AVL List GmbH (Headquarters)

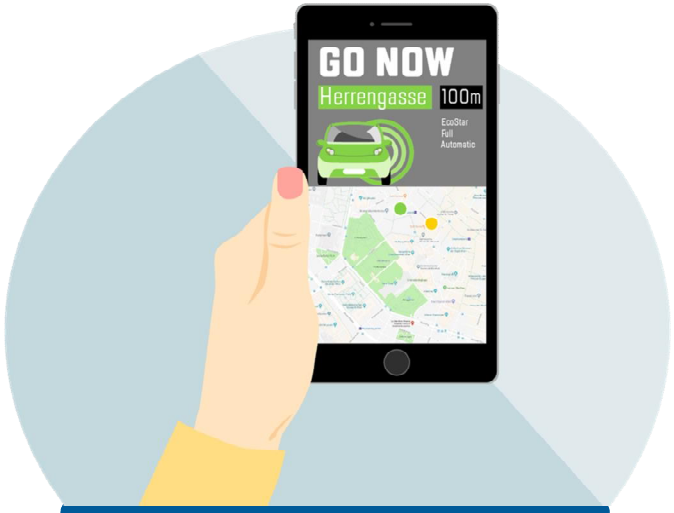
Global Trends of Powertrain

Joint symposium Waseda - AVL

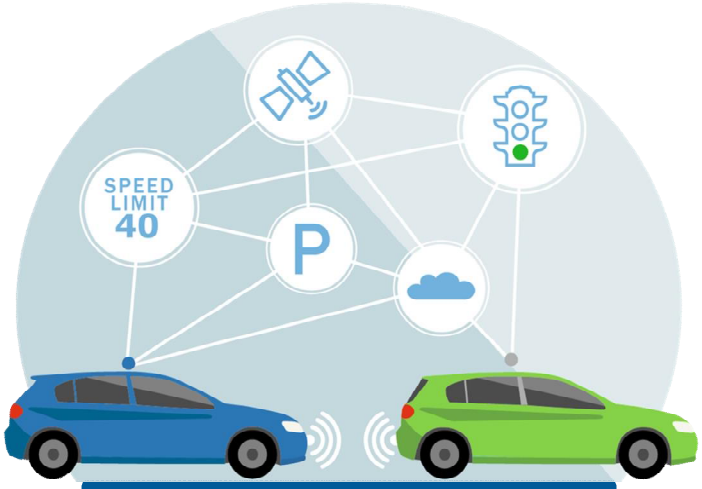
Prof. Dr. Uwe Dieter Grebe

Mobility in the digitized World

Autonomous



Shared



Connected

Data availability and data processing will change transportation and the automotive industry

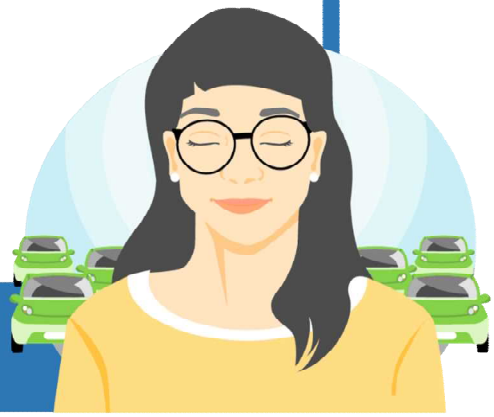
Challenges in Transportation

REDUCE GHG Emissions (CO_2)

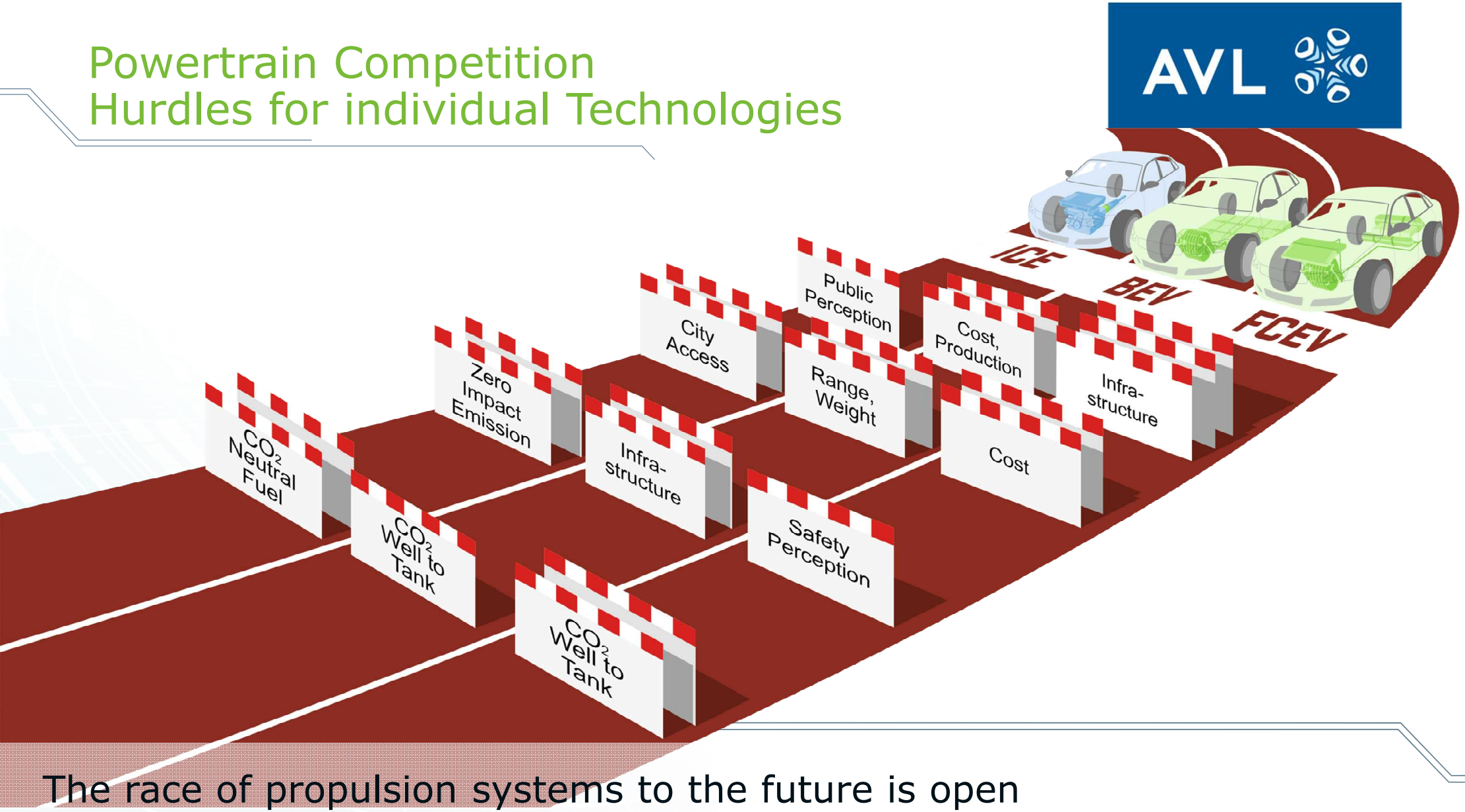
IMPROVE Local Air Quality

KEEP Mobility Affordable

REDUCE Noise Emissions

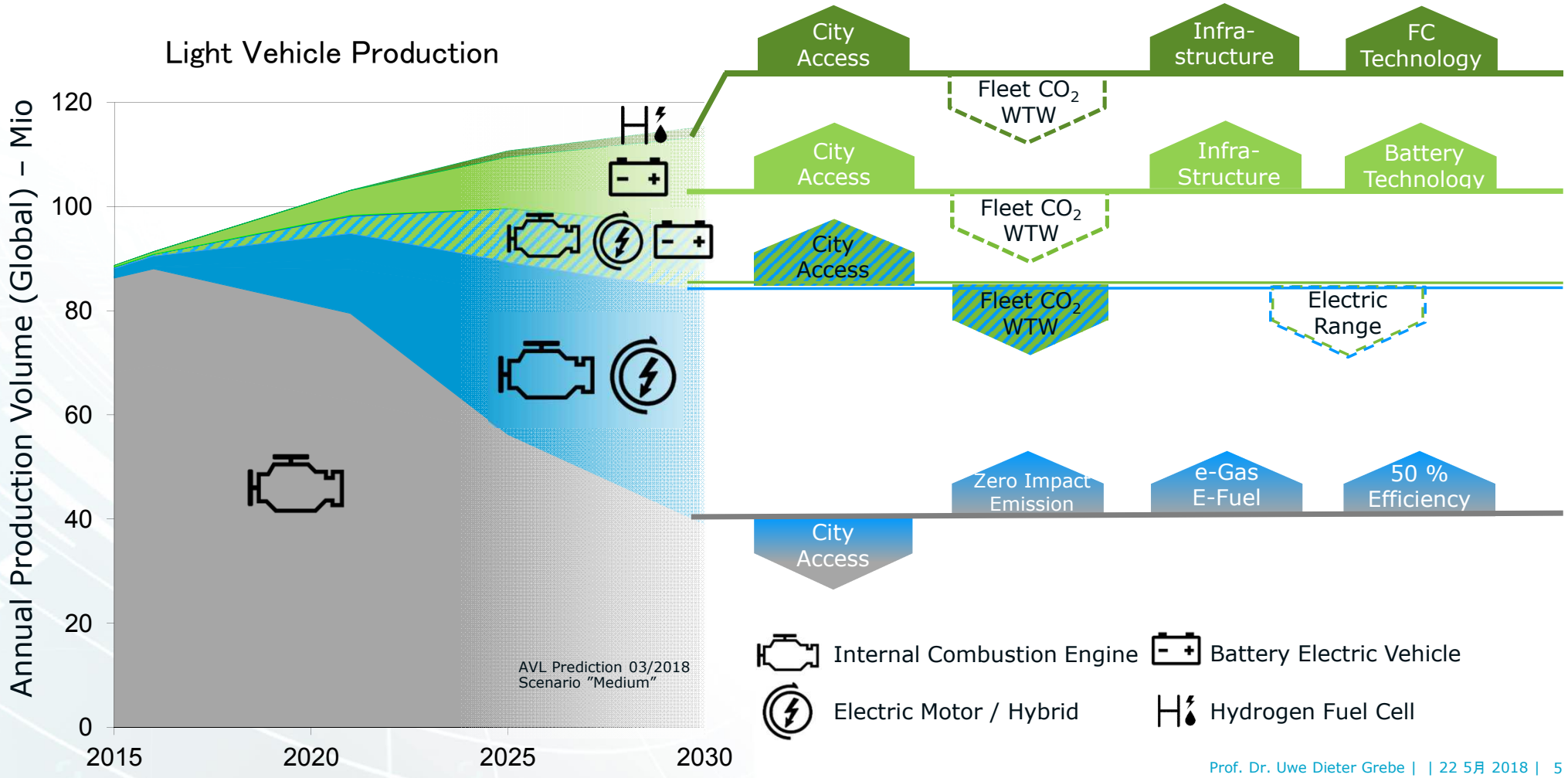


Powertrain Competition
Hurdles for individual Technologies



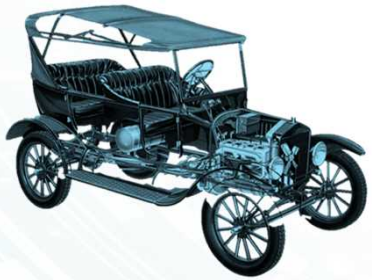
The race of propulsion systems to the future is open

Impacts on Global Technology Shares



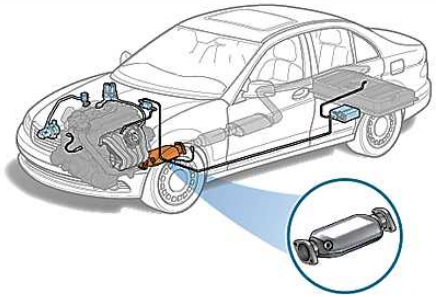
Generations of ICE Based Powertrain Systems

ICE 1.0



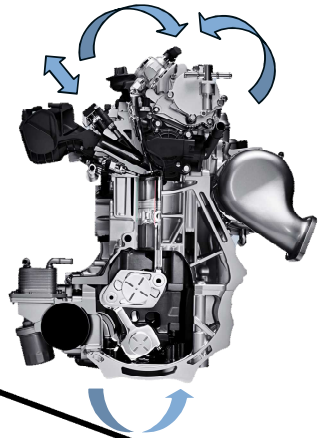
Affordable & Reliable

ICE 2.0



Emission Compliant & Convenient

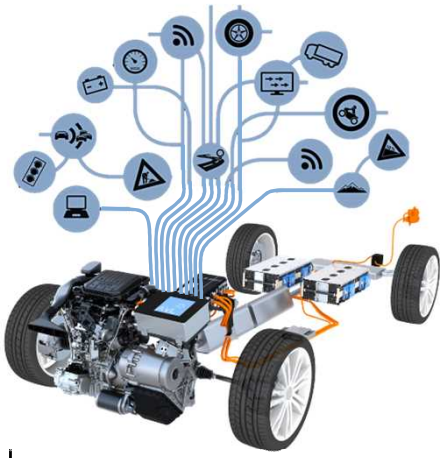
ICE 3.0



Emission Compliant & Fuel Efficient

➔ "Fully Flexible ICE"

ICE 4.0

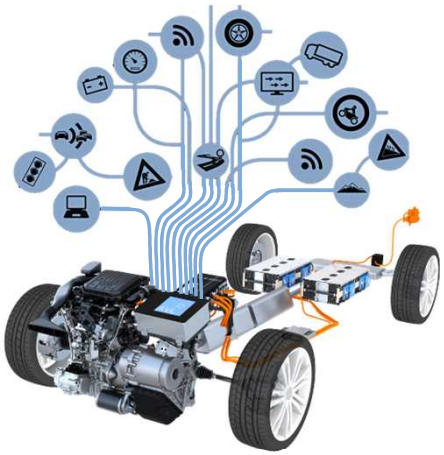


Hybridized & Connected

➔"Fully Flexible Powertrain"

ICE 4.0 – on the Way to Zero Impact Emission

ICE 4.0

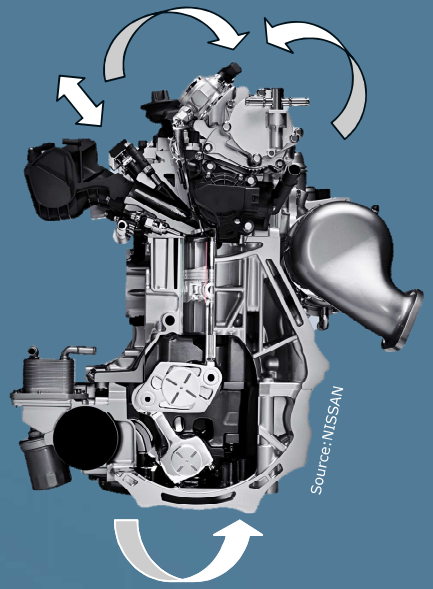


Hybridized & Connected

➔"Fully Flexible Powertrain"

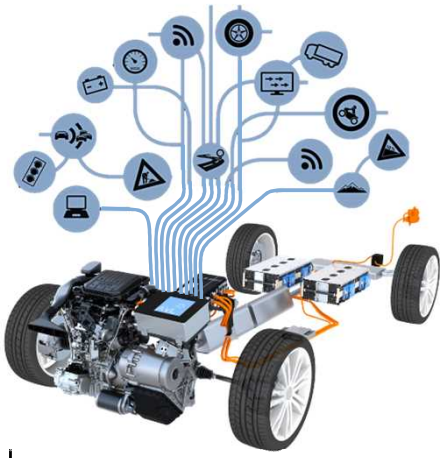
From "Fully Flexible Combustion Engine"

Combustion Engine



Functionality ICE

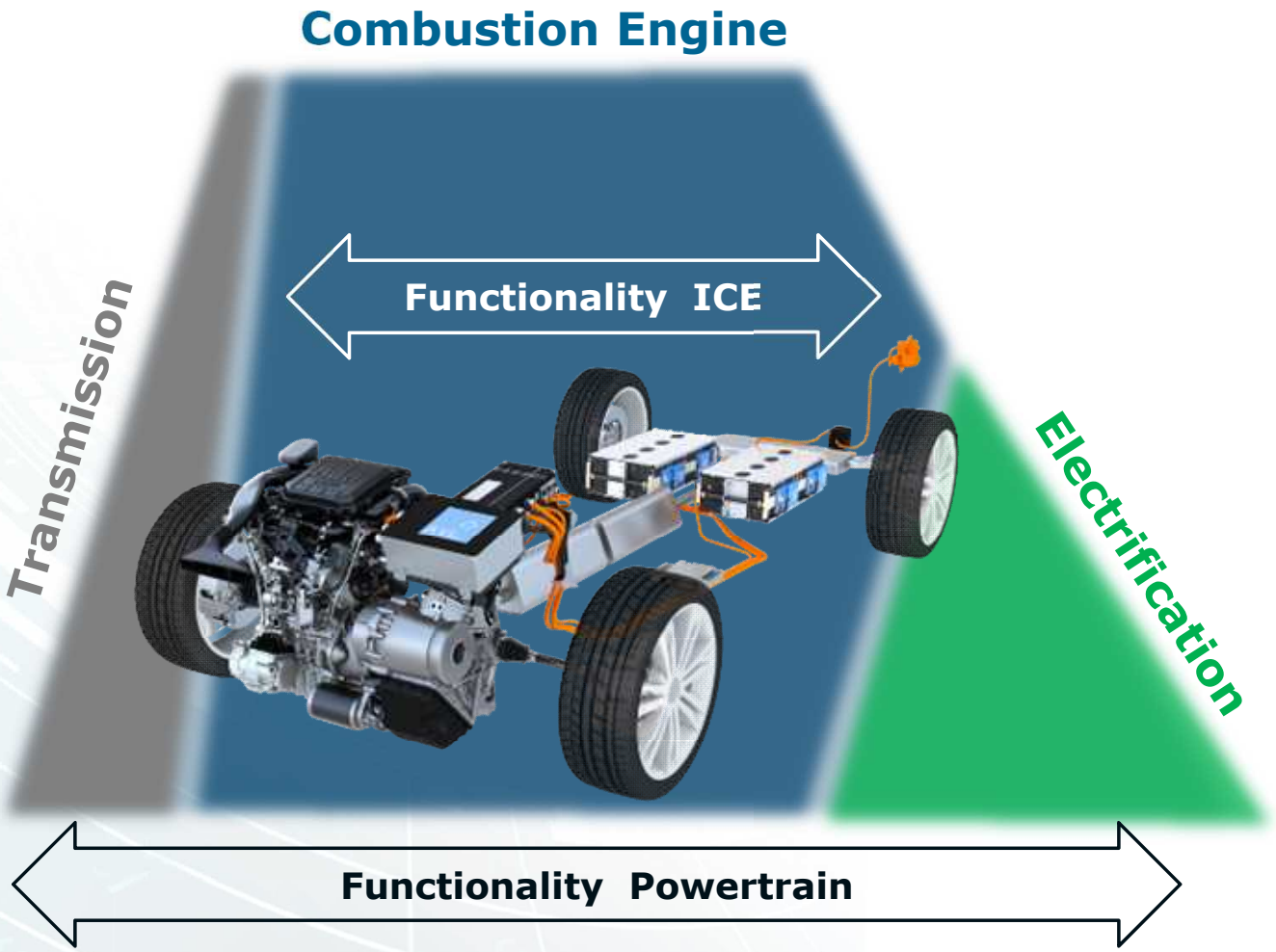
ICE 4.0



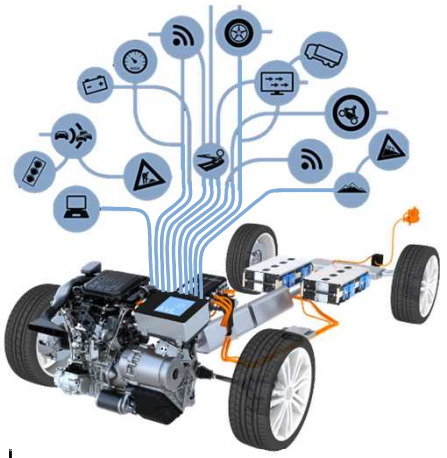
Hybridized & Connected

➔"Fully Flexible Powertrain"

From "Fully Flexible Combustion Engine" to "Fully Flexible Powertrain"



ICE 4.0



Hybridized & Connected

➔"Fully Flexible Powertrain"

Technology Trends - Spark Ignition Engines

Today

Miller, Atkinson

Tomorrow

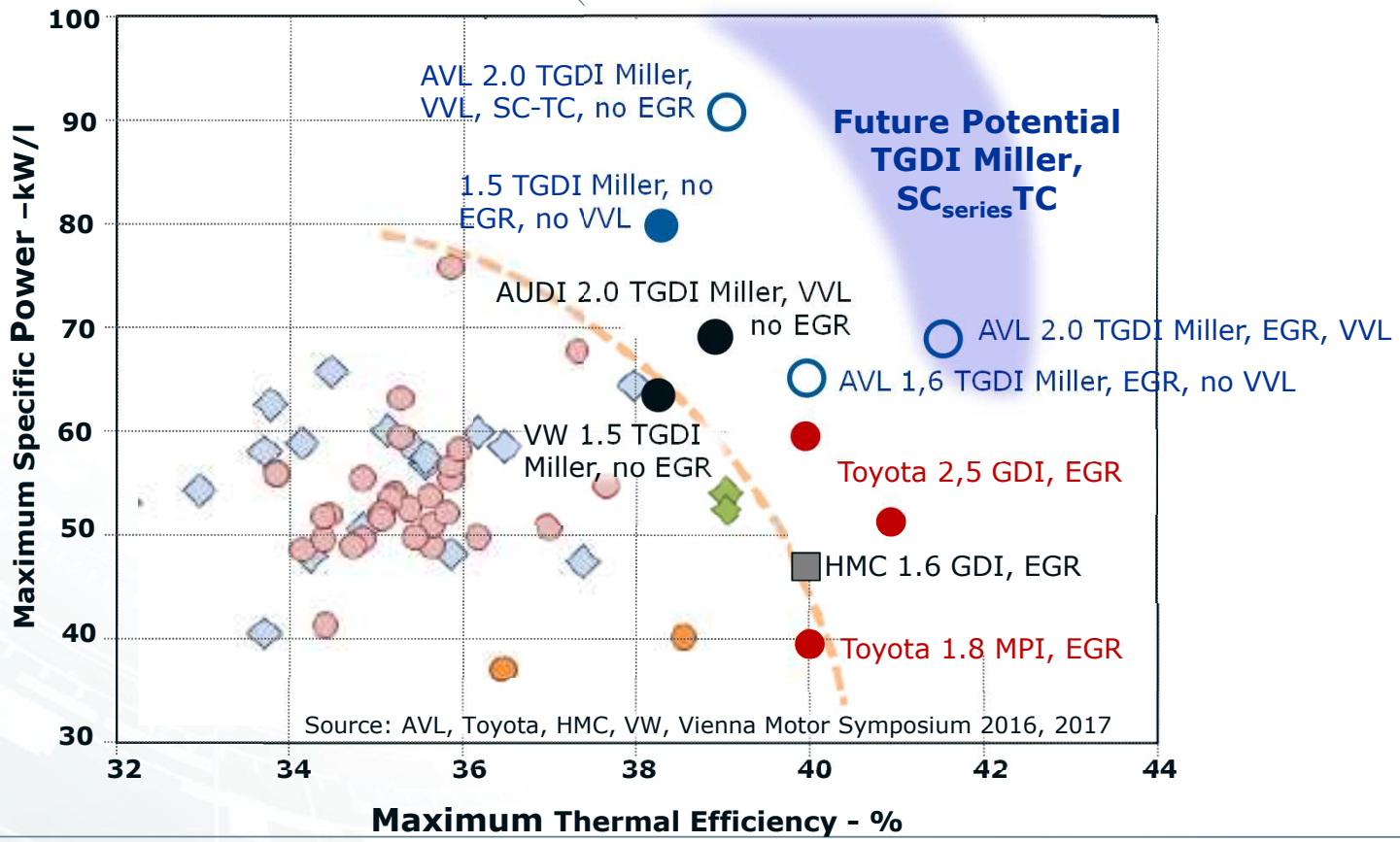
VCR, HCCI, UHP, ...
Extended Miller,
Advanced Boosting

Mild Hybrid SI

e.g. extended 48V systems (20 ➔ 30 kW)
as enabler for low emission & CO_2

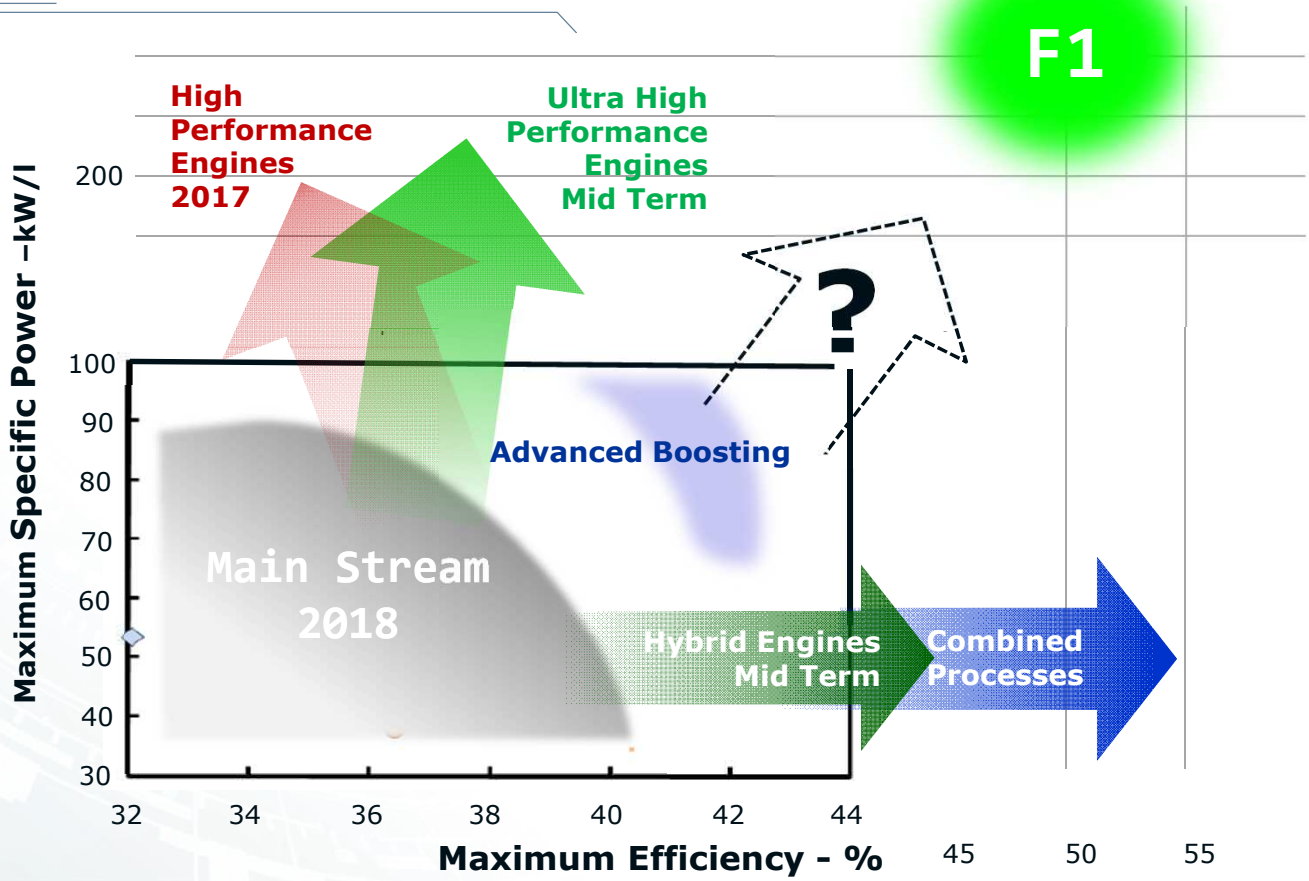
HCCI: Homogeneous Charge Compression Ignition. VCR: Variable Compression Ratio. UHP: Ultra High Injection Pressure

Trade-off between Max. Efficiency and Max. Specific Performance – Short Term



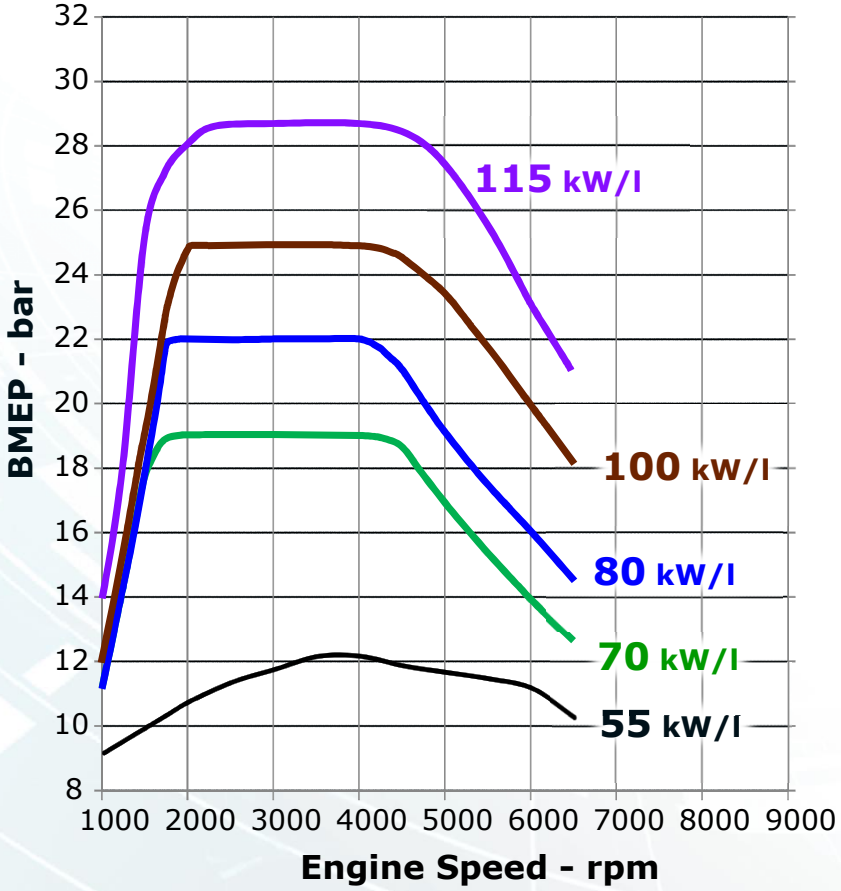
TGDI Miller + ext. cooled EGR + SC-TC → 42 % efficiency & >90 kW/l

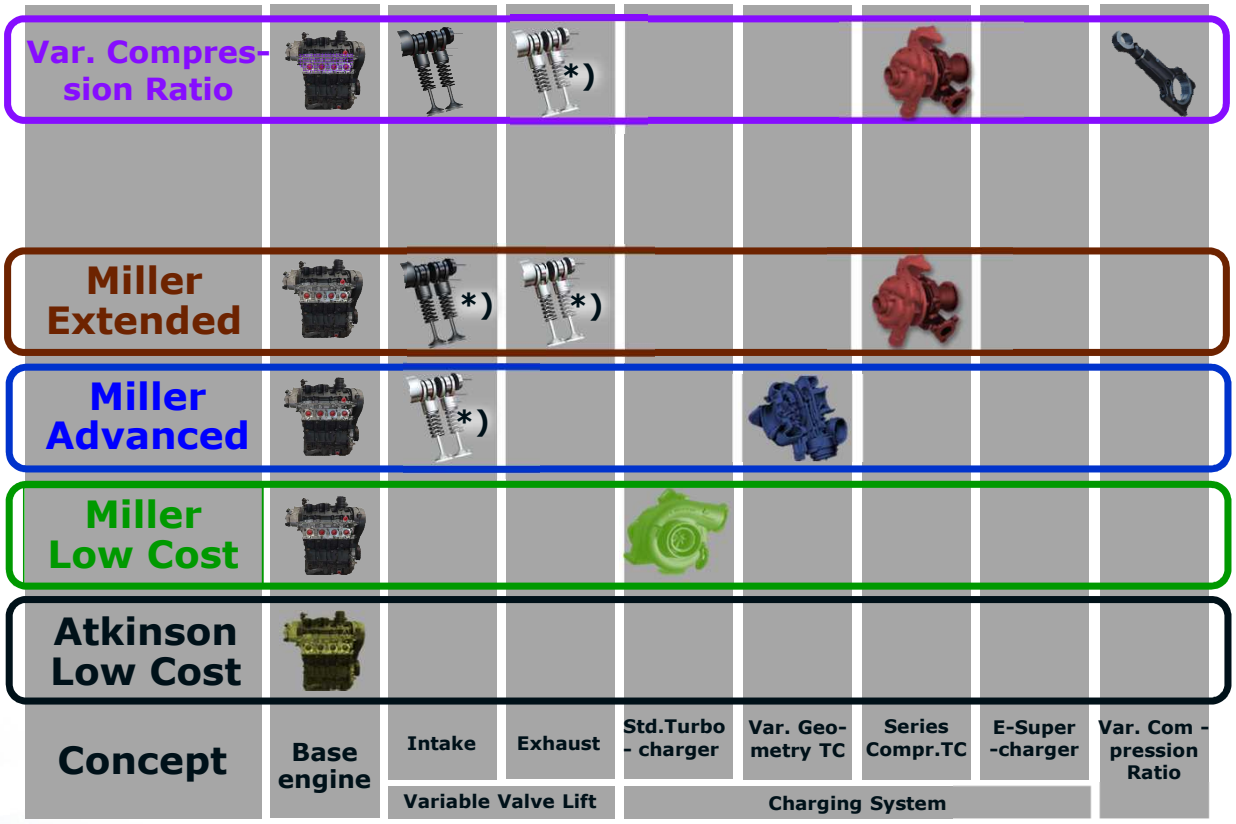
Trade-off between Max. Efficiency and Max. Specific Performance – Long Term



Different development directions: high performance + moderate efficiency, moderate performance + high efficiency

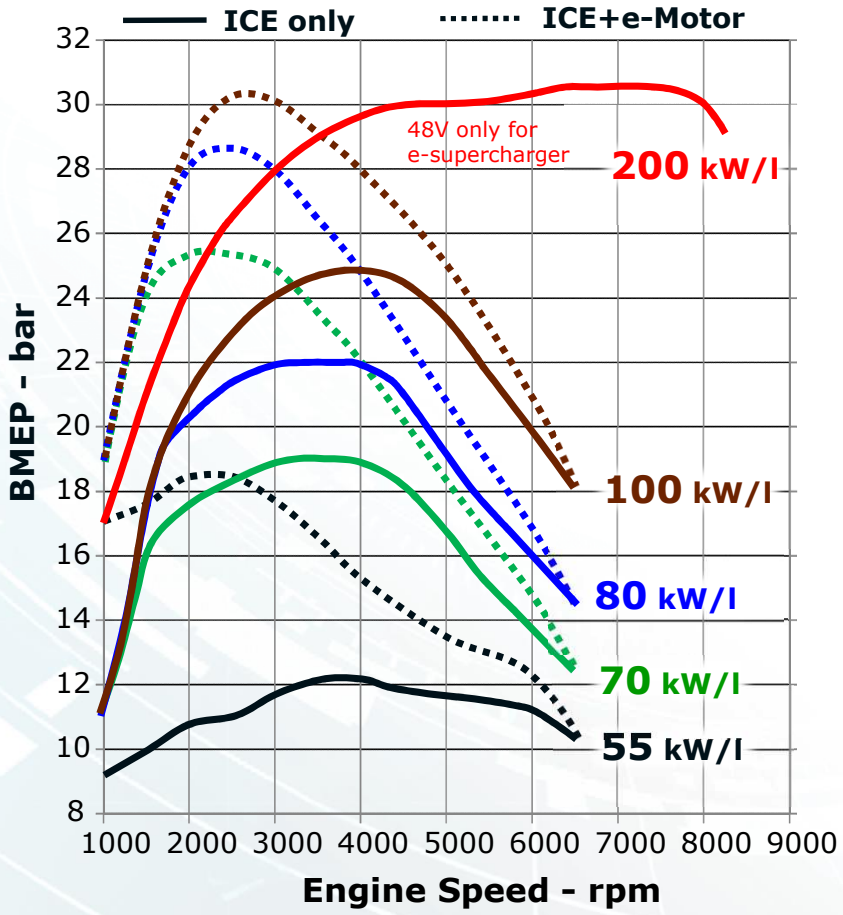
Modular Gasoline Powertrain Family (ICE only)



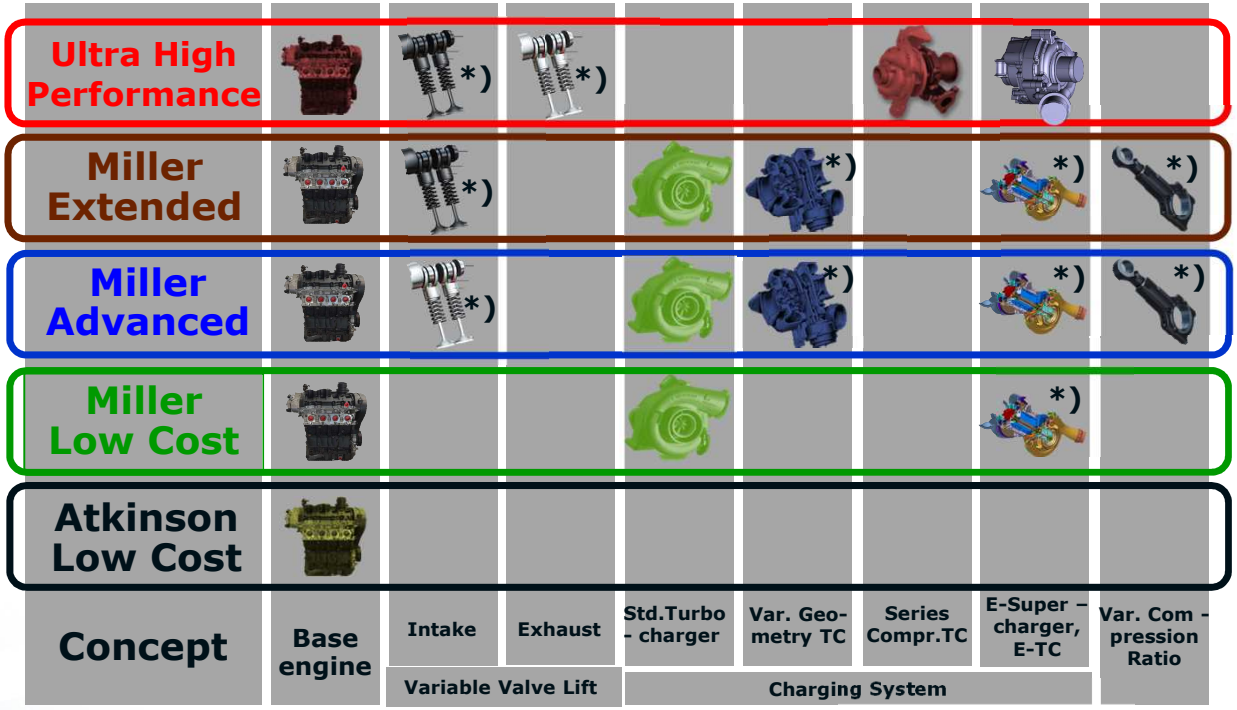


*) optional

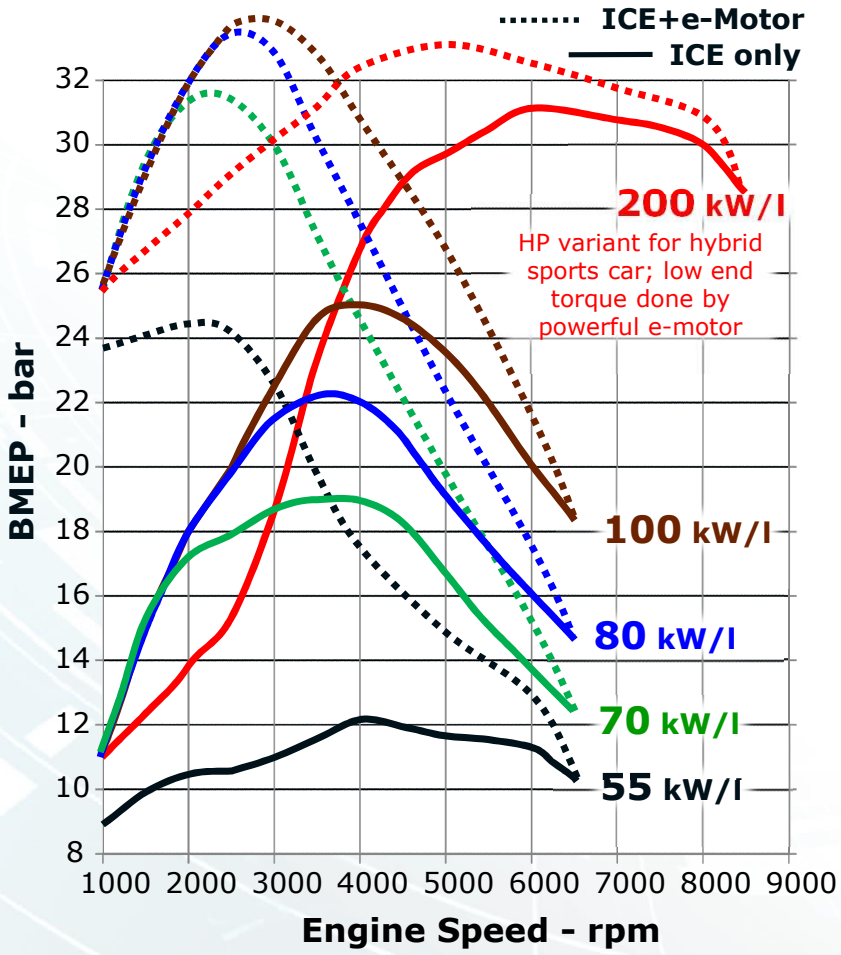
Modular Gasoline Powertrain Family
Mild Hybrid (48V)



E- Motor 98 Nm / 23 kW related to 1,5 l ICE displacement



Modular Gasoline Powertrain Family (High Voltage Hybrid)

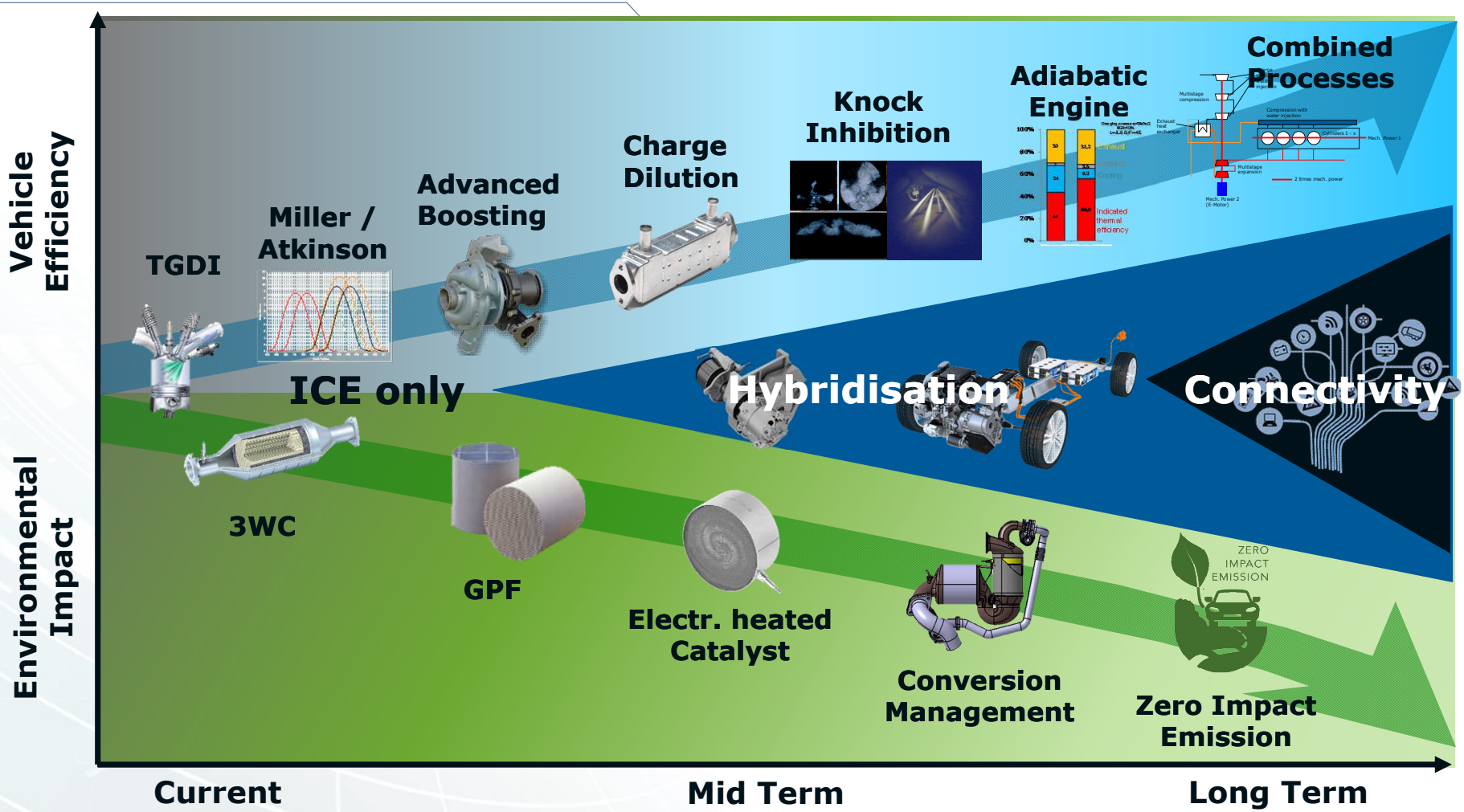


E- Motor 240 Nm / 57 kW, related to 2.0 l ICE displacement

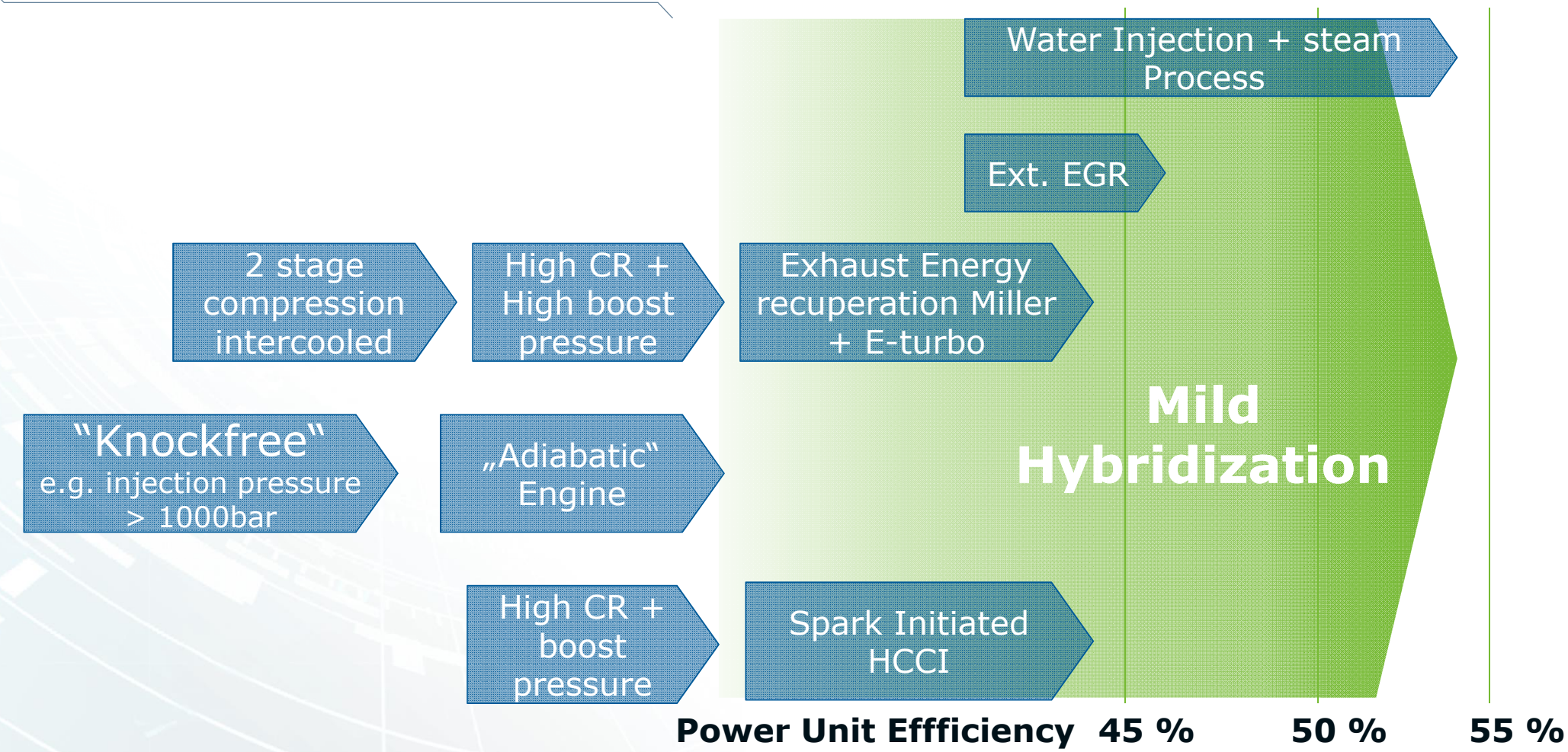
Concept	Base engine	Intake	Exhaust	Std.Turbo - charger	Var. Geo-metry TC	Series Compr.TC
		Variable Valve Lift		Charging System		
Ultra High Performance		*)	*)			
Miller Extended		*)			*)	
Miller Advanced		*)			*)	
Miller Low Cost						
Atkinson Low Cost						

*) optional

Technology Roadmap Gasoline Engine



Gasoline Engine Technology Philosophies



Technology Trends – Diesel Engines

Today

Lean NOX
Trap + SCR

Tomorrow

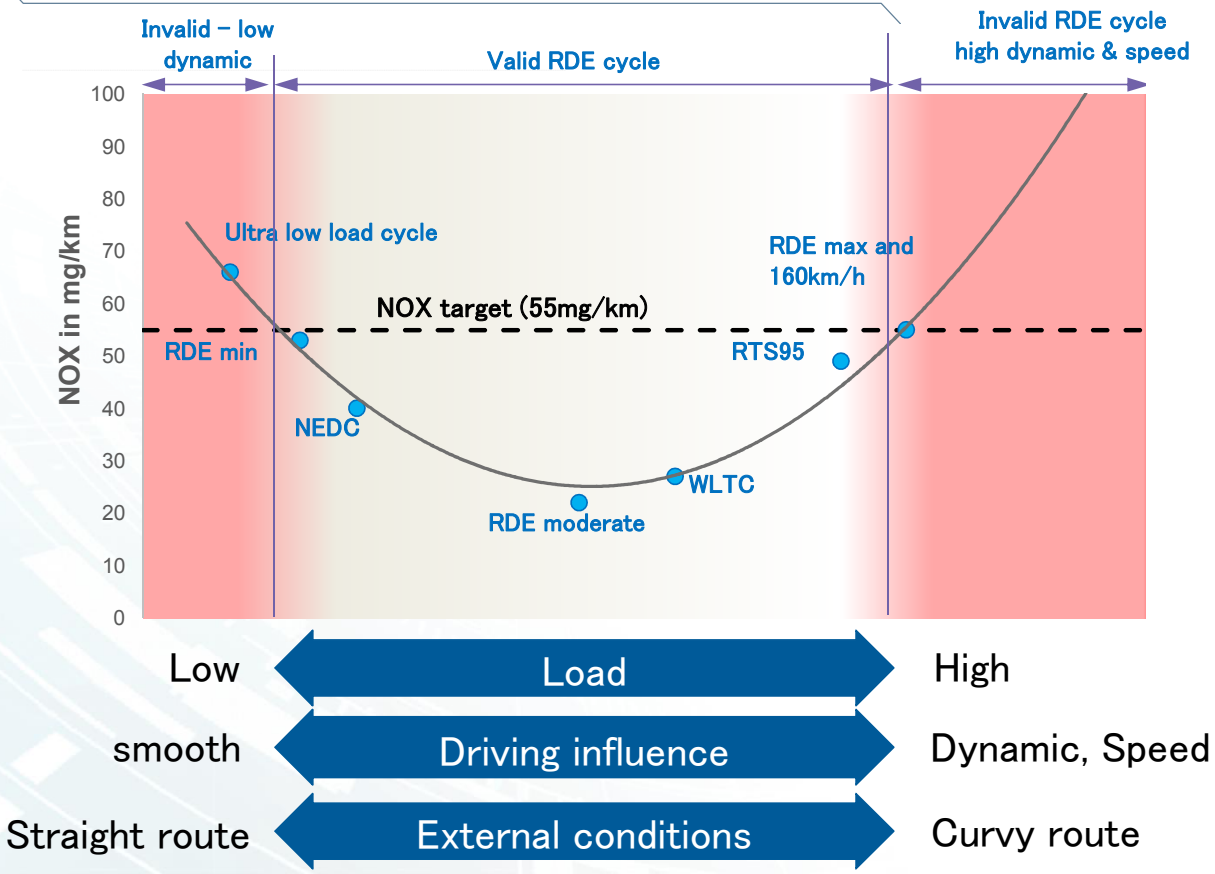
Advanced EAS &
Temperature Management,
Refined Operation
Strategies

Mild Hybrid CI

e.g. extended 48V systems (20 ➔ 30 kW)
as enabler for low emission & CO_2

Refined temperature management of the exhaust aftertreatment and electrification are key enablers for lowest emission with Diesel Engines

Diesel emission compliance
Next Step in Emission reduction



Challenges

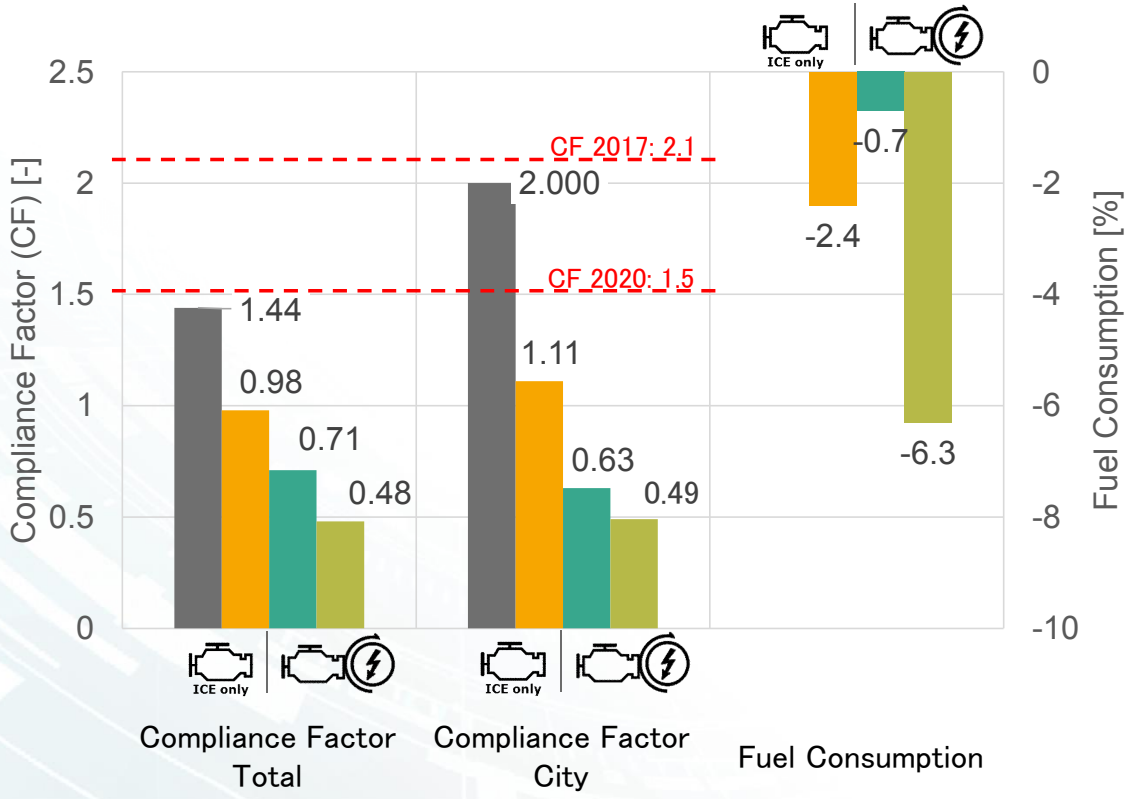
- ❑ **Temperature management in low load city operations**
- ❑ **Aggressive driving style**
- ❑ **Too high temperature and space velocity for aftertreatement due to**
  - ➢ **Heavy weight, small engine (big SUV, Van, LCV)**
  - ➢ **Long time high speed driving e.g. German Highway**

➔ **Areas outside RDE legal boundaries to be considered**

Emission improvements need to focus on the extremes of very low and very high dynamic operation

Low Emission Diesel
Extended RDE emission compliance

Example: PC 2.0L Diesel, HP EGR, LNT + SDPF, CW 1700kg



DIESEL –Walk towards CF<<1

- HP-EGR
- HP-/LP /-EGR
- 48V with 4kW Ecat
- 48V with 4kW Ecat and e-Motor Boost / Recuperation

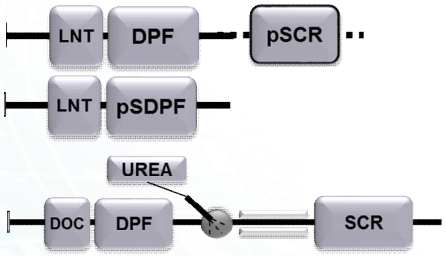
Reduction of Fuel Consumption & Emissions.

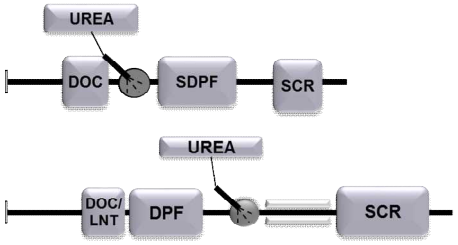
EAS aged to full useful life | **Ambient Temperature** 0°C | **LNT full loaded** (NO_X), **SCR empty** (NH3)

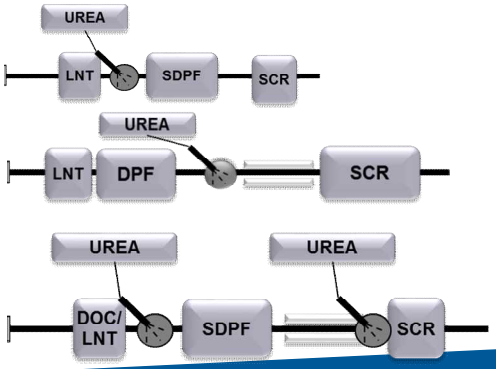
EU6d final compliance achieveable with standard technology
NEXT STEP: Over-fulfillment of legal requirements

Main Elements towards EU7 / SULEV20

EU6d temp | EU6d Final | EU7

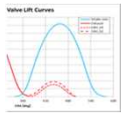


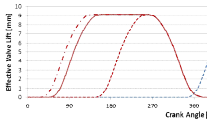




Coatings,
NH3 solid/gas,
...

Advanced Temperature Mgmt.





Coatings,
Insulations,
integrated Exhaust
Cylinder deact.
...

Electrification

P0

P2

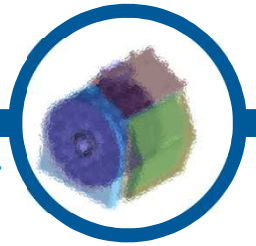
Dedicated ICE

Integrated Family Concept

Technology Trends Electrification

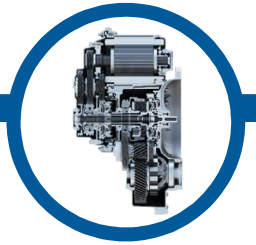
xEV Systems

High Power 48V Hybrid



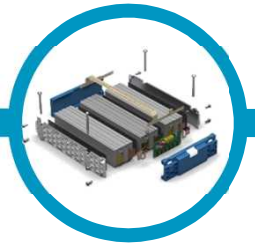
Integrated Electric Axles & SiC Inverter

Dedicated Hybrid Transmission Family



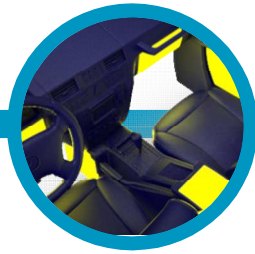
Energy Storage & Thermal System

High Energy Density (1000V Ready)



Low Height Battery

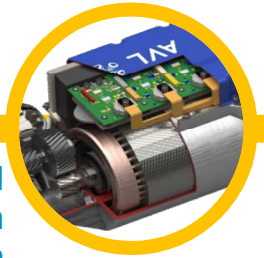
Advanced Conditioning Systems



Fuel Cell & Charging

800V / Fast Charging

Medium size PEM with Plug-In Battery System



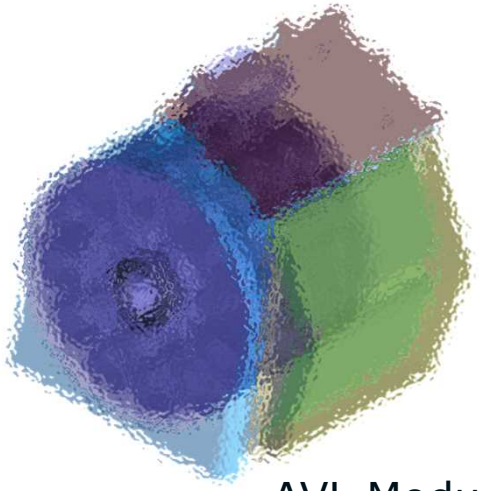
SOFC as Range Extender with Fast Starting Time

Technology Trends Electrification

xEV Systems

High Power
48V Hybrid

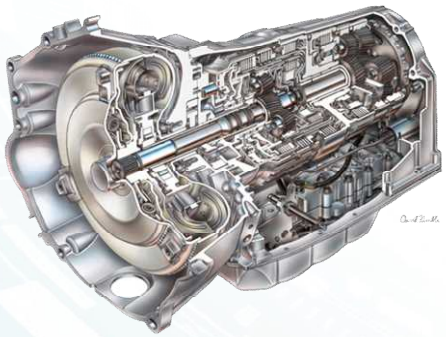
AVL Integrated
Power Module

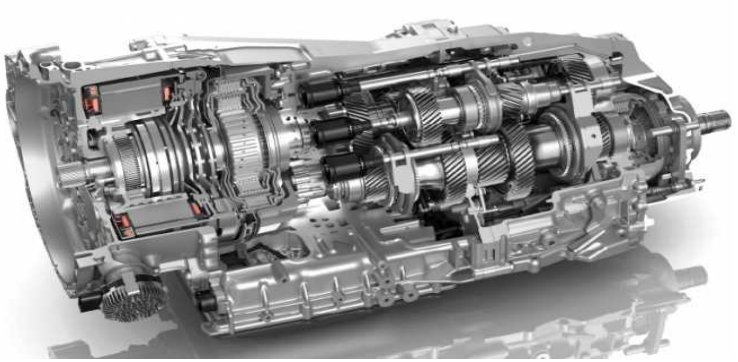


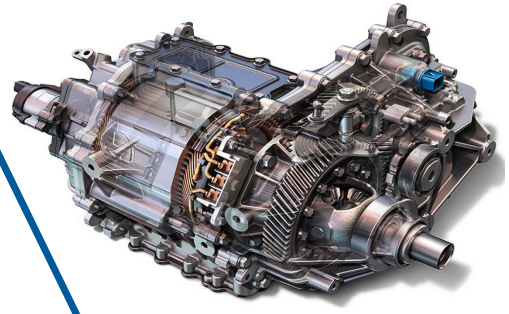
AVL Modular
Inverter

48 Volt:
>30kW **Peak Power**

Transmission Trends







Conventional Transmissions

Hybrid Transmissions

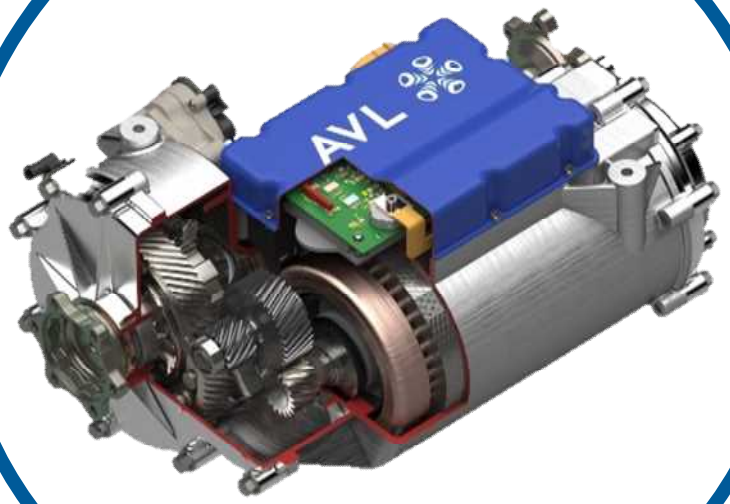
e-Drive Units

Transmission technology transitions towards electrification –
Co-existence of all transmission types

Technology Trends Electrification

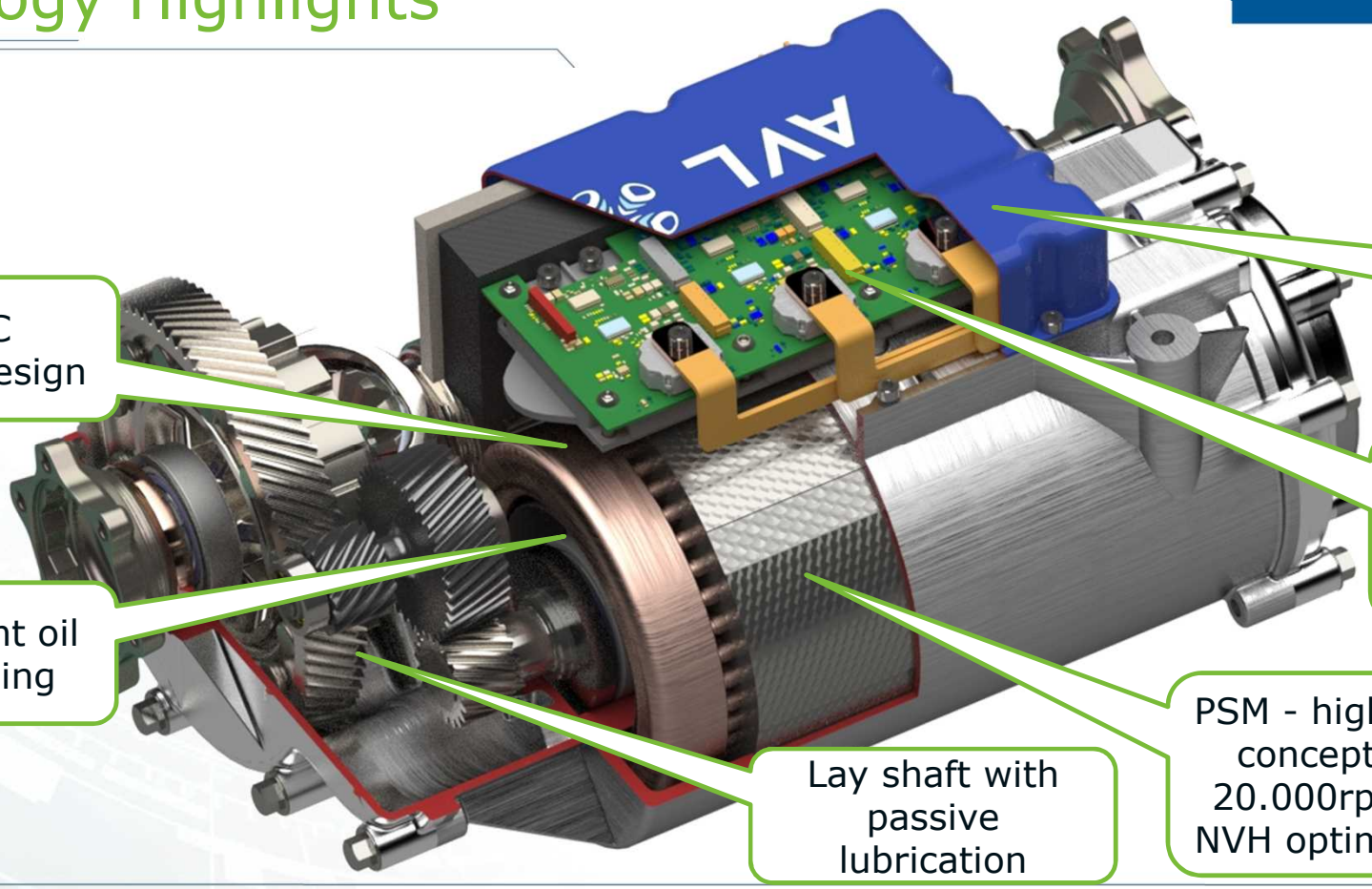
xEV Systems

Integrated Electric Axles & SiC Inverter



Highly Integrated Electric Axles

Technology Highlights



Full EMC optimized design

High efficient oil stator cooling

Lay shaft with passive lubrication

PSM - high speed concept with 20.000rpm and NVH optimization

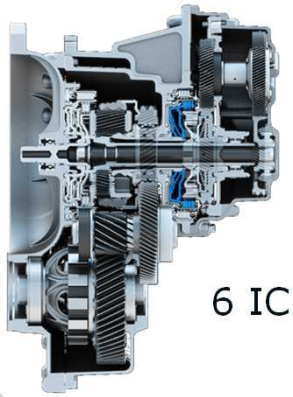
SiC - further potential for efficiency & integration

Full integrated power inverter

Full integrated E-axle for best EV range @ affordable cost

Technology Trends Electrification

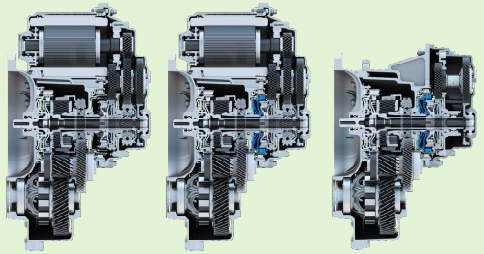
Today



AT

6 ICE + Rev.

Tomorrow



HV
4 ICE/PH
2 EV
1 eCVT
2 Charge Standstill

HV+
6 ICE/PH+Rev.
2 EV
1 eCVT
3 Charge Standstill

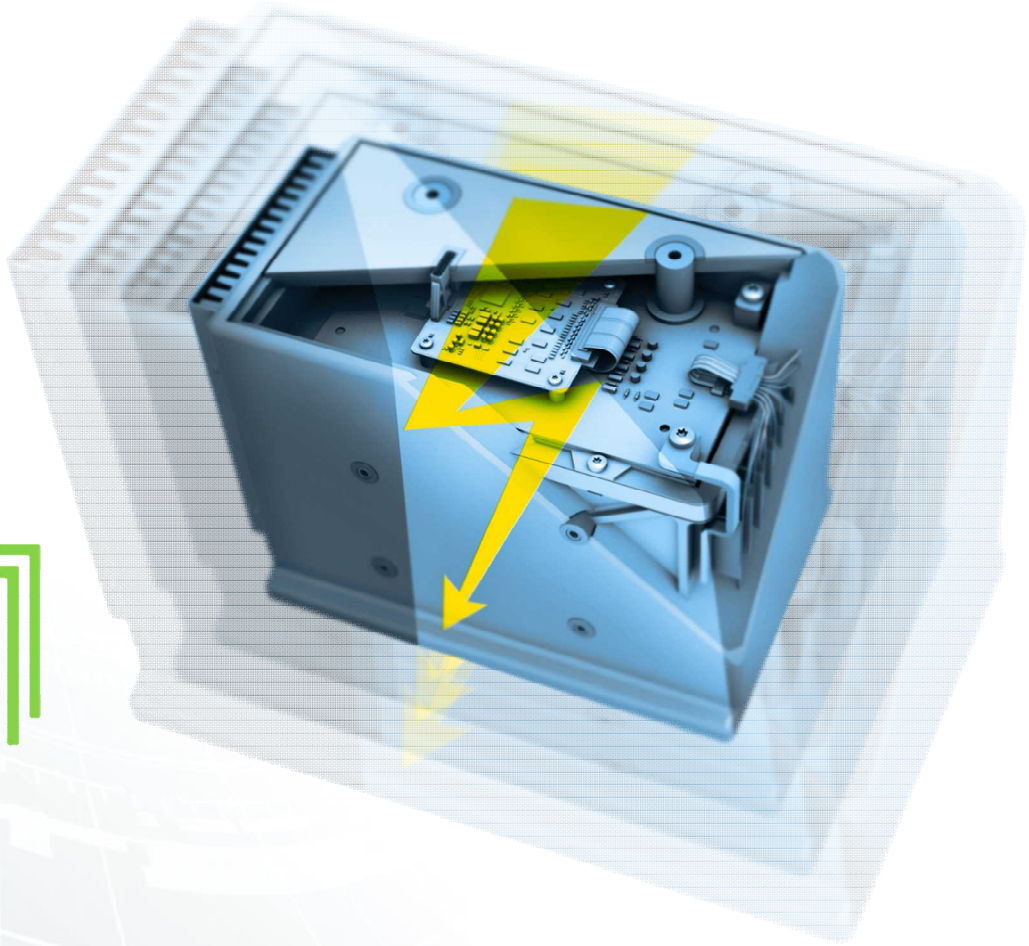
AT
6 ICE +Rev.

48V
6 ICE/PH+Rev.
2 EV
3 Charge Standstill

Dedicated Hybrid Transmission Family

Conventional Automatic Transmission, 48V and high voltage
Dedicated Hybrid Transmission within one production line

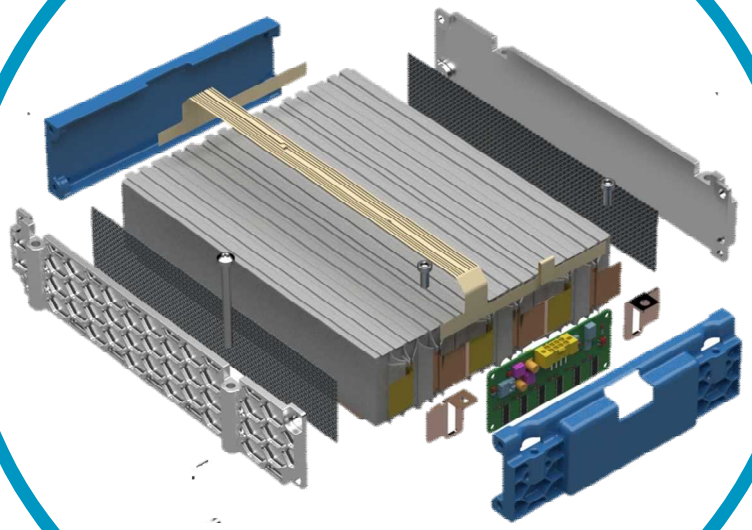
Limiting Factors for Battery Development



Technology Trends Electrification

Energy Storage & Thermal System

High Energy Density (1000V Ready)



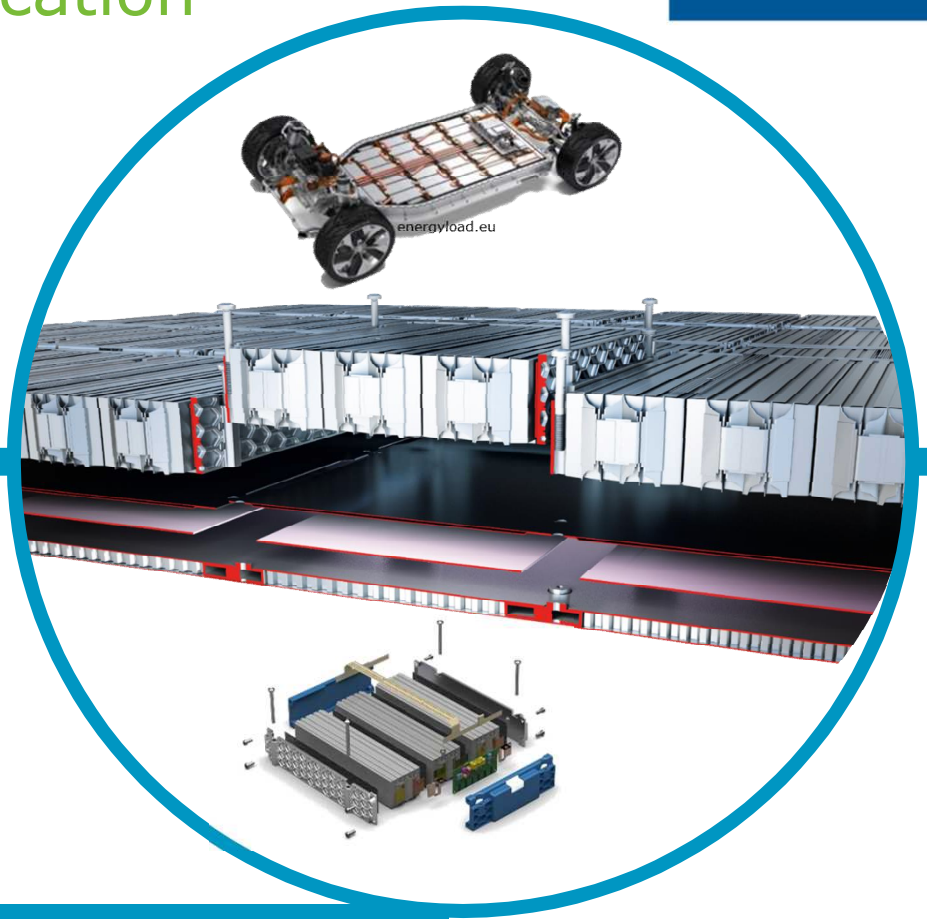
High Energy Density Battery

Significantly better than state of art

Technology Trends Electrification

Energy Storage & Thermal System

Low Height Battery



Low height Battery: 80mm

- **~10% weight** saving
  ~60kg weight saving **@ 96kWh**
- **~5% package** density increase

Technology Trends Electrification

Energy Storage & Thermal System

Advanced Conditioning Systems

Optimize the use of energy

Technology Trends Electrification

Fuel Cell & Charging

800V / Fast Charging

Minimize recharging time

Technology Trends Electrification

Fuel Cell & Charging

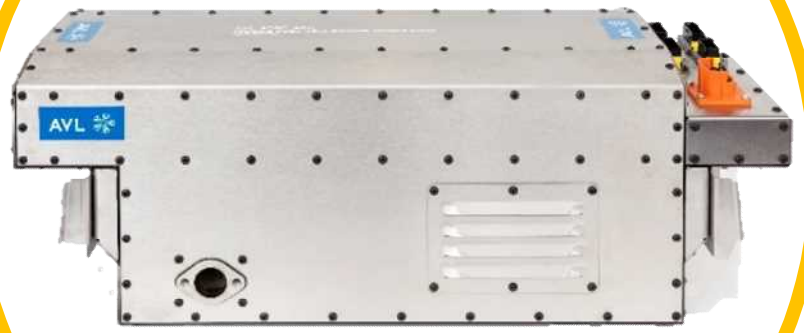
Medium size PEM with Plug-In Battery System

Polymer Electrolyte Fuel Cell (PEMFC)

Technology Trends Electrification

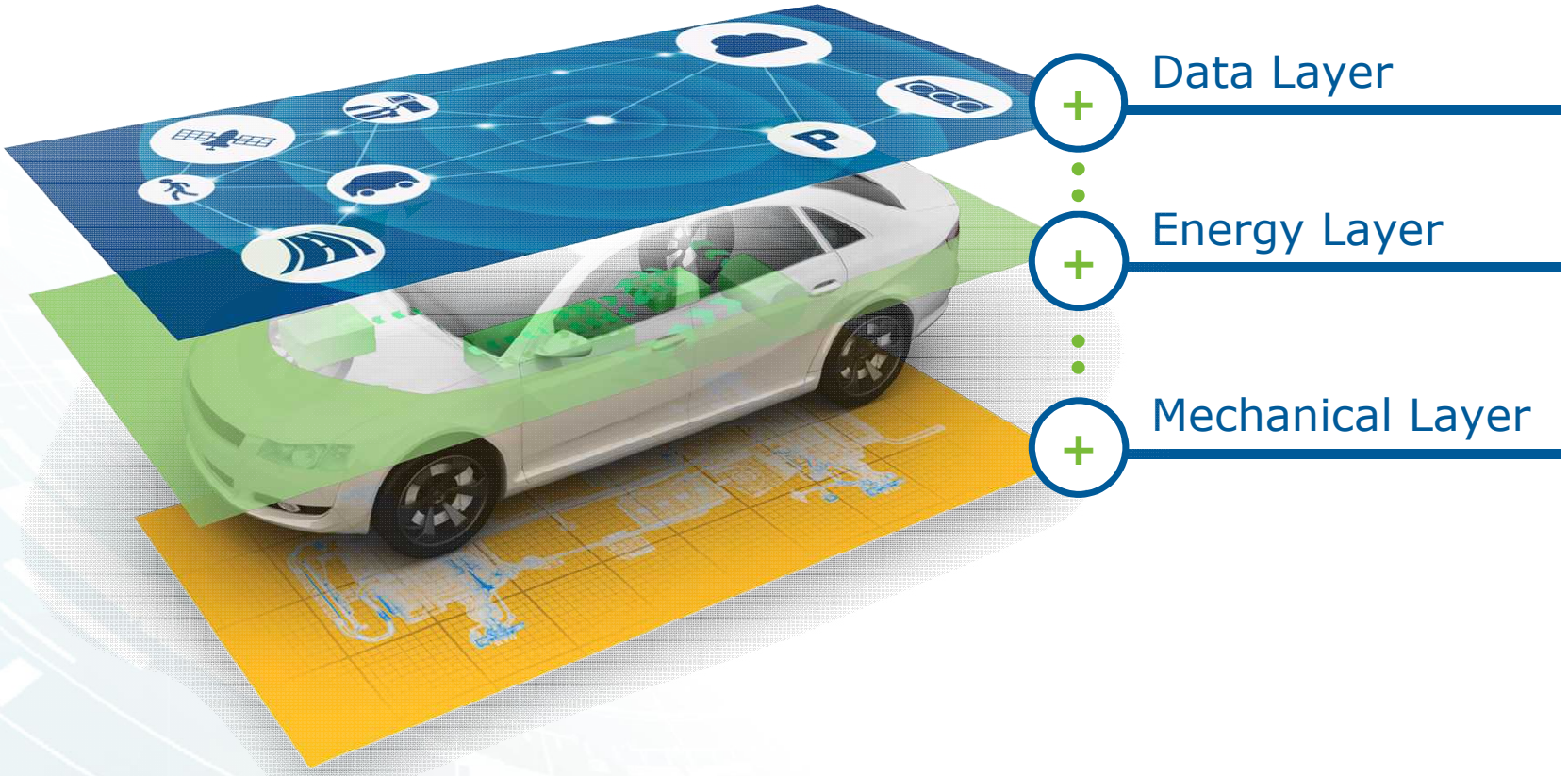
Fuel Cell & Charging

Medium size PEM with Plug-In Battery System



SOFC as Range Extender with Fast Starting Time

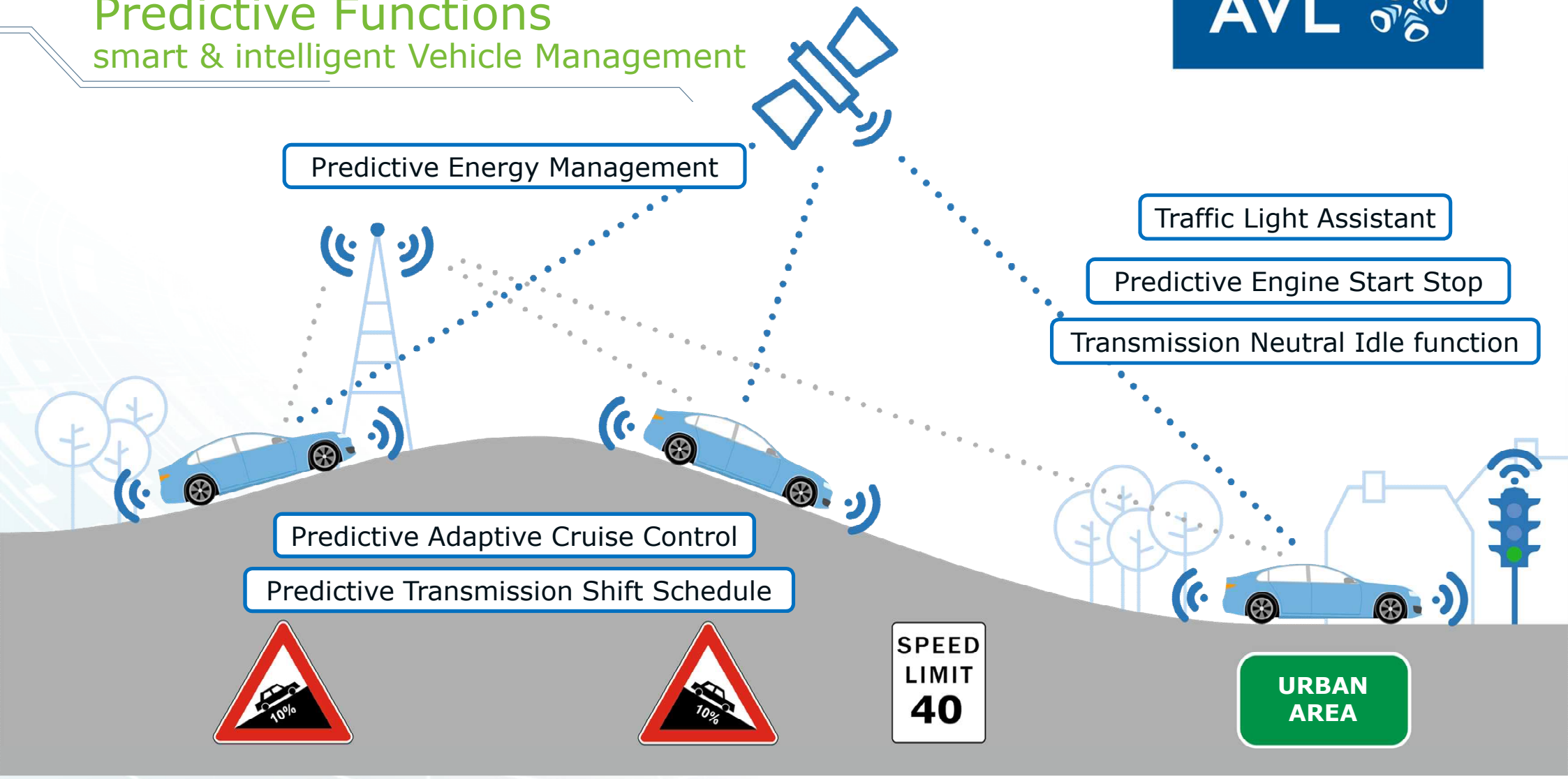
Seeing the World Differently



Leveraging technologies in the vehicle and in the connected world

Predictive Functions

smart & intelligent Vehicle Management



AVL Development Approach
objective assessment of driver feeling

Selection of sensors and measurement method

Perform test drives with a multiple of experienced drivers

Correlation of human perception and sensor signals / physics

Scale	Safety & Comfort
9-10	very convenient
8-9	convenient
7-8	acceptable
6-7	almost acceptable
5-6	disturbing
4-5	very disturbing
3-4	almost unacceptable
2-3	unacceptable
1-2	fail

Development Applications
with objective assessment technology

L3+ systems
Cloud Lab

Requirements Engineering

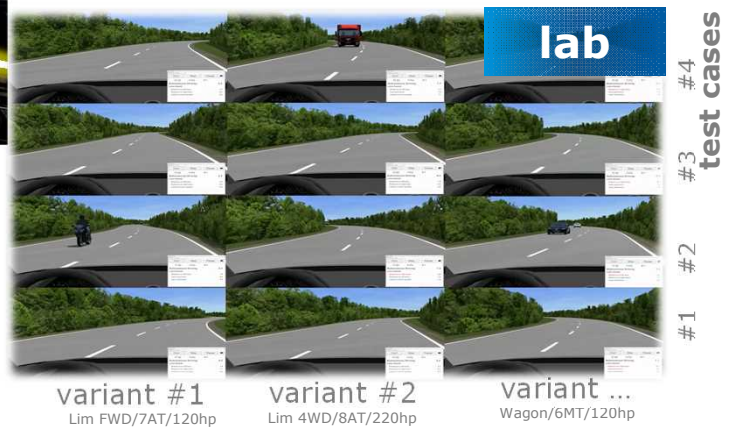
- Competitors comparison
- Targets setting
- Use cases, test cases

Function & Controls

- Embedded trajectories definitions
- **Testing of functions in lab**

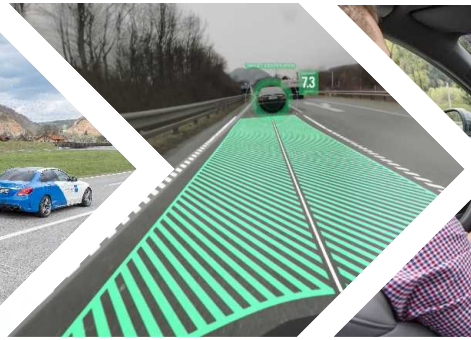
High level ADAS/AV

- High number test cases
- Different lead variants & derivatives



Fully automated assessment of driver feeling plus powerful simulation as enabler for virtual validation & optimization

Development Applications
with objective assessment technology



Requirements Engineering

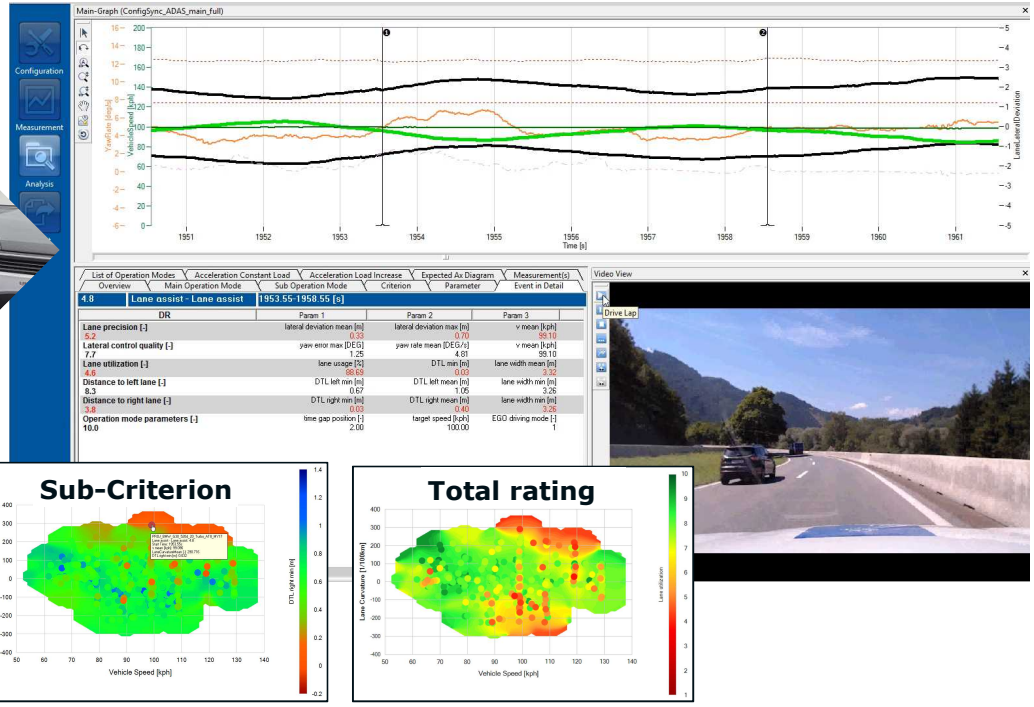
- Competitors comparison
- Targets setting
- Use cases, test cases

Function & Controls

- Embedded trajectories definitions
- Testing of functions in lab

Calibration/ Application

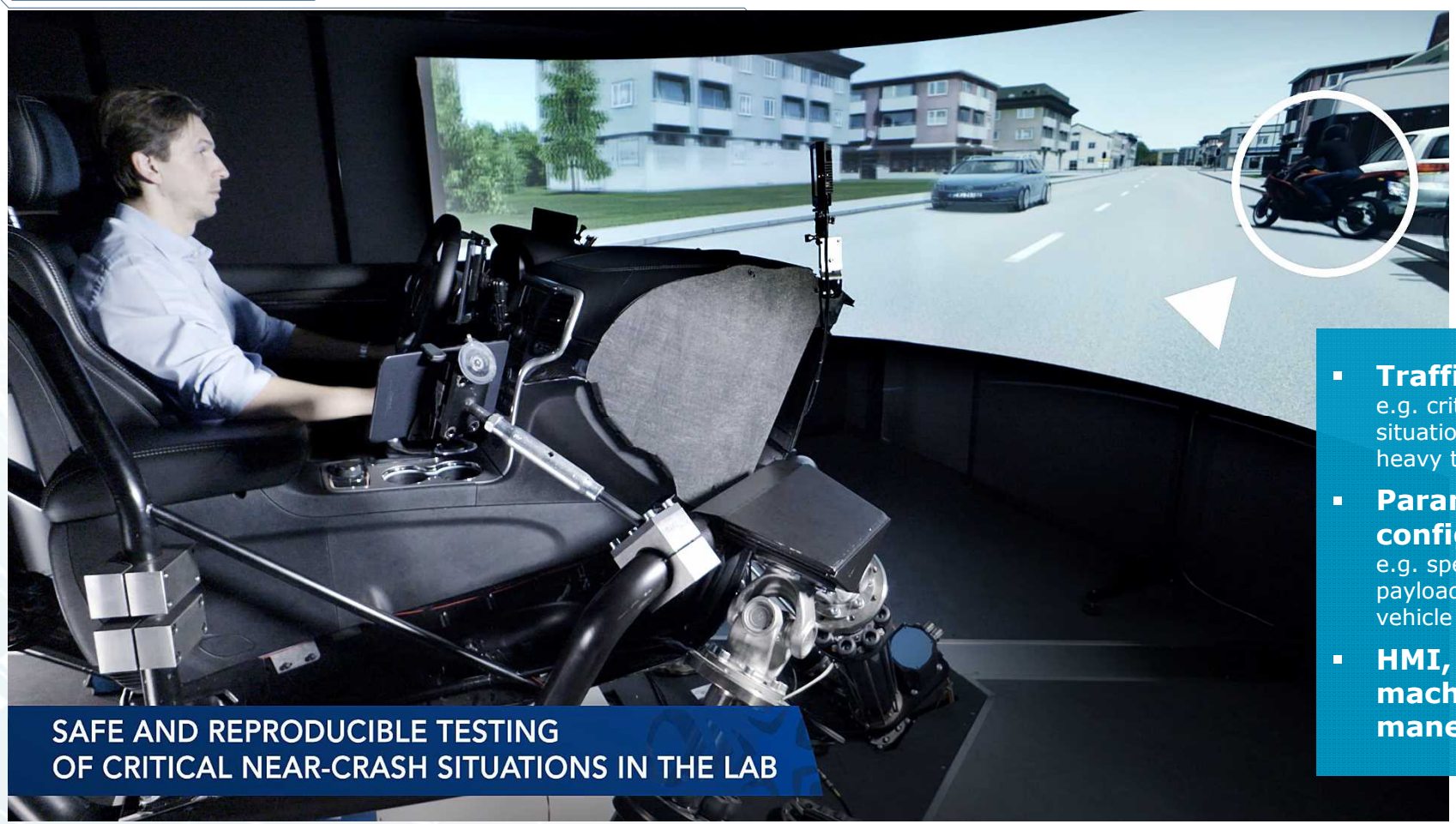
- **Optimization of comfort & perceived safety**
- Issues resolution



All sub-criteria including physical measurements available for quality optimization & fast issues resolution

Safe & Reproducible Testing

Driver Simulator

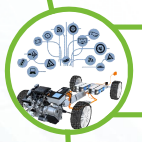


- **Traffic scenarios**
  e.g. critical near crash situations with passengers or heavy traffic
- **Parameter/vehicle config changes**
  e.g. speed, accelerations, payload, distances, sensor & vehicle configurations
- **HMI, human & machine take over maneuver**

Summary

Data availability and data processing will change transportation and the automotive industry.

The race of propulsion systems to the future is open.



The ICE 4.0 has “zero impact emission” potential.

Electrification helps the ICE to overcome shortfalls regarding emissions.

Weight, range, costs and charging time of the BEV are being improved.

Connected functions will increase the powertrain efficiency.


Thank You
AVL
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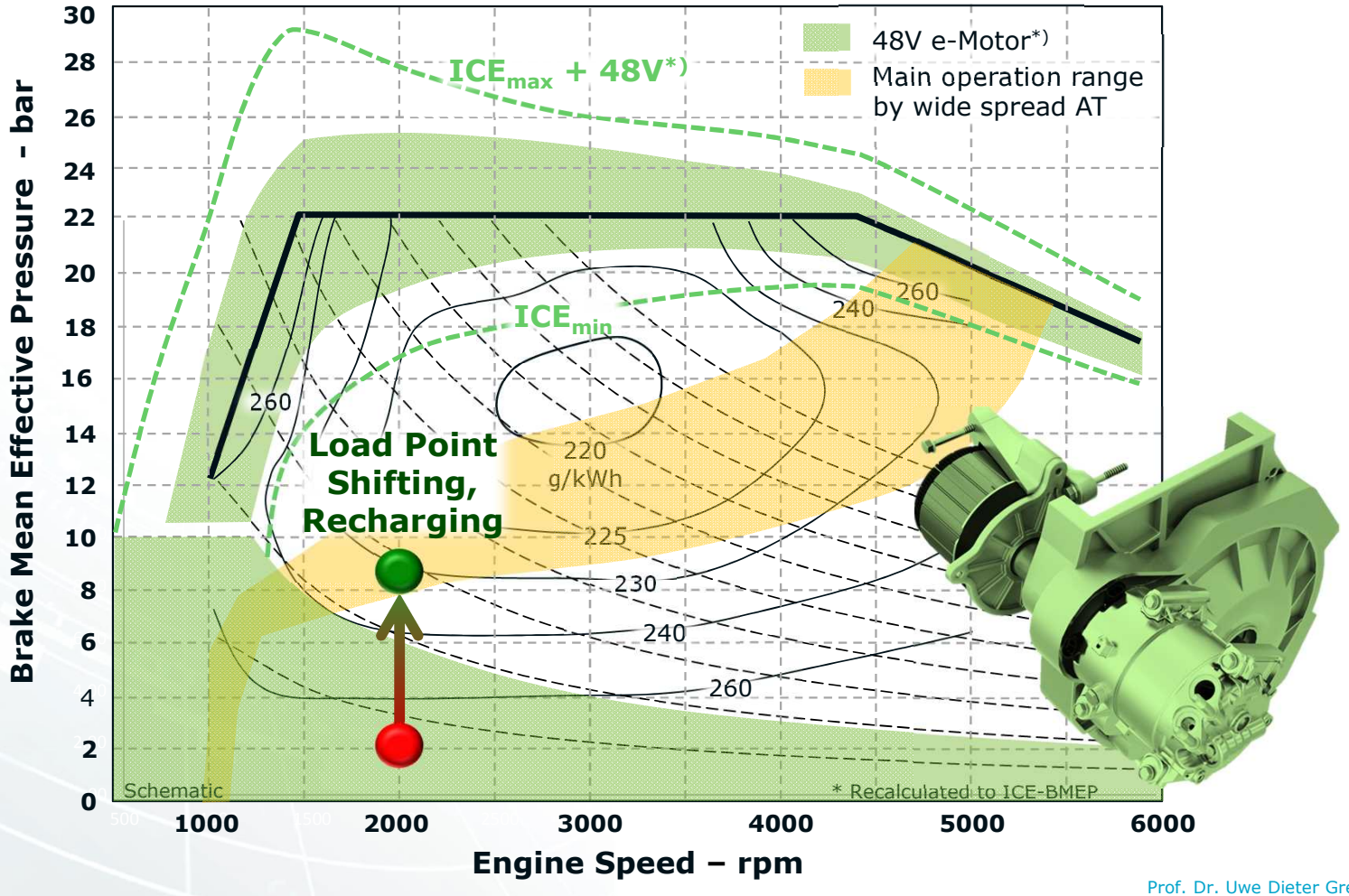
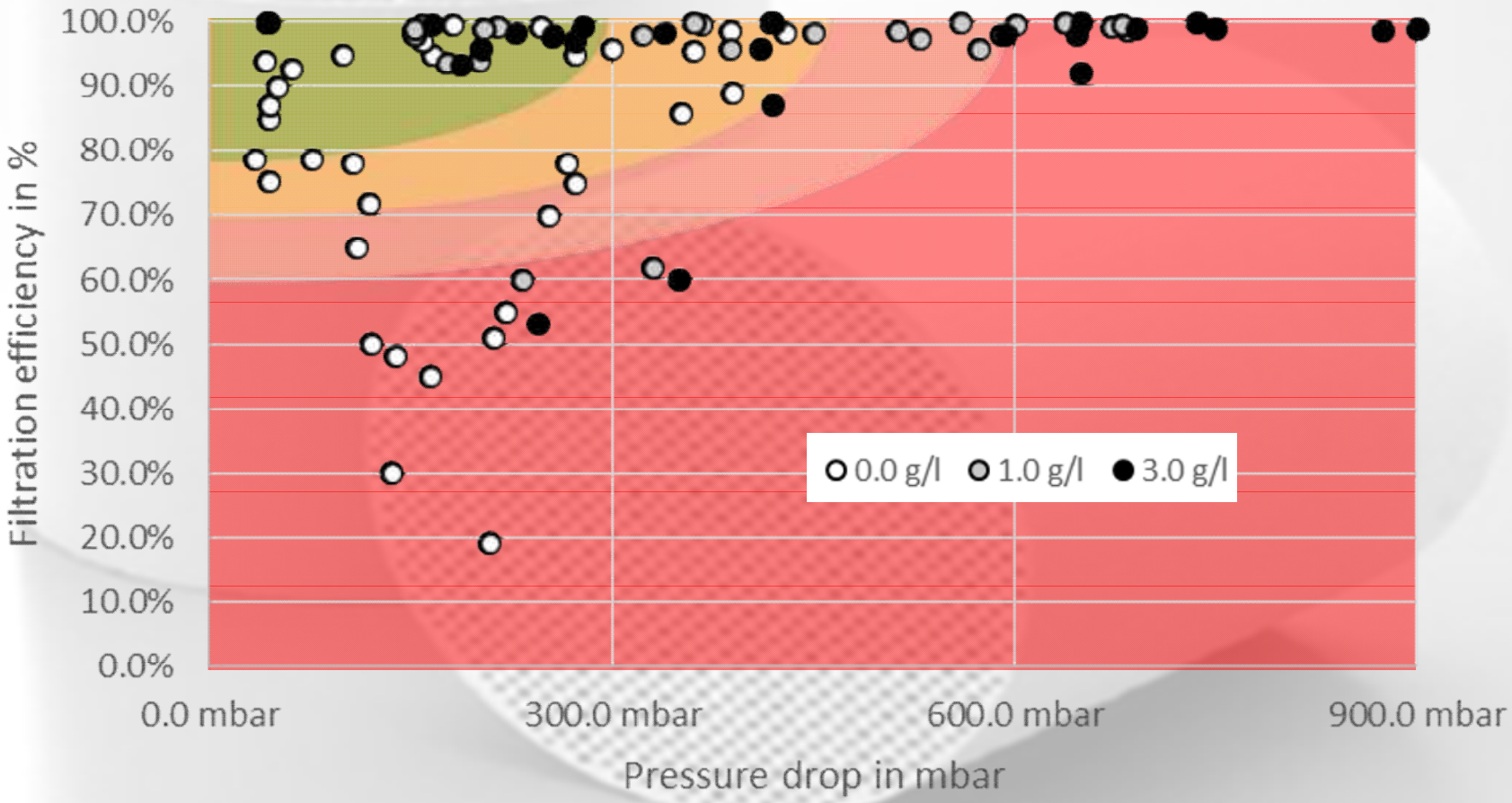
Electrification of ICE-Based Powertrains



Trade-off between Filter Efficiency and Exhaust Back Pressure with Different Soot Loadings



Charging
Overview Of Standards and Technology