



# Silicon carbide boosting the path to e-mobility in various applications

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Semicon 2022, Nov. 16<sup>th</sup> 2022

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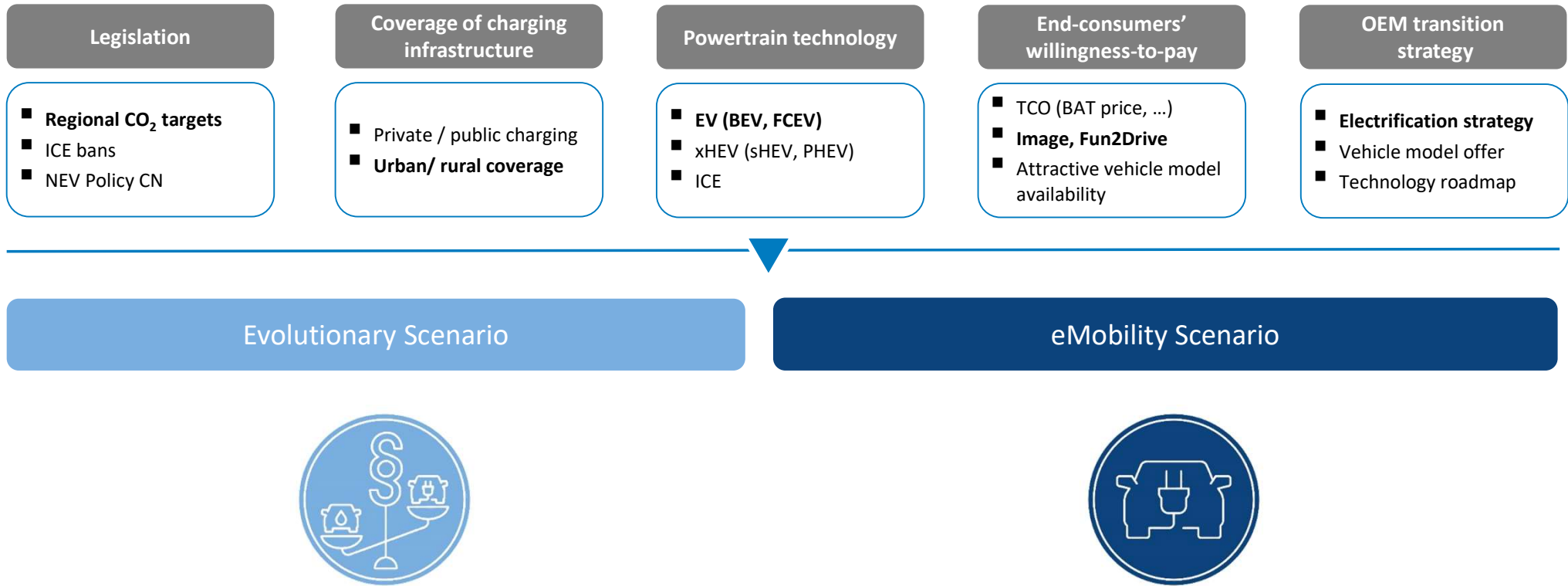


# Agenda

1. Drivers towards “mission zero”
2. E-mobility market
3. Efficiency and voltage level
4. SiC Technology as key enabler
5. Performance Improvement for drive train and charger
6. System optimization and vertical integration
7. Market Forecast

# Silicon carbide boosting the path to e-mobility

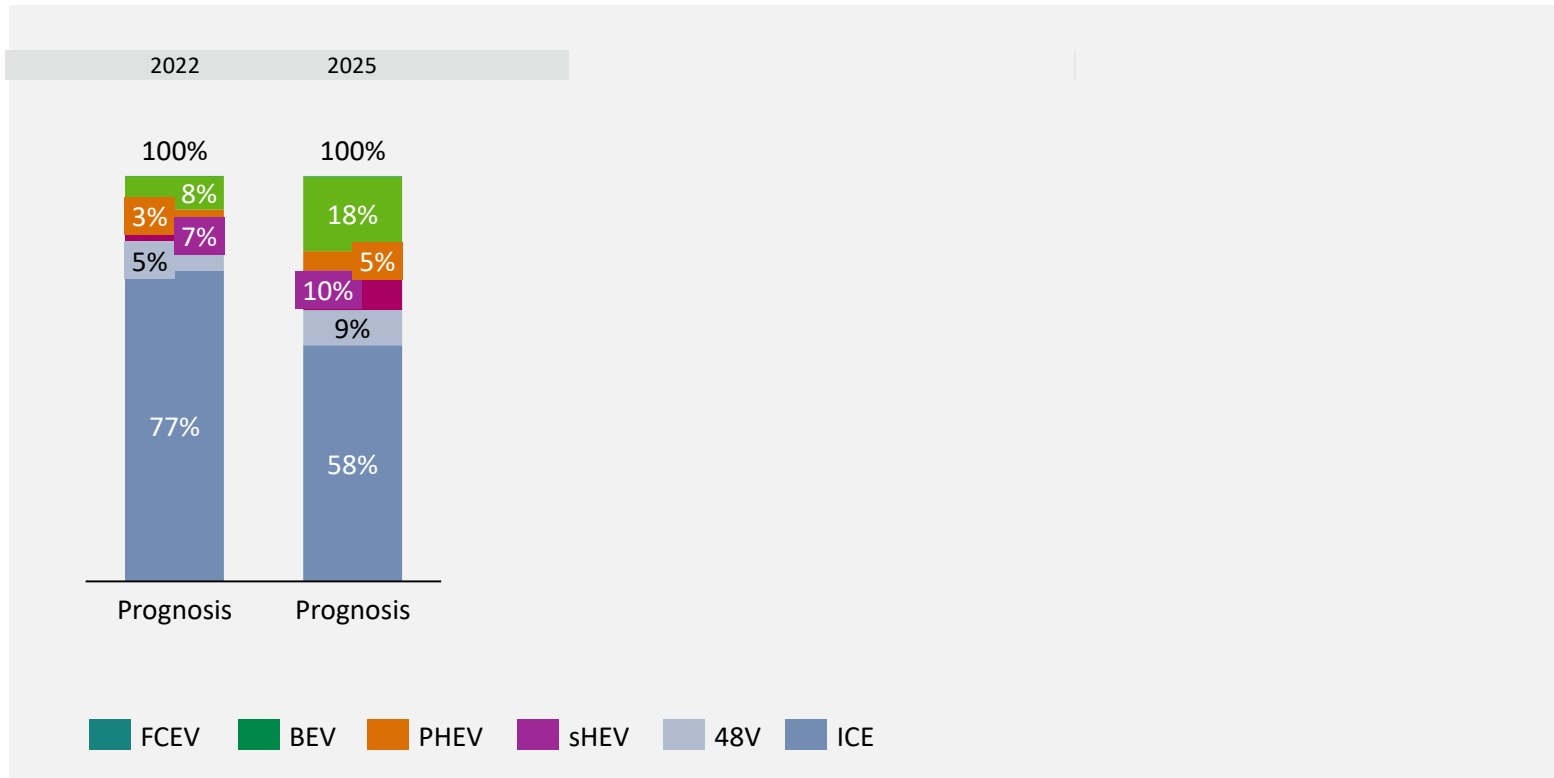
## Drivers towards “mission zero”



# Silicon carbide boosting the path to e-mobility

## By 2030, more than every 3rd new vehicle is an EV

New vehicle sales PC incl. LCV < 6t | Worldwide



- The way to achieve climate targets becomes clearer.
- By 2030, more than 1/3 of new vehicles will be an EV.
- However, in 2030 at least 50% of new vehicles will still have an ICE, with 25% being hybridized.
- In 2035, we expect at least 50% of the new vehicles to be an EV.
- Renewable fuel blends for the existing fleet will be essential to achieve global climate targets.

Note: difference to 100% due to rounding

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## Trends towards higher voltage and higher efficiency

### Benefits with higher voltage

#### Charging Speed

- Higher power supports fast charging
- The voltage increase is the most feasible way of power increase (e.g., 400V to 800V system)

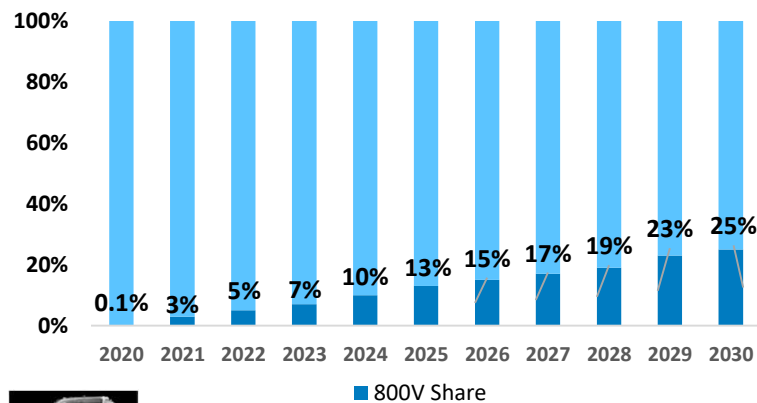


#### System Compactness

- By mating with SiC is possible to minimize 800V system and weight
- Porsche 800V Taycan saved 4kg in the high-voltage cable harness



### Global Forecast of 800V System Share in BEV



2020: 800V Porsche Taycan



2021: Hyundai-Kia 800V E-GMP platform



2021: 800V Xpeng G9

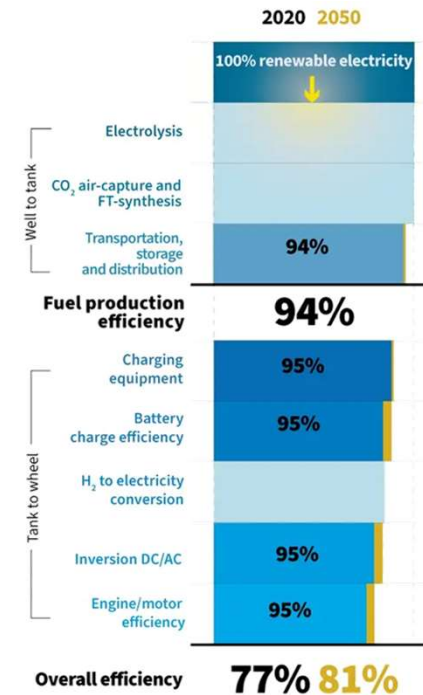


From 2023 on, intensive COEM 800V models market launch in plan

2026: VW 800V Trinity/SSP platform

Source: Yole Power semiconductor report 2022

### Higher efficiency of complete electrification path as key resource- and cost saving



Source: TRANSPORT & ENVIRONMENT, transportenvironment.org

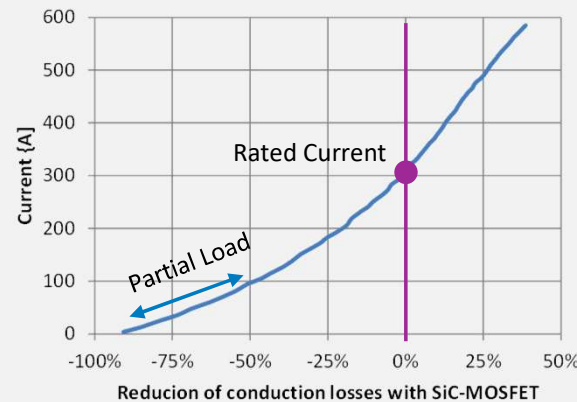
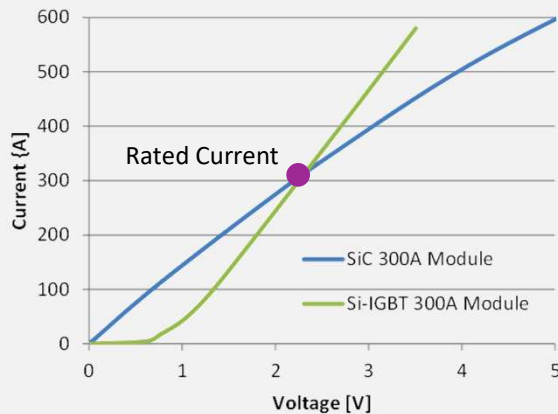
# Silicon carbide boosting the path to e-mobility

## SiC Technology as key enabler for superior performance

- SiC enables low-resistive unipolar devices at high blocking voltages

### Conduction Performance

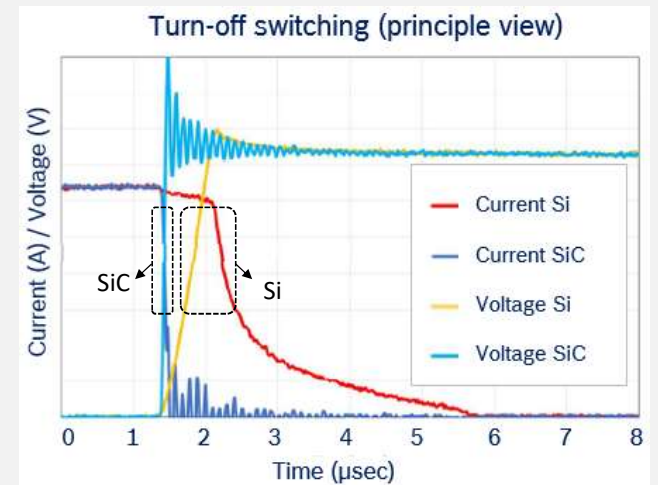
- Absence of PN-voltage drop leads to reduction of conduction losses, especially at partial load
- Comparison of 300A/1200V rated modules\*



\*Same nominal current rating with  $T_{case}$  85-90°C and max. Junction temperature)

### Switching Performance

- Unipolar structure enables fast switching
- Intrinsic diode with low reverse recovery



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## Overview of Automotive Applications

- Several systems operating at high voltage will profit from SiC performance
- Spectrum is even broader if fuel-cell driven cars and commercial vehicles are considered

### Drive Train

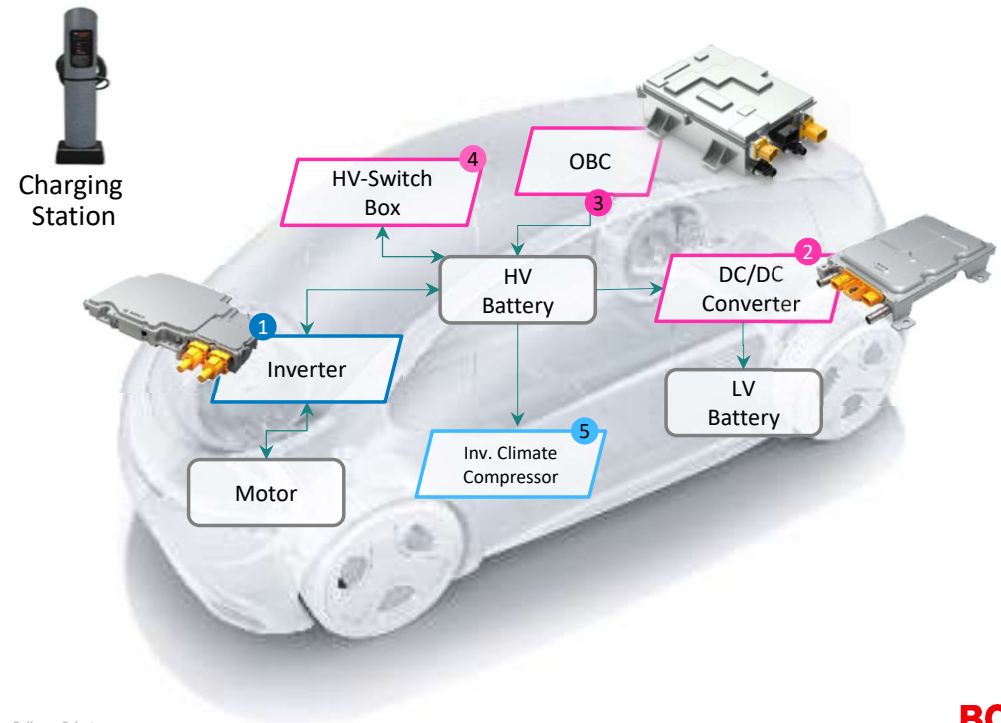
**INVERTER** ① **TRACTION CONVERTER**

### Energy Management

**CONVERTER** ② High-voltage to low-voltage  
**CHARGER** ③ Onboard  
**HV-Switch Box** ④ Offboard

### Auxiliary Systems

**Inv. Climate Compressor** ⑤ **Inv. Fuel Cell Compressor** **Electric Break for CV**

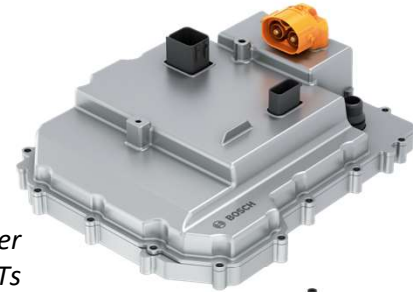


# Silicon carbide boosting the path to e-mobility

## Performance improvement for inverter

- Reduction of inverter cycle losses up to 50%
- Higher efficiency enables <sup>1,2</sup>
  - Lower energy consumption
  - depending on driving cycle and electric machine up to 6% increase of driving range or reduce battery size (enabling savings of 500€)
- Space savings due to smaller power module size
- Significant size reduction (DC-Link capacitance) by higher frequencies cannot be achieved due to system constraints (transients, resonances, ...)

1+2: Compared to 800 V Si-IGBT inverter for WLTC Cycle  
2: At \$100 battery costs per kWh and calculated with 80 kWh battery



1<sup>st</sup> Bosch Inverter  
with SiC MOSFETs



Bosch Power Module  
w/ SiC MOSFETs

400V system: SiC to extend 5% more driving range than Si



800V system: SiC to extend 12% more driving range than Si



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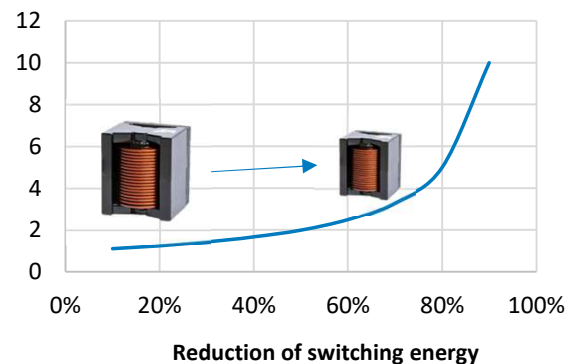
## Performance improvement for charger

- **Switching frequency** → key parameter to define size of filter elements
  - **Grid interface (PFC)** with hard-switching → low switching energy enables up to 3x higher frequency
  - **Isolating stage** with soft-switching → low output capacitance and resistance enables 2...5x higher frequency
  - Further increase of switching frequency does not bring much gains as cooling of filter elements becomes bottleneck
- 50% size reduction with 50% lower losses achievable with SiC → significant energy savings during lifetime, not only in charging but also “discharging” mode (V2X modes)

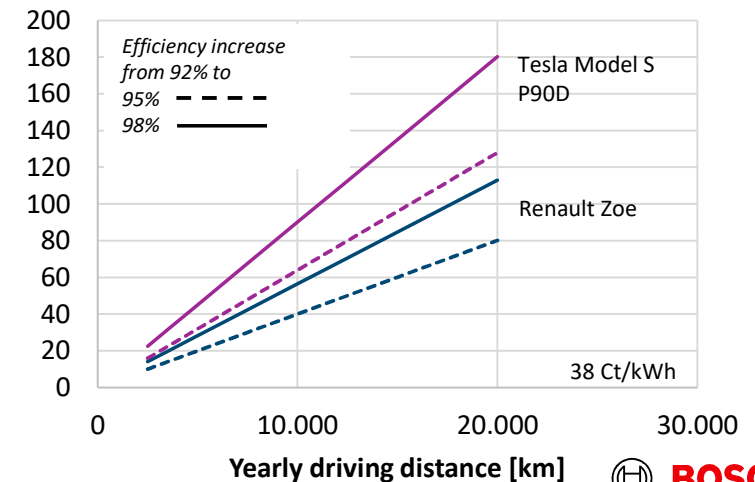
1<sup>st</sup> Bosch Charger  
with SiC MOSFETs



Switching frequency increase  
at same efficiency with SiC



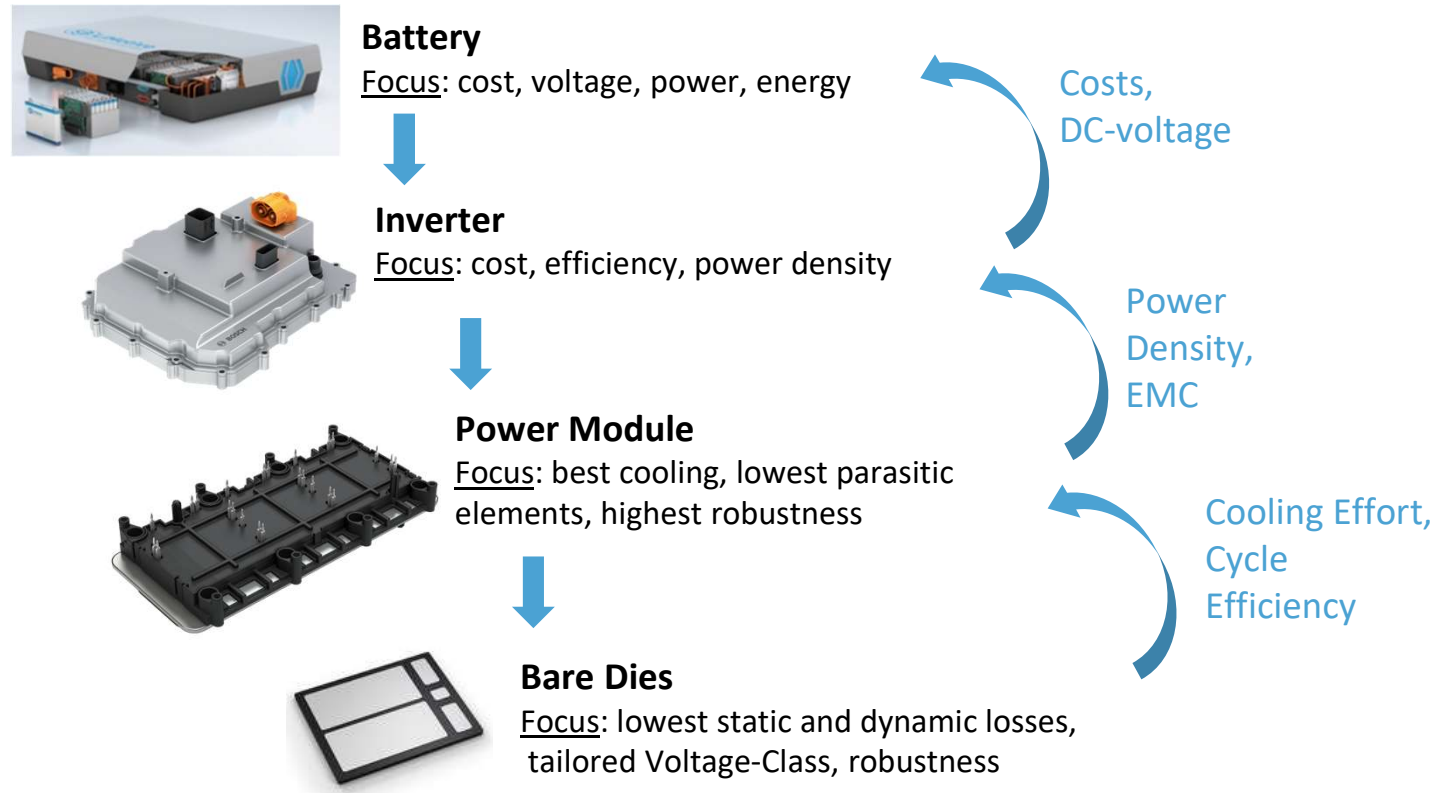
Yearly savings (€) due to higher efficiency of charger



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## System optimization with vertical integration

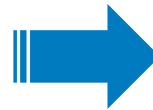
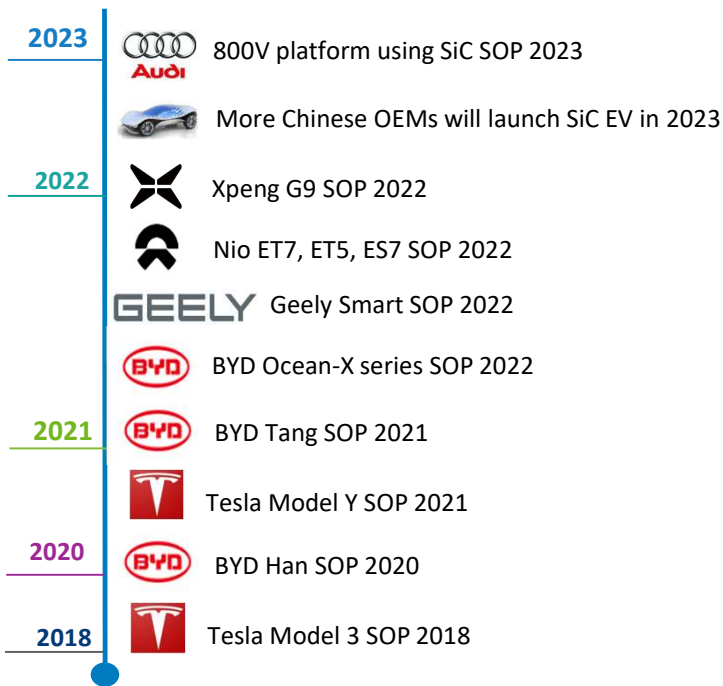
- System optimization is not a “one-way road”, but rather a multi-dimensional task with multitude of variants
- Best trade-off can be achieved with holistic approach in close cooperation with all domains



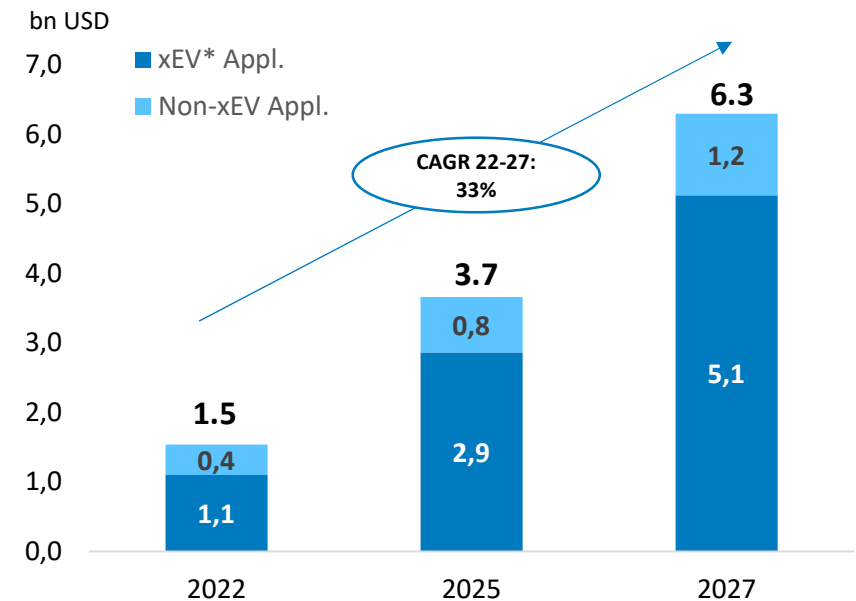
# Silicon carbide boosting the path to e-mobility

## Promising SiC market forecast in xEV applications

### OEM NEV Models with SiC Inverters



### Global SiC Market Forecast



\*xEV application: include NEV inverter, OBC, DC-DC and off board charger

Source: Yole Power semiconductor report 2022

SiC matching with 800V trend addresses key future directions:

- higher efficiency,
- fast charging,
- system compactness.

Therefore, a steady growth of global 800V share in BEV with SiC is foreseeable.

A close-up, angled view of a microchip or circuit board, showing a grid of colorful, rectangular components in shades of blue, green, yellow, and red. The components are interconnected by a network of fine lines.

Thank you!