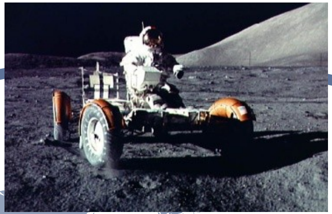
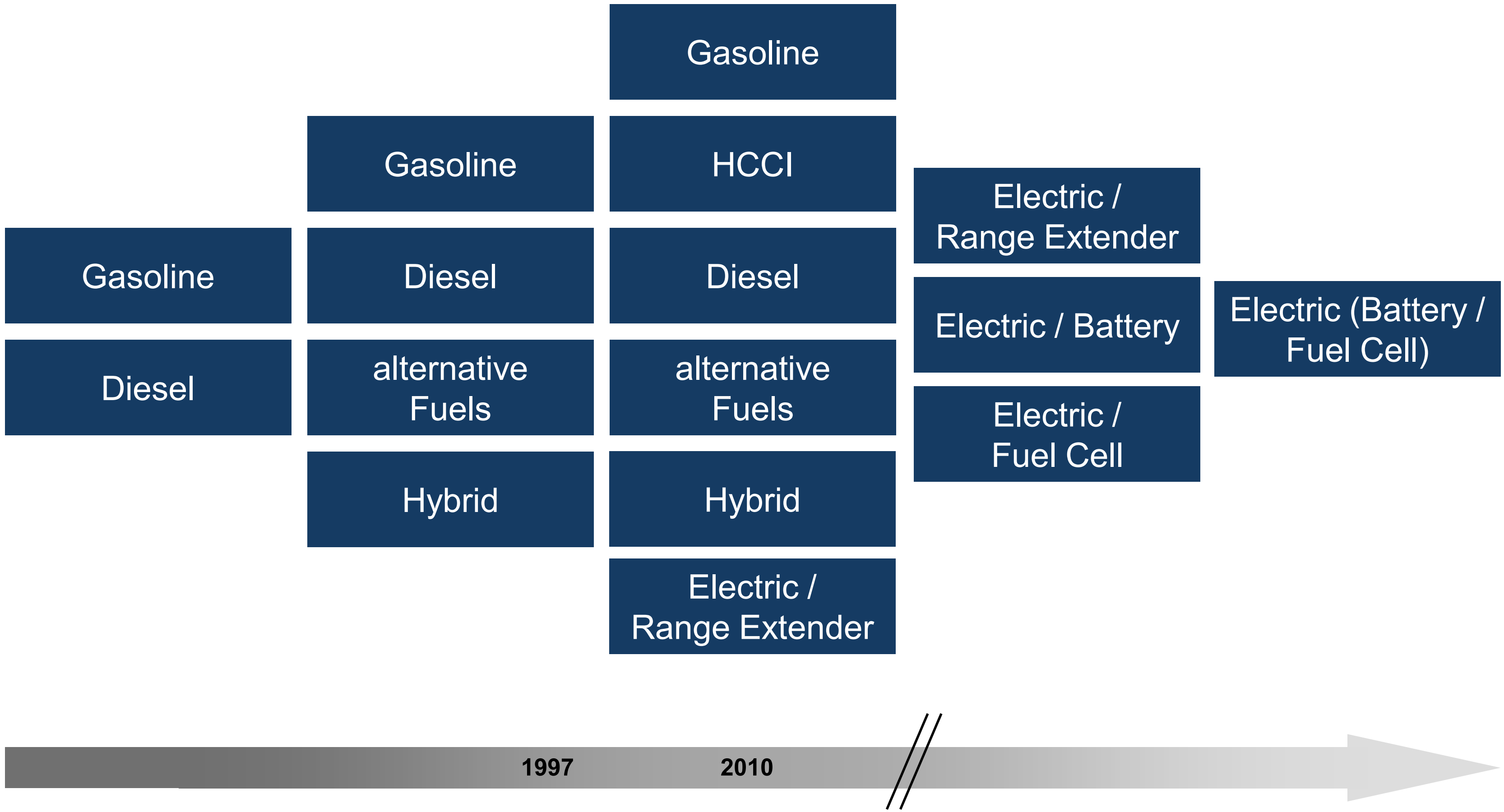


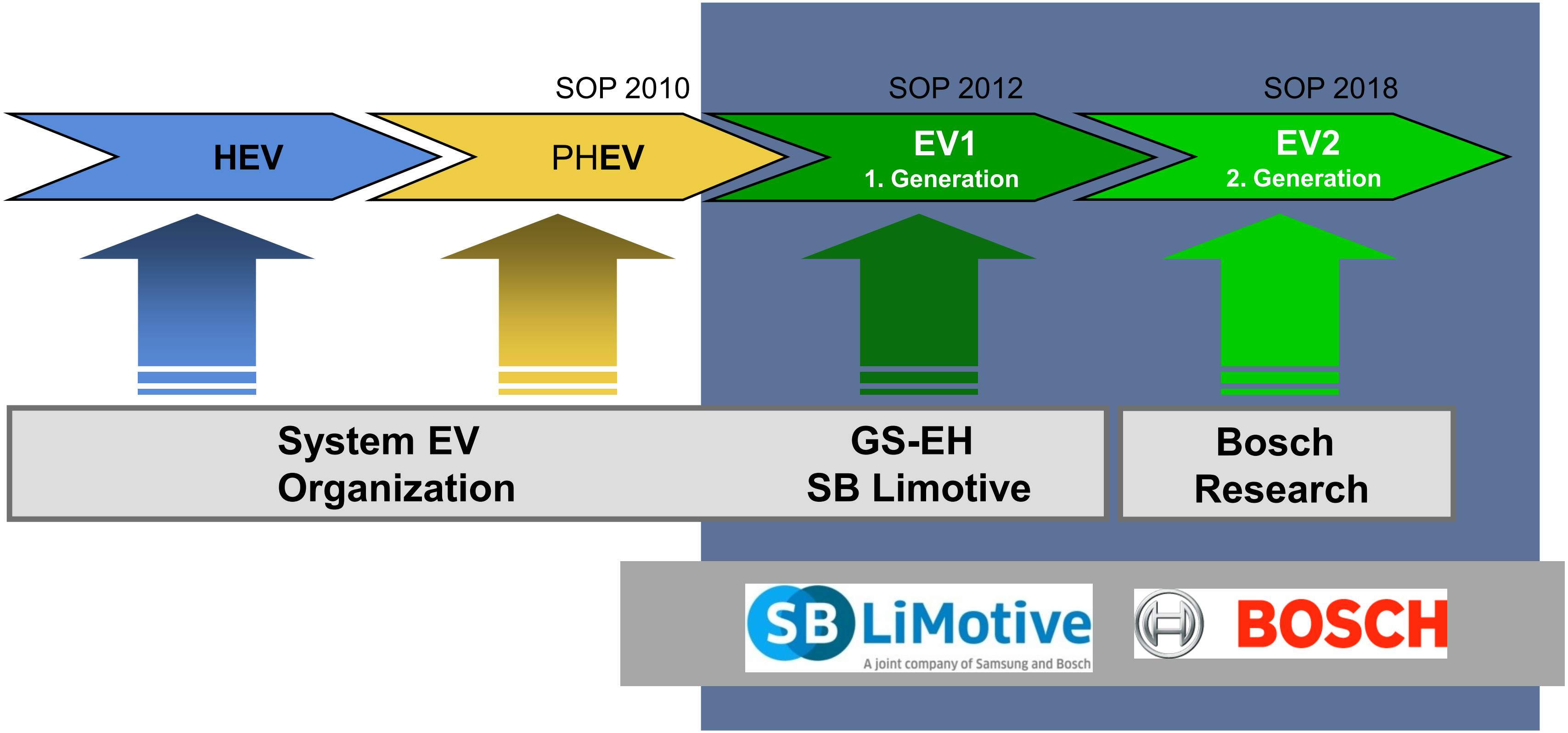
Battery will drive the world ? and when ?

EV - Storage Module and BMS - Roadmap

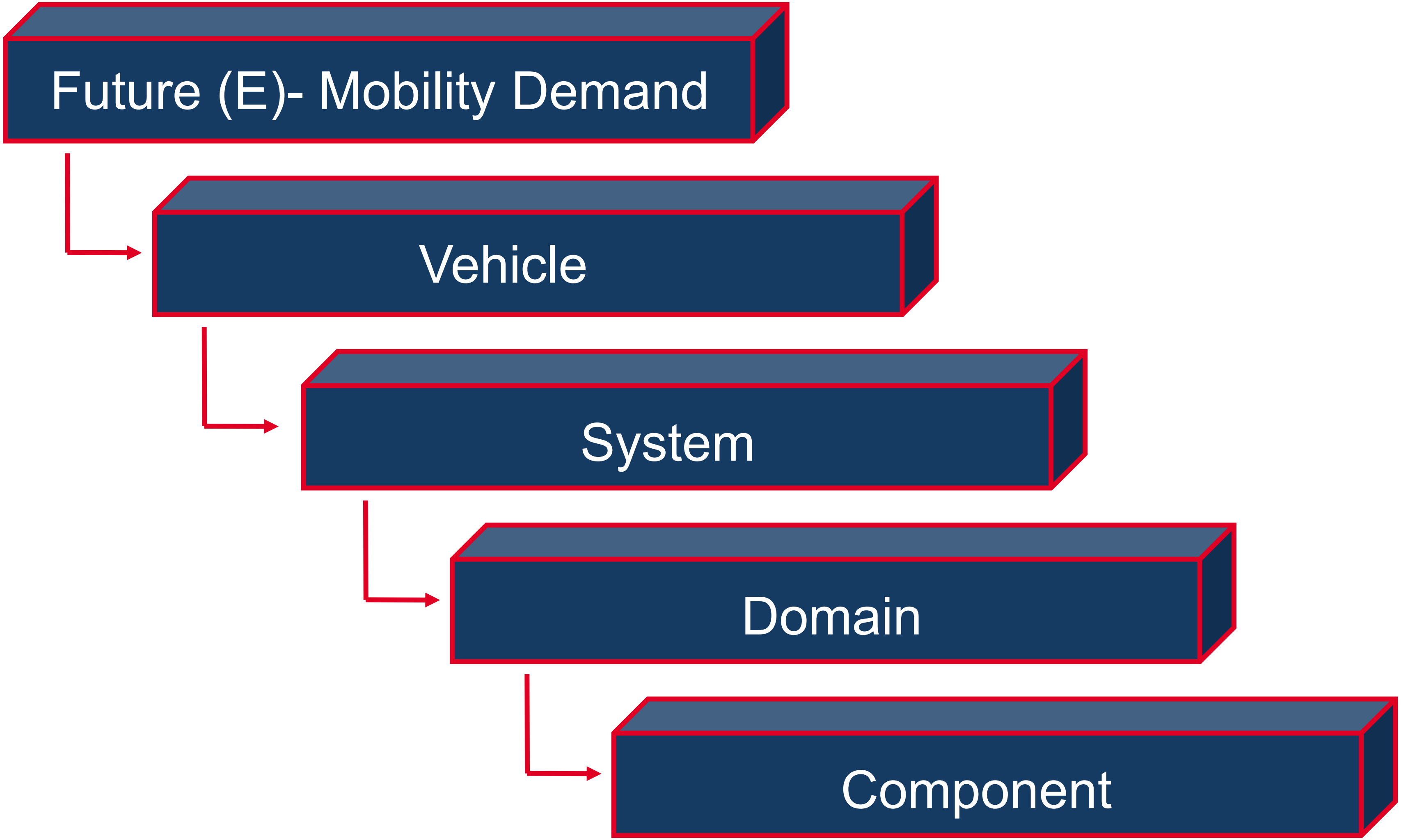
The “Powertrain-Map”



Development Roadmap E-Mobility



EV - Storage Module and BMS - Roadmap



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EV - Storage Module and BMS - Roadmap

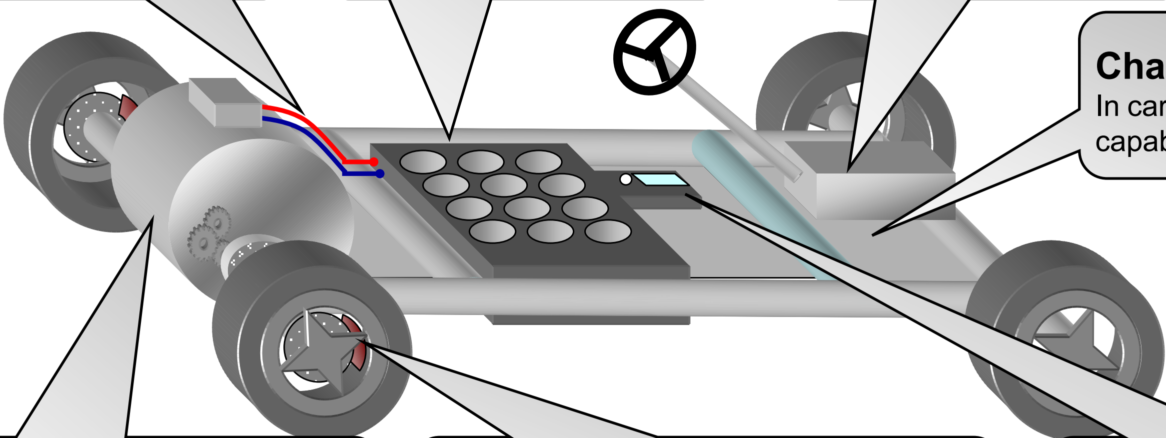
EV System

E/E-Architecture
Reduced number of ECUs

Battery
Increase energy density by factor 2-3 & lower cost

Accessories
Electric assisted, efficient

Charger
In car charging capability



Infrastructure
i.e. fast charger, battery change station, vehicle to grid, car multimedia etc.

Drive
Evaluation and definition of best drive topology

Braking + Vehicle Dynamics
- Recuperation with electric drives
- Application of ESP + ABS

Thermal Systems
Minimize energy consumption of HVAC by factor 3-4

→ **The Battery Module is one component in highly integrated system**

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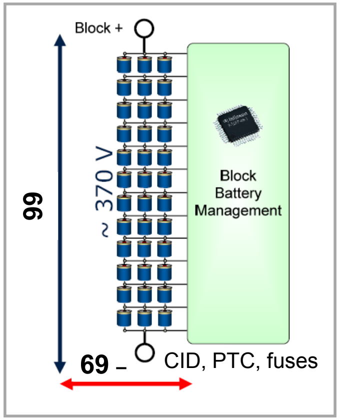
Example State of the Art Energy Storage Systems

Tesla Roadster (EV) Battery

- 150 Ah | 366 V | 53 kWh | 200 kW | 450 Kg
- 6831 2.2Ah (Panasonic?) 18650 type cells
- 99 cells in series and 69 cells in parallel
- Passive safety for the cells in parallel
- 7 years pack lifetime and 500 full cycles (160,000 km)
- Since 2008: 250+ produced and 1000+ reserved



Mercedes S-Class (HEV) Battery

- 6.5 Ah | 126 V | 0.8 kWh | 19 kW | 25 Kg
- 35 Johnson-Control Saft cells / Pack design - Continental
- Cells are connected in series
- Active safety – single cell supervision
- 10 years pack lifetime and 600.000 shallow cycles (160,000 km)
- Middle of 2009 can be purchased

→ not many Li-Ion Application on the Road Today

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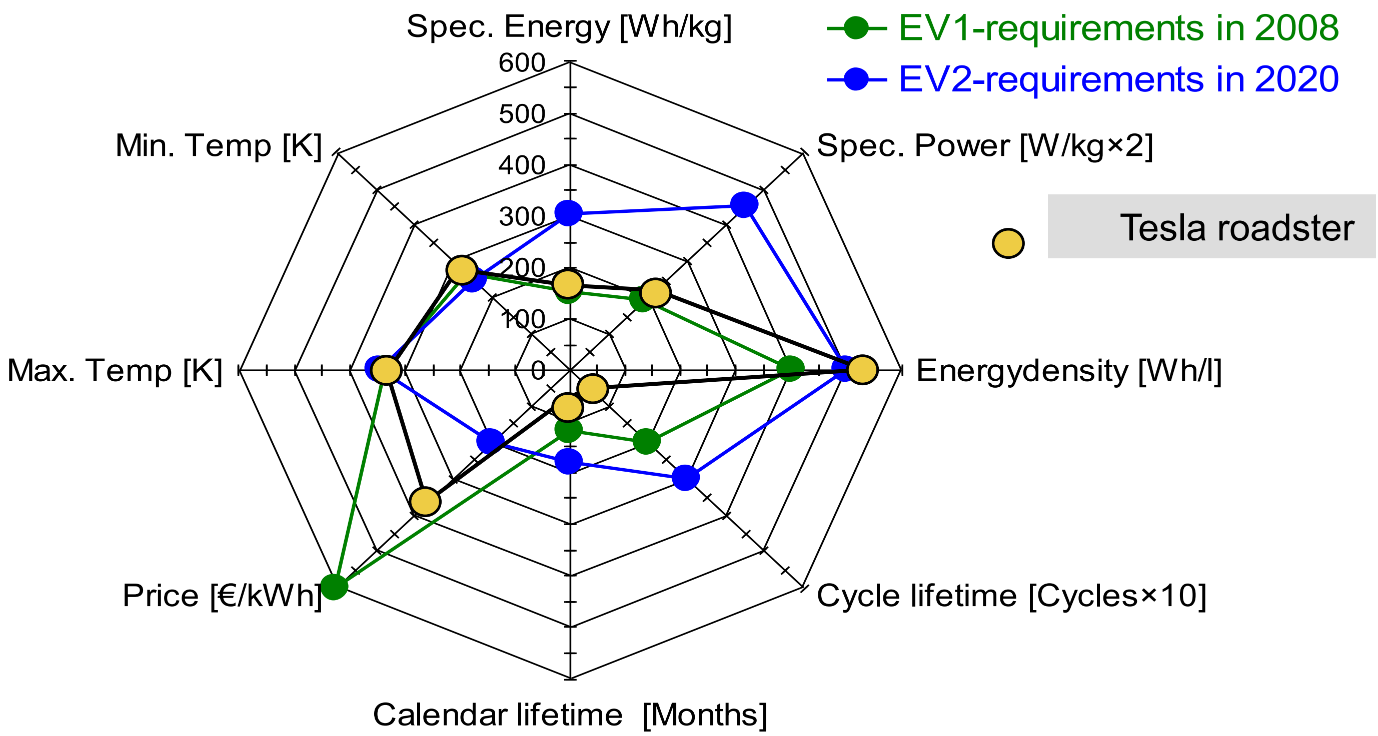
EV-battery requirements (on cell level)



Cell Types in General

Lithium secondary cells can be devided into three different types:

cylindrical

prismatic

pouch

- All types are in development for EV Applications
- All types might carry charges from <1Ah to 100Ah
- The cell design (e.g. housing, electrodes, electric contacts and <u>all</u> other passive and active components result in the overall performance and safety
- Each cell type has its specific advantages and disadvantages

As of today there is no clear trend towards one favorite cell design

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Key Success Factors for Automotive Applications

Lifetime

> 10 years
> 250 000 km

Safety

0 thermal incidents in field

Performance

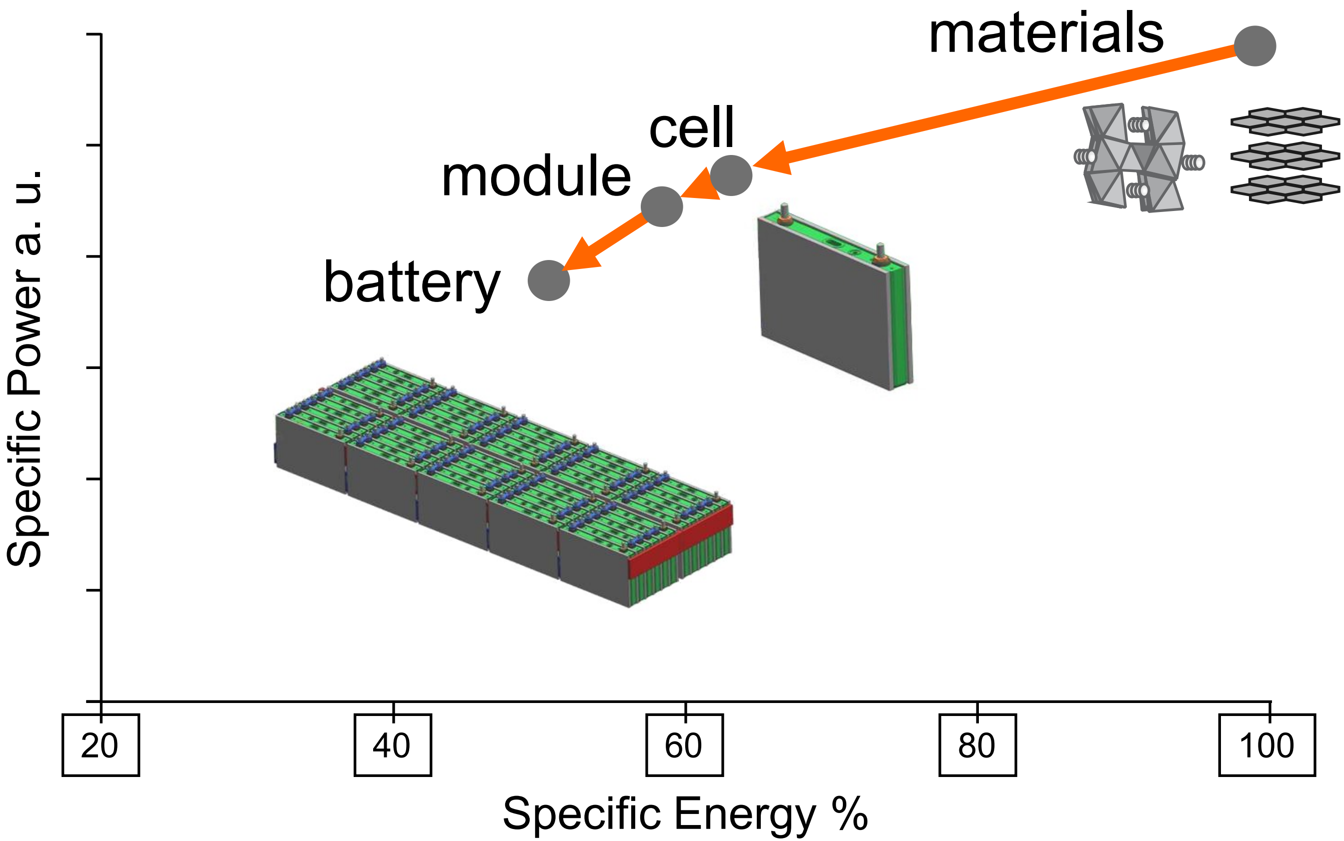
Power > 5000 W/kg (HEV)
Energy > 200 Wh/kg (EV)

Quality

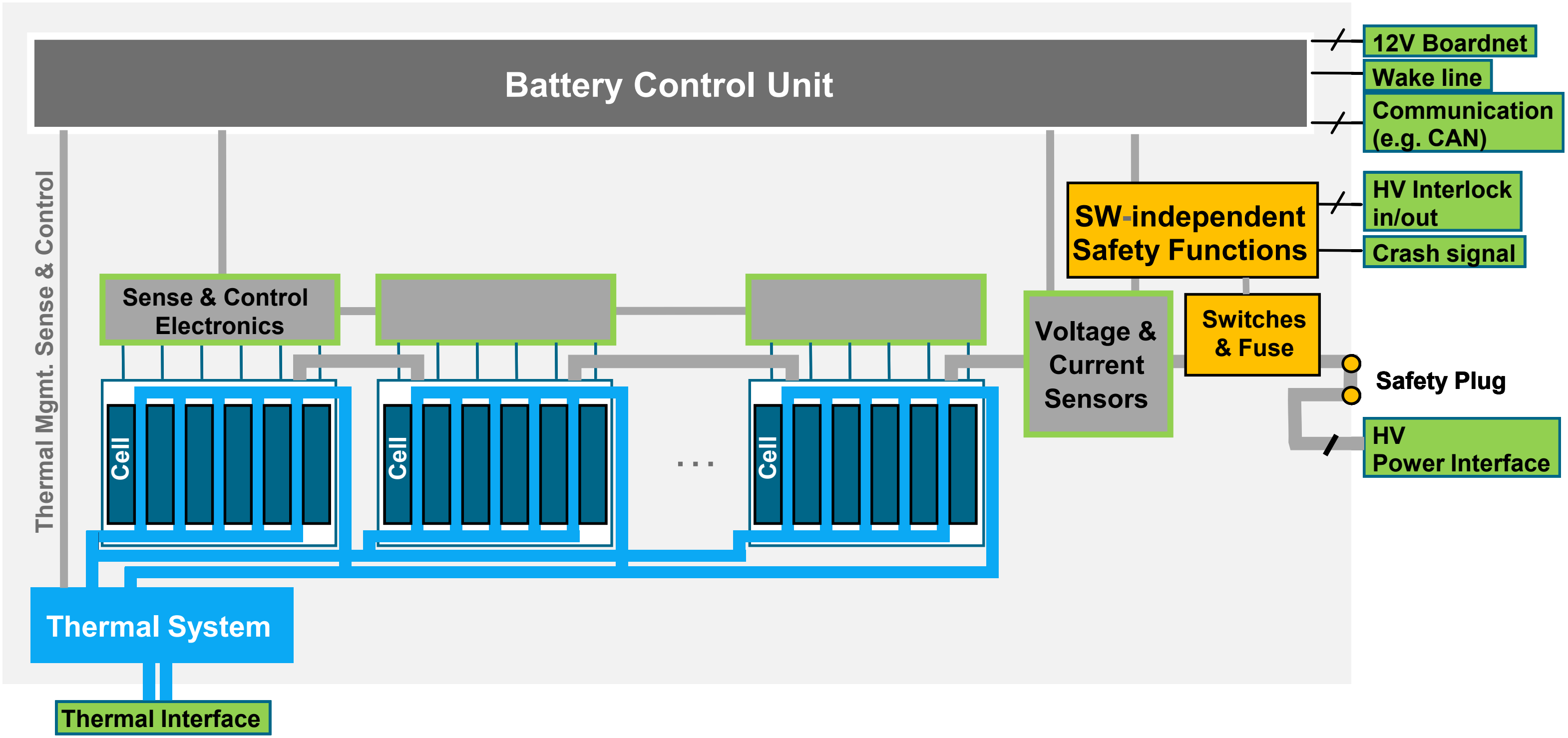
Cost

< 30 $/kW(HEV)
< 300 $/kWh (EV)

From Material to Battery System



Battery System
Architecture

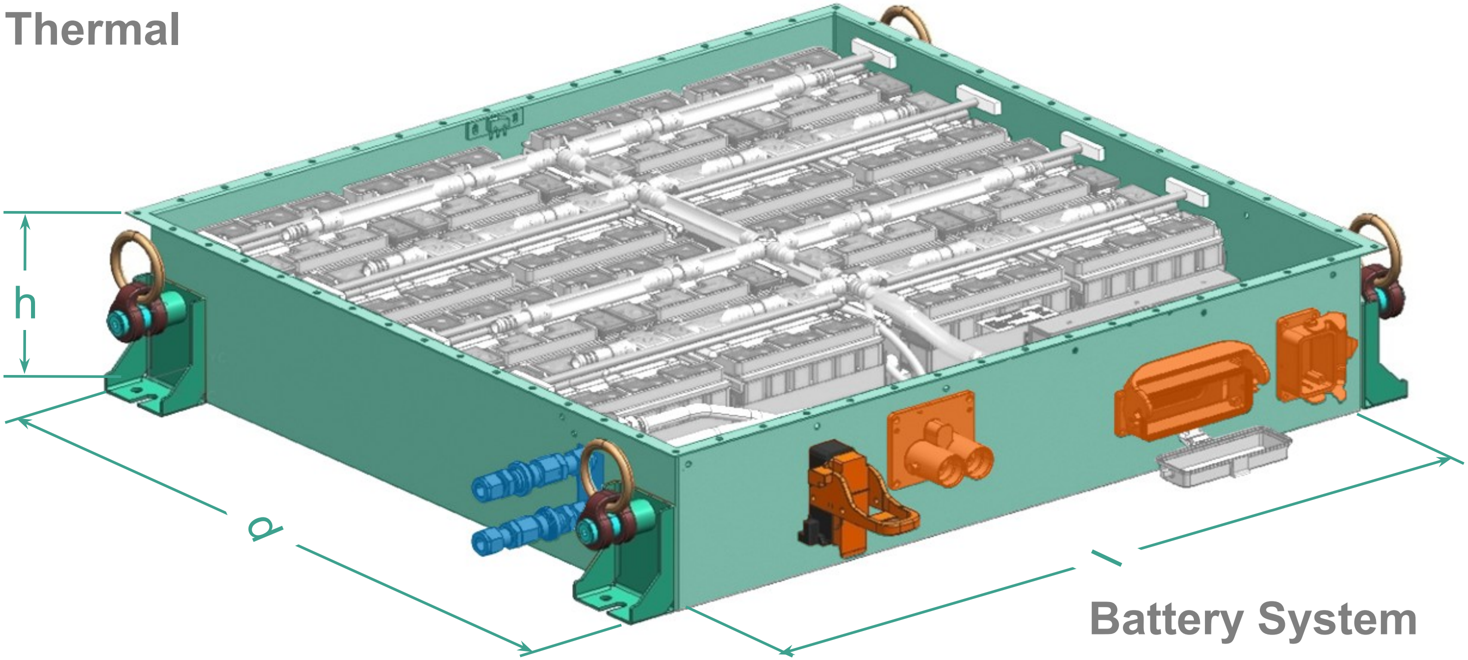


Battery System

Interfaces

Interfaces

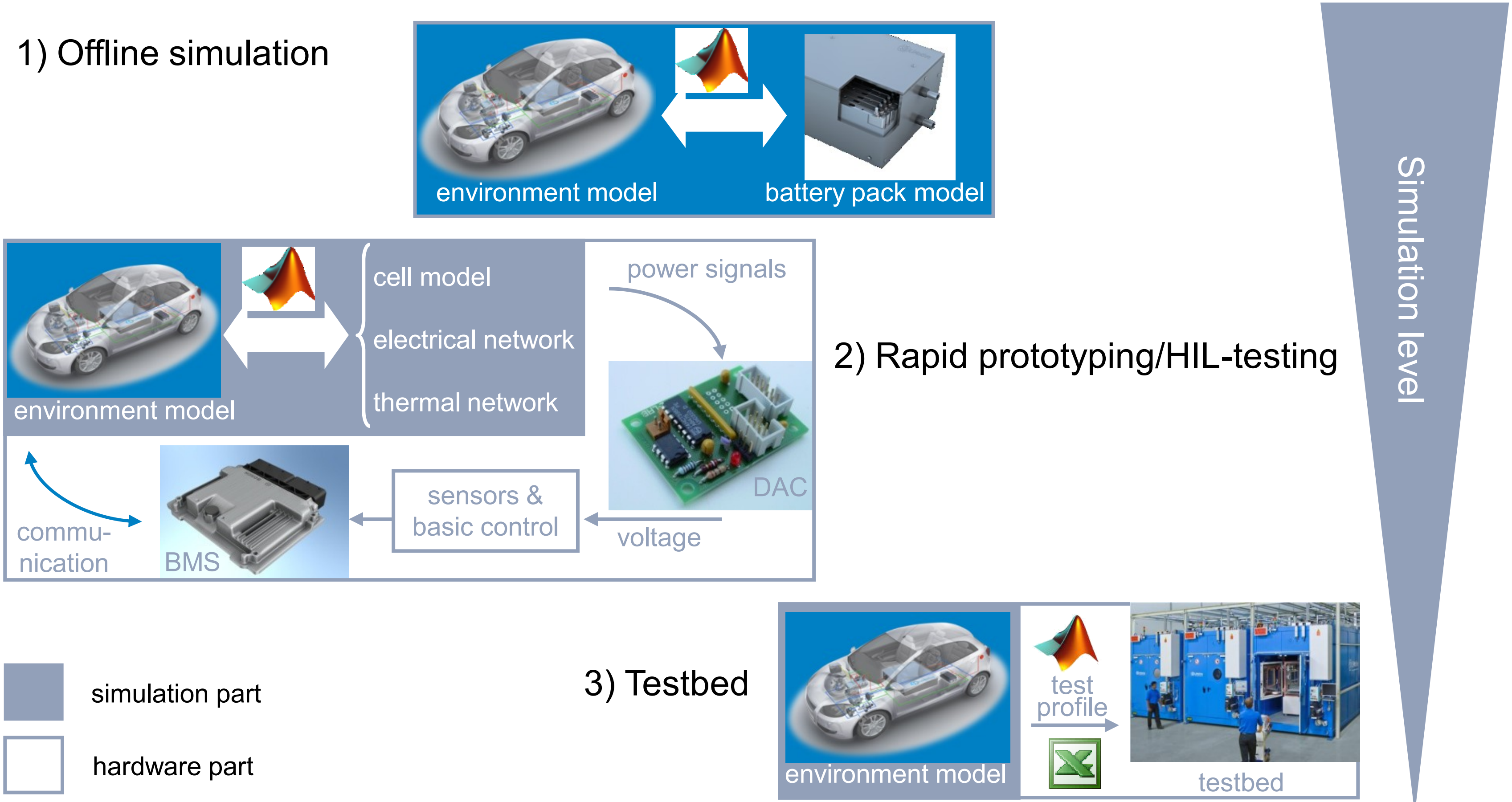
- Electrical
- Mechanical
- Thermal



Battery System

EV - Storage Module and BMS - Roadmap

Modeling and Simulation

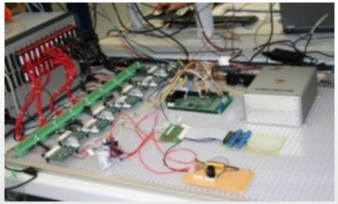


Multistage Validation

System

Test equipment for module and pack

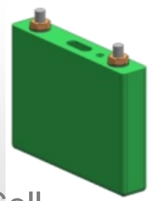
Integration



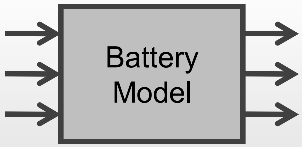
Test assembly for BMS-HW and SW

Battery simulator (HiL)

Component



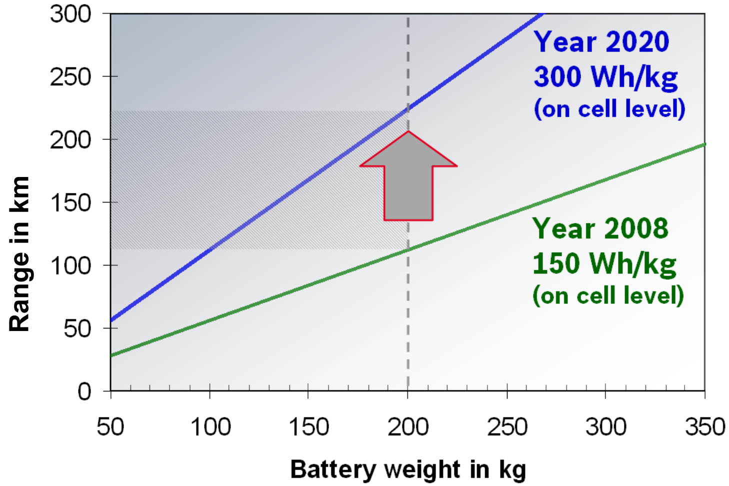
Cell



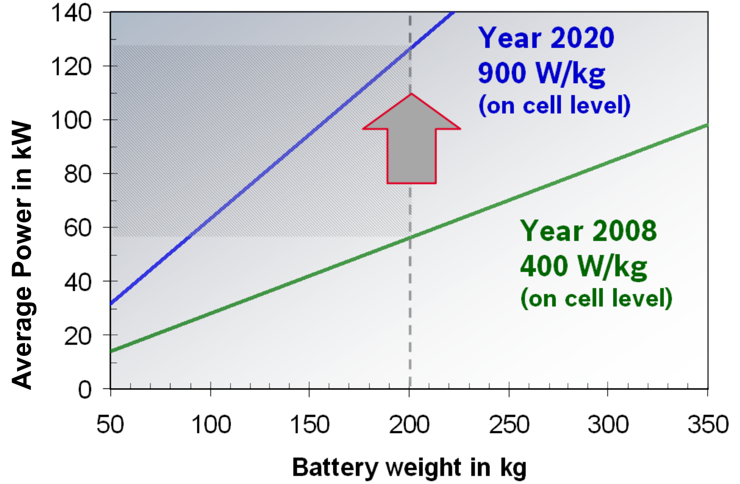
Test equipment for cells

Future Li-Ion Battery Cell Technology

Compact class vehicle up to 1000 kg with a maximum Li-ion battery weight of 200 kg, P_{max}/P_{av}=100 kW / 70 kW



NEDC → 15 kWh / 100 km (w/o air conditioning/heating)
Battery Spec. energy = 0.7 Cell spec. energy
DOD = 80%



Battery spec. power = 0.7 Cell spec. power

- → **Increase energy- and power density through future cell technology, improved battery management and better safety.**
- → **Cell Technology: Li-Sulfur, Li-Air and oxide cathodes**

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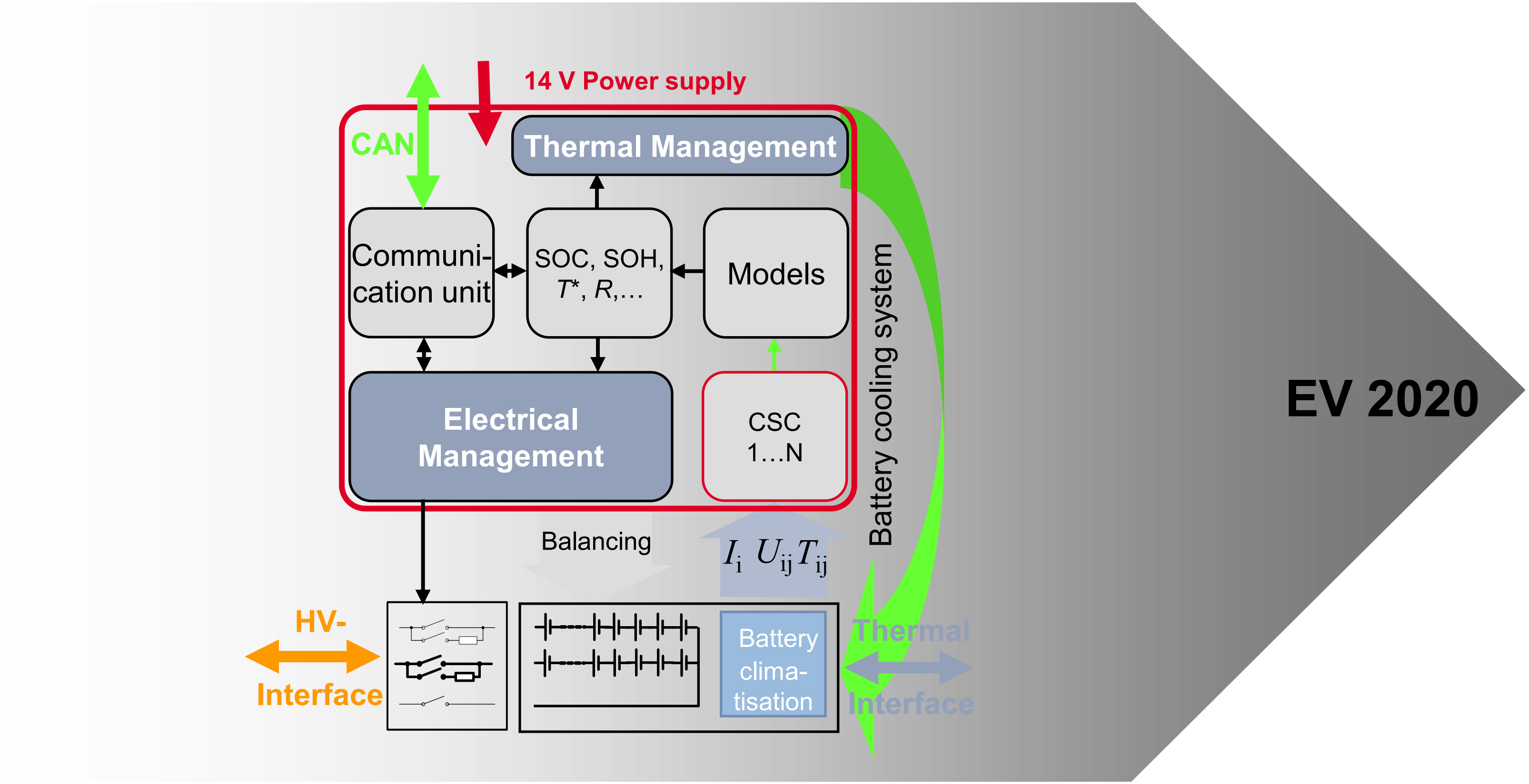
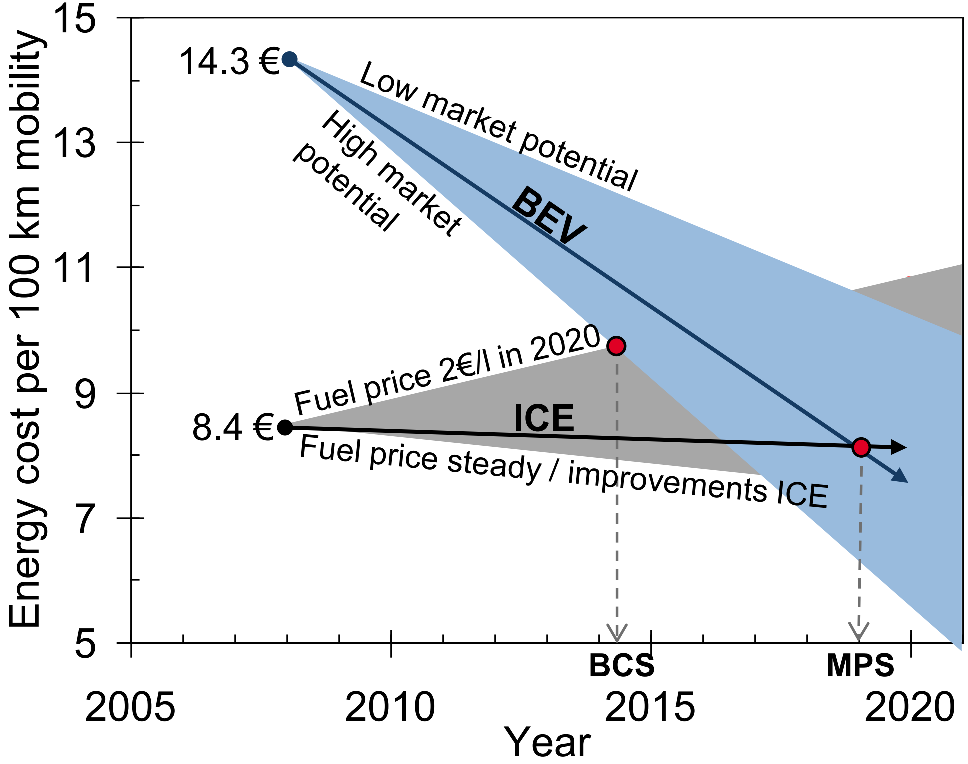
Intelligent BMS of the Future



Further specification details will be available once the future EV and EV system is understood

Energy Cost for Mobility



Assumptions taken:

Compact class vehicle up to 1000 kg
€/ICE = €/BEV w/o battery

ICE consumption = 6 l/100km
Fuel costs = 1.4€/l

BEV Energy consumption = 15 kWh/100km
Battery capacity = 20 kWh
Total mileage = 120,000 km
Electric energy costs = 0.12€/kWh

Energy specific Li-ion battery costs:
•Year 2008 → 750 €/kWh
•Year 2020 → 500/350/250 in €/kWh (Market potential low/base/high respectively)
•BEV w/o subsidization & consideration of tax

→ **Battery costs are expected to decrease by about 50% by 2020.**
→ **No cost benefit for EV till 2015 due to high battery costs.**

Best Case Scenario (**BCS**): BEV and ICE costs equalize in 2014
Most Probable Scenario (**MPS**): BEV and ICE costs equalize in 2019

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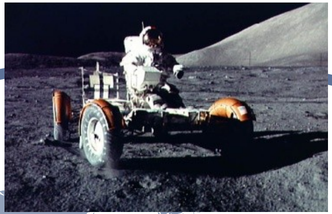
EV - Storage Module and BMS - Roadmap



Thank you for your attention !

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