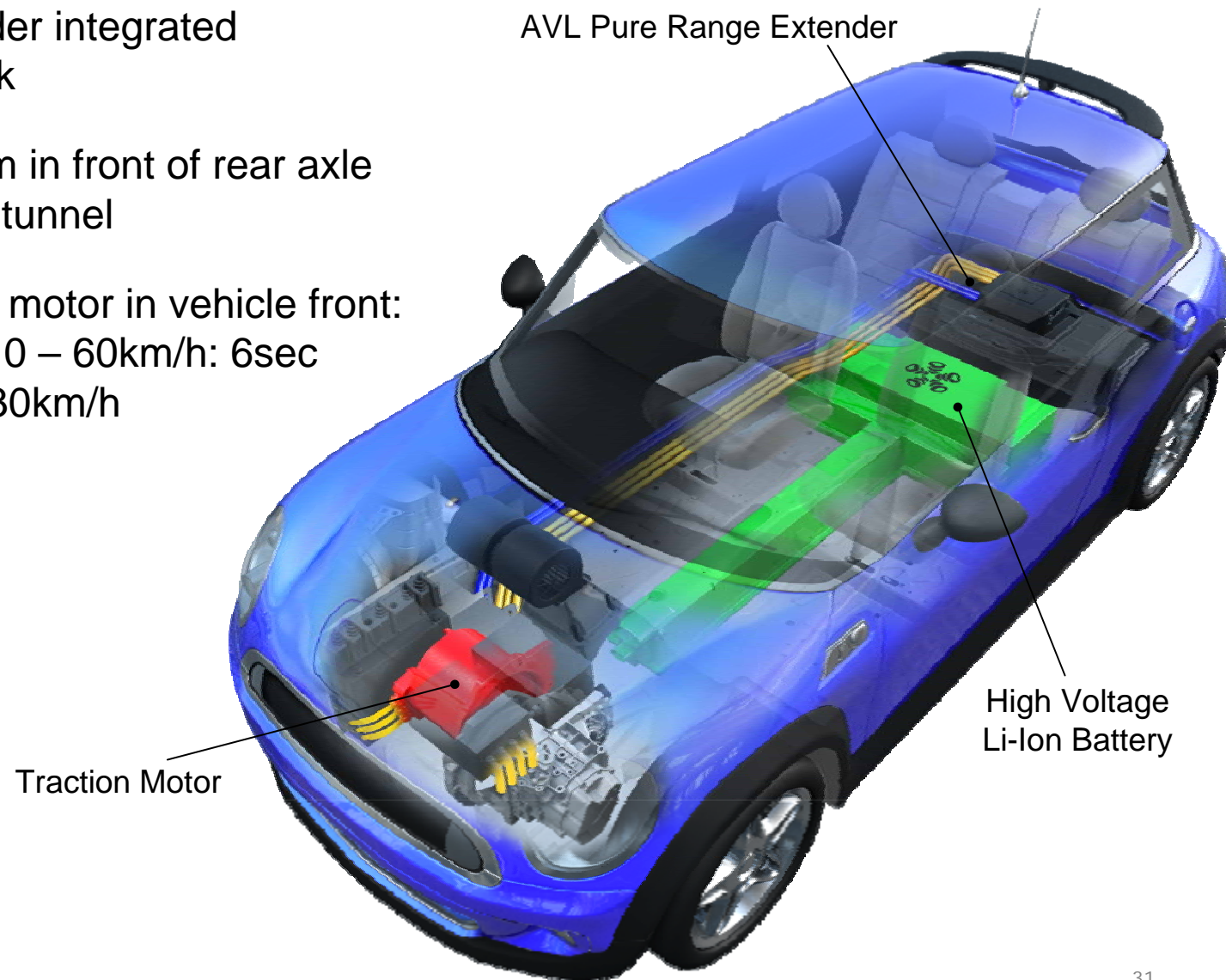


AVL PURE RANGE EXTENDER

Vehicle Integration



- Range Extender integrated in vehicle back
- Battery system in front of rear axle and in middle tunnel
- 75kW traction motor in vehicle front:
 - acceleration 0 – 60km/h: 6sec
 - top speed 130km/h

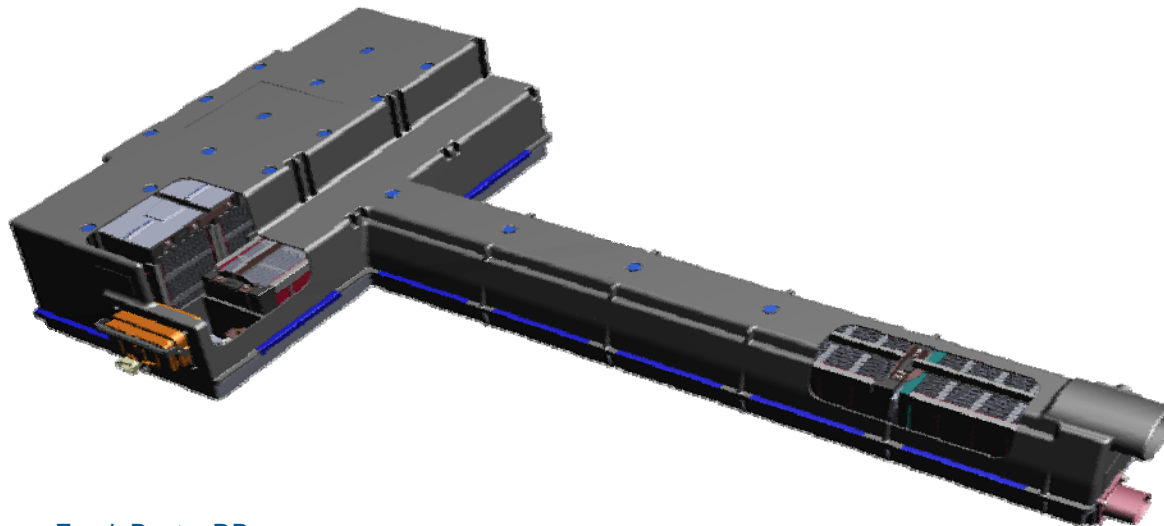


AVL BATTERY DEVELOPMENT

Development Content

Optimized, reliable and fully integrated battery system development to maximize vehicle fuel economy potential:

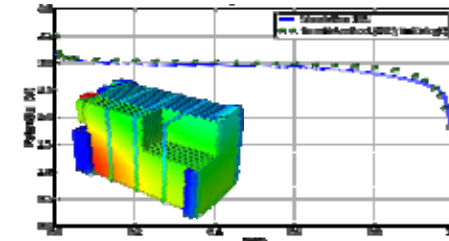
- Requirement development
- Design and integration of battery system
- Function and software development
- Robustness and safety
- Testing and validation
- Battery benchmarking



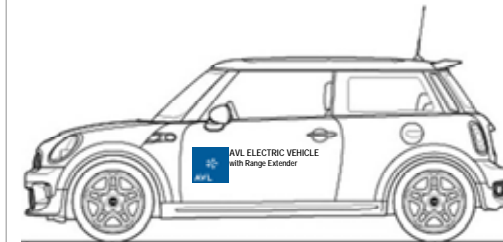
Frank Beste, DB



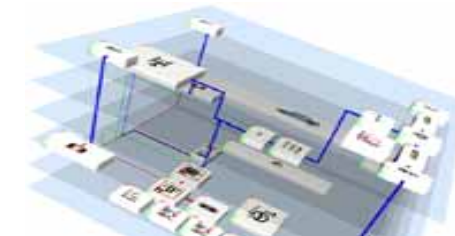
BATTERY DESIGN AND SIMULATION



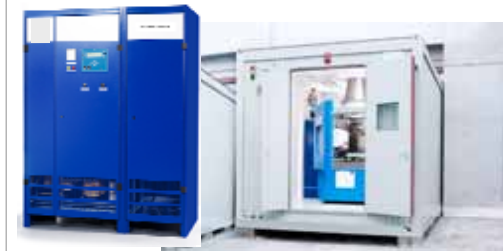
BATTERY INTEGRATION



BATTERY FUNCTION AND SOFTWARE



BATTERY TESTING AND VALIDATION

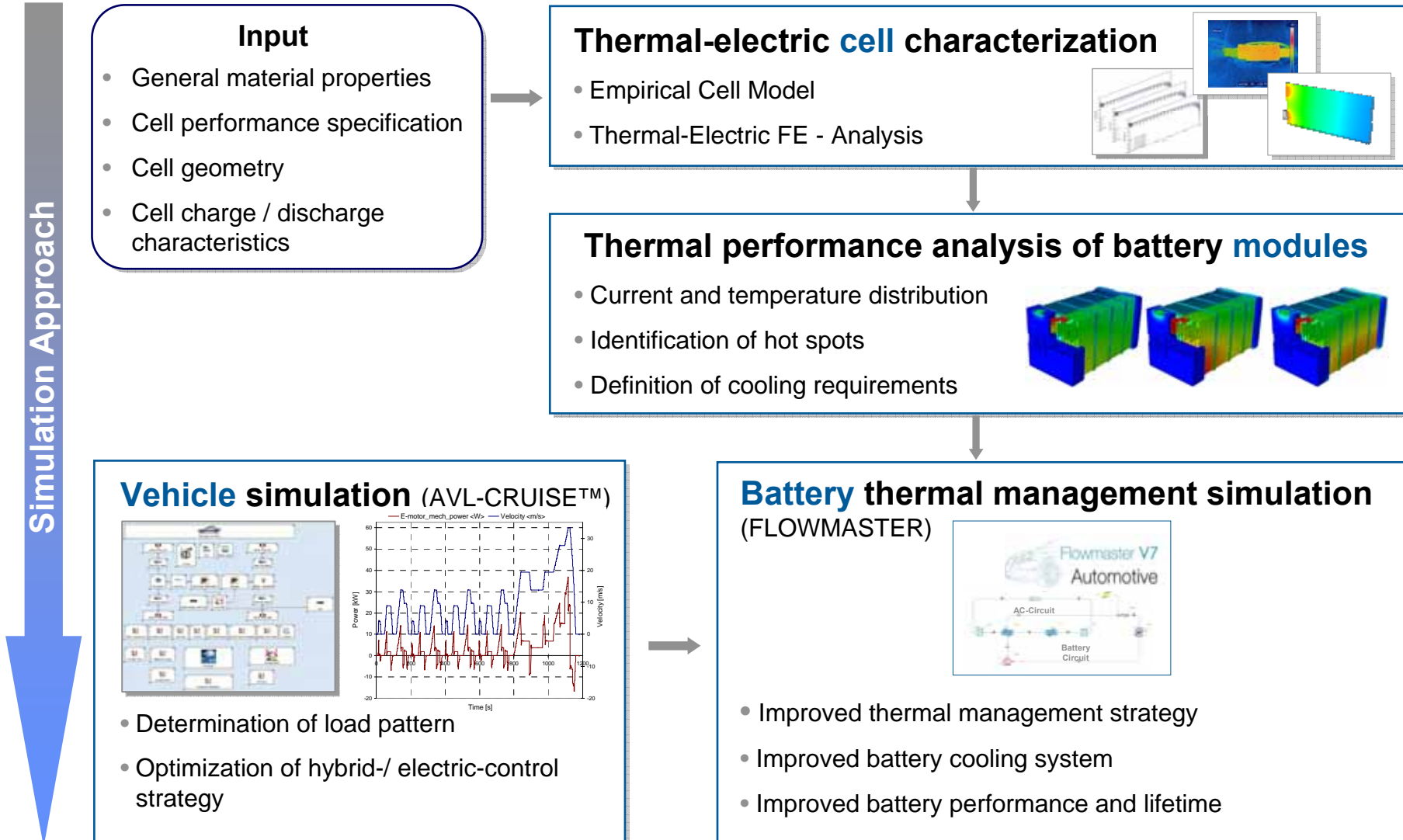


AVL REQUIREMENT ENGINEERING & SIMULATION

From Cell-Level to Battery-Pack



Simulation → A key discipline within the requirement engineering process ...





AVL ELECTRIC VEHICLE WITH RANGE EXTENDER



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