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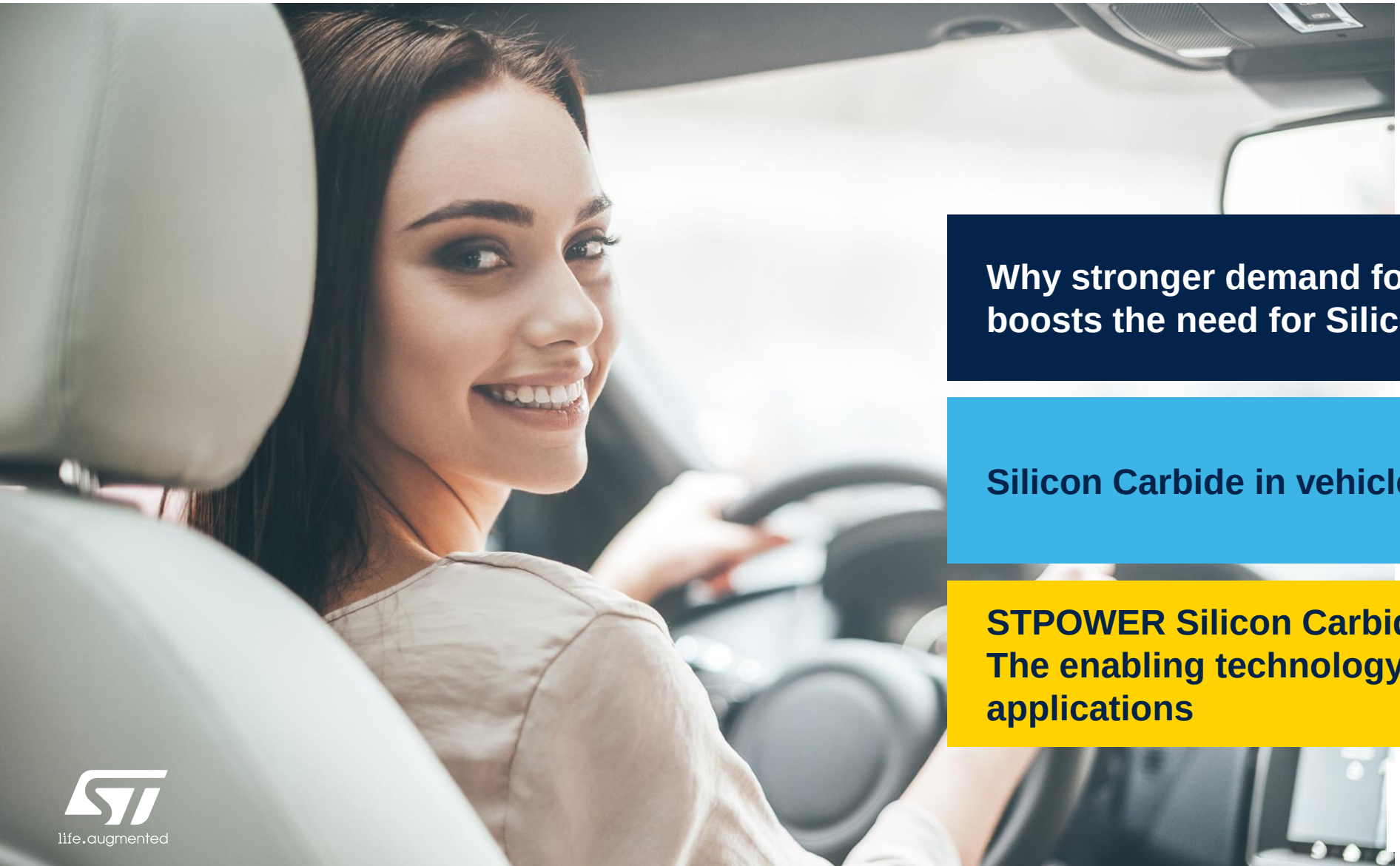
SiC power modules for your electric vehicle design

STMicroelectronics

STPOWER Silicon Carbide (SiC) MOSFET offers for electric vehicles



Why stronger demand for e-vehicles boosts the need for Silicon Carbide (SiC)

Silicon Carbide in vehicle applications

STPOWER Silicon Carbide
The enabling technology for automotive applications

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Why stronger demand for electric vehicles boosts the need for SiC

Replacing silicon based IGBTs and Diodes by SiC solutions will result in

- Higher efficiency and extended vehicle range
- Smaller form cost and weight
- Less cooling effort and faster recharging

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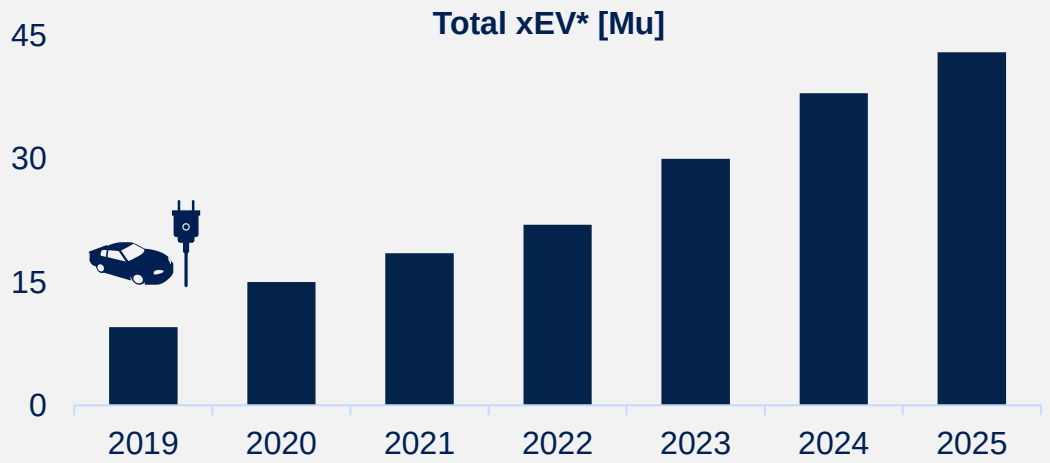
Electrification Market Outlook

Electrification Boosted by Power Silicon & New Materials will Accelerate Growth of a Flattish Light Vehicles Market

Continuous and Consistent Growth of Electrified Light Vehicles - xEVs



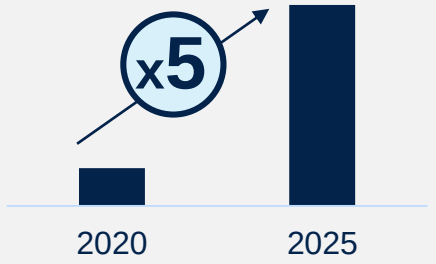
- Total Electrified Vehicle **CAGR '19-'25 → >28%**
- By **2025 Battery Electric Vehicles** will be **>25%** of Total Electrified Vehicles

Silicon Carbide allows Battery Electric Vehicles to go Beyond the Limits of Silicon

Replacing Silicon based IGBTs and Diodes in the **Traction Inverter** and **On-Board Charger** by **SiC MOSFETs** resulting in:

- Higher efficiency
- Smaller form cost & weight
- Less cooling effort
- Faster recharging
- Extended vehicle range

Today **>40% BEVs** are using **SiC**

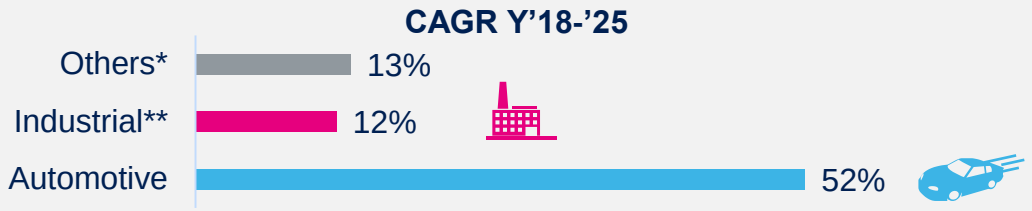


*including Mild Hybrid, Full Hybrid, Plug-in Hybrid, Battery Electric Vehicle

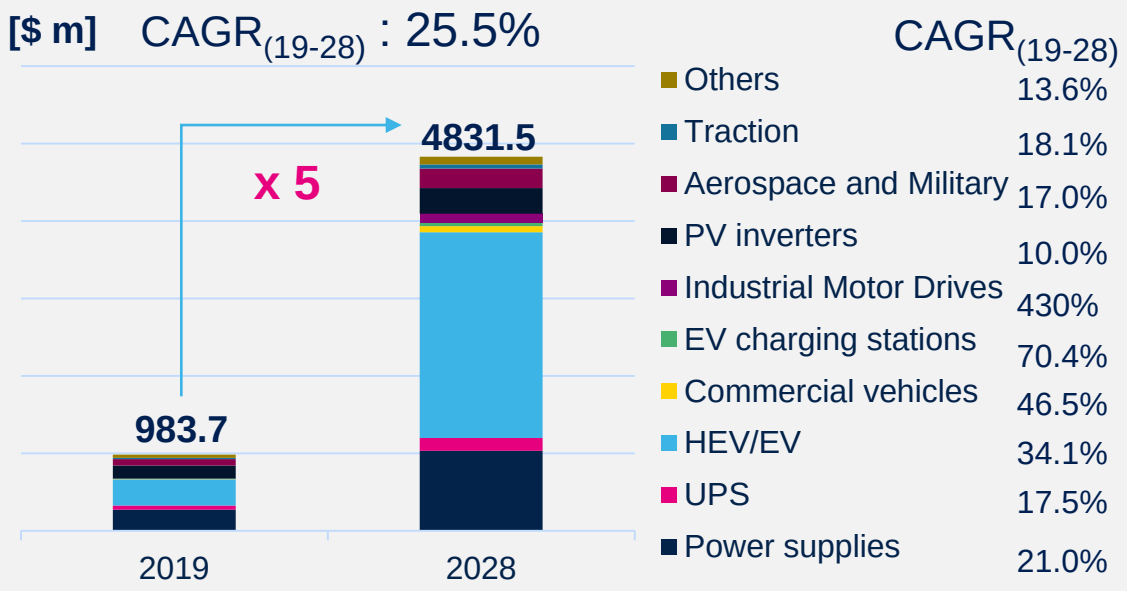
xEV source: SA, IHS, ST Internal
SiC source: IHS, Feb 20, ST internal

Silicon Carbide Market Outlook

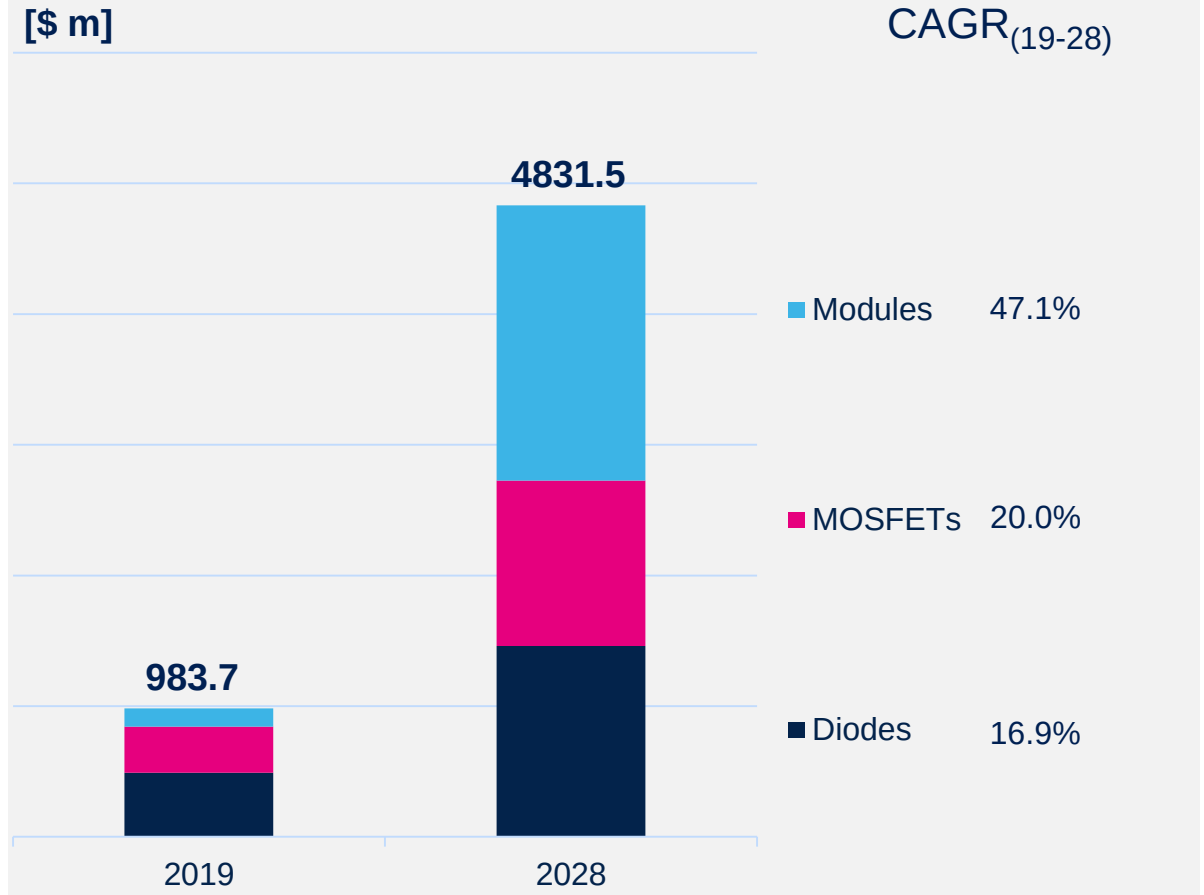
SiC power semiconductors by application



Silicon Carbide Continuous Growth



SiC power semiconductors by macro product family



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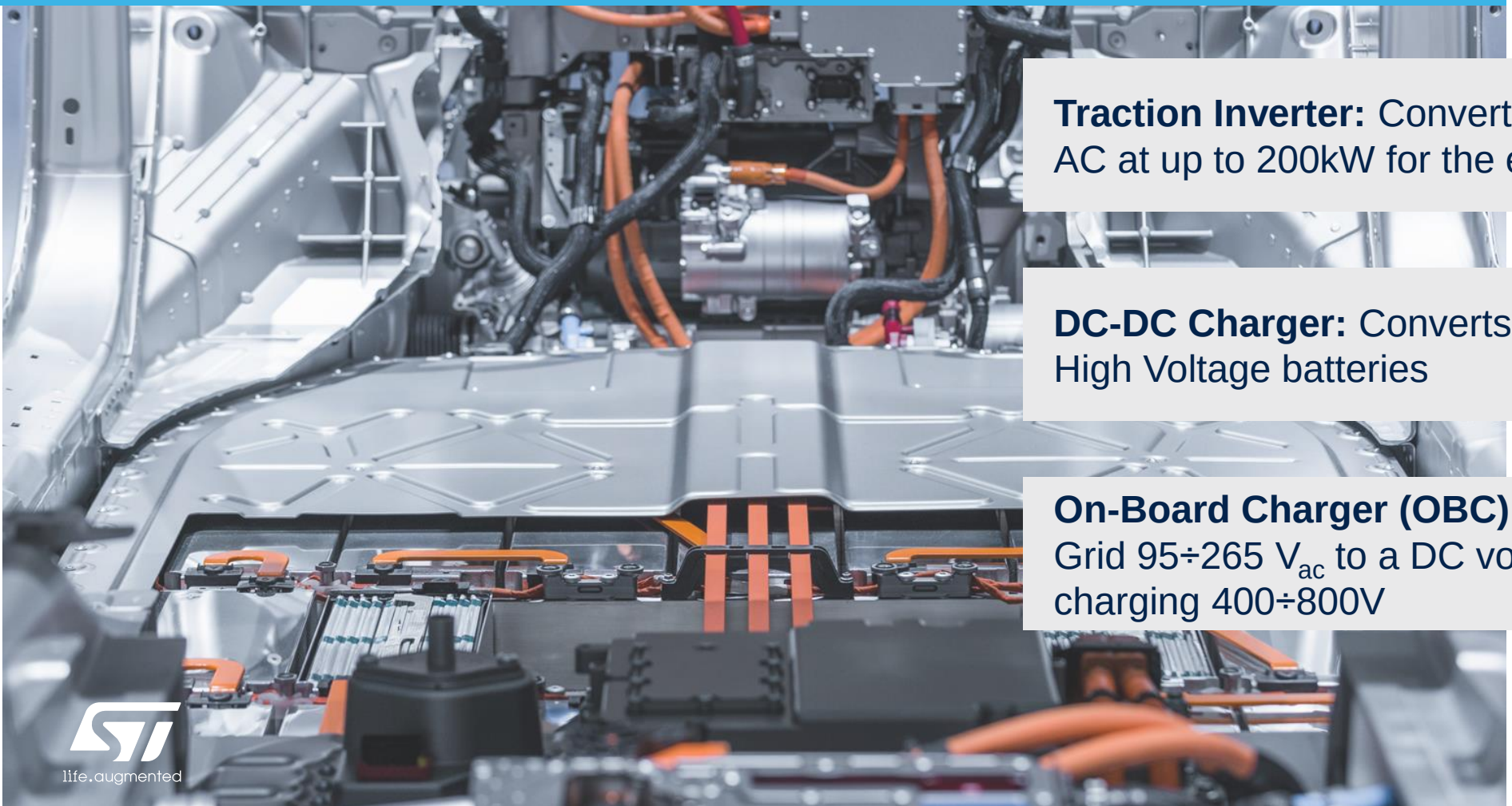
**Military and aerospace, traction, Other applications*
***renewable energies applications included*

Source: IHS – SiC & GaN Power Semiconductor Report (May 2019), mid case.
(SAM by segments including: SiC MOSFET + SiC Diodes + Hybrid modules + full SiC modules)

Silicon Carbide in electric vehicle applications

One key technology based on Wide Band Gap (WBG) semiconductors for multiple applications



Traction Inverter: Converts DC Voltage into 3-phase AC at up to 200kW for the electric motor

DC-DC Charger: Converts High Voltage DC from High Voltage batteries

On-Board Charger (OBC): Converts AC from the Grid 95÷265 V_{ac} to a DC voltage required for battery charging 400÷800V

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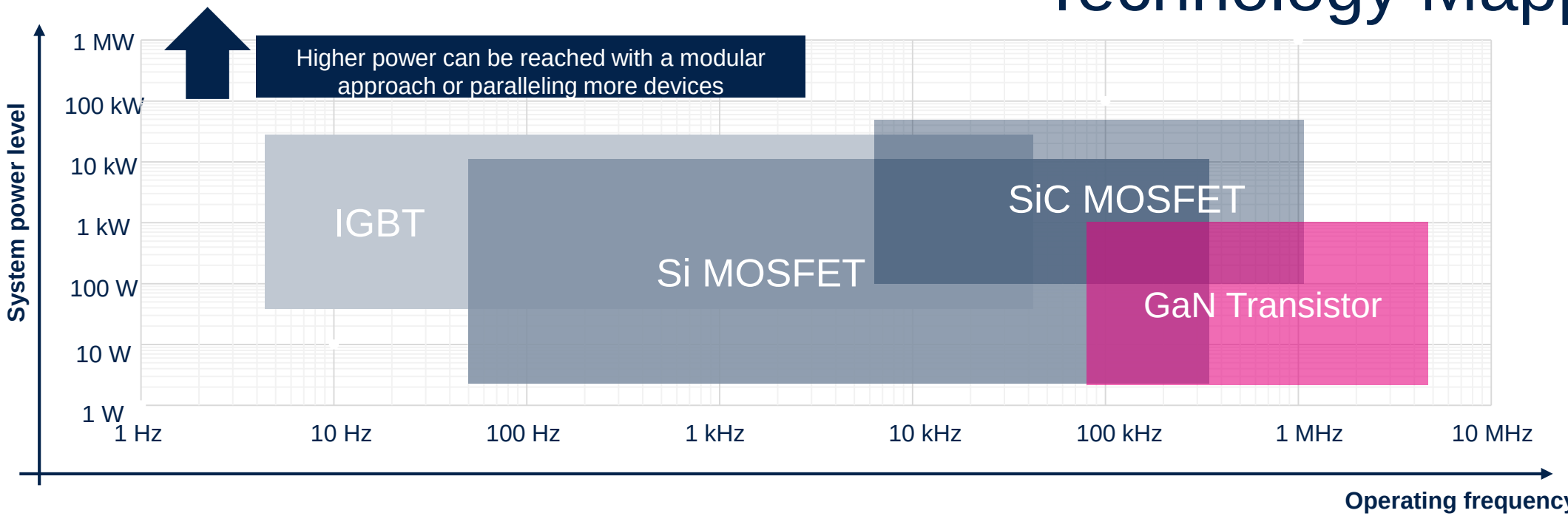
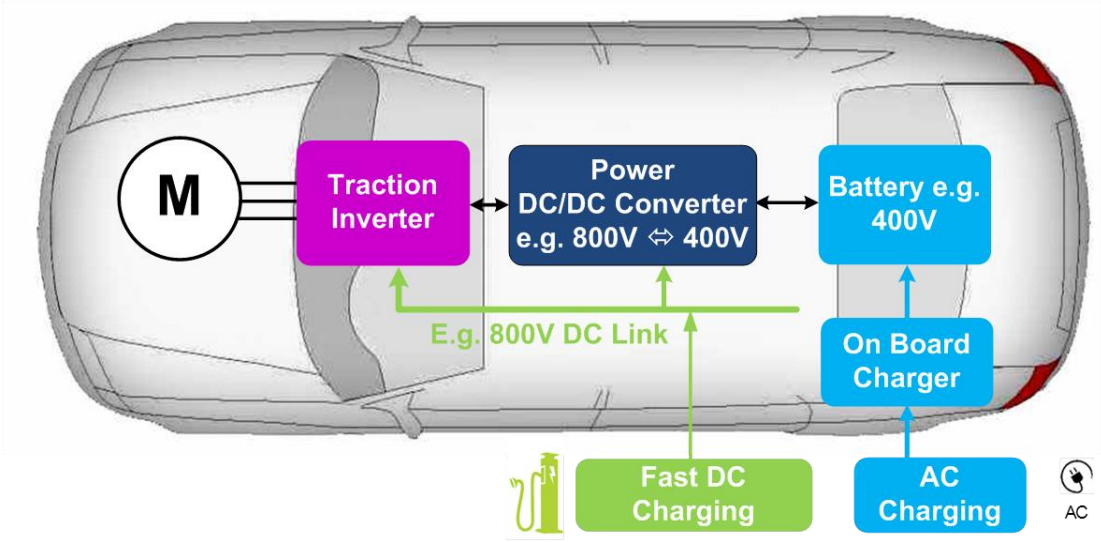
Wide Band Gap Technology Mapping



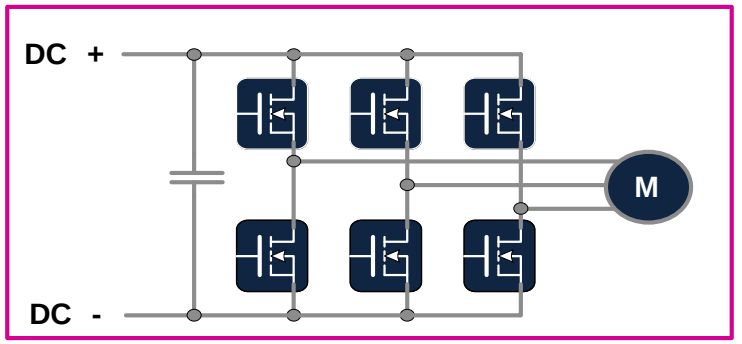
Technology	Features	Preferred for (some example)
Si HV MOSFET	Medium-high power, high voltage, up to several kW, high frequency	SMPS, server and telecom, DC/DC, low power motor control, OBC, charging station, …
IGBT	Very high power, high voltage, medium frequency up to 50 kHz	HV motor control, H.A., UPS, welding, induction heating, main traction, …
SiC MOSFET	Very high power, high voltage, high frequency, high temperature ratings	High power DC/DC, UPS, charging station, main traction inverters, OBC, …
GaN Transistor	Very high frequency > 80 kHz, medium-high power up to several kW	SMPS, Telecom Power, DC/DC, OBC, PV inverters, LiDAR, …

Electric vehicles applications

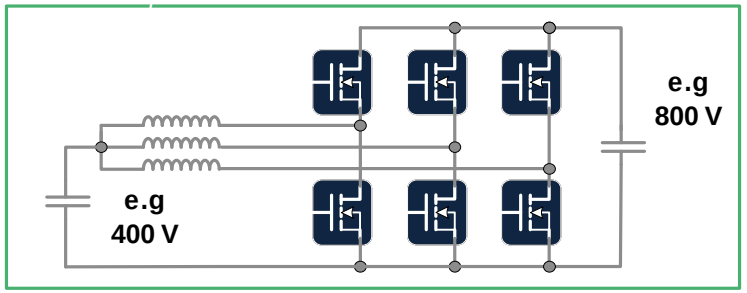


- **SiC MOSFETs**, results in **higher efficiency**, smaller form factor, less complexity in cooling Vs. Si approach
- High power DC-DC converter for fast and reliable **DC Charging** reduces the charging time of HEVs and EVs

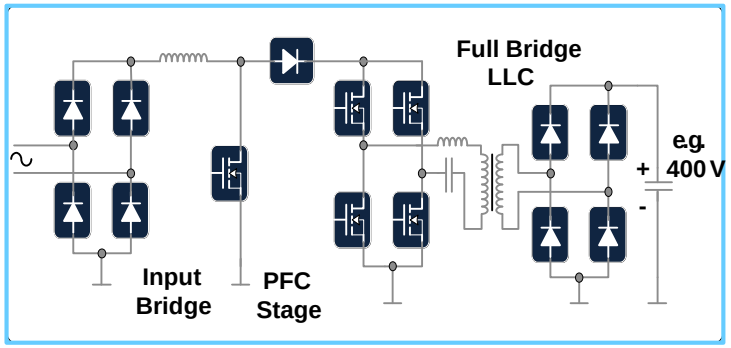
Traction Inverter



HV DC-DC Converter



On-Board Charger



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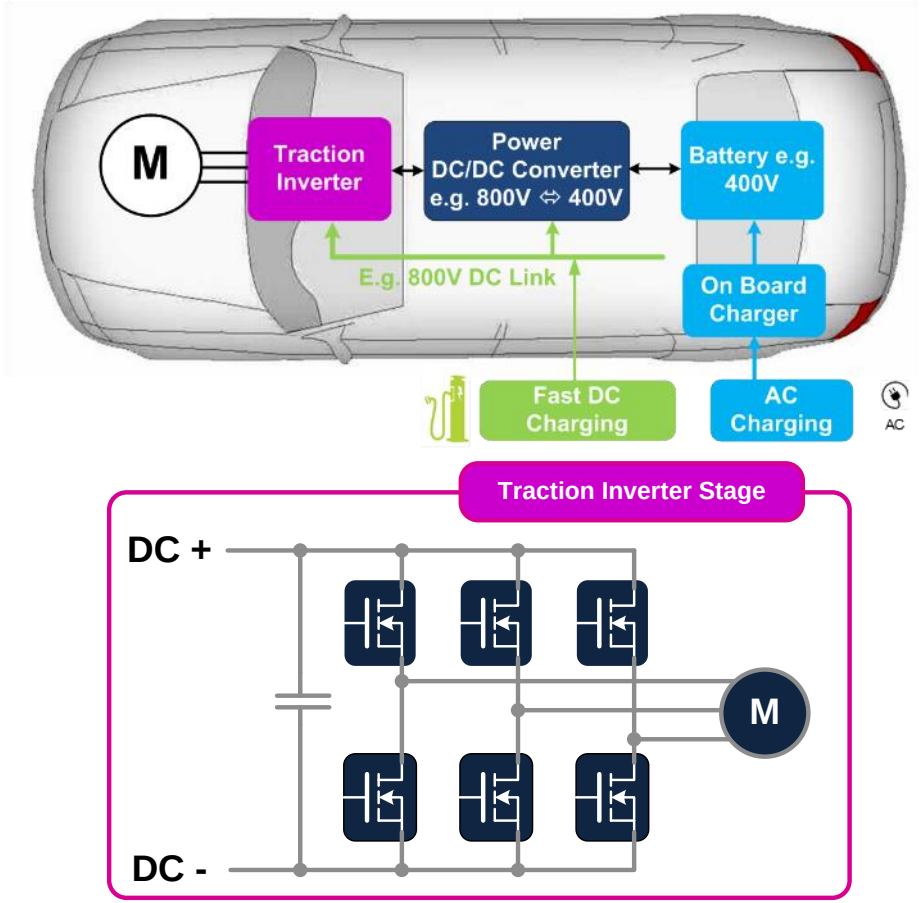
SiC technology for traction inverter

To enhance traction inverter efficiency



- High power inverter stage to **drive the vehicle traction motor.**
- Replacing silicon based IGBTs and diodes in the inverter stage by **SiC MOSFETs**, results in **higher efficiency**, smaller form factor, less cooling requirements, …
- Comprehensive **ST portfolio of STPOWER SiC MOSFETs** as bare die, package or module solution in 650 V as well as 1200 V technology.

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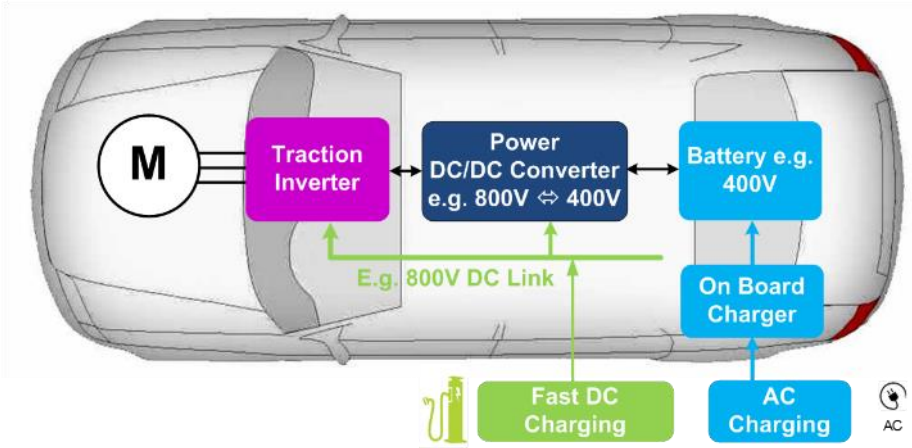
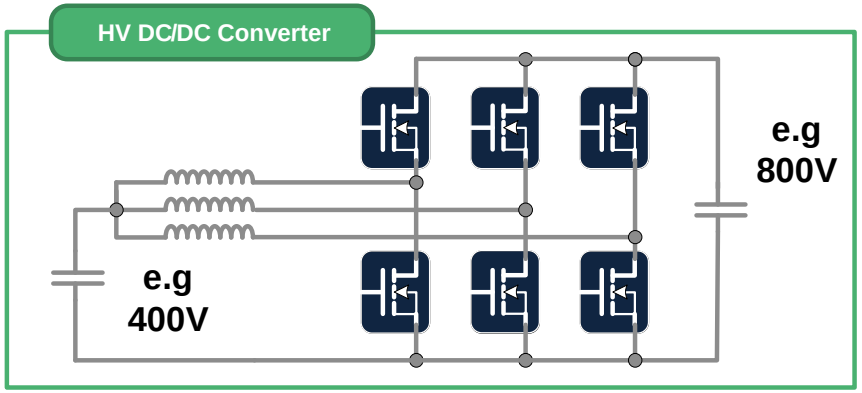
SiC technology for HV DC-DC converter

To minimize conduction and switching losses





- High voltage DC-DC converter to **boost battery voltage up,** enabling operation of the traction motor within optimized voltage range.
- High voltage DC-DC converter for fast and reliable **DC Charging** in dual voltage domains reducing significantly the charging time of HEVs and EVs.
- **STPOWER** SiC MOSFET solutions from ST operate at **higher switching frequency** and at **higher temperature** enabling
  - minimized magnetic losses
  - a smaller, lighter cooling system
  - the highest power levels

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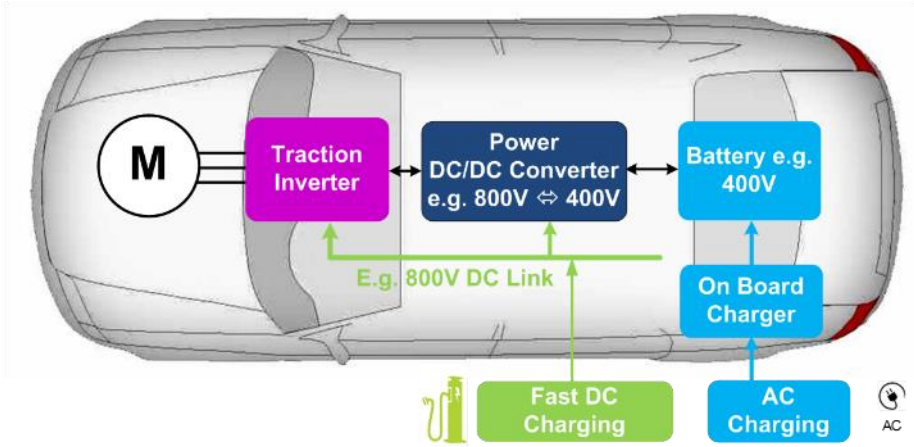
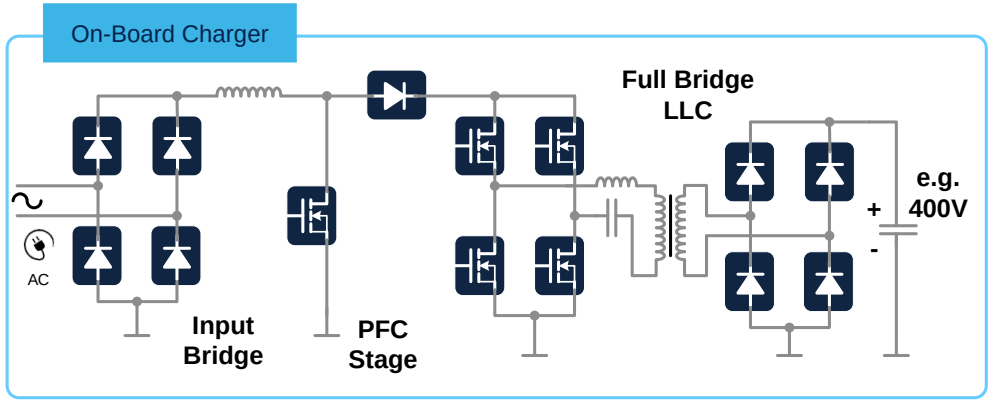
SiC technology for on-board charger

To speed-up systems charging time





- **Charging the battery** of plug-in HEVs and EVs from the single-phase or 3-phase power grid.
- Different architectures and topologies in automotive are required to **support scalable solutions.**
- ST solutions enable **compact and efficient** designs
  - STPOWER SiC MOSFETs & SiC Diodes
  - STPOWER SJ MOSFETs, IGBTs, fast Diodes & SCRs

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STPOWER Silicon Carbide
The enabling technology for automotive application

ST best-in-class SiC Technology

ST offers a broad range of SiC solutions: Discrete, Bare Dice, Module

ST continue capacity expansion to support market acceleration

ST invests on advanced package technologies with HiP247-4™ leads, HU3PAK™, STPAK™, ACEPACK™ SMIT

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STPOWER SiC MOSFET families Overview

The best high voltage and high frequency switch for high density applications

Gen1 **1200V-1700V**	The best option for **R_{ON} vs. Tj** behavior: highly suitable for motor drive applications
Gen2 **650V, 1200V**	The best **R_{ON} vs. Q_g trade-off** : highly suitable for a broad range of automotive and industrial **applications**
Gen3 **650V, 750V, 900V, 1200V**	An ultra-fast series with the **best R_{ON} vs. Q_g trade off:** highly suitable for very high frequency applications

SiC MOSFET: the true R-evolution for high voltage power switches

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STPOWER Silicon Carbide the enabling technology for automotive applications

Silicon Carbide product portfolio

AG 650V SiC MOSFETs: Gen 2 High Voltage Product Family in production

- SCTx35N65xx
- SCTx100N65xx

H²PAK-7

HiP247™

HiP247™ long leads

AG 1200V SiC MOSFETs: Gen 2 Very High Voltage High Product Family in Production

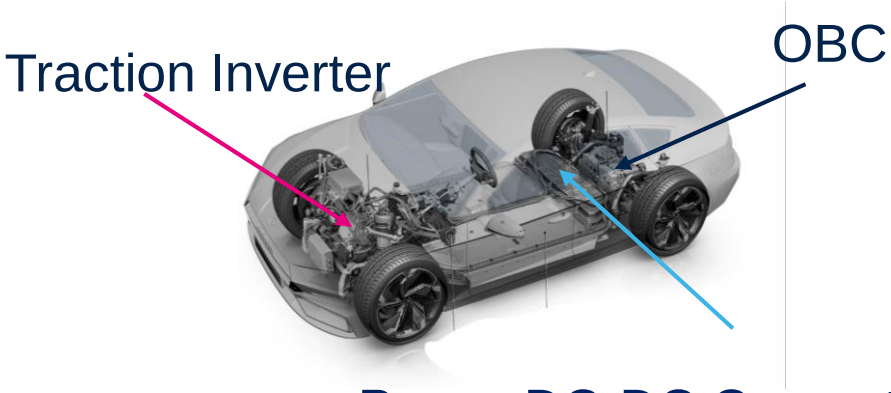
- SCTx40N120xx
- SCTx70N120xx
- SCTx100N120xx

H²PAK-7

HiP247™

HiP247™ long leads

Main applications



Key benefits

- Smaller form factor with high power density
- Higher system efficiency at high frequency
- Reduced size/cost of passive components
- Low power losses at high temperatures
- Compact design and cost-effective system approach
- Simpler topologies

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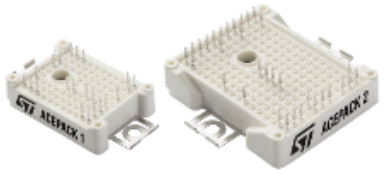
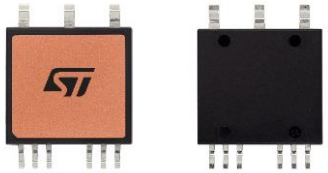
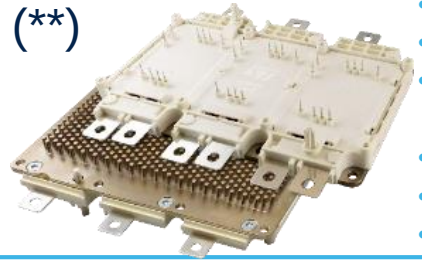
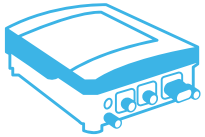
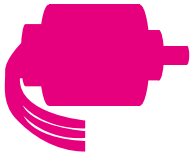
STPOWER ACEPACK* module
Adaptable Compact Easier PACKage

Option	Key features	Configurations
A1 - A2 (*) 	• 100% controlled by ST for SiC, MOSFETs, IGBTs and Diodes • Compact design and cost-effective system approach for a plug & play system solution • Configuration flexibility • 2500 V_{RMS} electrical isolation	• CIB • Six-pack • Three level • Boost interleaved • ….
SMIT (**) 	• 2500 V_{RMS} electrical isolation • SMD assembly • Total footprint 32.7 x 22.5 mm • Top side cooling • Low thermal resistance	• Bridge rectifier • Half-bridge • Single-boost • ….
DRIVE (**) 	• Optimized for 200 kW inverters • SiC MOSFET based switch • Improved light load power losses for extended EV driving ranges • Extreme low conduction losses • Short circuit ruggedness • Direct cooled Cu base plate with pin fins	• Six-pack

Target Applications
 On Board Charger
DC-DC Converter
 Traction Inverter

(*) available (**) Engineering Samples available

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STPOWER SiC MOSFET product portfolio by application

Breakdown Voltage	650 V	750 V	1200 V			1700 V
Series	Gen2	Gen3	Gen3	Gen1	Gen2	Gen3	Gen1
On-state resistance	18 mOhm to 55 mOhm	55 mOhm	11 mOhm	52 mOhm to 520 mOhm	25 mOhm to 75 mOhm	70 mOhm and 15 mOhm	1 Ohm and 65 mOhm
Focus Applications	**OBC & DC-DC Renewable energy Power Supply Industrial drives**	**OBC & DC-DC Power Supply Solar**	**DC-DC Renewable energy**	**Photovoltaic HVAC Power supply**	**OBC & DC-DC Inverter Street Lighting Charging stations Industrial drives**	**Inverter DC-DC Power Supply**	**DC-DC Power Supply Renewable energy**

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30+ years' experience with STPOWER and Discrete
The success factor of fast growing EV market

GaN HEMT

650 V and 100 V normally off solutions to boost efficiency and power density thanks to fast switching operation

OBC

48V DC-DC

HV Si MOSFET: MDmesh

Super-Junction MultiDrain

series

- **DM** → **Higher Efficiency**
- **K** → **Higher Voltage Range**
- **M** → **More Power Density**

OBC and DC-DC converter

IGBT

High Power IGBT Trench Field-stop

Narrow MESA

Traction

series

- **M** → **Electric heater and aircon**
- **V** → **OBC and DC-DC**
- **HB** → **PTC Heater, OBC, aircon**

ST commitment

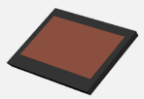
Investing in new facilities to sustain **Power Silicon** growth

Agrate Fab

300mm

Continue innovation on **Power Package**

2SPAK



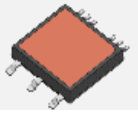
PowerFLAT 8x8 DSC

STPAK

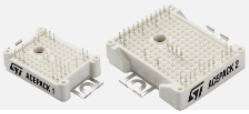
TO-LL

PowerFLAT 8x8 HV

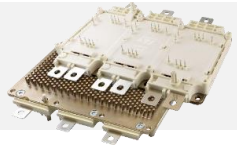
HU3PAK



ACEPACK SMIT



ACEPACK 1, 2



ACEPACK DRIVE

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Thank you

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