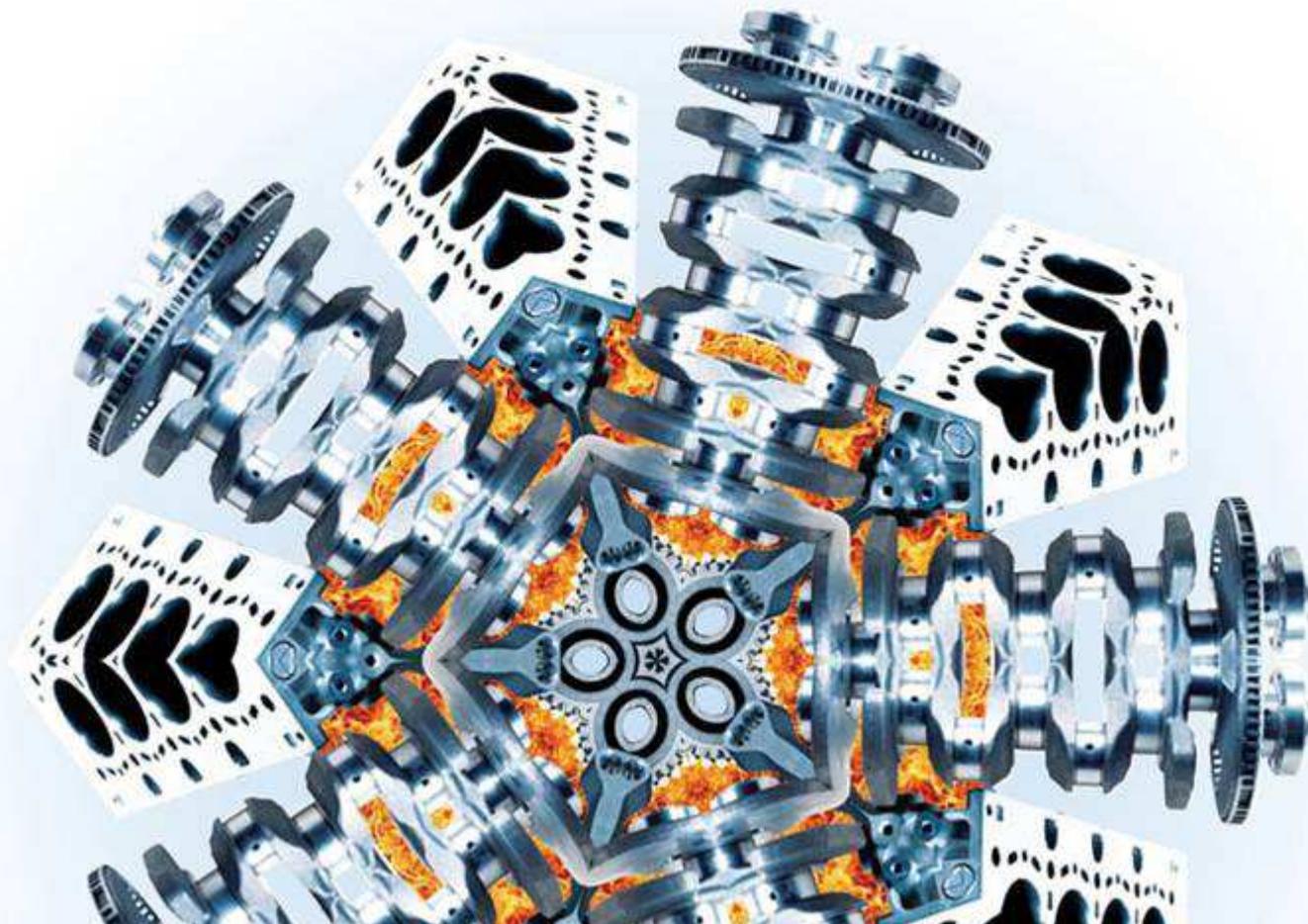


48V Mild Hybrid Systems

Market Needs and Technical Solutions



Ulf Stenzel
AVL Engineering and Technology





Content

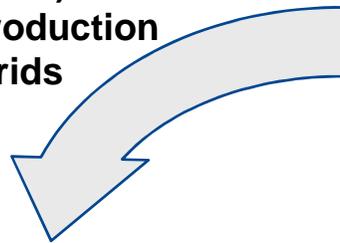
- 48V Market Situation & Needs
- 48V Powertrain Technologies and Challenges
- AVL's Project Examples



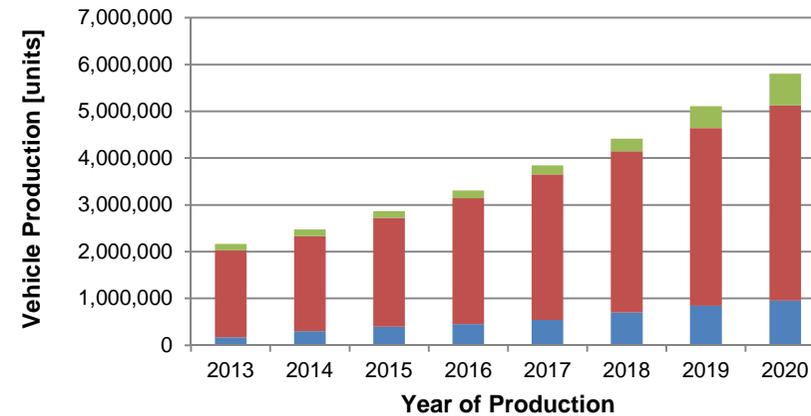
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Mild Hybrids – Global Market Overview

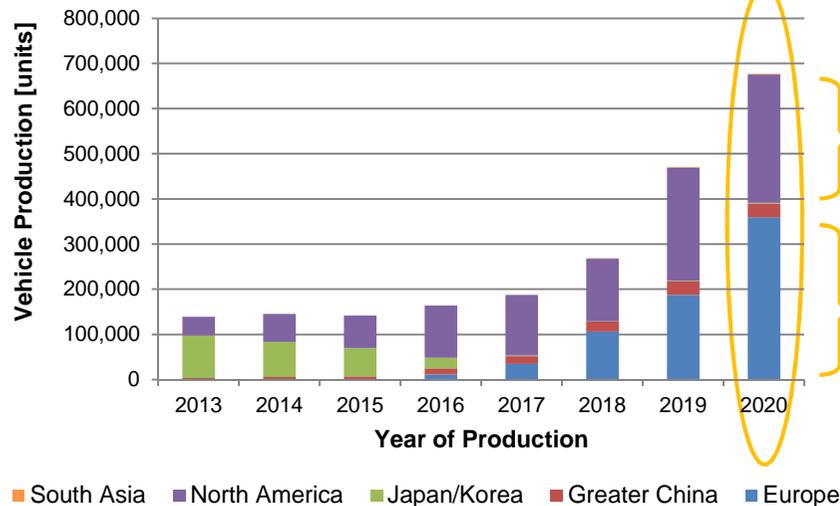
In 2020 → (10-15)% of global xEV production are Mild Hybrids



Global xEV Production



Mild Hybrids, per Region



Mild HEVs produced in NA in 2020 will most likely be dominated by High Voltage Systems

In 2020 almost all Mild HEV's produced from European OEMs are 48V Systems

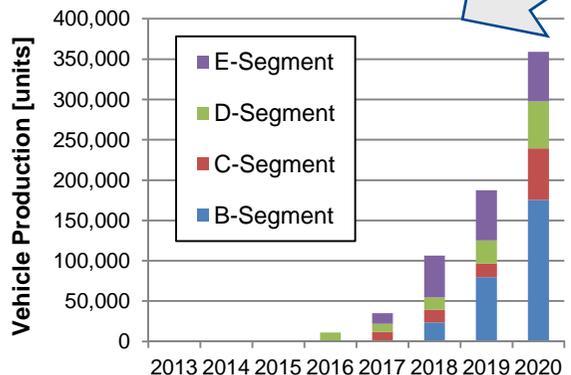
Source: IHS Q3 2013



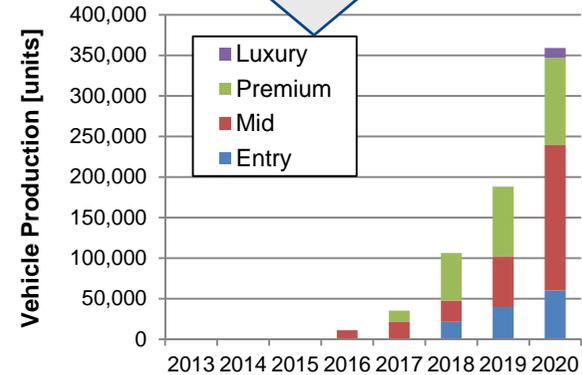
Mild Hybrids – Market Overview Europe

Mild Hybrids produced in Europe (of which 98% is 48V in 2020)

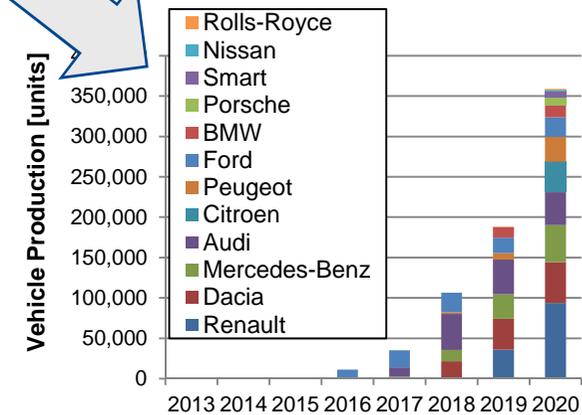
per Segment



Per Regional Sales Price Class



per Vehicle Brand



- No 48V applications in the A segment (e.g. Ford Ka, Chevrolet Spark) forecasted until 2020
- Significant 48V shares in larger vehicle classes and in the B segment (e.g. VW Polo)
- Early implementation in E segment vehicles (e.g. BMW 7 series, MB E-Class) (see 2018)

- Large share of 48V applications in the Mid (e.g. Renault Clio, Ford Mondeo) and Premium (e.g. BMW 7 series, Smart Forfour) segment
- Entry: e.g. Renault Duster, Dacia Logan
- Luxury: Porsche Macan, Rolls-Royce Ghost

- High share of German premium OEMs
- No share from Volkswagen projected
- No share from Fiat (and it's sub brands) forecasted until 2020

German OEMs are pushing for 48V

TITELTHEMA ENERGIEEFFIZIENZ

DIE NEUE SPANNUNGSEBENE 48 V IM KRAFTFAHRZEUG



Seite 8
LV 148
29.08.2011

2.3.2 Spannungen und Ströme

Berührungsbereich	60 V $U_{48hprotect}$
Überspannungsbereich	58 V U_{48r}
oberer Betriebsbereich mit Funktionseinschränkung	54 V $U_{48max,high,limited}$
	52 V $U_{48max,unlimited}$
Betriebsbereich ohne Funktionseinschränkung	48 V U_{48n}
	36 V $U_{48min,unlimited}$
unterer Betriebsbereich mit Funktionseinschränkung	24 V $U_{48min,low,limited}$
Unterspannungsbereich	20 V $U_{48stoprotect}$

Abbildung 1: Definitionen der statischen Spannungsbereiche

Berührungsbereich
In diesem Bereich ist für Gleichspannungen nach ECE-R 100 ein Berührungsschutz erforderlich.

Überspannungsbereich
Zwischen $U_{48max,high,limited}$ und U_{48r} liegt der Überspannungsbereich inkl. aller Toleranzen. In diesem Bereich soll der Überspannungsschutz aktiv sein und Spannungen größer $U_{48max,high,limited}$ müssen durch einen Fehlerspeichereintrag protokolliert werden.

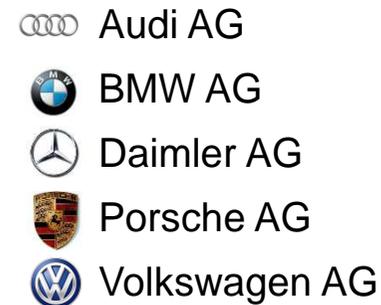
Der Bereich zwischen U_{48r} und $U_{48stoprotect}$ beinhaltet die Sicherheitsreserve.

Oberer Betriebsbereich mit Funktionseinschränkung
Der Bereich zwischen $U_{48max,unlimited}$ und $U_{48max,high,limited}$ ist für die Kalibrierung des Speichers und die Aufnahme von Rückspeiseenergie vorgesehen.

Die steigenden Anforderungen an die elektr. 12-V-Bordnetz an seine Grenzen geföh und Volkswagen wurde das Thema 48 V I Spannungsebene wurde erarbeitet. Die OI tung des Spannungsbereichs und die Kon dieser Spannungsebene möglichen Komp für eine Standardisierung und Normung d

20

- The LV 148 standard defines a 48V power supply system including its functions and interfaces.
- The standard describes all relevant electrical requirements and test procedures for the new 48V components
- It is defined by the big 5 German automakers and shows a clear trend out of Europe to push 48V technology towards production.
- These five OEMs have been involved:

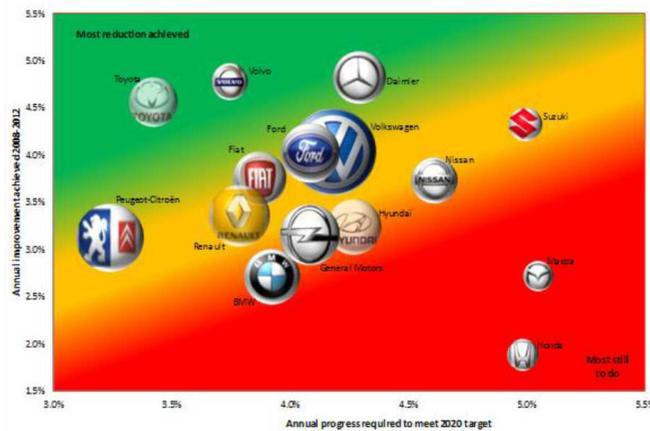




Past and Future Progress to meet the 2020 Target

Ranking	Progress as % year on year		
	2000-2008	2008-2012	2012-2020
1 Peugeot-Citroën	1.9%	3.1%	3.2%
2 Toyota	1.8%	4.6%	3.4%
3 Volvo	n/a	4.8%	3.7%
4 Renault	1.5%	3.4%	3.8%
5 Fiat	1.6%	3.8%	3.9%
6 BMW	3.6%	2.7%	3.9%
7 General Motors	0.8%	3.2%	4.1%
8 Ford	2.4%	4.0%	4.1%
9 Volkswagen	0.6%	4.0%	4.2%
10 Hyundai	2.8%	3.2%	4.3%
11 Daimler	1.5%	4.8%	4.3%
12 Nissan	1.0%	3.7%	4.6%
13 Honda	3.0%	1.9%	5.0%
14 Suzuki	1.3%	4.3%	5.0%
15 Mazda	2.1%	2.7%	5.1%
All Manufacturers	1.4%	3.6%	4.1%

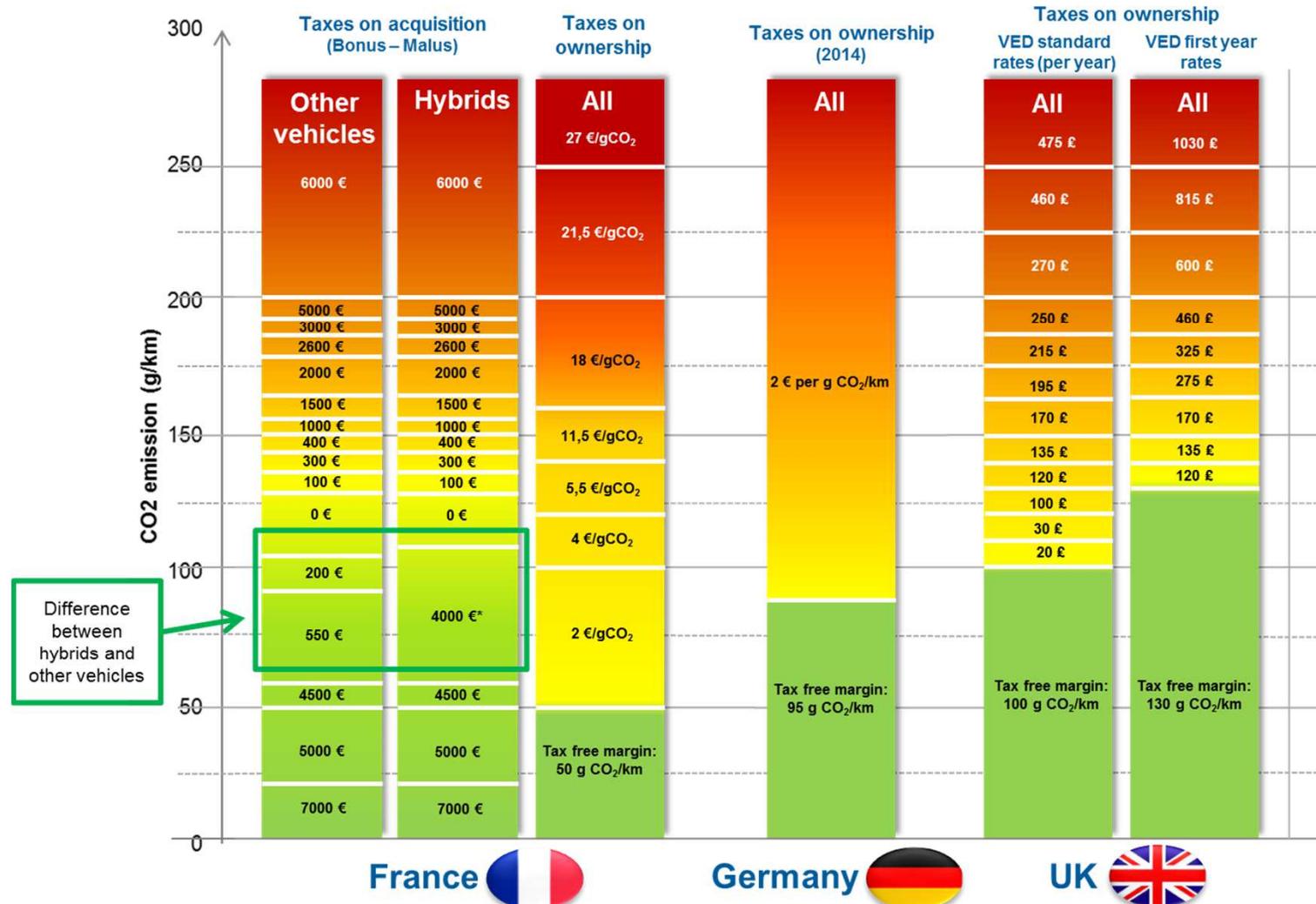
- Overall the required rate of progress to the proposed 2020 targets is slightly greater (4.1%pa) than the rate that has already been achieved over the past five years (3.6%pa).
- However, these figures do not include the effect of flexibilities (i.e. supercredits) that effectively provide free grams. Carmakers are therefore even closer to achieving targets than the data suggests.
- The clear conclusion is that the 2020 target is achievable for makers of all types and sizes of cars with appropriate planning and introduction of fuel consumption reduction measures.



Source: European Federation for Transport and Environment (T&E)



Taxes and Incentives for Mild Hybrids in Europe

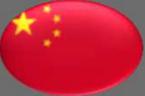


* The bonus amounts to a minimum of 2000€ but cannot exceed 10% of the vehicle purchase price including VAT, increased if necessary by the battery cost, if the latter is rented.

Definition of Hybrids according to Legislation by Region

From ECE R101: ... means a vehicle,.... that, *for the purpose of mechanical propulsion*, draws energy from both of the following on-vehicle sources of stored energy/power:

- (a) a consumable fuel;
- (b) a battery, capacitor, flywheel/generator or other electrical energy/power storage device

	EU 	USA 	CHN 	JPN 	KOR 
12V ST/ST SIN	X	X	X	X	X
12V ST/ST SIG w/o TA	X	X	X	X	X
12V ST/ST SIG with TA	✓	✓ ⁽¹⁾	✓ ⁽¹⁾	✓ ⁽²⁾	✓
48V Alternator (aux. supply only)	X	X	X	X	X
48V Mild HEV	✓	✓ ⁽¹⁾	✓ ⁽¹⁾	✓ ⁽²⁾	✓

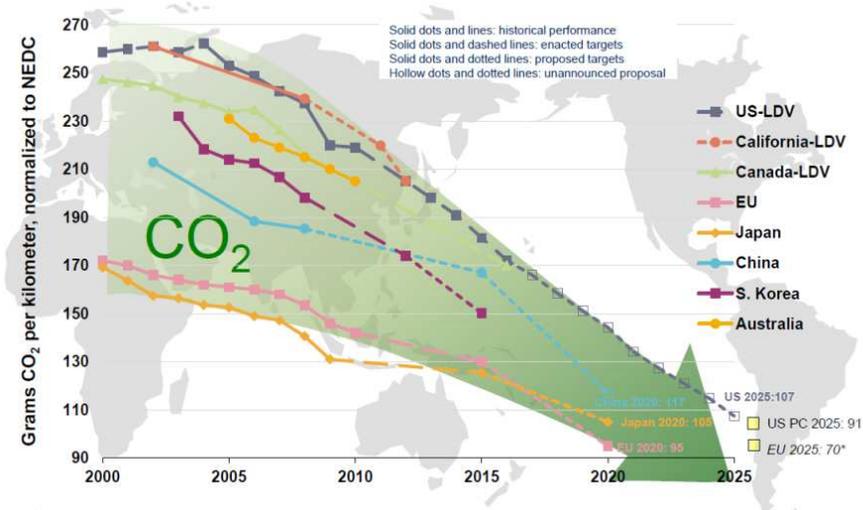
SIN...Start in Neutral
SIG...Start in Gear

TA... Torque Assistance

⁽¹⁾ Yes, if energy storage is rechargeable

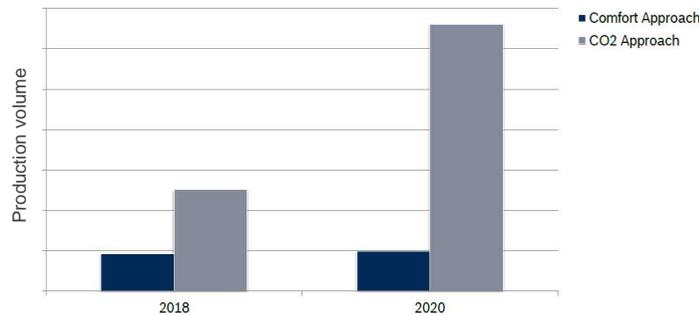
⁽²⁾ Yes, if rechargeable and kinetic energy converter

48V Main Drivers – Summary



- Reduction of CO₂ emission to meet future emission legislation
- Comfort enhancement and new functions
- Less integration effort, weight & cost, compared to HV systems (safety, battery)

Market Potential 48V Power-Nets 2018 and 2020



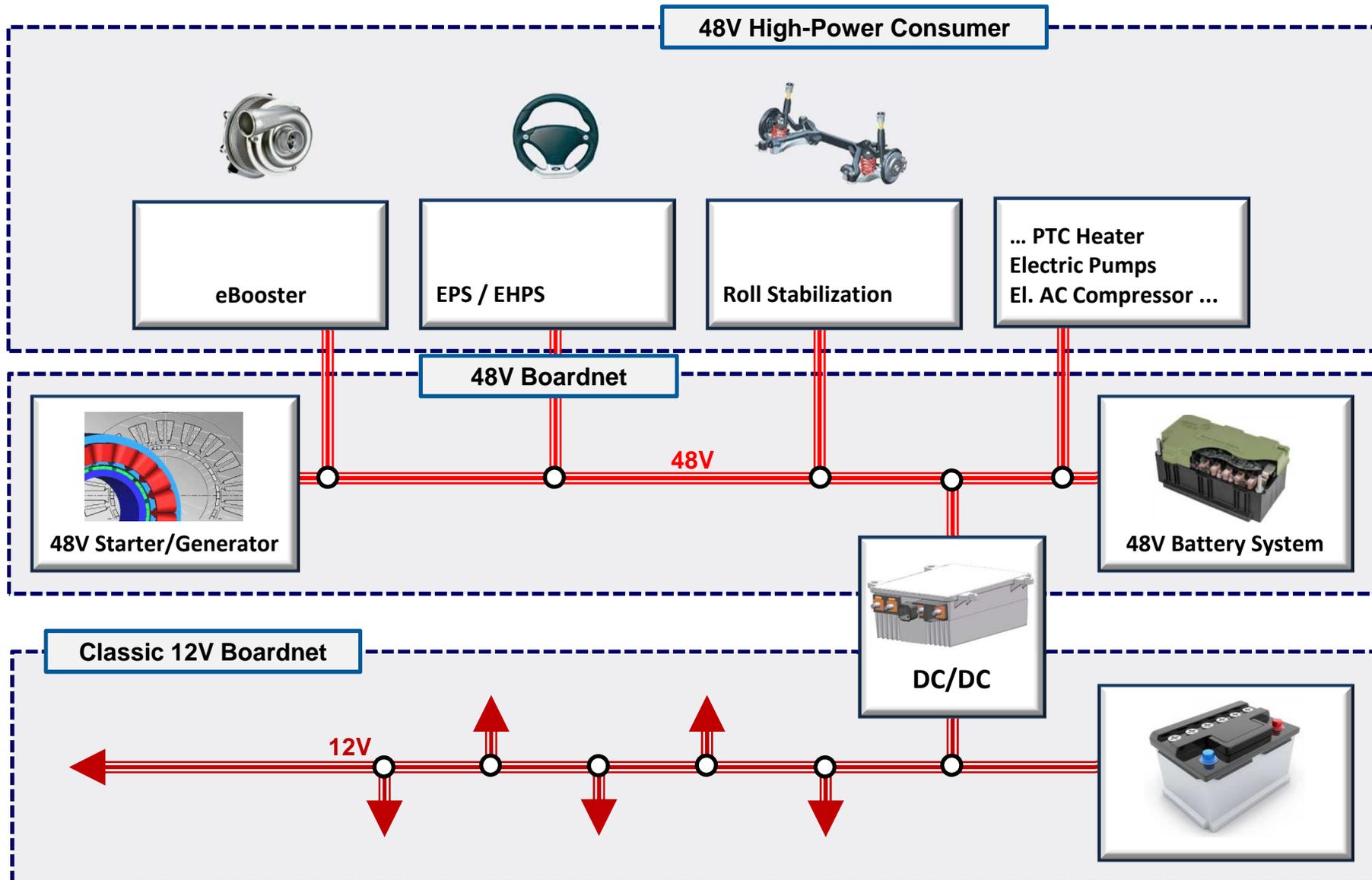
Source: Bosch on „48V Power Supply“ Conference 2013

48V systems have the potential to fill the gap between state-of-the-art 12V Start/Stop systems and high voltage hybrid powertrains.

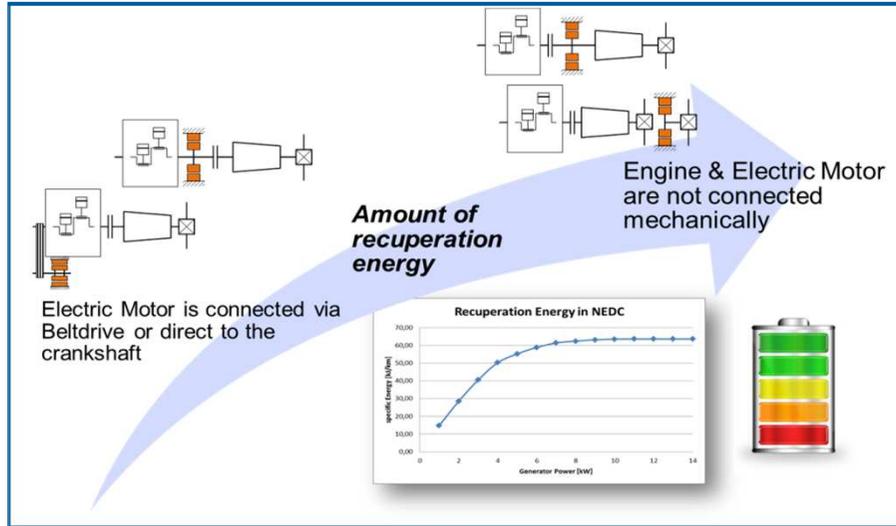


- 48V Market Situation & Needs
- 48V Powertrain Technologies and Challenges
- AVL's Project Examples

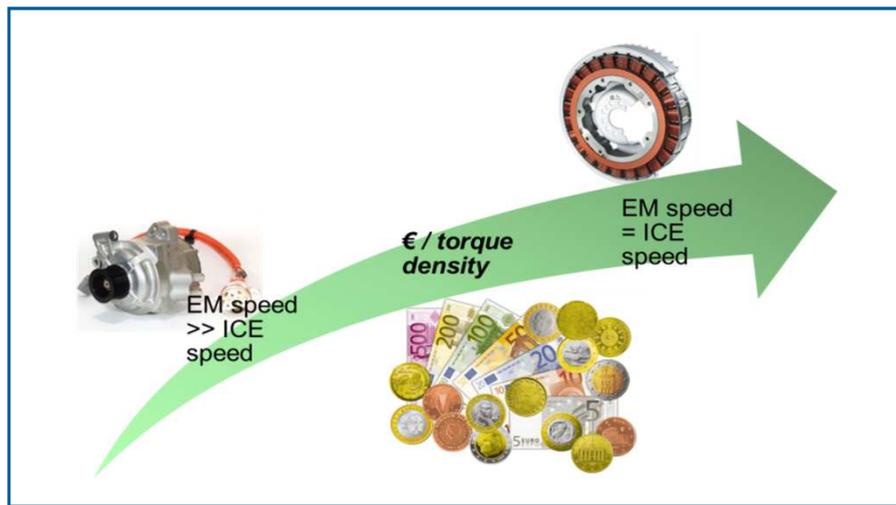
12V/48V Electrical Architecture



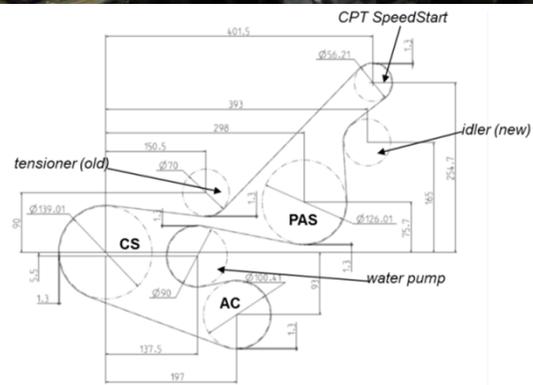
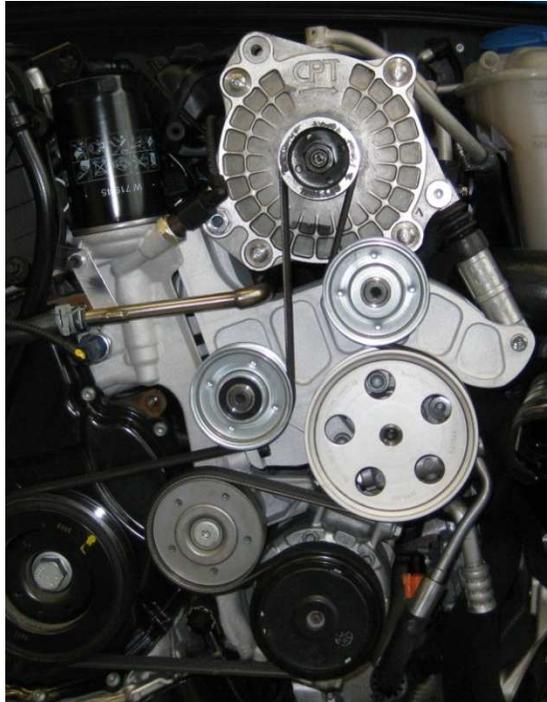
E-Machine Integration



- The integration of the E-machine defines the recuperation potential; the engine drag torque reduces the amount of recuperative energy (P2 versus P1/BSG)
- Cost advantage high speed E-machine (BSG) versus high torque (ISG); high torque density leads to higher cost
- Integration cost & effort; package (ISG, P2), transmission modification (P2)
- Preferred system architectures, functionalities and the resulting cost to benefit ratios are depending on vehicle class & vehicle application

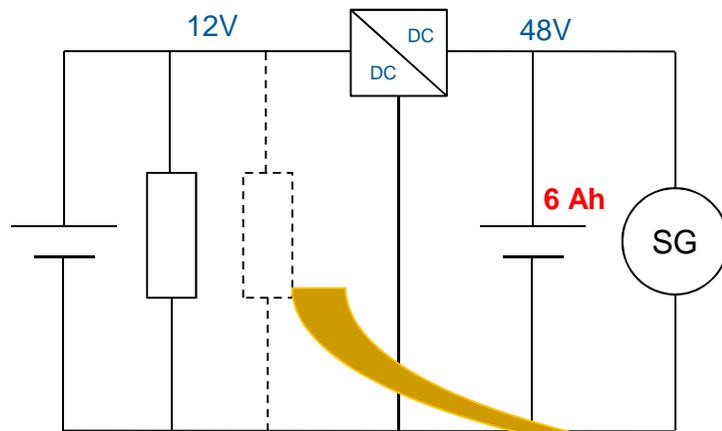


BSG Integration Challenges - Impact on Engine

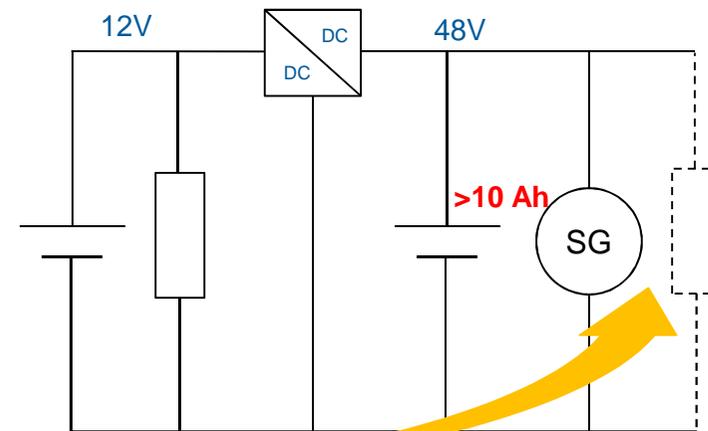


- FEAD Design
 - Belt Durability
 - Variable Belt Tensioner
 - Increase tension during cranking and boost (machine to engine)
 - Increase tension during recuperation (engine to machine)
 - Reduce tension during normal driving to reduce friction loss
 - NVH
 - Belt chirp during cranking
- Crankshaft Main Bearing
 - Durability

48V Electrical Load Migration – Impact on eStorage

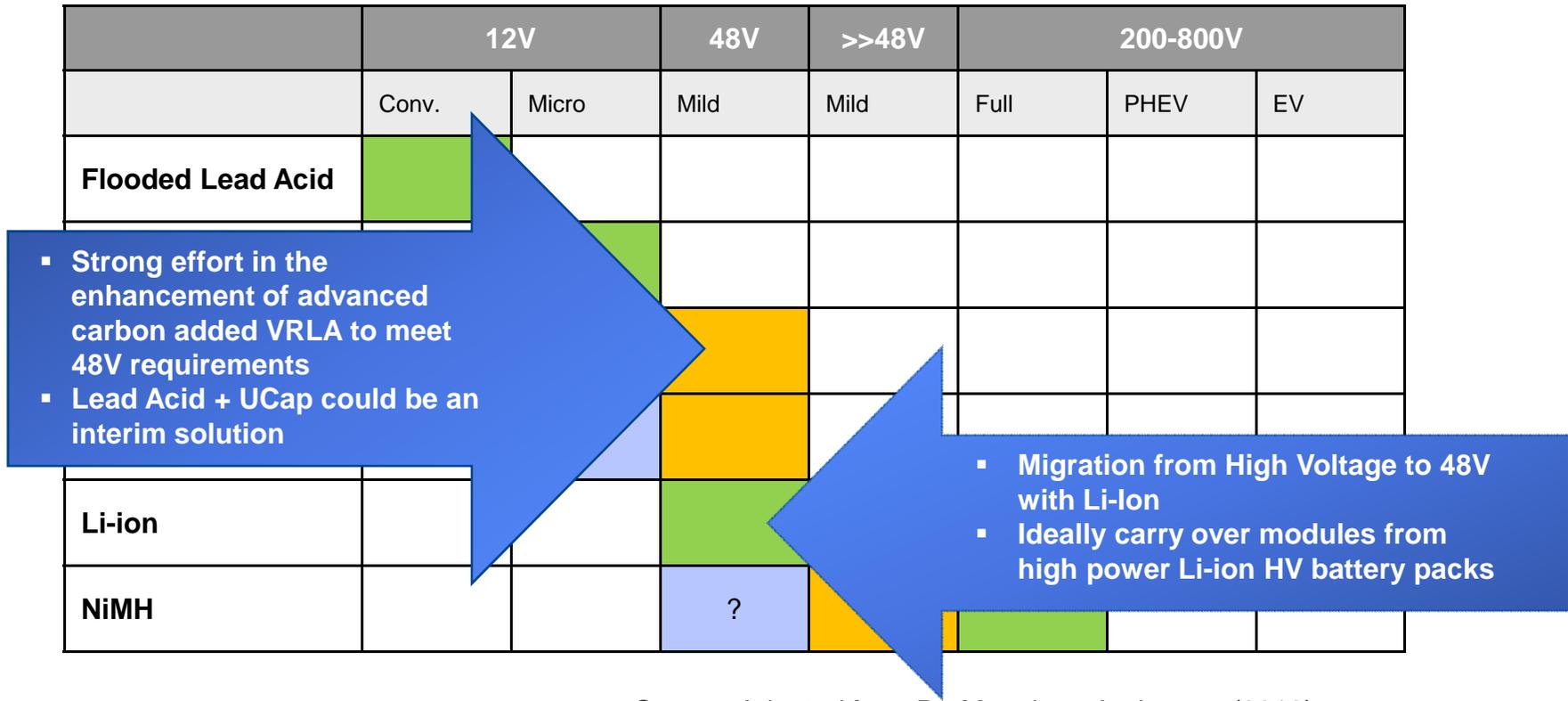


CO₂ reduction only
Start/Stop, Boost, Recuperation



Electrical Load Migration
Chassis Control, Climate
Comfort, Engine Components
Electrification, eBooster, etc...

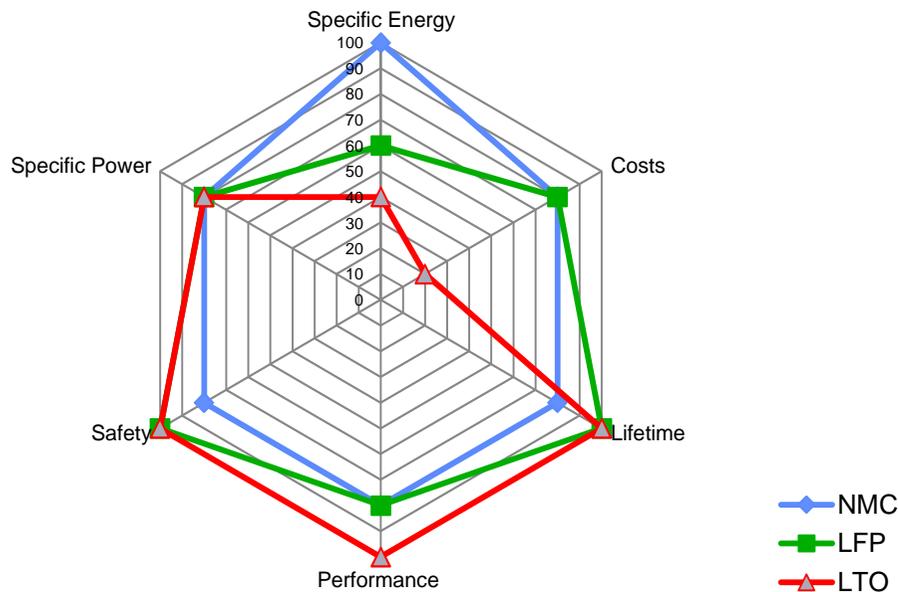
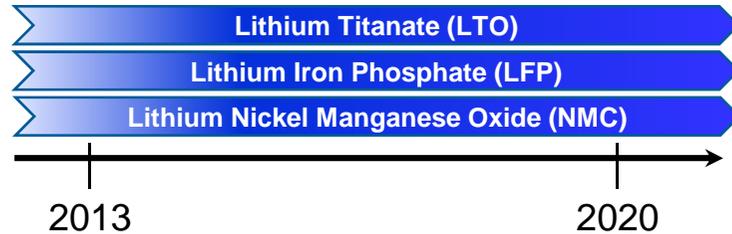
Powertrain Key Components – eStorage System



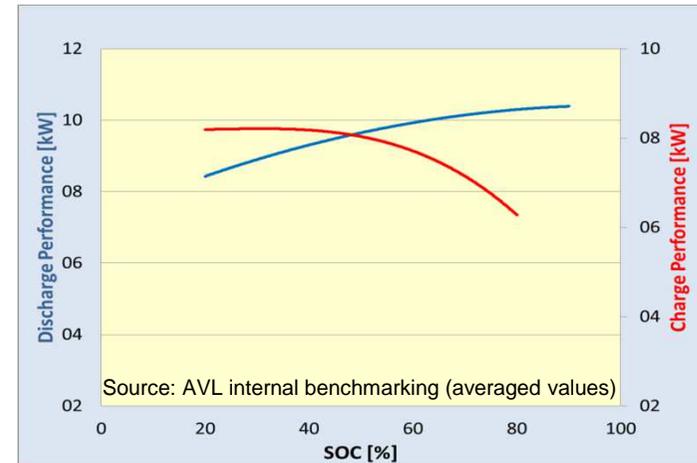
Source: Adapted from Dr. Menahem Anderman (2013)

Legend:	<i>Dominating</i>	<i>Potential</i>	<i>Candidate</i>
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48V Li-Ion Battery Technology Roadmap

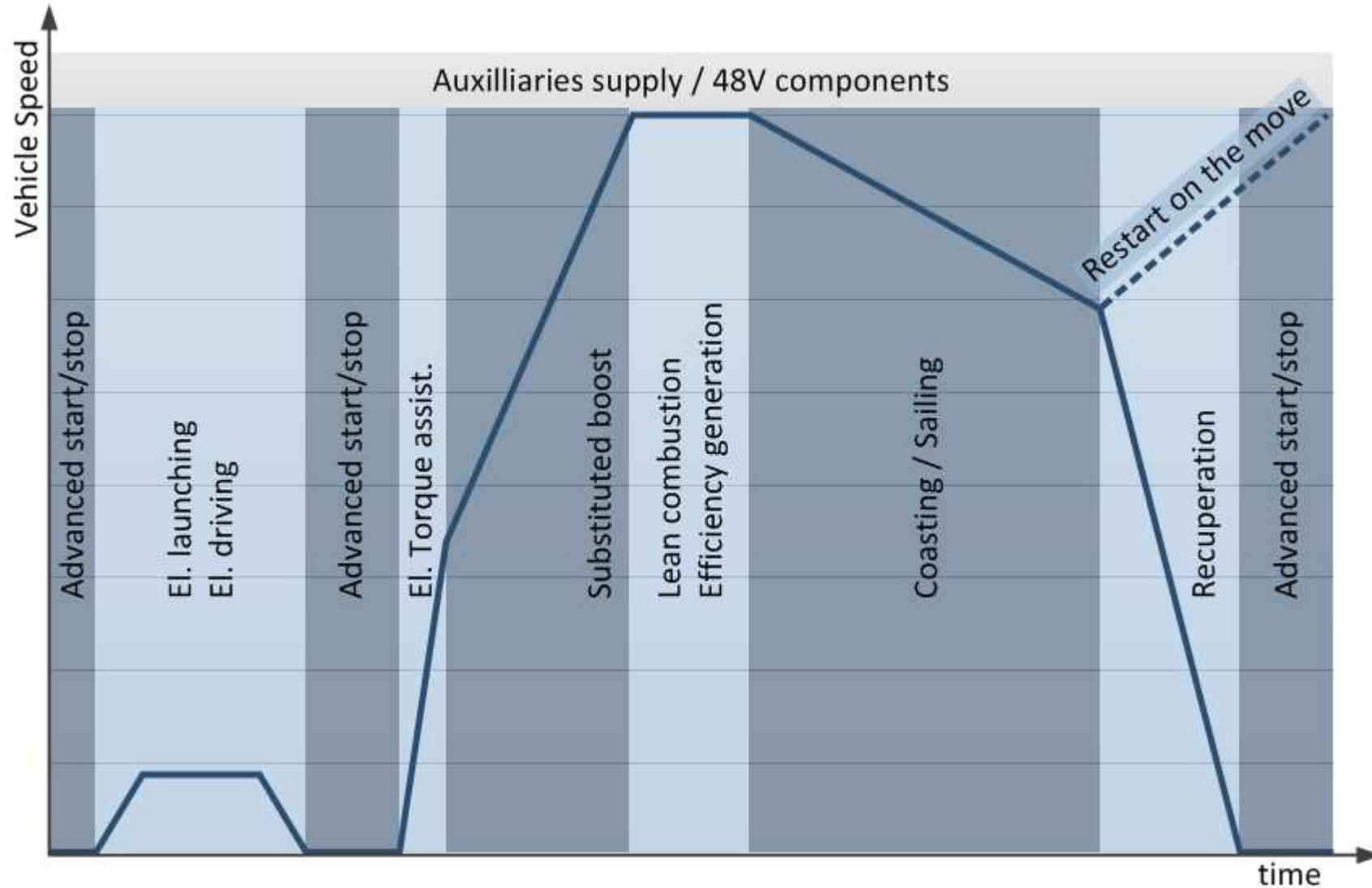


- The cell performance varies across cell technologies

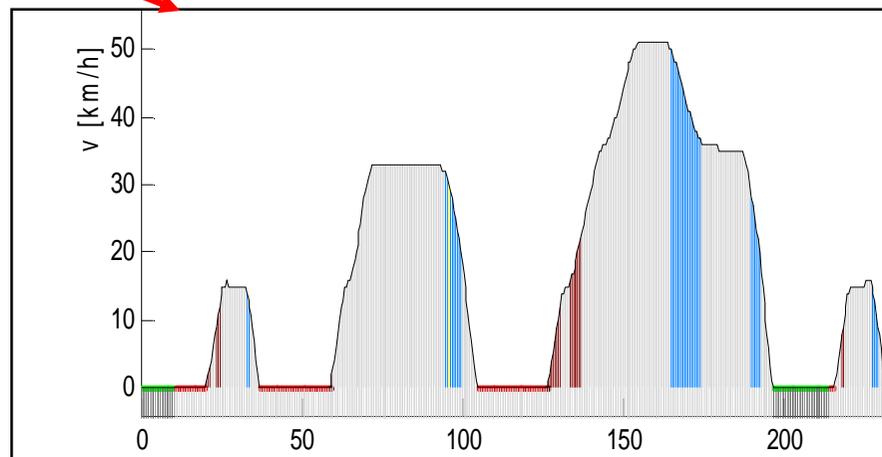
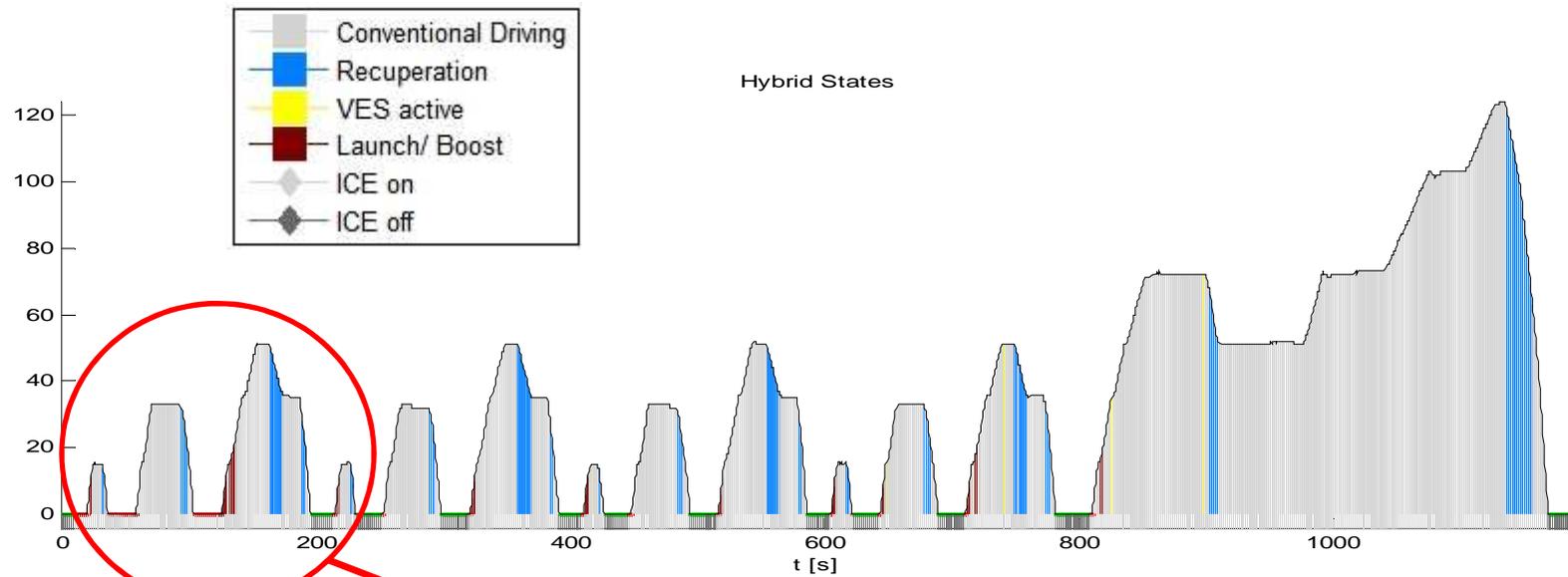


- NMC & LFP cathode materials fulfil current 48V automotive requirements in terms of performance and safety and will be the dominating Lithium-ion technologies in 48V applications
- LTO (lithium titanate oxide) anodes show excellent life, low temperature performance, safety but lead to high system costs

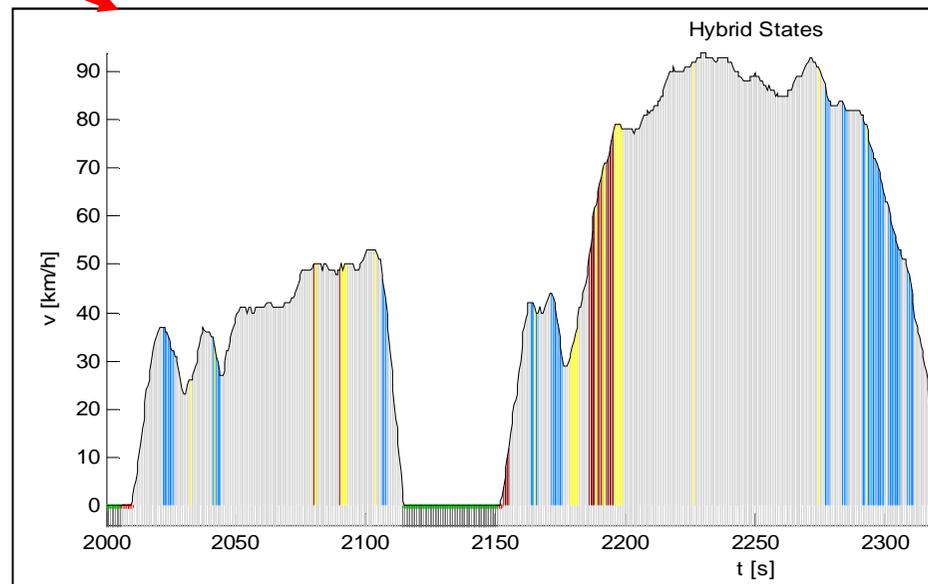
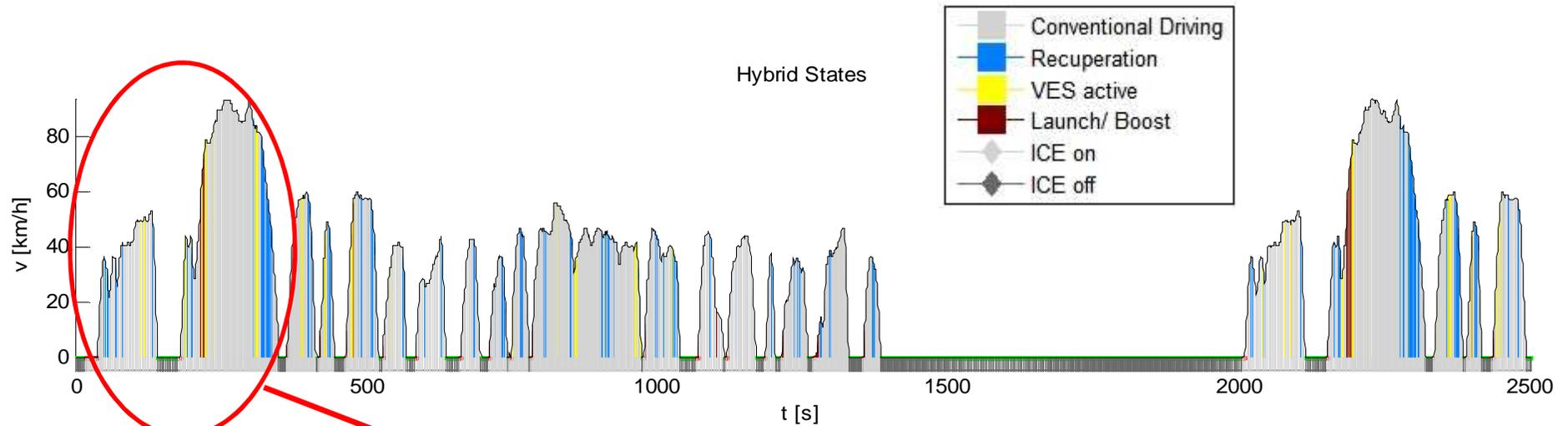
Overview 48V Main Functions



ADV. 48V FUNCTIONALITIES IN LEGAL CYCLES – NEDC



ADV. 48V FUNCTIONALITIES IN LEGAL CYCLES – FTP

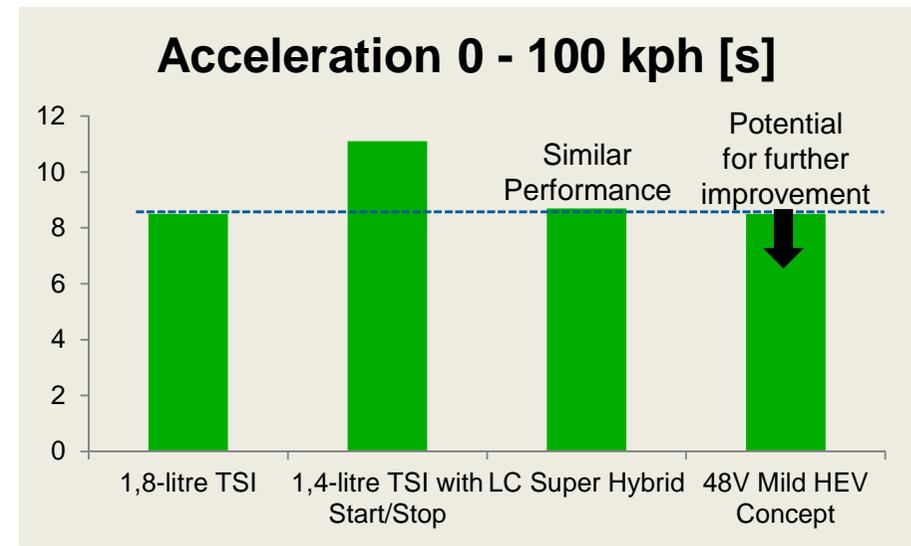
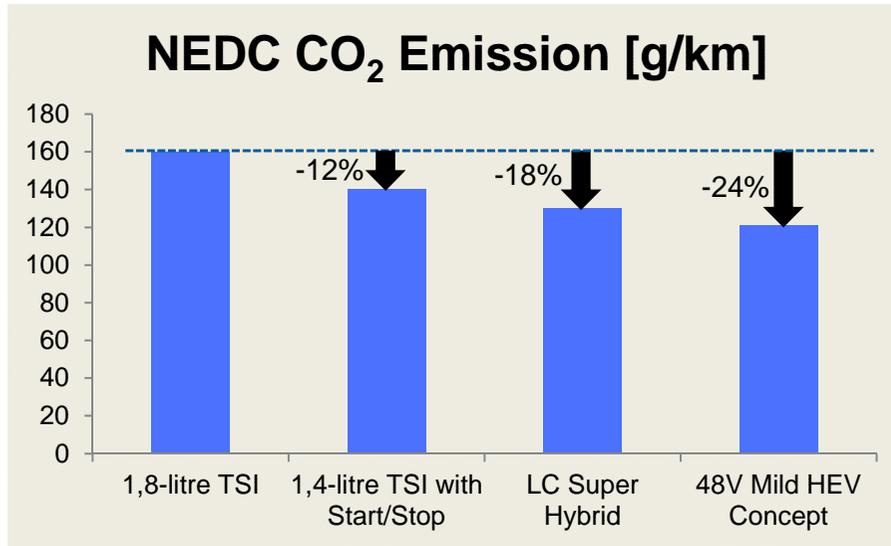




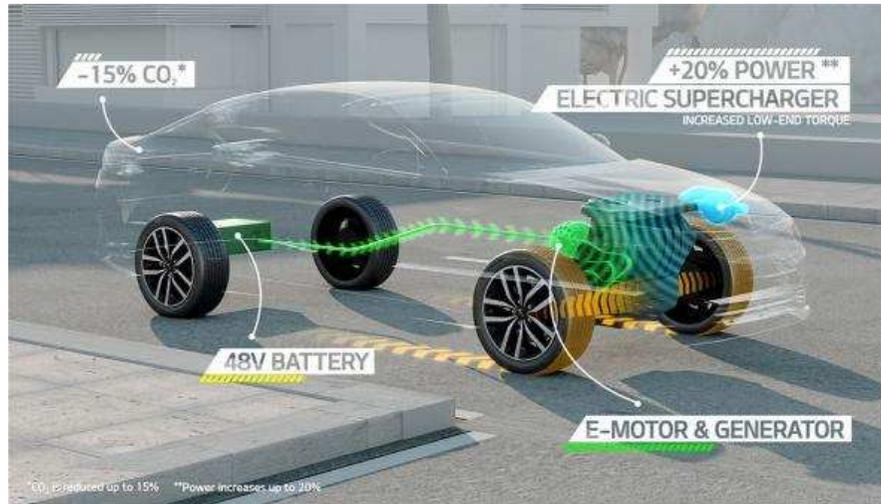
Content

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The "TWINS": 12V and 48V LC Super Hybrid



48V Advanced Lead Carbon Battery Diesel Hybrid Prototype Project Overview



Features:

48V mild hybrid with Belt Starter Generator (BSG) & electric supercharger (VES)

- +20% Power
- -15% CO₂

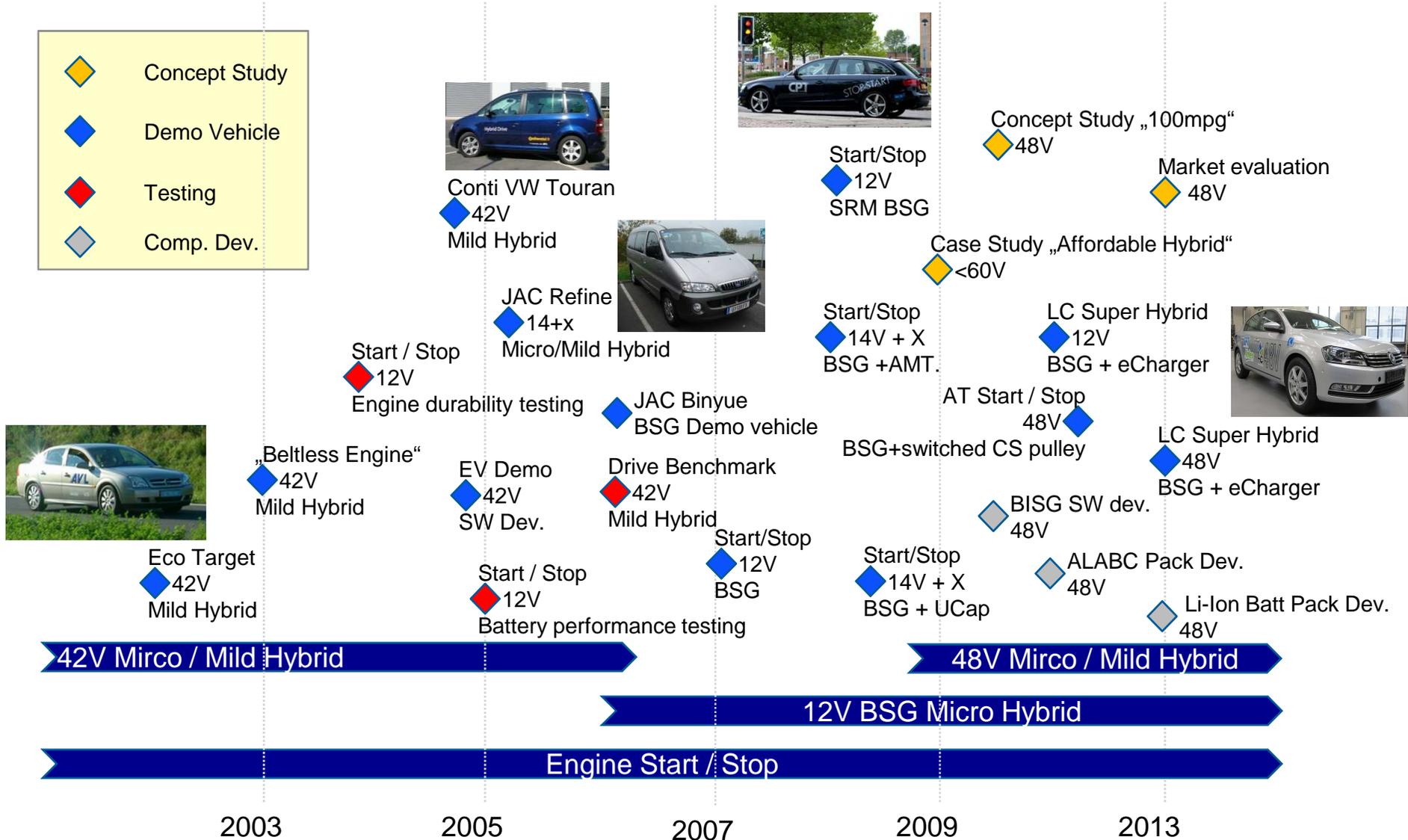


Engine update for BSG
Controls / Operating Strategy
Demo Vehicle Built & Calibration



AVL Engineering Project History since 2002

-  Concept Study
-  Demo Vehicle
-  Testing
-  Comp. Dev.





Summary

- In 2020 almost all Mild HEV's produced from European OEMs are 48V Systems. German OEMs are pushing towards 48V
- Implementation of new 48V HEV functions into an existing platform requires a systematic approach and an independent holistic view on the powertrain architecture and components
- Interdependencies between components need to be fully understood to avoid undesirable impact on:
 - ...Emissions and fuel consumption
 - ...Performance
 - ...Drivability / comfort
 - ...Energy mgmt. / charge balance



**Thank you
for your
Attention!**

