

# E-MOBILITY.

BMW GROUP TECHNOLOGY WORKSHOPS.



December 2017



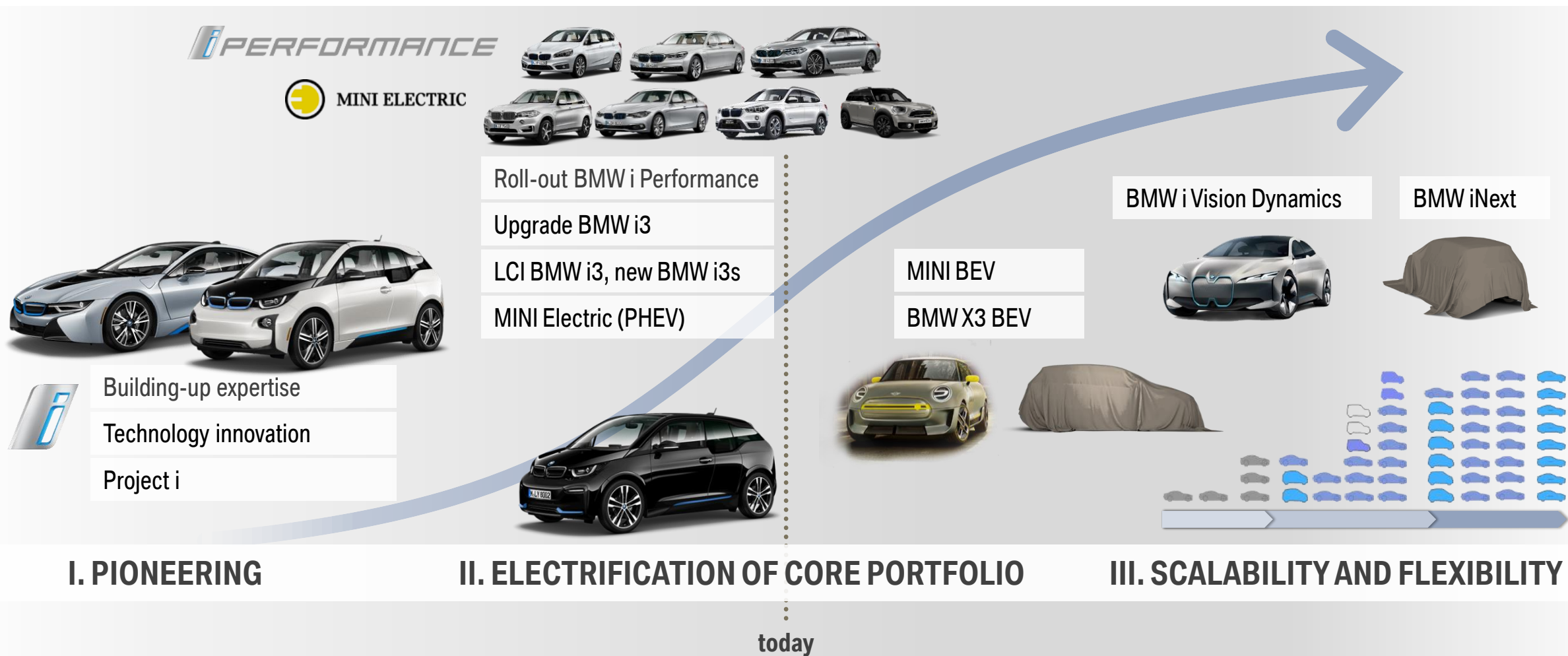
Rolls-Royce  
Motor Cars Limited



# FLEXIBLE ARCHITECTURES.

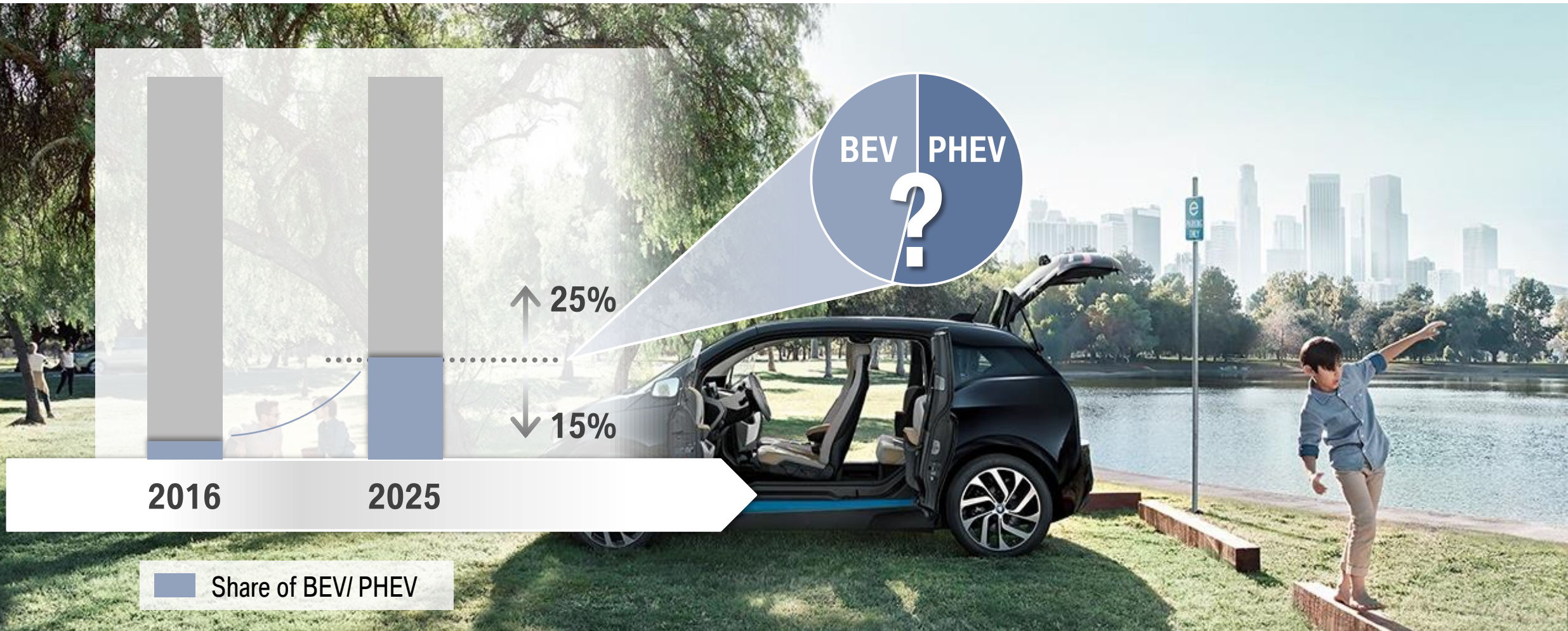


# BMW GROUP'S ELECTRIFICATION PATHWAY.





# FLEXIBILITY IS THE KEY FOR E-MOBILITY.



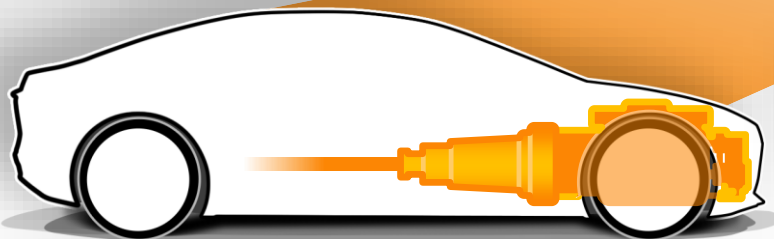
# BMW i. FROM "BORN ELECTRIC" TO "ONE PLATFORM SERVES ALL".

2013

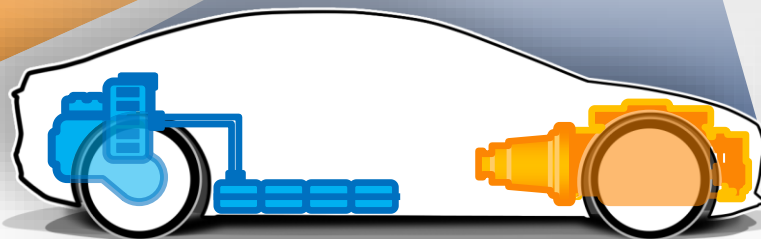
"Born electric"



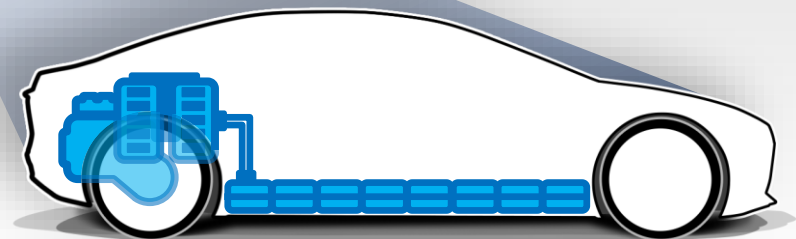
FROM  
2021 ON



➤ Combustion engine



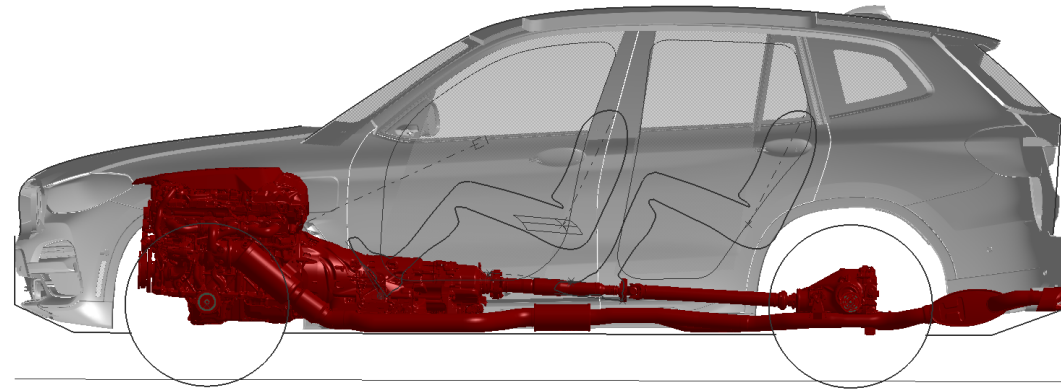
➤ Plug-In-Hybrid



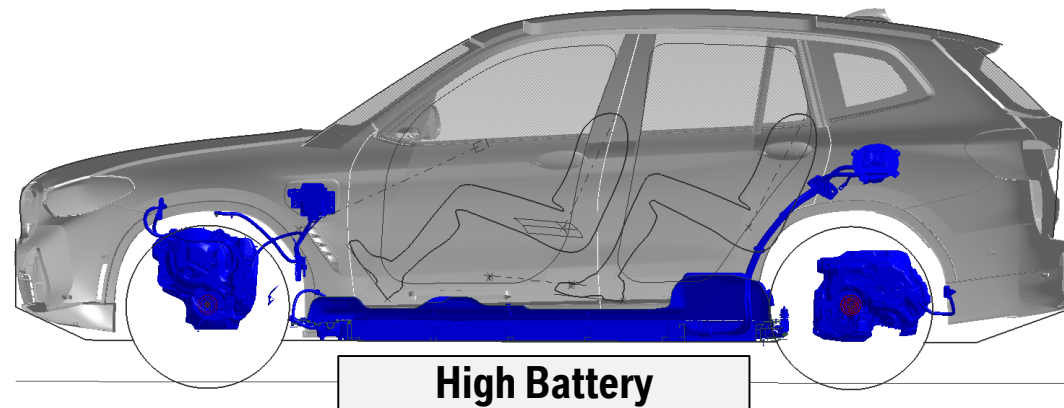
➤ Pure electric

# CONVENIENT INTEGRATION OF THE ELECTRIC DRIVETRAIN IN HIGH CARS.

**SAV – Combustion Engine**

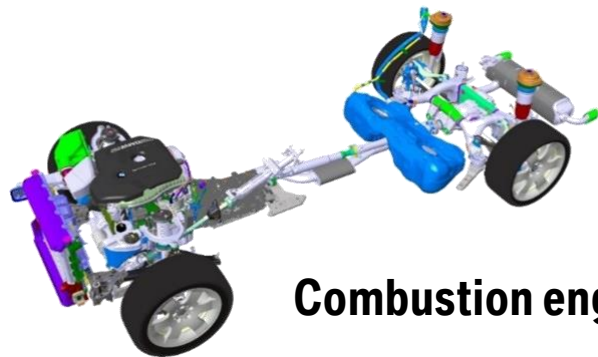
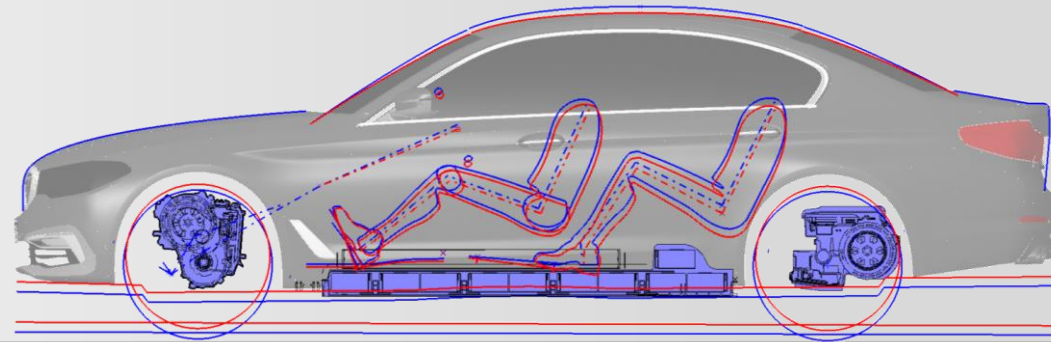


**SAV – EV**

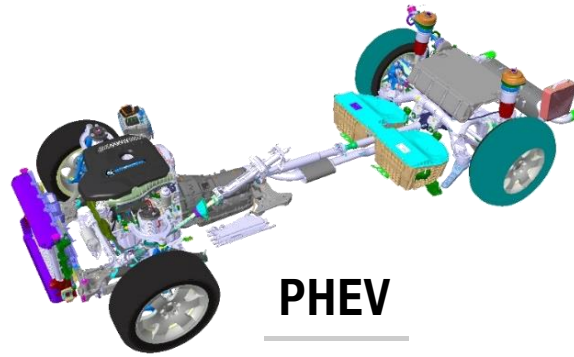




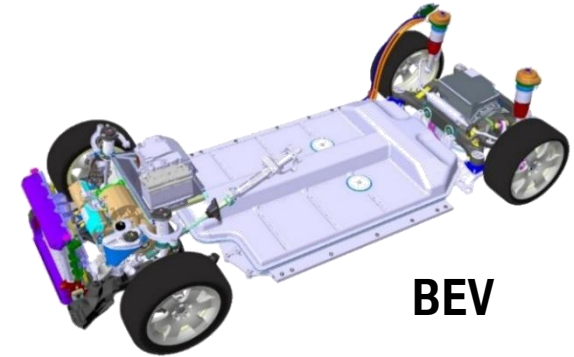
# OUR VEHICLE ARCHITECTURE ENABLES INTEGRATION OF CONVENTIONAL DRIVE TRAINS, PHEVS AND BEVS IN THE SAME MODEL-LINE.



**Combustion engine**



**PHEV**



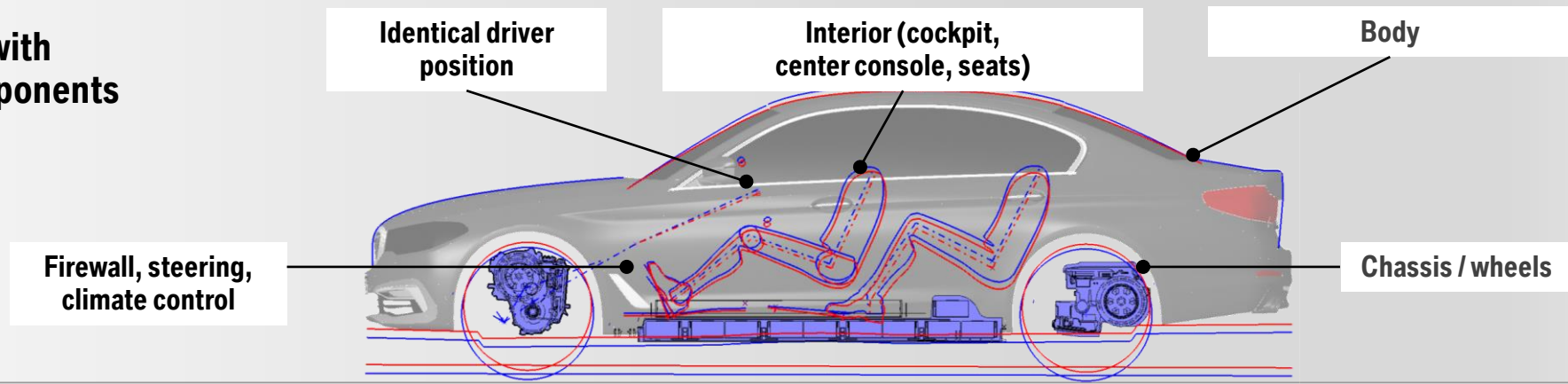
**BEV**

PHEV-prepared since 2015

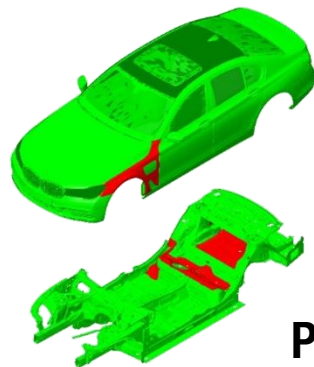
Additional BEV-integration starting 2021

# COMMON MODULAR SYSTEMS FOR ALL DRIVETRAIN-VERSIONS. INCREASED FLEXIBILITY AND REDUCED INVEST.

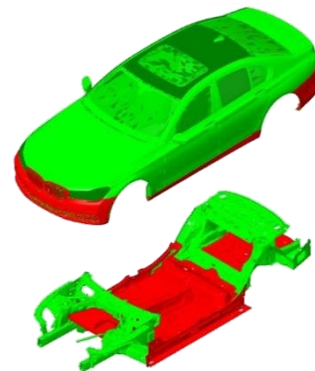
## Architecture with common components



Sedan as example



**Plug-in Hybrid**

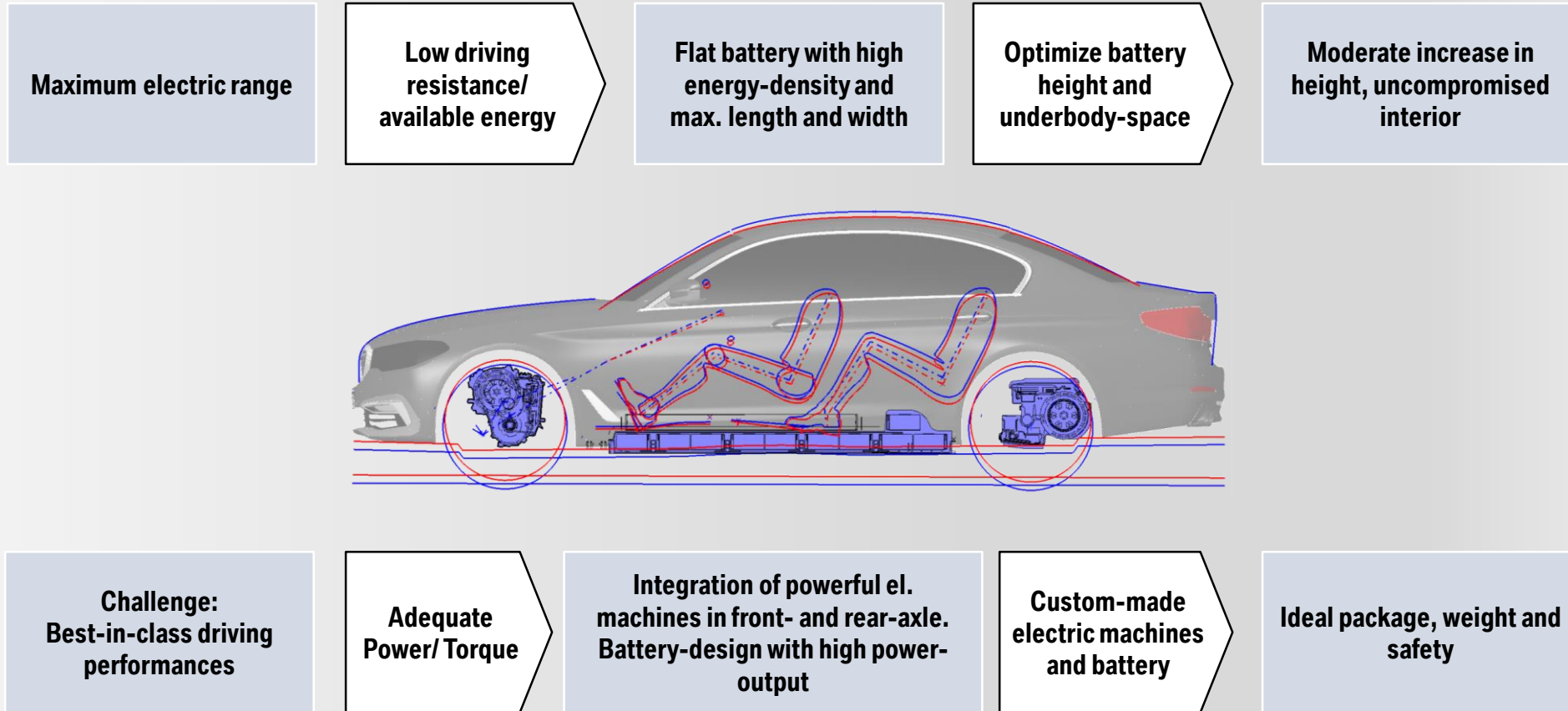


**Electric Vehicle**

 delta-parts different to conventional drivetrain



# CHALLENGES OF BEV INTEGRATION IN LOW VEHICLES.



# MODULAR E-TOOLBOX.





# THE ROAD TO 2025: WIDE ROLLOUT OF PHEVS AND BEVs WITH NEXT GEN OF MODULAR ELECTRIC POWERTRAIN.

GEN 3

GEN 4

GEN 5

Pure electric



BMW i3  
60 Ah / 22 kWh



BMW i3  
94 Ah / 33 kWh



BMW i3s  
94 Ah / 33 kWh



MINI BEV



BMW X3 BEV



BMW iNext



2013 — 2014 — 2015 — 2016 — 2017 — 2018 — 2019 — 2020 — 2021 — 2022 — 2023 — 2024 — 2025



BMW i8



BMW 530Le



BMW 225xe  
iPerformance



BMW X1 xDrive25Le  
iPerformance



BMW i8 Roadster



BMW X5  
xDrive40e  
iPerformance



BMW 330e  
iPerformance



BMW 5 Series  
iPerformance



Plug-In-Hybrid

BMW 740e  
iPerformance




MINI Cooper SE  
Countryman ALL4

# GEN3 AND GEN4 UP TO 2020: EMOTIONALISATION OF OUR EXISTING xEV DRIVE TRAIN ARCHITECTURES.

PHEV P2  
Example: 7 Series

**+10 kW**  
electric power

**+40%**  
electric range

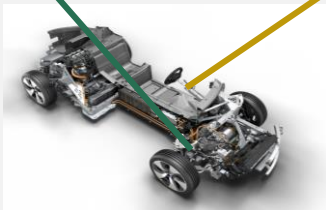


elec. Range WLTP: 33 km → **46 km**  
0-100 km/h: 5,4 s → **5,2 s**

PHEV axle hybrid  
Example: i8 LCI

**+10 kW**  
electric power

**+60%**  
electric range




elec. Range WLTP: 30 km → **50 km**  
0-100 km/h: 4,4 s → **4,4 s**

BEV  
Example: i3s

**+10 kW**  
electric power

**+60%**  
electric range

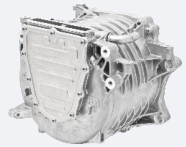


elec. range WLTP: 150 km → **235 km**  
0-100 km/h: 7,2 s → **6,9 s**



# INTEGRATION OF E-MACHINE, GEARBOX AND POWER ELECTRONIC IN ONE SYSTEM.

## Today



E-Machine



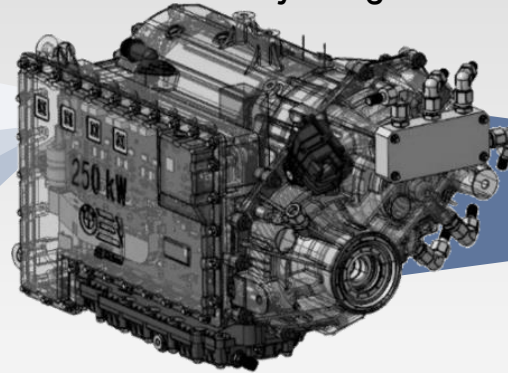
Gearbox



Power Electronics

## Tomorrow

E-Machine, Gearbox and Power electronics fully integrated



Weight reduction

Increase of power density

Cost reduction

Adaptive production system

New semi-conductor technologies (SiC, GaN)

Securing technological leadership

## Vehicle Integration



# OUR FUTURE PHEVs: UNCOMPROMISING CUSTOMER VALUE PROPOSITION.

## LONG-DISTANCE DRIVEABILITY.

LOW FUEL CONSUMPTION AND  
LARGE-VOLUME FUEL TANK.

## BMW DRIVING DYNAMICS GENES.

BALANCED AXLE LOAD DISTRIBUTION,  
LOW CENTRE OF GRAVITY.

## HIGH ELECTRIC RANGE.

INCREASED BATTERY CAPACITY.

## MAXIMUM PERFORMANCE.

TUNED ELECTRIC POWERTRAINS.

## UTILITY VALUE.

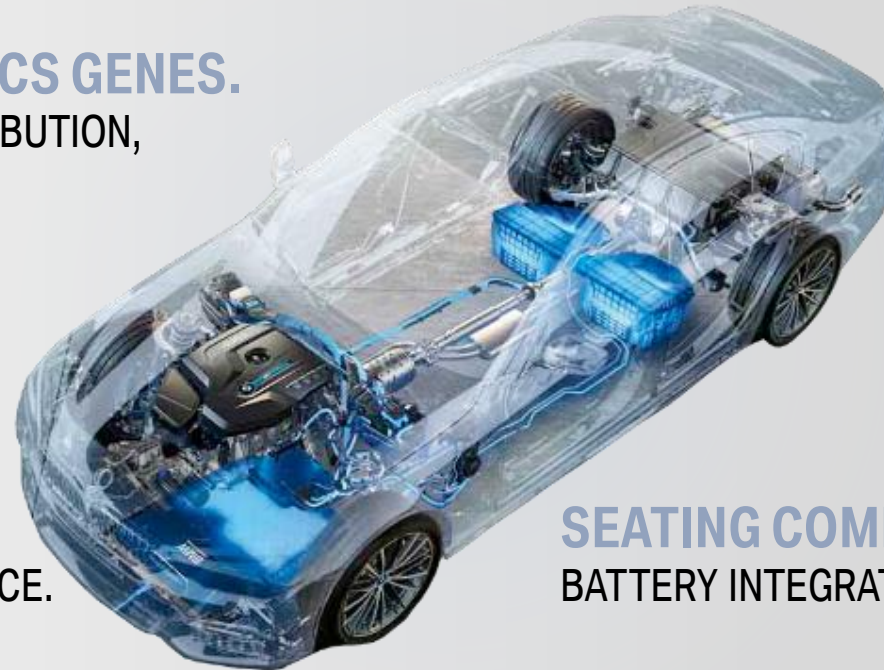
MAINTAINS FULL LUGGAGE VOLUME.

## INDUCTIVE CHARGING.

GREATER CHARGING CONVENIENCE.

## SEATING COMFORT.

BATTERY INTEGRATION WITHOUT LOSS OF COMFORT.



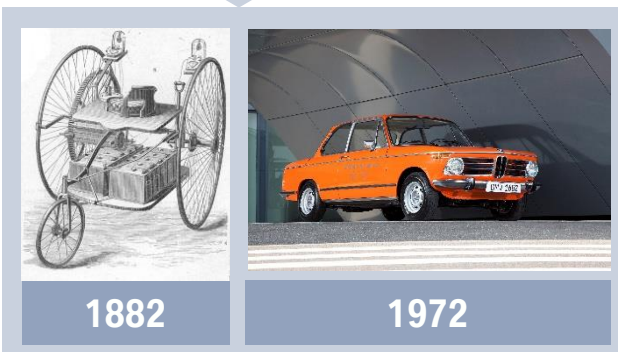
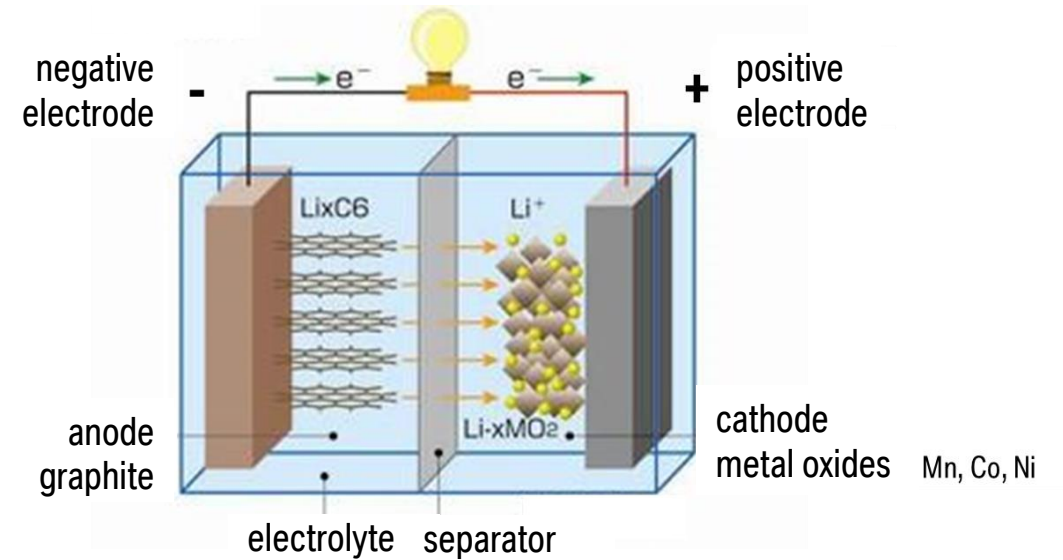
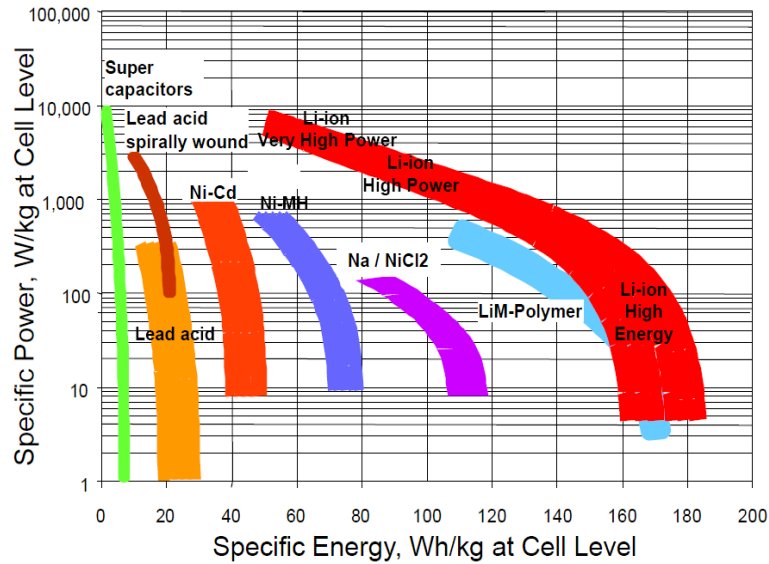
PHEVs must be refined to offer customers an uncompromising value proposition.



# BATTERY CELL.



# BATTERY PERFORMANCE IS THE BASIS FOR SUCCESS OF E-MOBILITY. LI-ION TECHNOLOGY IS THE ENABLER FOR CURRENT ELECTRIC VEHICLES.



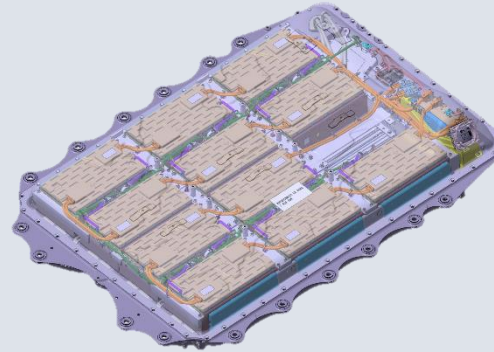


# BMW INHOUSE DEVELOPMENT AND PRODUCTION OF BATTERY MODULS AND PACKS SINCE 2008. FULL COMPETENCE IN CELL DESIGN.

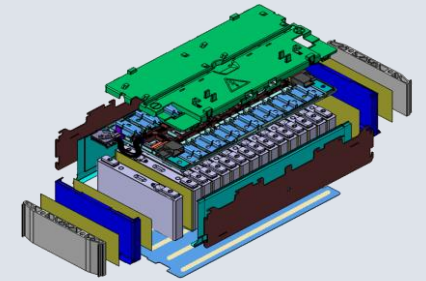
Development and Production Inhouse



xEV Vehicle



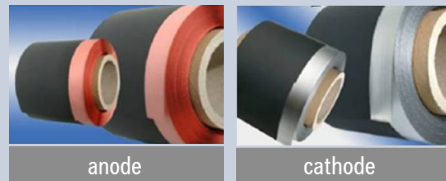
Battery Pack



Subsystem/Module



Full Specification and Design Competence



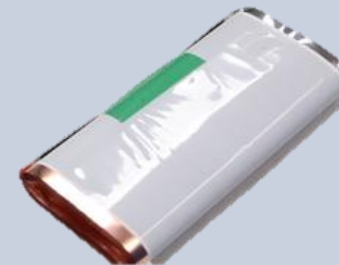
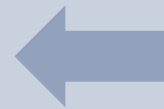
anode

cathode

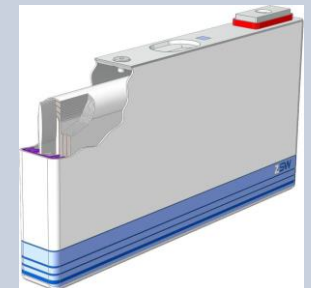
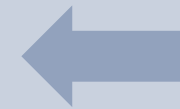


separator

Subcomponents / Electrodes



Jelly Roll



Cell



# BMW CONTINUOUSLY INCREASES CELL COMPETENCE TO ENHANCE THE LEVERAGE FOR REALIZATION OF CUSTOMER RELEVANT INNOVATIONS.

## R&D



## Materials & Analytics



## BMW Competence Center Battery Cell

... in combination with worldwide network

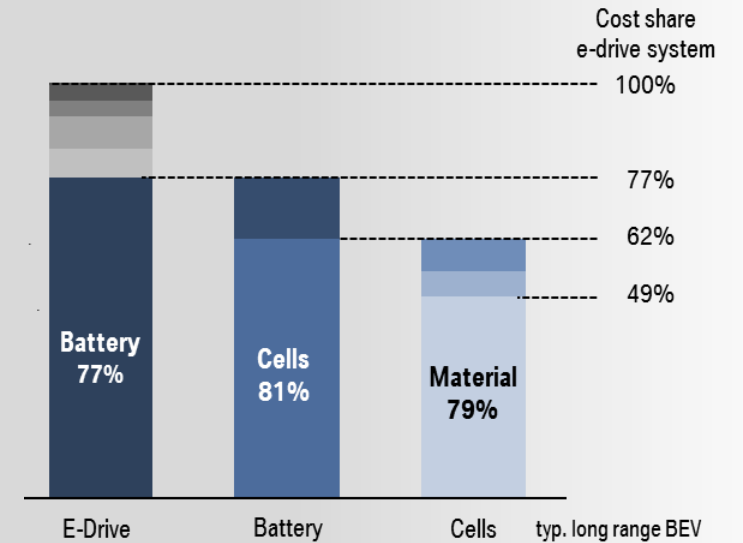
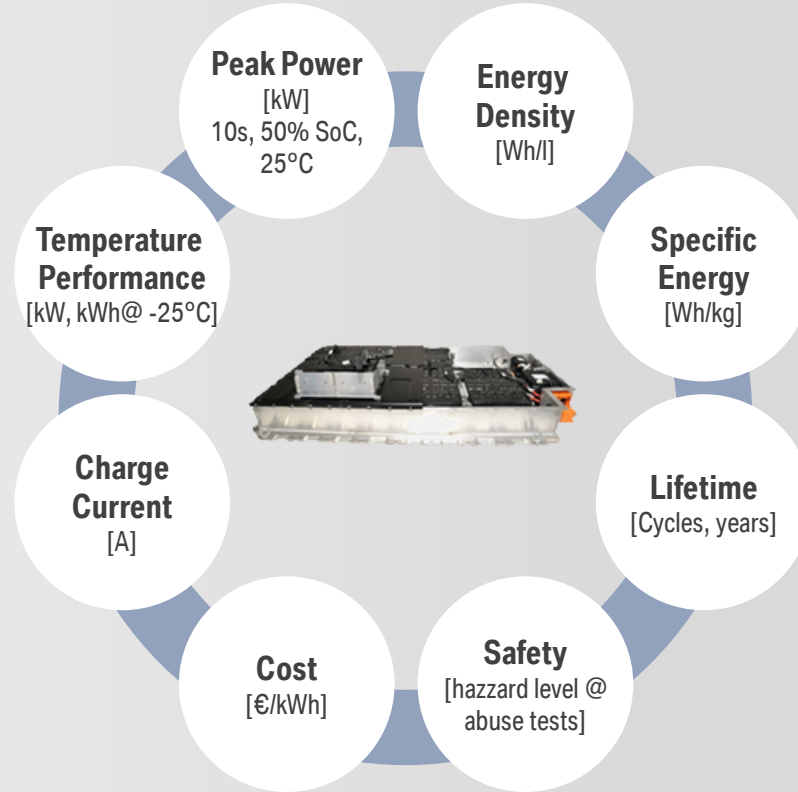
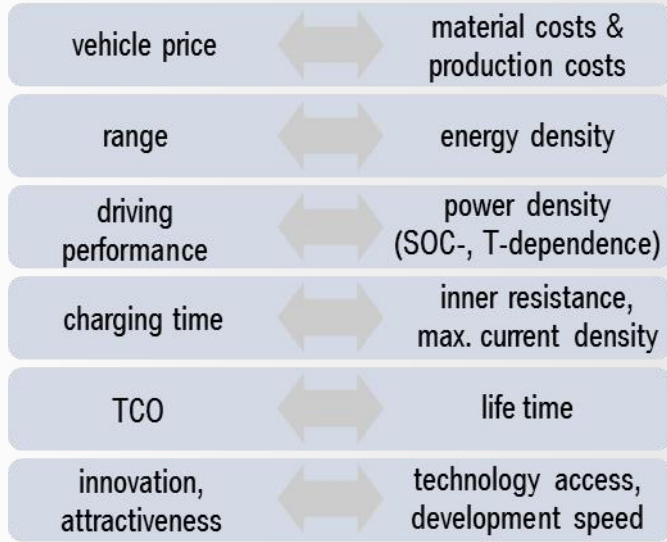
## Securing Supply



## Prototypes & Testing



# BATTERY DEFINES PERFORMANCE AND COSTS OF ELECTRIC VEHICLES. MATERIALS DOMINATE COST STRUCTURE.



Key Performance Indicators Vehicle



Key Performance Indicators Battery



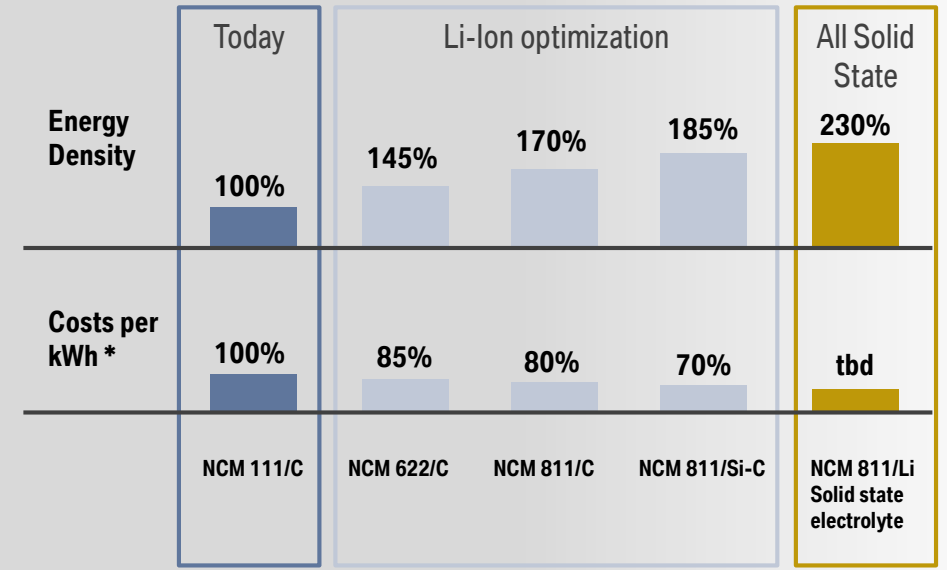
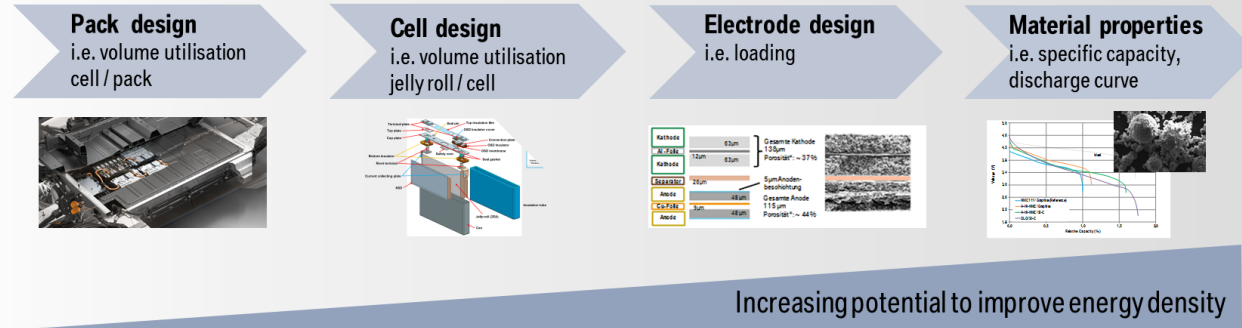
Cost Structure Battery

# SUBSTANTIAL ENERGY DENSITY INCREASE AND COST REDUCTION EXPECTED. HIGHEST POTENTIAL FOR IMPROVEMENT ON MATERIAL LEVEL.

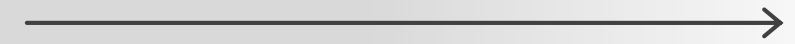
## Integration Levels of Battery



## Energy Density and Costs



\* Costs per Cell depend on Cellsize and might increase on a per Cell basis.



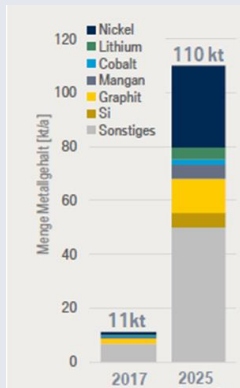
Time



# BMW CONSIDERS TOTAL VALUE CHAIN OF CELL – FROM CRADLE TO GRAVE.

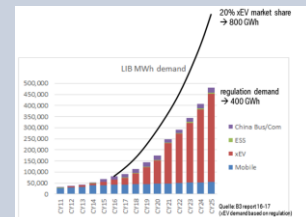
## Raw Materials and Refining

- Environmental and social standards
- Raw material optimised for chemistry design
- Use of recycled raw materials
- Securing raw material supply



## Cell Design and Production

- Optimised performance/costs based on BMW application
- Securing production capacity
- Reduction CO2 footprint



10x (!) Anstieg Produktionskapazitäten notwendig  
Der Sektor „automotive“ wird den LIB Markt dominieren (> „consumer“ ab 2018)

## Battery „2nd Life“

- Cell/module/pack design allows for secondary use
- Application on BMW sites
- Business Modells to secure markets

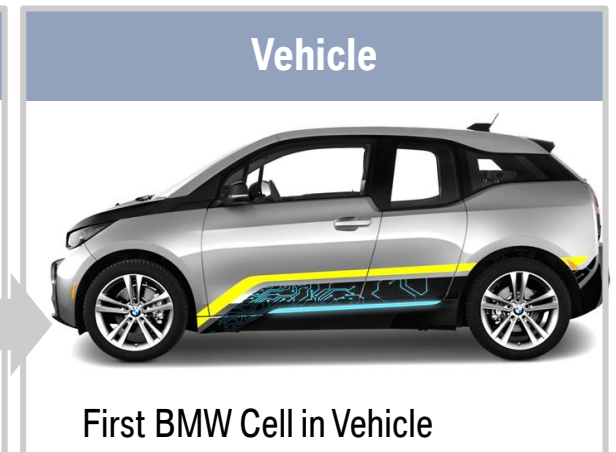
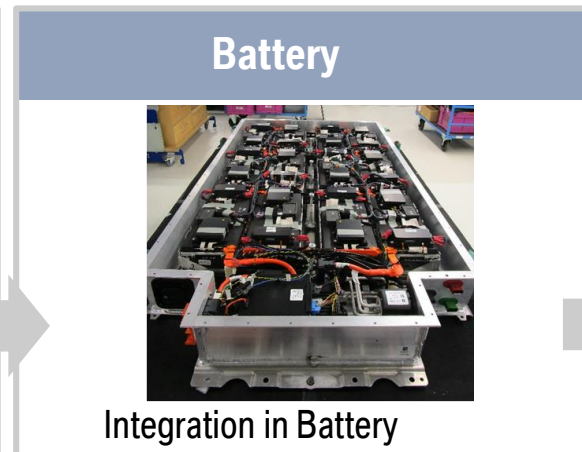
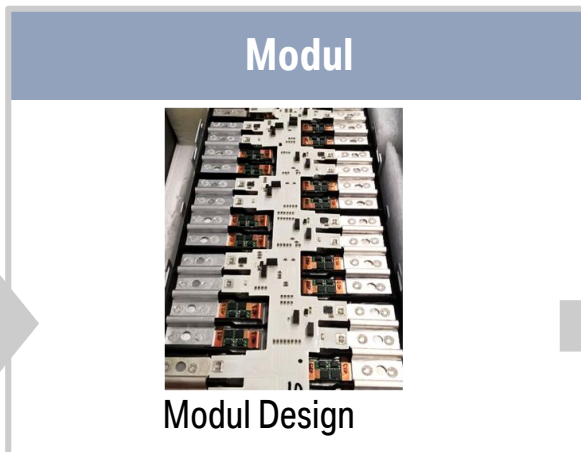
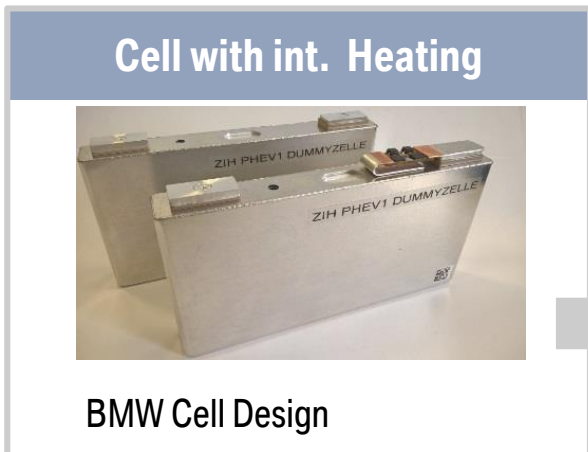
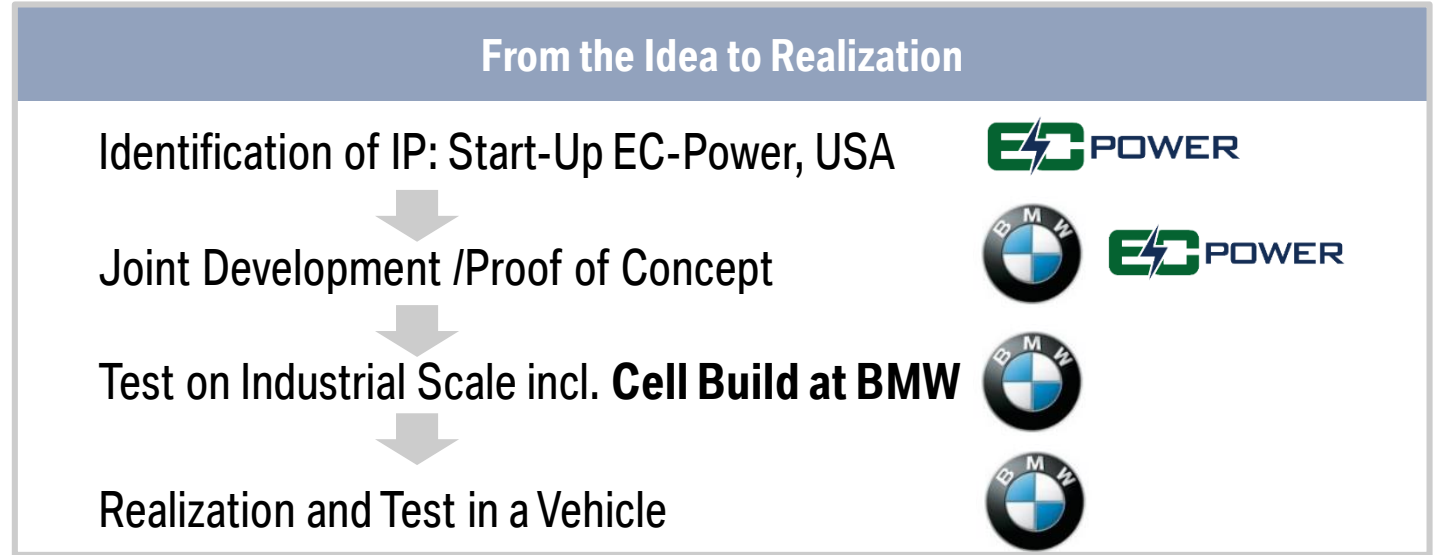
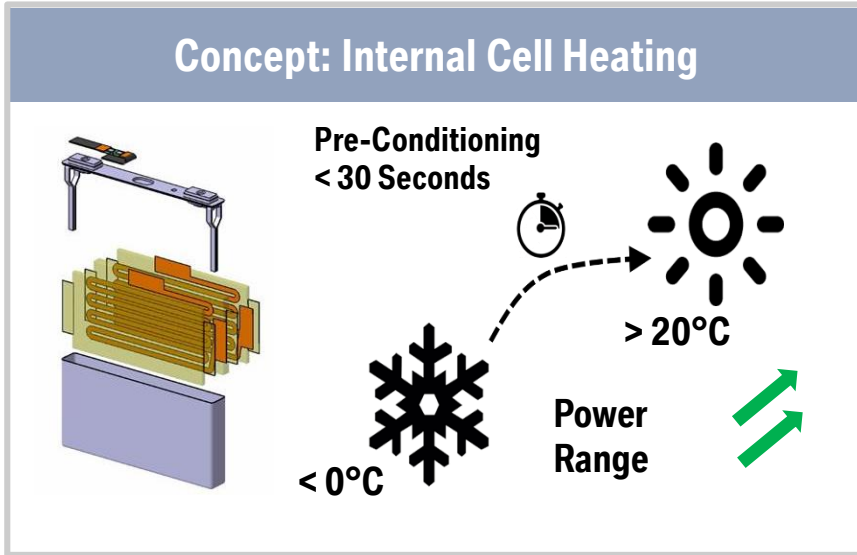


## Recycling

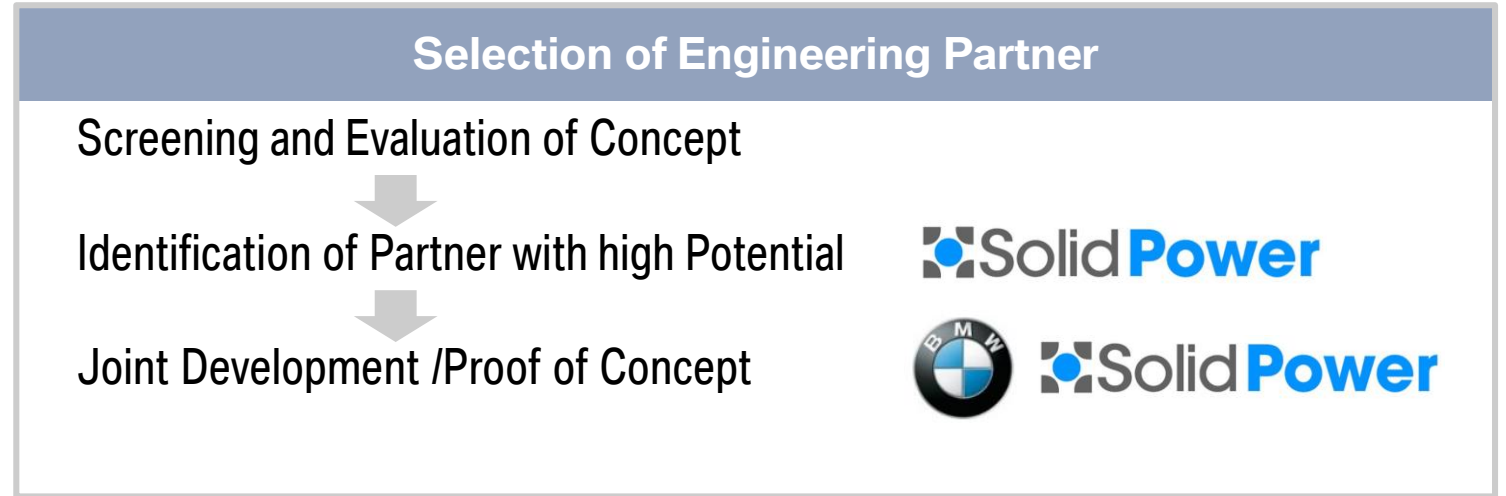
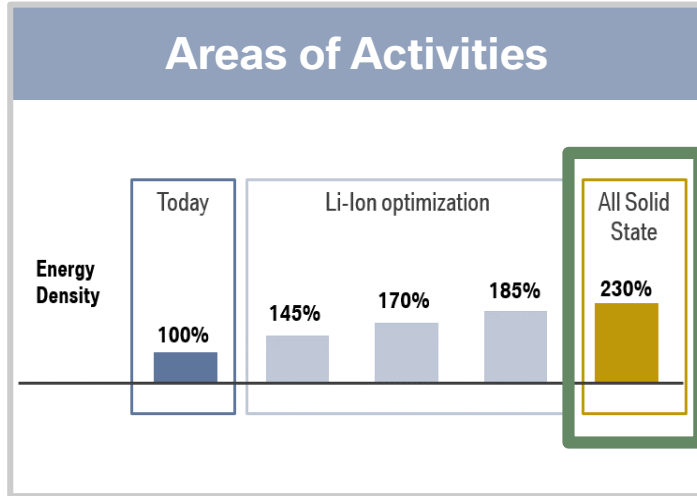
- Cell/modul/pack design to foster recyclability
- Development of recycling processes with ability to close material loops
- Securing recycling capacities



# INTERNAL CELL HEATING TO IMPROVE LOW TEMPERATURE BATTERY PERFORMANCE IS AN EXAMPLE FOR BMW INNOVATION.



# ALL-SOLID-STATE: IMPROVEMENT OF ENERGY DENSITY AND COSTS. BMW EVALUATES AND ACTIVELY DRIVES THE TECHNOLOGY.



### Material Groups

<b>Oxides / Phosphates</b> <ul style="list-style-type: none"> <li>+ Mainly stable</li> <li>- Processing</li> <li>- Interfaces</li> </ul>	<b>Sulfides</b> <ul style="list-style-type: none"> <li>+ Processing</li> <li>+ Interface</li> <li>- Stability</li> </ul>
<b>Polymers</b> <ul style="list-style-type: none"> <li>+ Processing</li> <li>- Voltage range</li> <li>- Operating temperature</li> </ul>	

### Electrodes

Roll-to-Roll All-Solid-State Electrodes

### Cell Assembly

Cell Stack

### ASSB Cell

1Ah All-Solid-State Cell



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December 2017



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