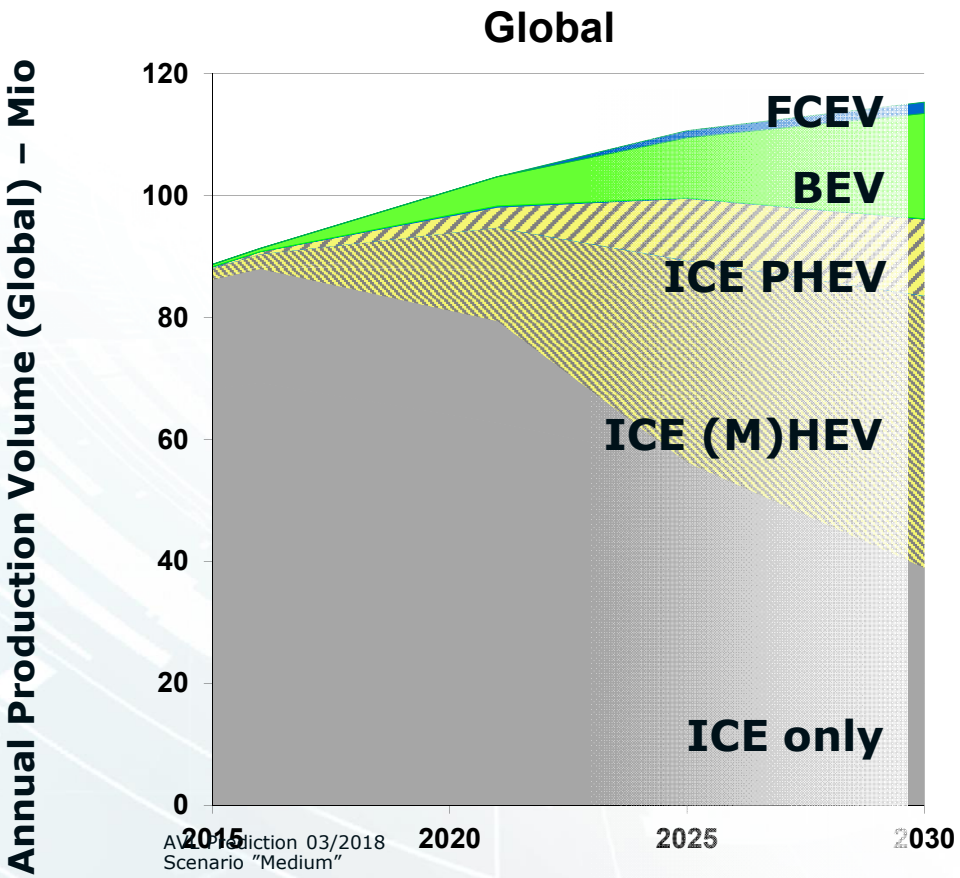
AVL Japan K.K.

Electrification of Passenger Vehicles

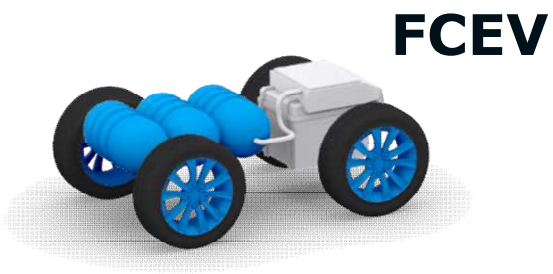
The 48 V Solution

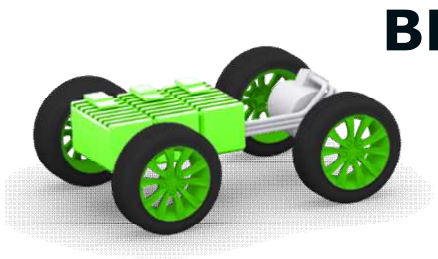
Michael Kozan

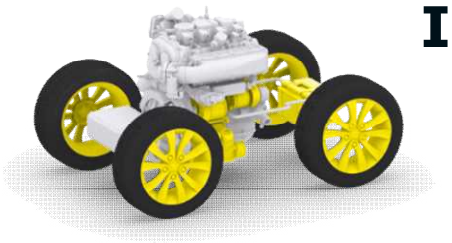
Global Technology Shares – One Potential Scenario



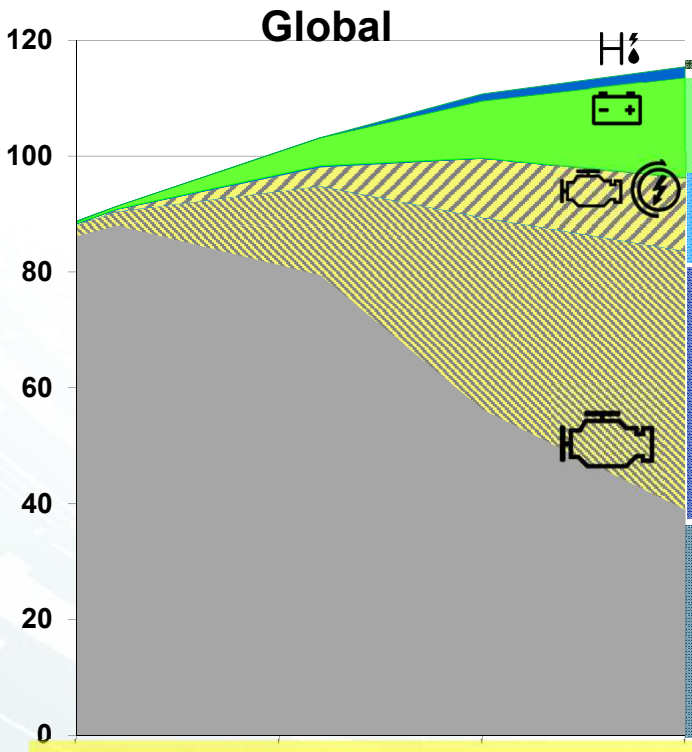
AVL Prediction 03/2018
Scenario "Medium"







POWERTRAIN TECHNOLOGIES 2025



Fuel Cell: limited to specific markets

2025

BEV: Dependent on infrastructure, incentives and access restr.

Full Hybrid: Primarily with Japanese OEM´s

Mild Hybrid:
- 48 V in various configurations P0 – P4
- Power Increase 15 → 20 → 30 kW
- ICE utilizes synergies

Conventional ICE:
- Significantly higher effort for emission compliance (RDE, China6, SULEV xx, ...),
- "Zero Impact Emission Concepts"

2025 → 50% electrified - still 100 mio ICE´s - high scatter of predictions

Solution Trend

today

Miller, Atkinson

tomorrow

VCR, HCCI, UHP, ...

Extended Miller, Advanced Boosting

48V

Spark Ignited

Extended 48V systems (20→30 kW) as enabler for low emission & CO_2

HCCI.. Homogeneous Charge Compression Ignition VCR Variable Compression Ratio, UHP .Ultra High Injection Pressure

Mild Hybrid as enabler for next refinement level of ICE

Solution Trend

today

Lean NOx Trap + SCR

tomorrow

Advanced EAS & Temperature Management, Refined Operation Strategies

Compression Ignited (Diesel)

48V

Extended 48V systems (20→30 kW) as enabler for low emission & CO_2

Mild Hybrid as enabler for next refinement level of ICE

AVL 48V Mild Hybrid Solutions
Roadmap - 3 Generations of functionalities

Add On Solutions

Functionality:

- ❑ Low-End Torque Fill
- ❑ Boost
- ❑ Recuperation (combustion engine off)
- ❑ Extended Coasting
- ❑ Engine Start (Low Temp tbc.)
- ❑ Generating while standstill
- ❑ AC - Conditioning while engine off
- ❑ Advanced Emission Management

Dedicated Propulsion

Functionality:

- ❑ Recuperation (combustion engine decoupled)
- ❑ Extended Coasting (Engine decoupled)
- ❑ e-Drive (incl. Launch and Creep; e.g. 30 kph)
- ❑ Autonomous parking (electrical)
- ❑ Engine Start (Low Temp tbc.)

Full Scale EE Ancillaries

Functionality:

- ❑ Heating
- ❑ Braking
- ❑ Steering
- ❑ E-Closure
- ❑ …

Roadmap today 2020 2025

Solution Overview 48V (M)HEV

Add On Solutions
Benefit 6 – 12%

P0 + eSC

Belt **electric Supercharger**

Modular & Dedicated
Benefit 12 – 20%

P0 + P4 **P2**

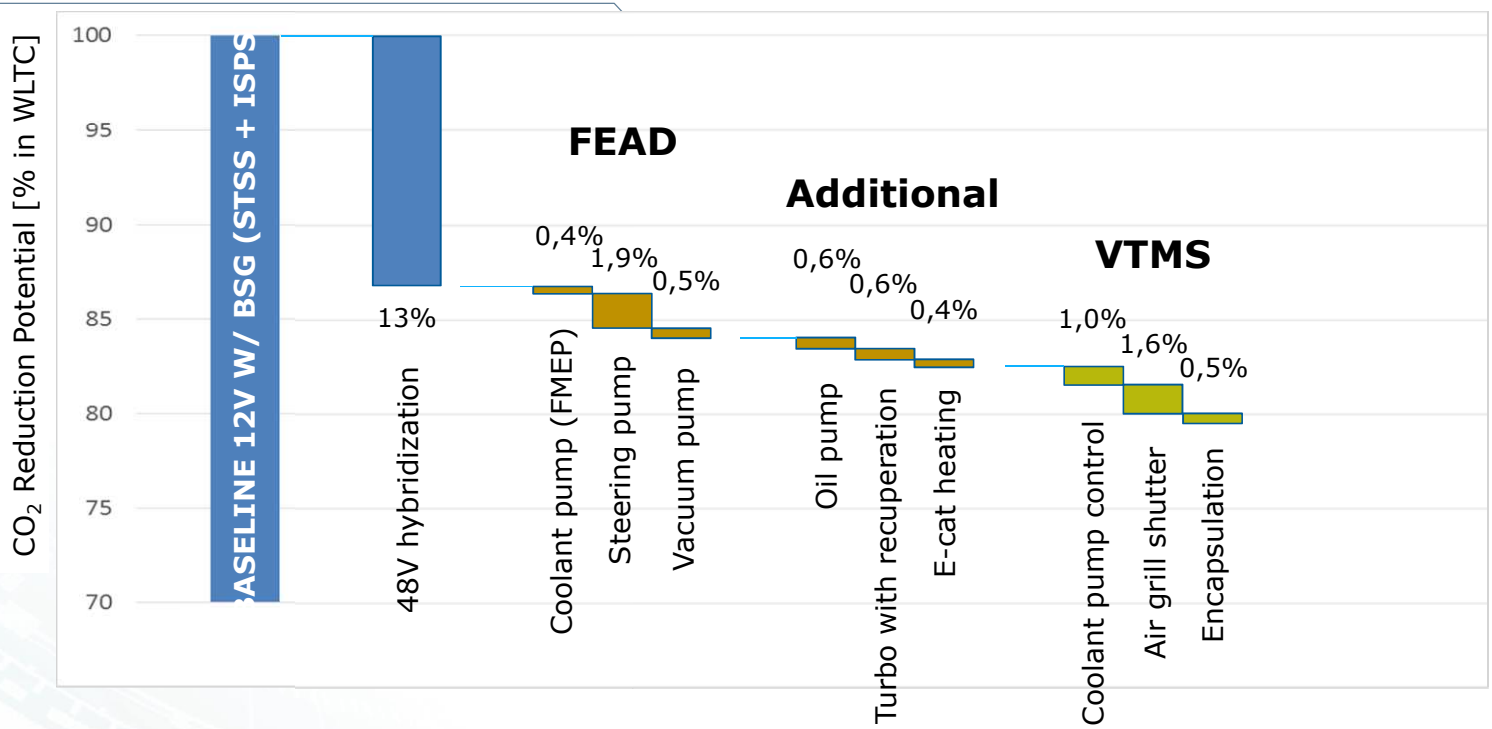
Belt **eAxle** **Parallel Module**

Vehicle Level Auxiliaries

Benefit 3-4%

Roadmap 2017 2020 2025

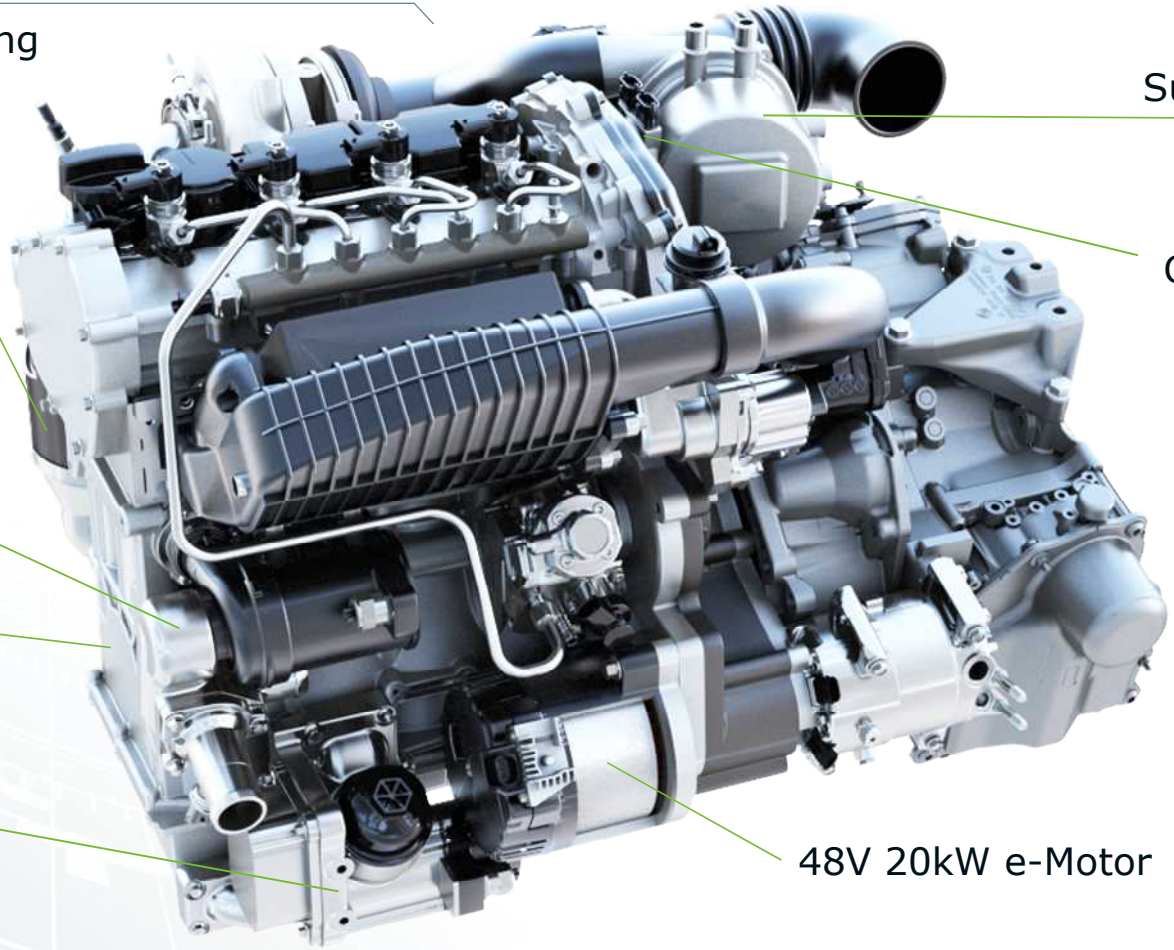
48V P2 Gasoline Vehicle
CO2 reduction potential in WLTC example



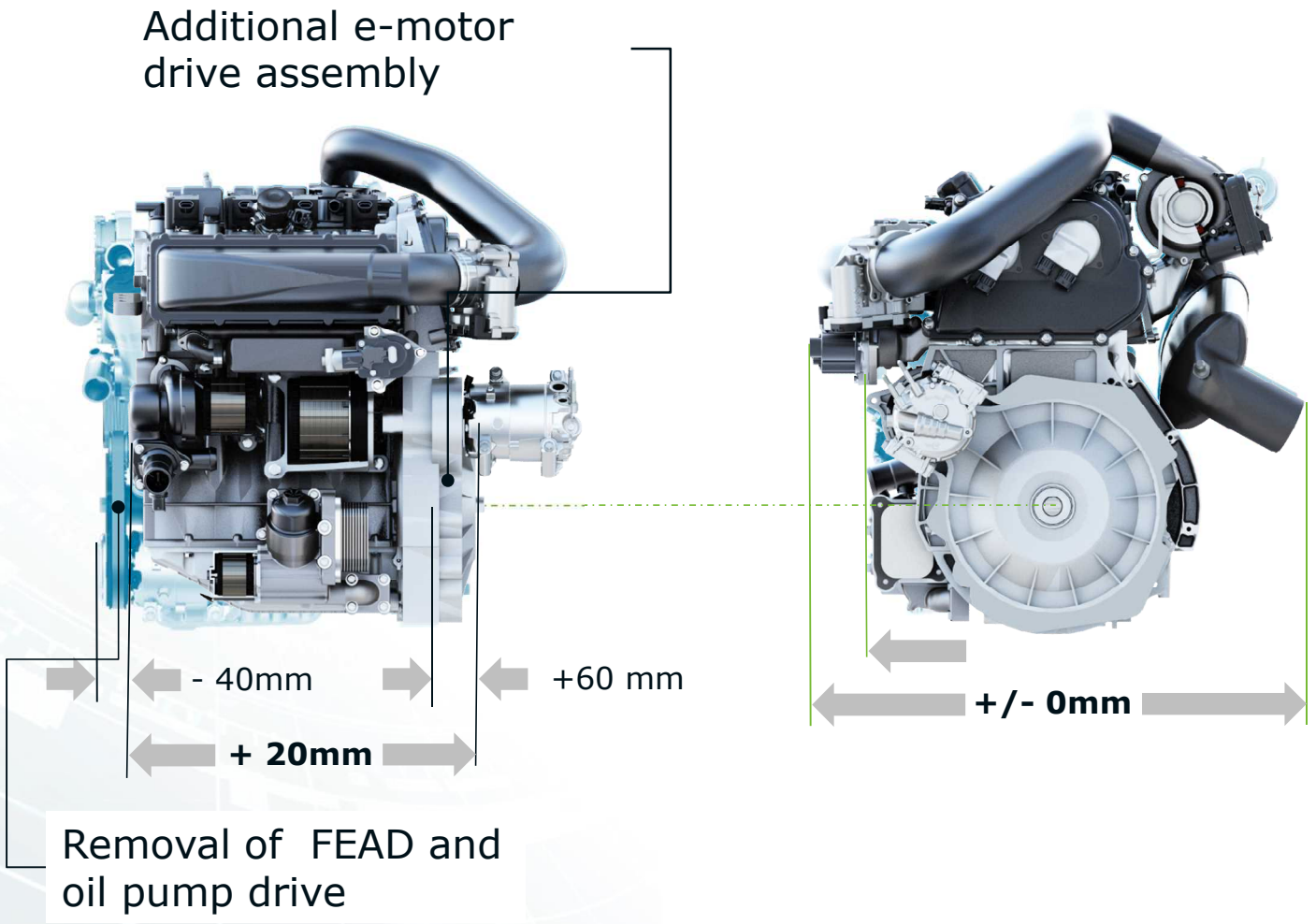
13% CO_2 potential reduction by means of 48V hybridization

- **Further 4,4% CO_2 potential reduction by means of additional base engine measures**
- **Overall WLTC CO_2 reduction up to 20,5%**

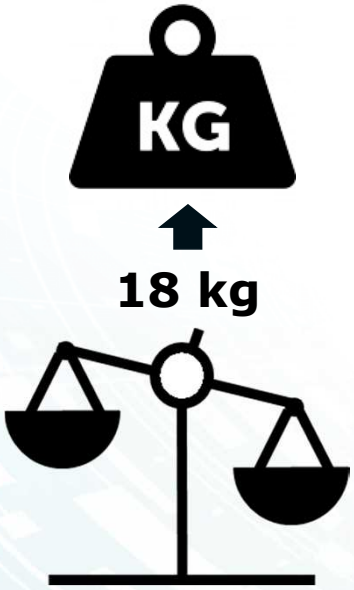
Electrification of the ICE
Features & Options

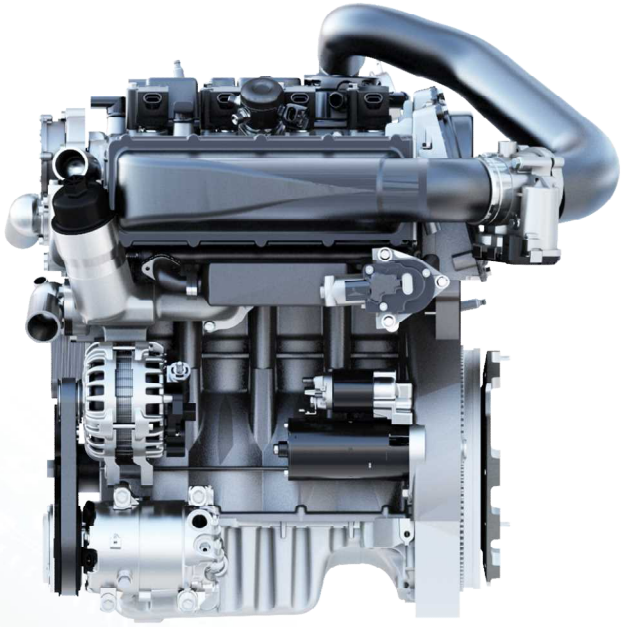


The ideal base engine for 48 Volts Package Envelope

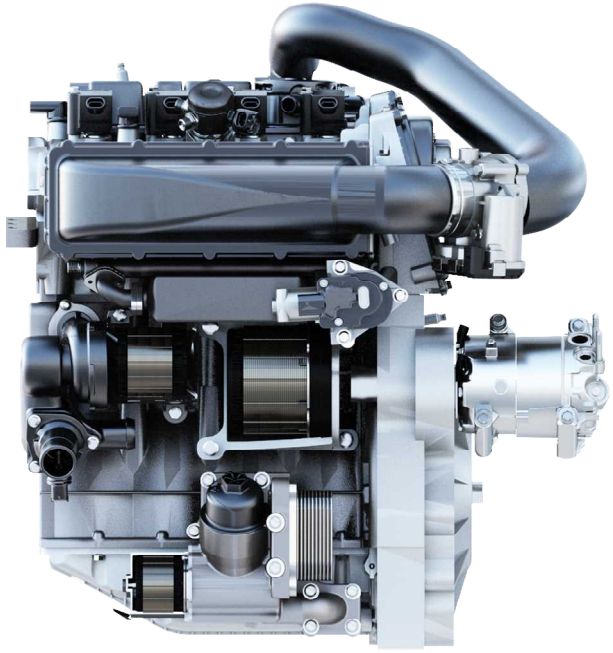


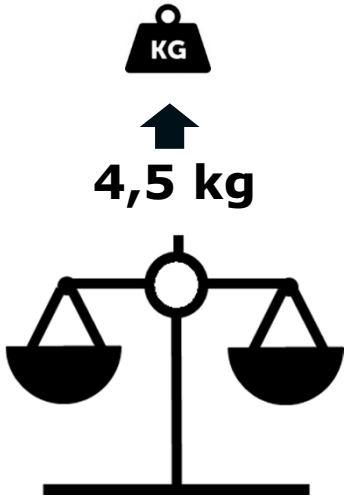
Ideal base engine for 48v
Minimised overall weight increase





Production engine
&
48V electrification





Electrified base engine
&
48V electrification

Integrated solutions will have a mass benefit

Electrification of the ICE Integration

Electrification of the ICE Integration

Fits to current vehicle tooling without major redesign of sheet metal

48V Solutions in the market

http://www.greencarcongress.com/2016/10/20161030-benz.html

Modular

The BSA fuel-saving hybrid functions:

- 48V Water Pump
- Easy start
- Boost up to 2500 rpm
- Energy recovery up to 12.5 kW
- Shifting of the load point
- Coasting with engine off
- extended stop/start with intelligent engine shutoff even at low speeds

Integrated

The six-cylinder gasoline engine M 256 features:

- 48 V electrical system.
- Electric auxiliary compressor (eZV) (300ms 0 to 70.000rpm),
- Integrated Starter-Alternator (ISG) provide excellent drivability with no turbo lag.
- Boost (15 kW)
- Almost imperceptible restart of the engine

Electrification Technologies Passenger Cars Hybrids

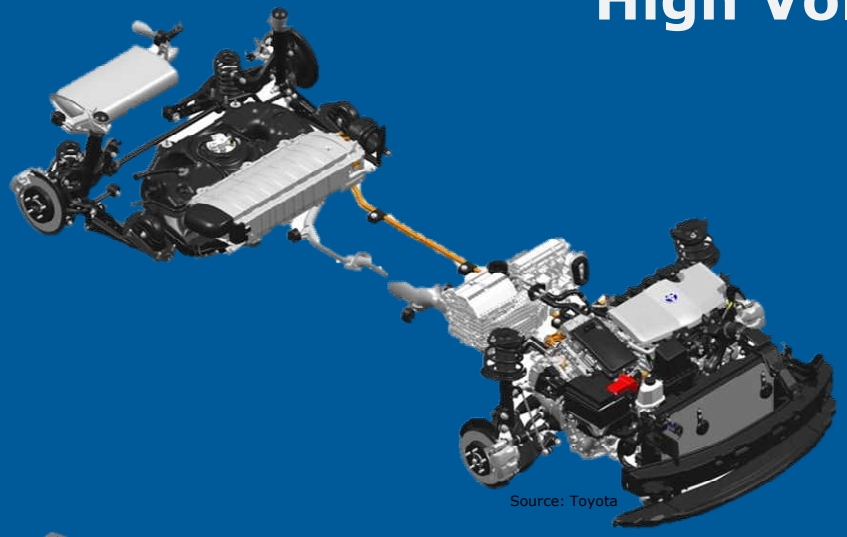
Large

Medium

Small

Vehicle Size

High Voltage Hybrids



Source: Toyota

Advantages:
- Re-Use of & Transition to BEV

Customer Value:
- Limited / regional advantage

Price

Entry

Luxury

Electrification Technologies Passenger Cars 48V

Large

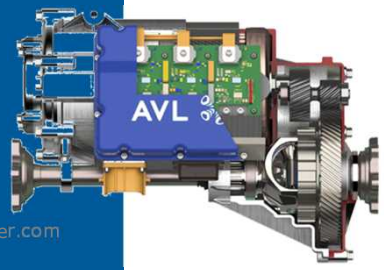
Medium

Small

Vehicle Size

12V/12V

Source: www.schaeffler.com



Advantages:
- Similar fuel consumption as HV
- Lower cost than HV

Customer Value:
- Inner city electric driving
- limited (!) e-Drive

Challenges:
- Upgradability of power

48V P2 / P4

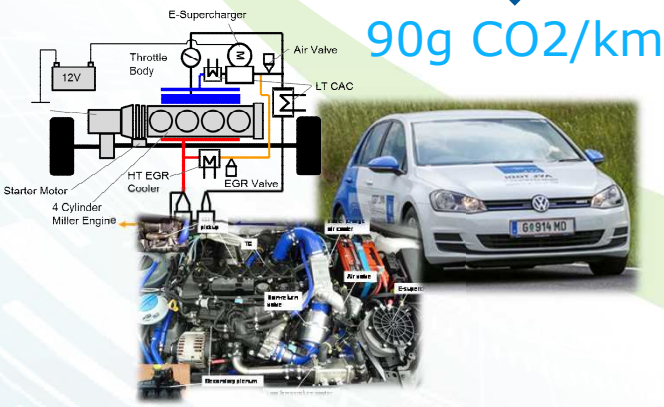
Price: Entry | Medium | Luxury

Making a Difference in the World
Secure City Access for Tomorrow

123g CO2/km

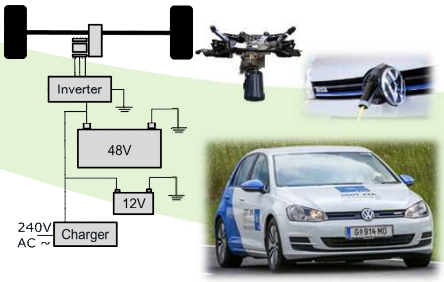
Highest Efficiency
Based using ICE
Technology

90g CO2/km



E-Axle 20kW,
PlugIn 3,3kW

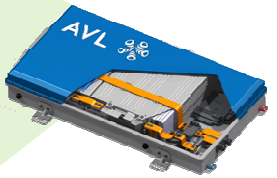
75g CO2/km



Electric Axle 30kW
Electric Range
15 – XX km
E-Speed 65kph

<60g CO2/km
(TARGET)

Power Module
Inside Inverter



Power Module
Inside Inverter

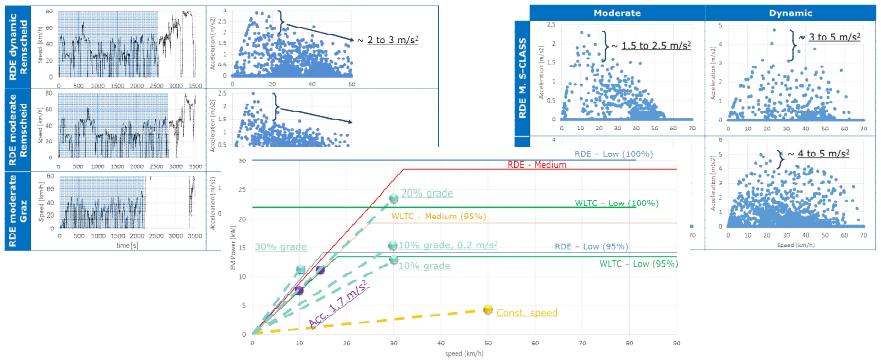
2016 2017 2018

CITY access hybrid
Performance req. 48V systems

- **Mild hybrid with 48V is the target vehicle**
- **Performance requirements in EV mode**
- **Urban driving**
- **Single architecture**
- **Vehicle segments:**
  - **B/C**
  - **D/E**

High Level Target Settings:

- **Inner City Range ~10 – 20 km in NEDC**
- **Overall system cost at same level of High voltage HEV**

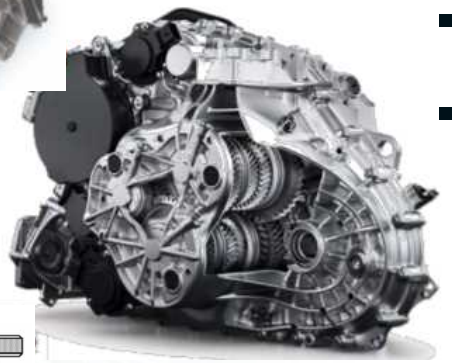


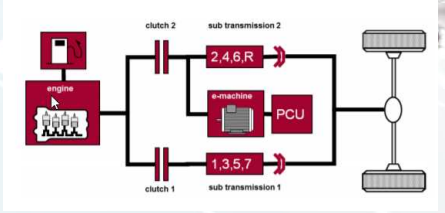
Up to **C-Segment** peak power requirement is **25 – 35 kW** for the electric system

D/E Segment > 45kW

Modular system design for power and torque scalability especially in the electrical system.

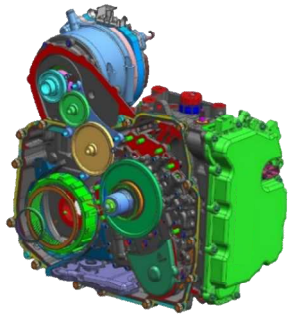
P2 Side Mounted Modules on Transmission

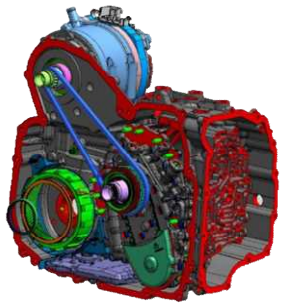




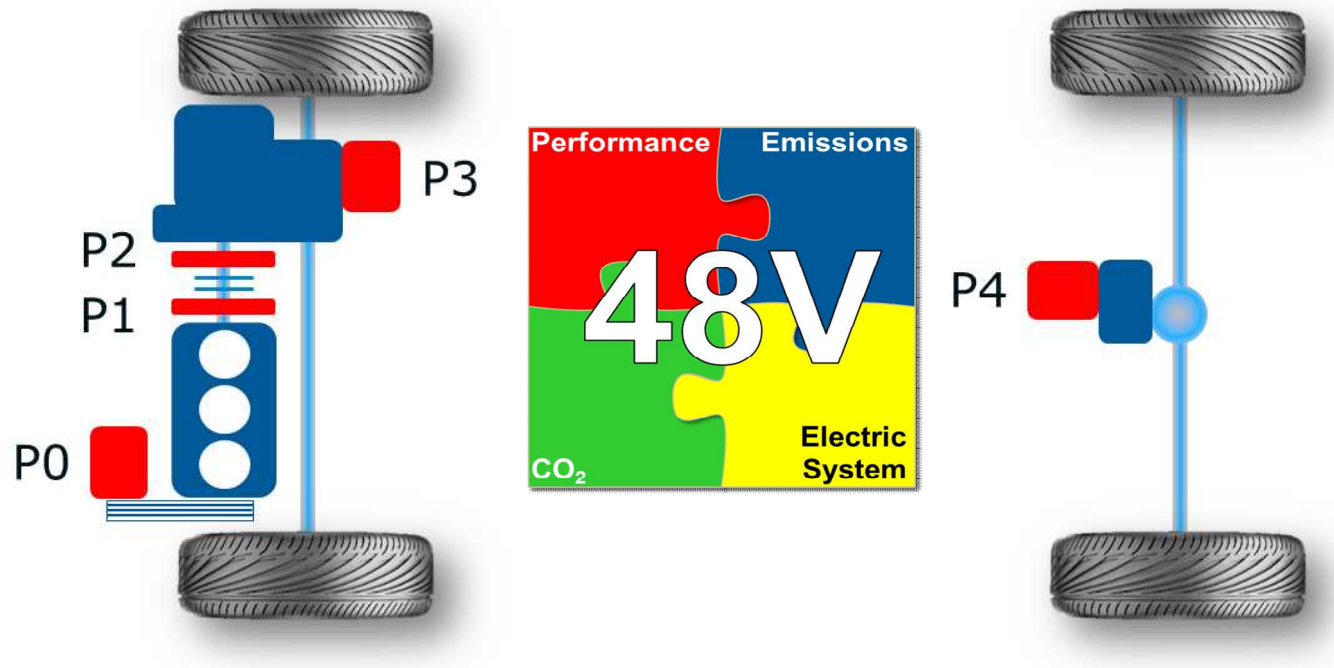
Source : Getrag

- Maximum flexibility to use different engines and transmissions
- Mechanical and functional integration of A/C compressor
- Easy assembly using pre-tested modules
- Torque transfer via belt, chain drive or helical gears
- Low Voltage Connection Systems





AVL 48V Mild Hybrid Solutions
Powertrain architectures



48V Powertrain architectures

- P0: The e-motor is installed in the belt drive system of the combustion engine.
- P1: The e-motor is fixed to the crankshaft of the combustion engine.
- P2: The e-motor is installed between combustion engine and transmission. A C0 clutch can decouple the engine from the powertrain.
- P3: The e-motor is connected to transmission output
- P4: electrical rear axle.

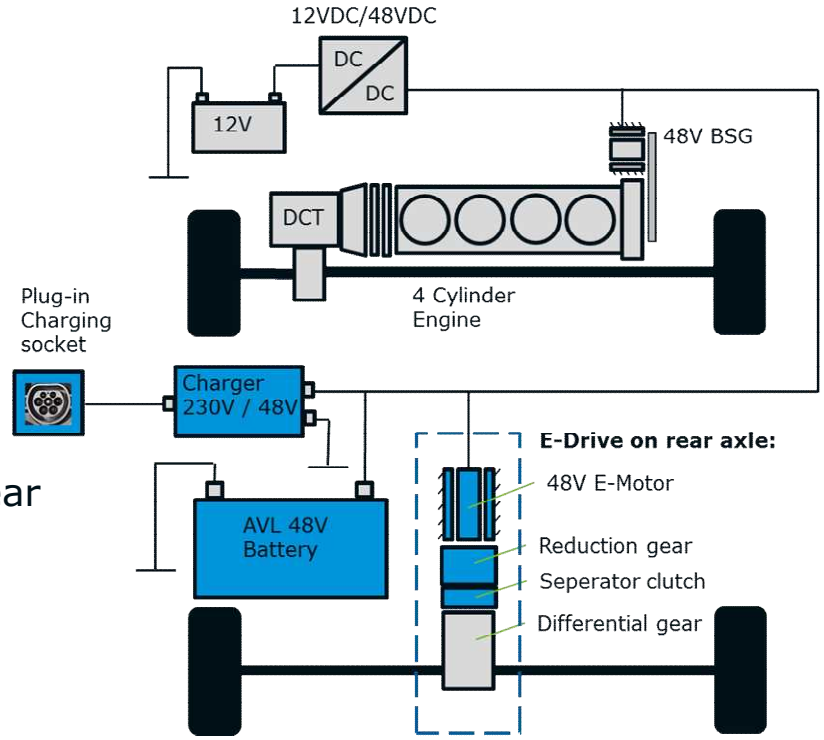
AWD System with BSG

AVL will identify requirements of P4 module, 48V BSG and battery with help of simulation (fuel consumption & performance) and packaging / mech. integration study.

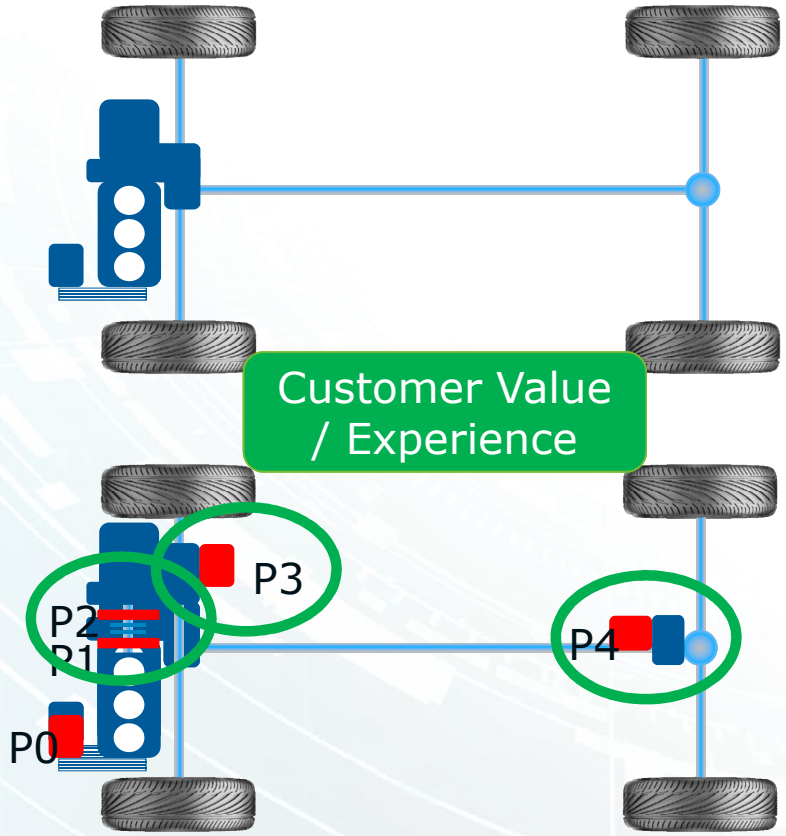
The selection of the components is driven by the following boundaries:

- Project Targets fuel economy increase tbd.
- Available space for mechanical integration
  - BSG including mounting concept and tensioner system
  - Battery including cooling interface
  - P4 module including mounting concept and interface to rear differential or drive shafts
  - DCDC Converter and Charging System
- Component availability
- Component cost

The final concept will be a result of iterative loops during the concept phase as shown on the following slide.



48 V
Features and functions vs. architectures



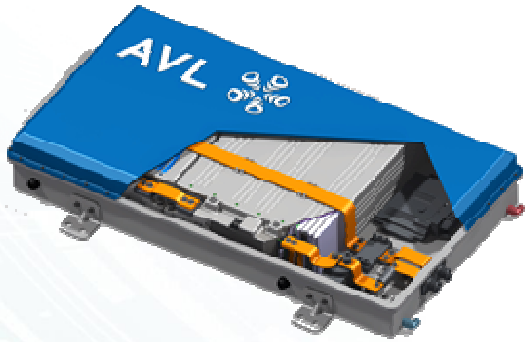
Function	P0	P1	P2	P0/P3	P0/P4
Advanced stop start	●	●	●	●	●
Charging at standstill	●	●	●	●	●
Charging at driving	●	●	●	●	●
Recuperation	◑	◑	●	●	●
Boost	●	●	●	●	●
Sailing	◔	◑	●	●	●
Coasting	●	●	●	●	●
eCreep	◔	◑	●	●	●
Electric drive	○	○	●	●	●
Engine shutdown assist	●	●	◕	●	●
Engine stall protection	●	●	●	●	●
eAWD	○	○	○	○	●

Customer Value / Experience

◑ Degree of fulfillment

System Approach

5,76 kWh



Scaling Range by 13 Cells
Power Output Limited

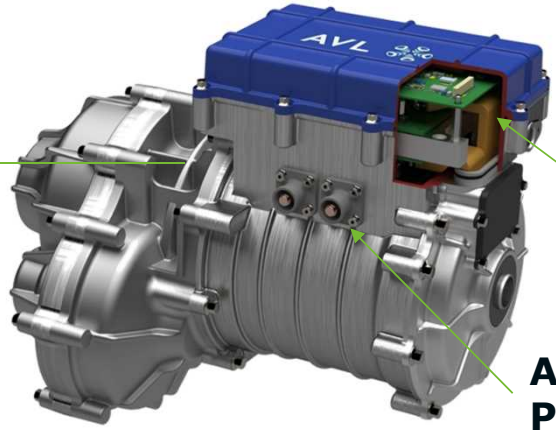
1 Module 13 Cells = 48V
1 Module 13 Cells = 2,88 kWh

58V

250A – 350A

34V

30kW+ Peak



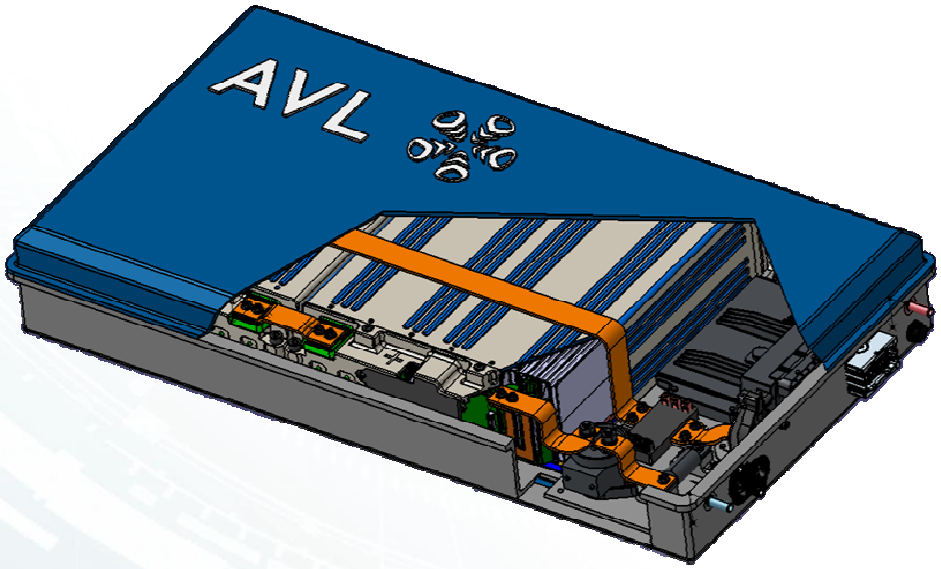
AVL Modular Inverter

AVL Integrated Power Module

6 – 9 Phases → $I^2 R$
Reduction of losses to less than an quarter

Modular system design for power and torque scalability –
3 Power Levels (M)HEV / City Access

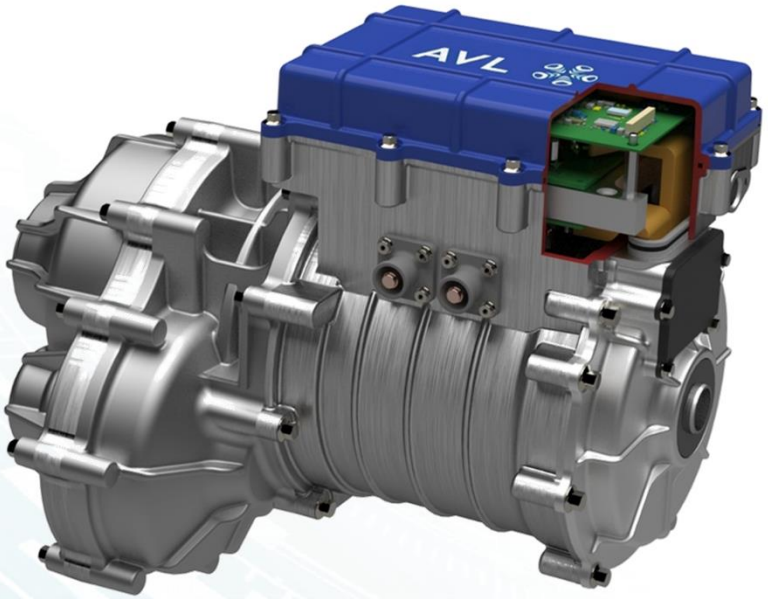
48V PHEV Demo
AVL 48V Battery 12s4p configuration



12s4p Configuration	
Nominal Voltage	44 V
Nominal Energy	10,6 kWh
10s Discharge Current	1600 A
30s Discharge Current	1144 A
Continuous Discharge Current	508 A
10s Charge Current	608 A
30s Charge Current	540 A
Continuous Charge Current	200 A
Weight (Module)	52 kg
Volume (Module)	27 L
Gravimetric Energy Density	203 Wh/kg
Volumetric Energy Density	392 Wh/L

All values at 25°C.

Final electric machine model: Requirements and simulation checklist

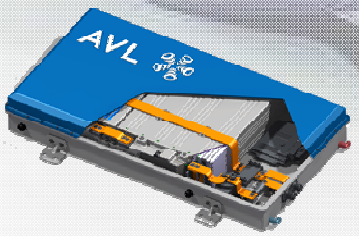


Achieved | Borderline | Not Achieved

E-machine design			
	Requirement	Simulation	
Active stack length	≤200mm	150mm	Achieved
Stator outer diameter	≤200mm	190mm	Achieved
E-machine torque (S2)	≥135Nm	134.5Nm	Borderline
E-machine torque ripple at max. torque (S2)	≤15%	16.6%	Ongoing
E-machine power (S2)	≥31kW	32.5kW	Achieved
E-machine power (S1)	≥5kW	26.6kW	Achieved
E-machine power factor	≥0.9	0.939	Achieved
E-machine max. speed	≥10500rpm	10500rpm	Achieved
Copper fill factor with 0.8mm diameter copper wire	≤42%	40.1%	Achieved Achieved
Inverter DC voltage	≤48V	48V	Achieved
Inverter maximum power	≤35kVA	34.6kVA	

Key System Attribute Targets

City Access	**-**	**Sellable value inner city driving.**
Agility	**-**	**Boost performance even at low temperature.**
Modularity	**-**	**3 Power Levels and Full Hybrid system for larger vehicles**
Emission	**-**	**Support even at low temperature**
Weight	**-**	**Less than 60kg additional weight for City Access PHEV**
Cost	**-**	**Lower than an high voltage HEV**



48V Solutions – Summary

- **48V standard by 2020+** for Europe and China and NA.
- The **predominant** volume will be **48V BSG** solutions with 12kW.
- Integrated solutions expected to be introduced beyond 2020 starting form top segment.
  - Power level expected to move from **15kW towards 30 kW**
  - New architectures will move to transmission side or will be transmission integrated family concepts
- **Strong focus on modular solutions 25+kW**
  - **P0/P4 e-axles**
  - **P2 parallel hybrids + starting device**
  - P0/P3
- **48 V Architectures are cost effective solutions between 12 V and High Voltage Hybridization**.
  - Cost of 30% of PHEV (¥85,000 to ¥125,000)
  - Ability to re-use common vehicle parts (Engines, Transmissions) with modular designs for hybrid and non-hybrid versions, or use current tooling

THANK YOU

Questions?

BACKUPS

48V PHEV Demo
AVL 30kW e-Axle