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SiC: the power revolution is approaching the car volumes

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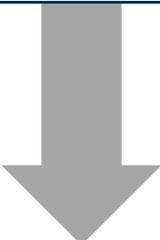
STMicroelectronics

The impact of global energy consumption (1/2)

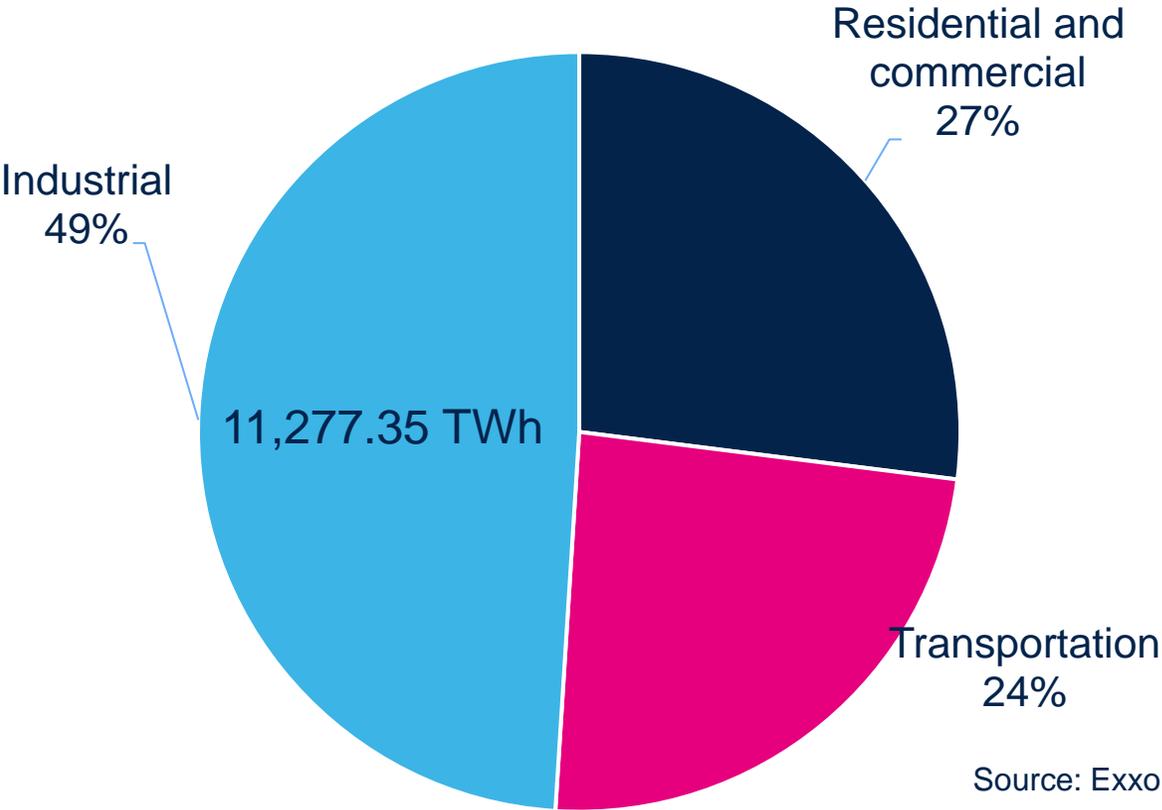
Electricity consumption by sector

23,015 TWh:
total worldwide
electricity
consumption
(2020)

1% efficiency improvement in
industrial electricity consumption



we get a total energy saving of
112.77 TWh



Source: ExxonMobil 2021 Outlook for Energy

The impact of global energy consumption (2/2)

By reducing our energy consumption, we can reduce our carbon footprint

Total energy saving equals
~ 18 standard nuclear plants

A photograph of a nuclear power plant with two large cooling towers and a high-voltage power line tower in the background.

66.08 MMBOe

A photograph showing a large stack of black oil barrels.

13.85 M tce

A photograph of two yellow coal trucks on a dirt road in a coal mine.

26.29 Tg CO₂

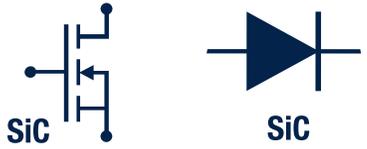
A photograph of an industrial facility with smokestacks emitting smoke, situated near a body of water.

9.63 M toe

A photograph of an offshore oil rig in the ocean.

tce: tons of coal equivalent, **toe**: tons of oil equivalent
MMBOe: million barrels of oil equivalent

Sources: ExxonMobil 2021 Outlook for Energy, STMicroelectronics



SiC value proposition

SiC technology benefits versus conventional silicon IGBT

Higher performance & voltage operation

- Extremely low power losses
- High efficiency at low current
- Intrinsic SiC body diode (four quadrant operation)

Higher operating frequency

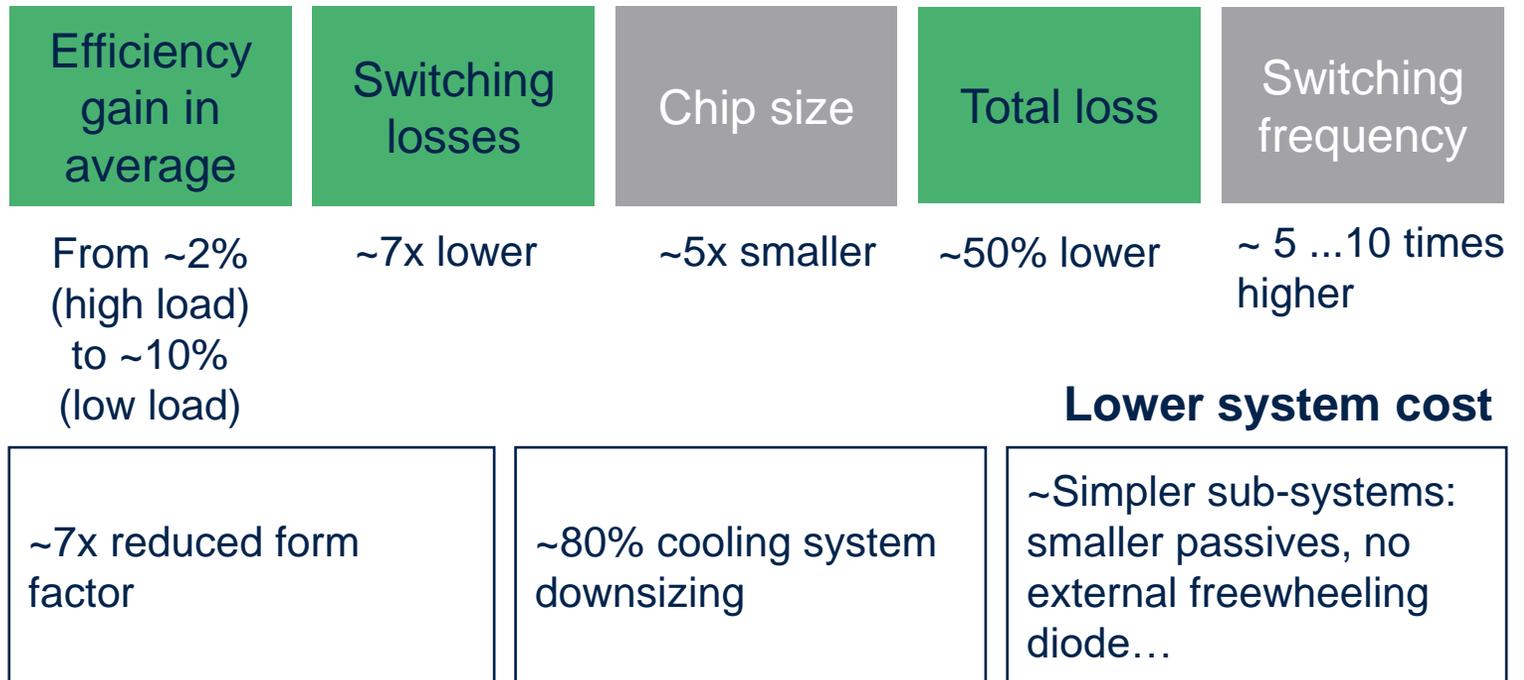
- Lower switching losses
- Excellent diode switching performance

Higher operating temperature

- Operating up to 200°C junction

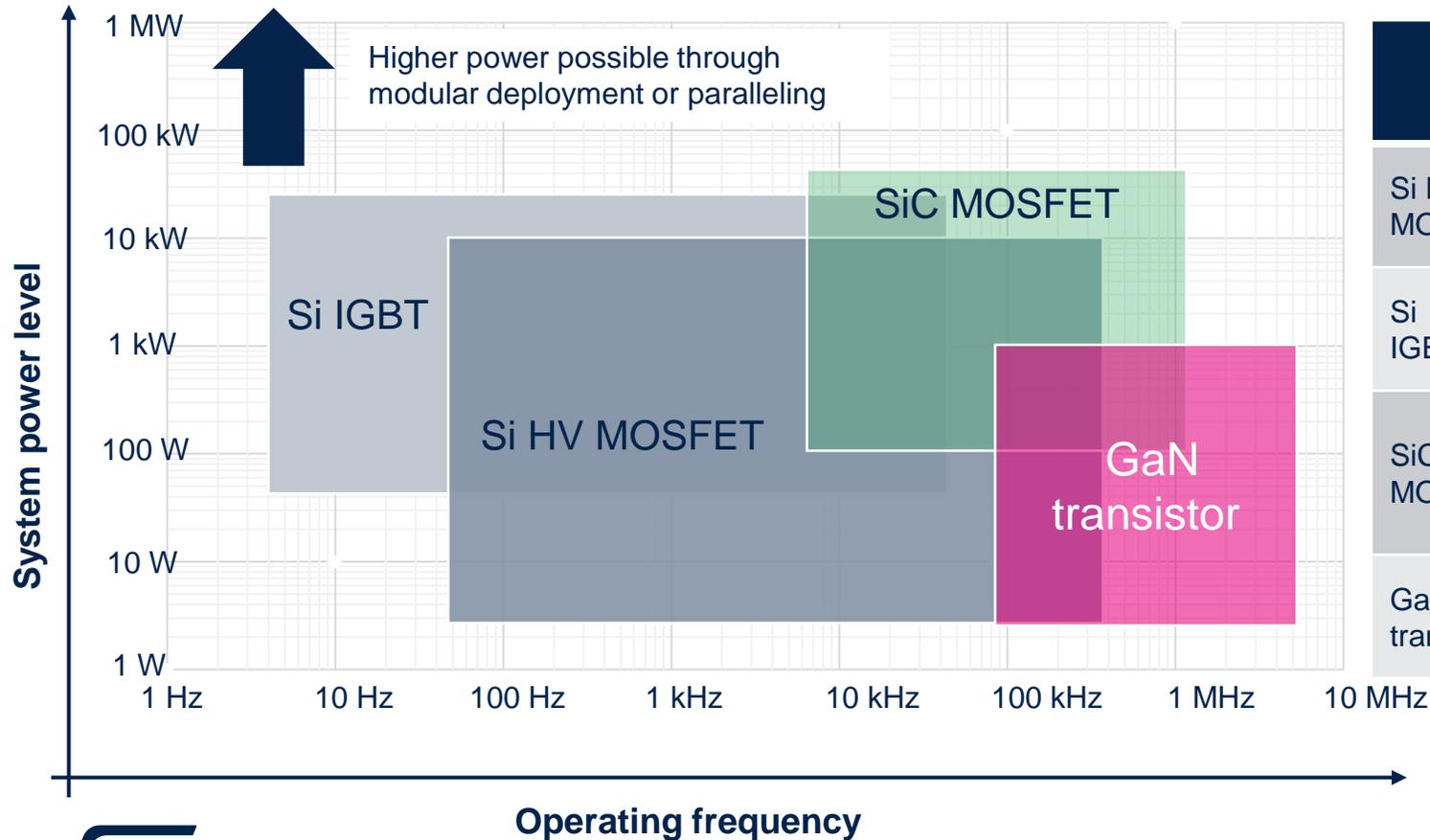
SiC advantages for automotive

Electrification - mileage extension, smaller battery (or increased battery reliability), fast & efficient charging



Silicon and wide-bandgap overview

Wide product range targeting automotive and industrial power applications



Automotive examples of power applications

Si HV MOSFET	DC-DC converter, low-power motor control, OBC, charging Station, DC link discharge ...
Si IGBT	HV motor control, PTC heating, traction inverter, DC link discharge...
SiC MOSFET	High power DC-DC converter, charging station, traction inverter, OBC, e-climate compressor, battery disconnect switch, smart power distribution, fuel cell (DC-DC and high-pressure pump), DC link discharge
GaN HEMT transistor	Class D amplifier, wireless charger DC-DC converter, OBC, LiDAR, ...

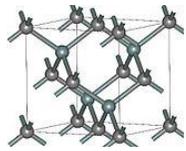
Si = Silicon; HV = High voltage; SiC = Silicon Carbide

More than 25 years of focus on SiC

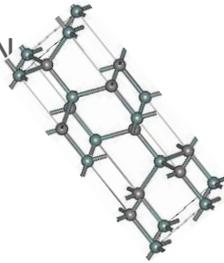
Si - Silicon

GaN - Gallium Nitride

SiC - Silicon Carbide



Si
Cubic



SiC
Hexagonal

Figure of Merit: Si, SiC & GaN

— Si — GaN — SiC
Electric Field [MV/cm]

High Voltage Operation

Energy Gap [eV]

High Switching Frequency

Electron Velocity [* 10⁷ cm/s]

Thermal Conductivity [W / (cm *K)]

High Temperature Application

Melting Point [* 1000°C]



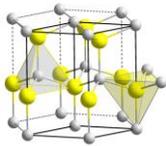
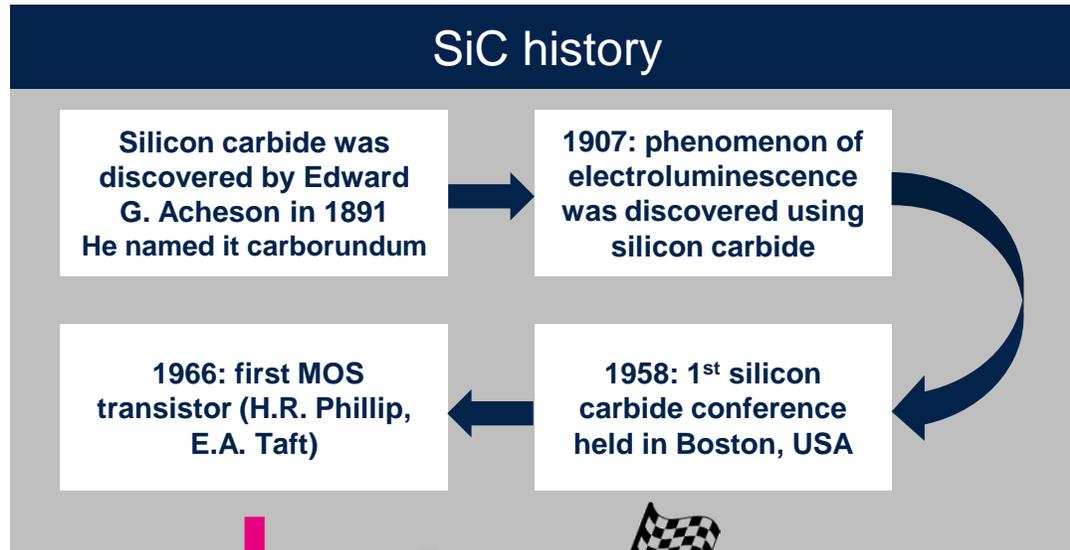
Oct 2022 Integrated substrate manufacturing facility in Italy

Dec 2020 3rd Gen MOSFET Qualification

June 2017 2nd Gen MOSFET start production

June 2014: 3rd Gen diode start production

September 2014: 1st Gen MOSFET start production



GaN
Hexagonal (cubic)



Car makers becoming mobility service providers

Traditional approach
“buy model”

Car makers

Inverter
producers

Tier-1



Module
manufacturers

Tier-2



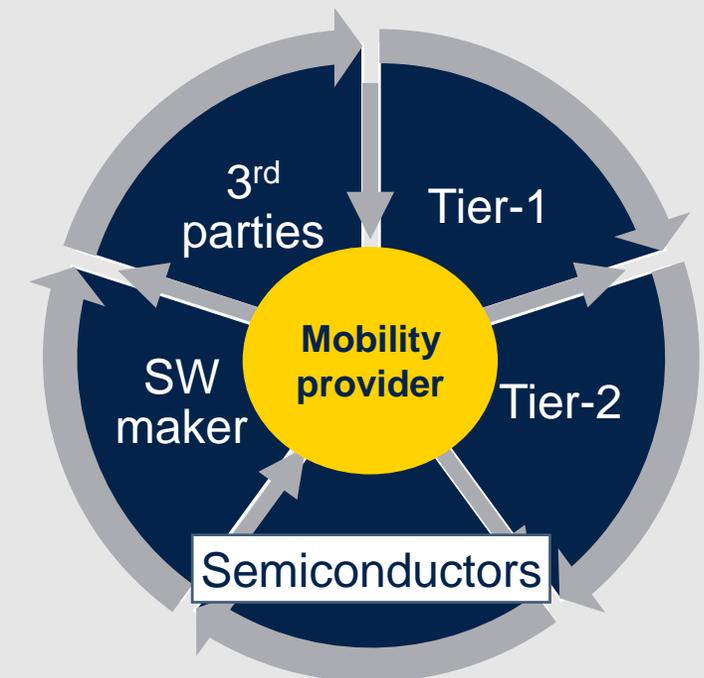
Semiconductors



- Deploy new technologies and semiconductor solutions more effectively and rapidly to the car
- Directly drive the semiconductor roadmap with a closer link to final application
- Secure capacity of key technologies applicable to electric vehicles

OEM direct contact with
semiconductor supplier

New ecosystem
“make model”



800V accelerates SiC adoption in EV subsystems

- Higher breakdown voltages more easily addressed by SiC
- System and component downsizing more easily realized with SiC
- At 800V, the benefit of low switching losses in SiC become more prevalent



Switch downsizing and system efficiency gain enabled by SiC increasing at 800V

400V /
160kW

~3x smaller semiconductor area

3-5% higher efficiency

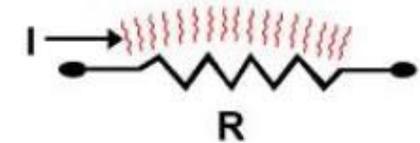
800V /
200kW

~5x smaller semiconductor area

8-12% higher efficiency

Widespread adoption of 800 V bus

Higher battery voltage in EV/HEV reduces losses in inverters and other EV subsystems, and facilitates faster charging

$$P = I^2 R$$


The diagram shows a resistor symbol labeled 'R' with an arrow labeled 'I' pointing to the right through it. Red wavy lines above the resistor represent heat being generated.

>400V
Up to 800V

Voltage

Current

Joule loss reduction



Ultrafast charging enabler (down to about 20 min of charging time)



>400V
Up to 800V

Voltage

Power increase

- More powerful cars while keeping device currents down to acceptable levels
- Allows use components with lower current rating (higher voltage)
- Enables fast battery charging

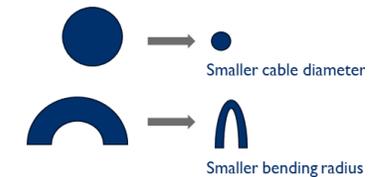
>400V
Up to 800V

Voltage

Current

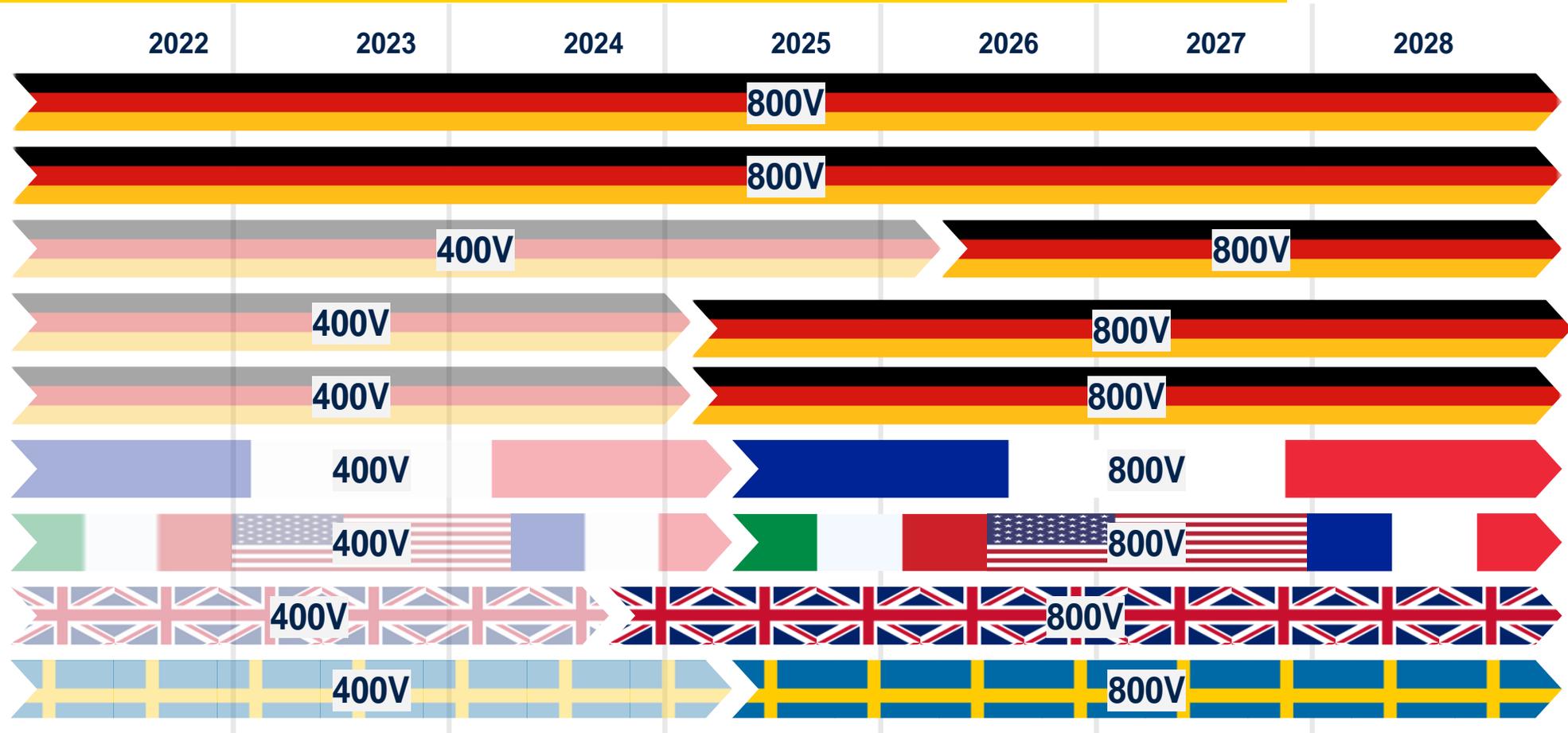
Cost and weight reduction

Easier integration in vehicle

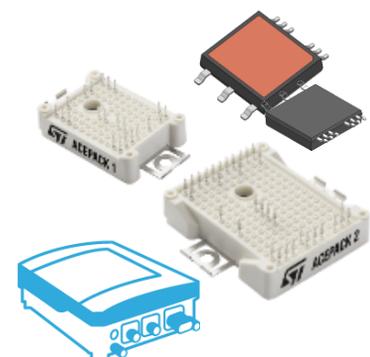
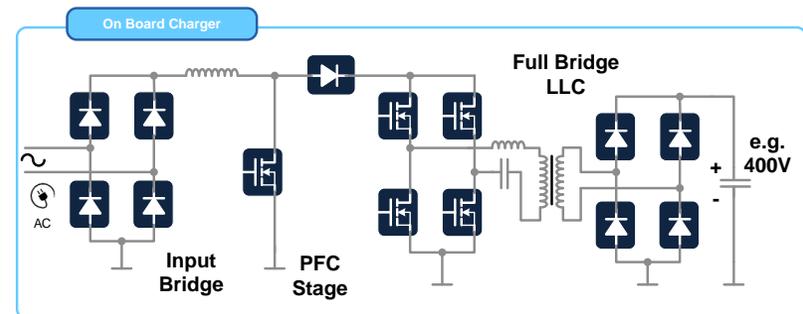
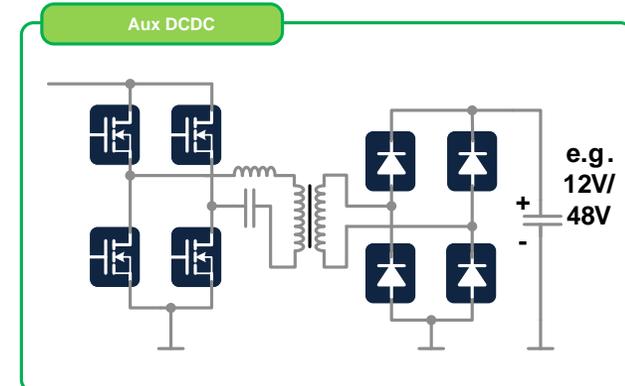
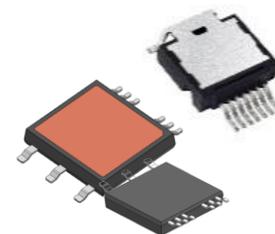
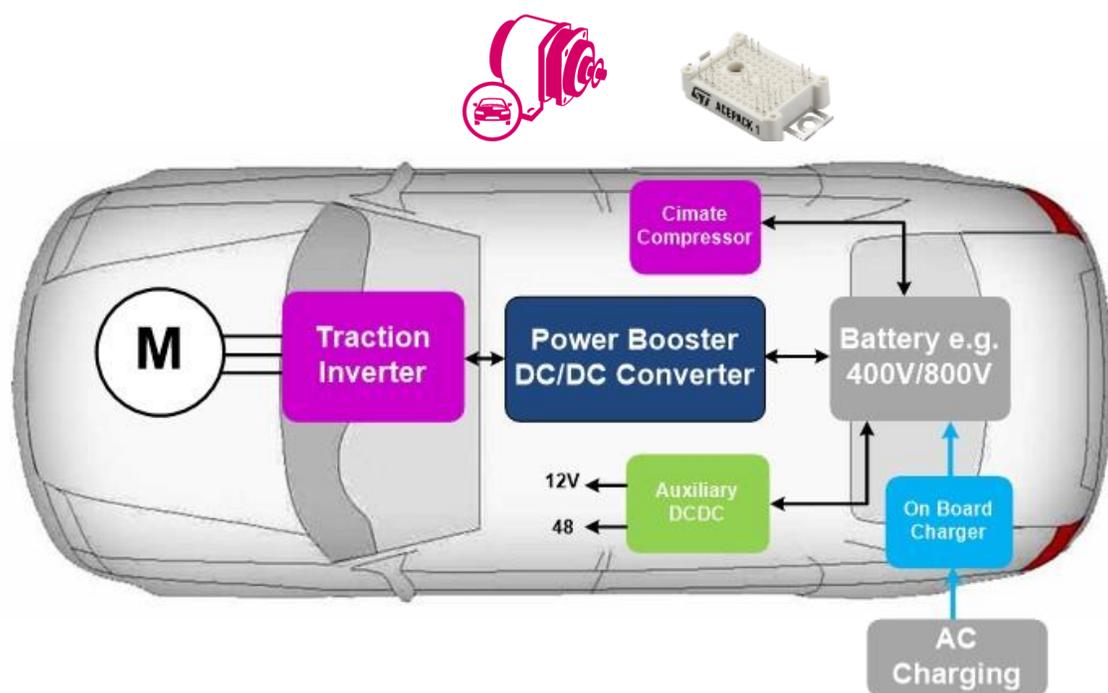
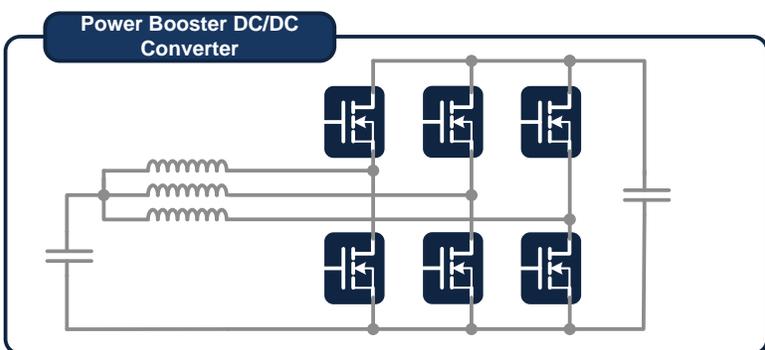
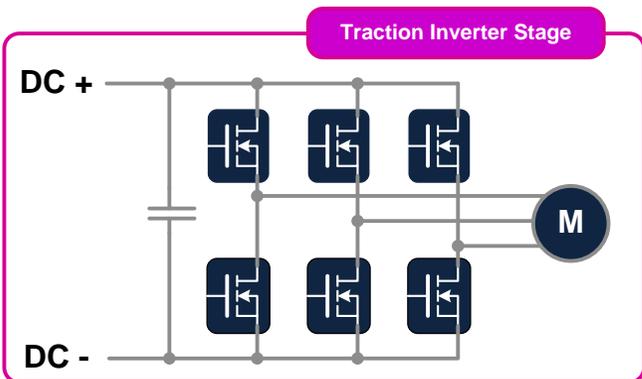


EMEA market DC BUS voltage evolution

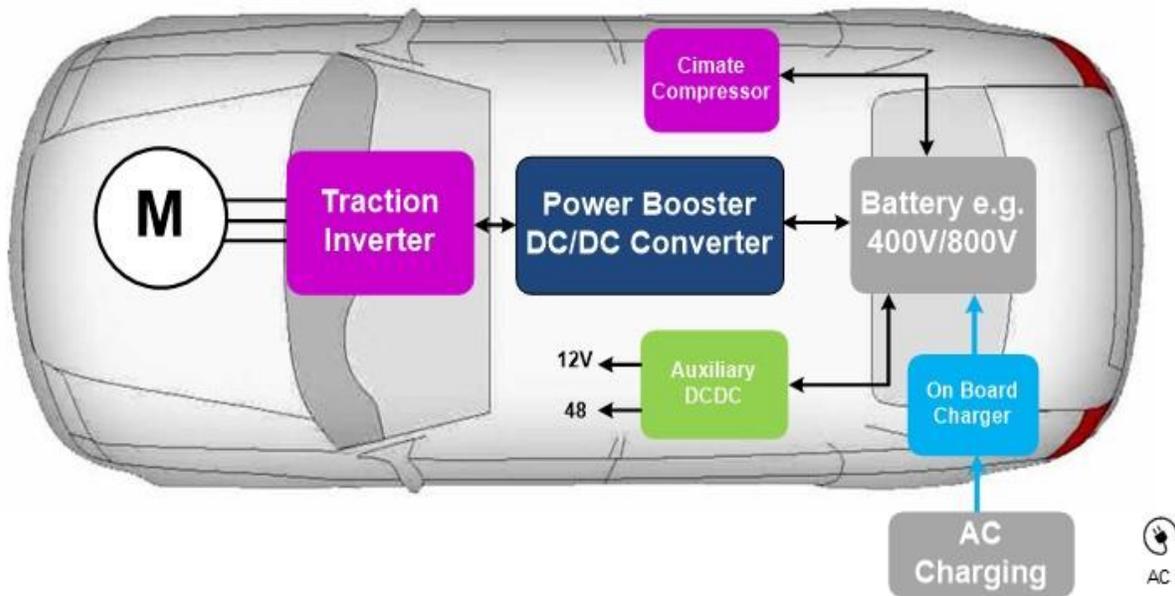
BUS voltage in EMEA converged to 800V in 2025 for BEV / PHEV very likely to stay on 400V



Key SiC applications in EV addressed by tailored packaging



New automotive application use cases powered by SiC



New applications realized with SiC

Fuel cell applications

- Interleaved power DCDC
- High speed pump

Battery disconnect

- Mechanical relay replacement

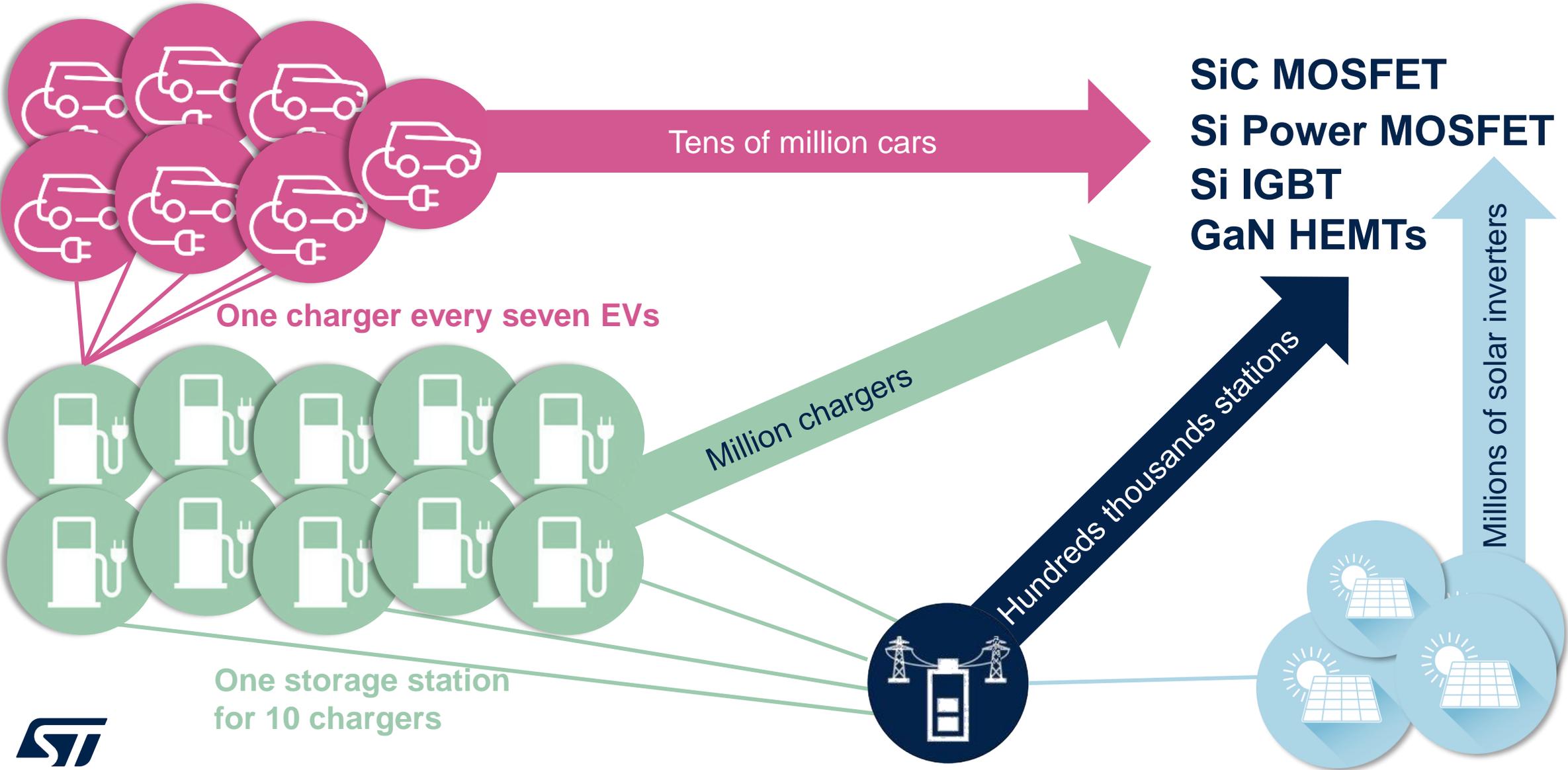
DC link discharge

- Discharging HV due to safety requirements

Smart power distribution

- Protection of auxiliaries
- Boardnet optimization

How car electrification impacts power semiconductors



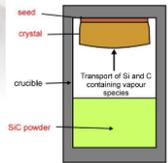
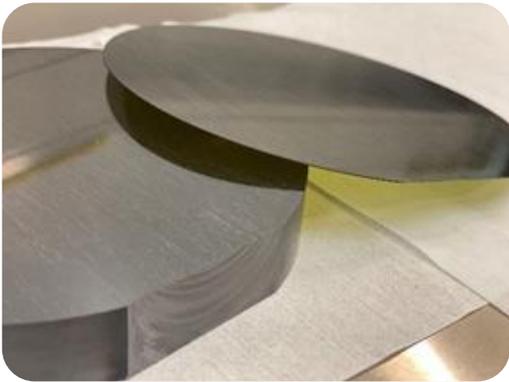
How car electrification impacts power semiconductors

	System	Power	Systems/vehicle			
	Traction inverter	100-250kW	1.5x	SiC MOSFET	Si IGBT	24-48 transistors
	OBC / DC-DC	50k-100kW	1x	SiC MOSFET	Si HV MOSFET	GaN HEMTs
	Charging station DC-DC	100k-250kW	0.15x	SiC MOSFET		12-18 transistors
	Energy storage	>1MW	0.015x	SiC MOSFET		>100 transistors

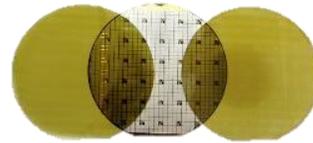
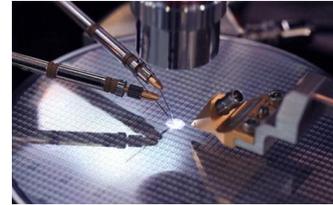
ST SiC MOSFET manufacturing strategy

Moving towards an integrated dual fab (**synoptic view**)

Substrate technology
From powder to ingot



Front-end technology
with Epy and EWS testing



Back-end technology
Bare dice, discrete, modules



Norrköping (R&D)

Catania substrate Fab
production in 2024

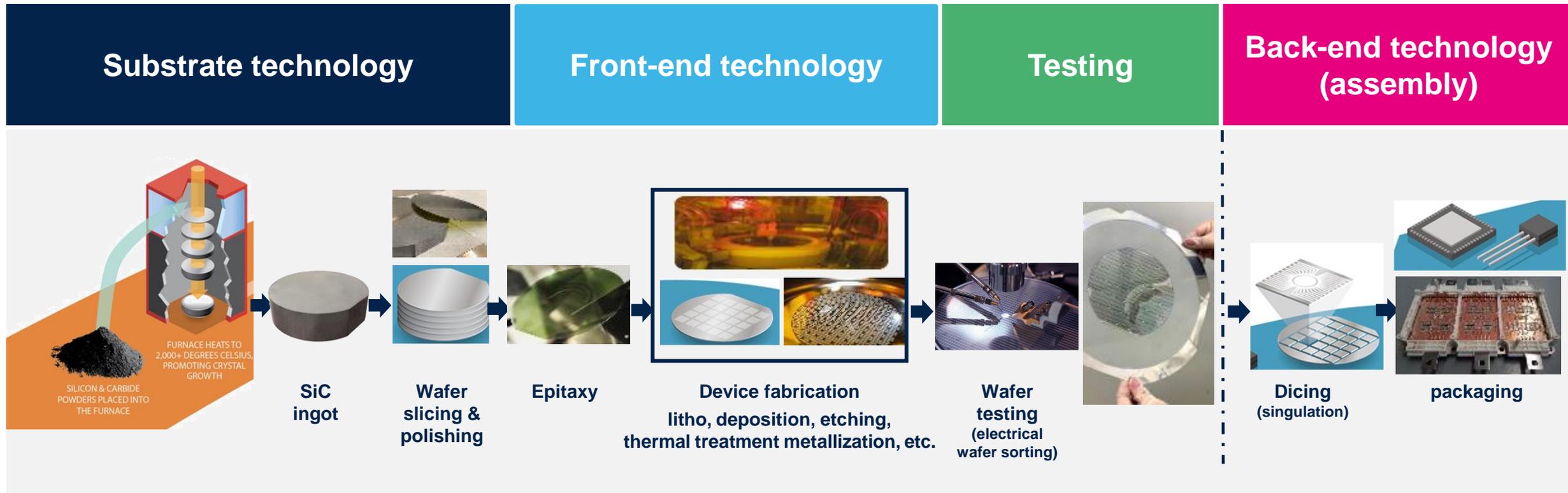
Catania

AMK (S'pore)

Shenzhen (China)

Bouskoura (Marocco)

SiC MOSFET vertical integration from powder to final product



Silicon Carbide vertical integration

ST-SiC substrate plant

Norrköping



150 mm volume production

200 mm with industrial quality and yields



New SiC integrated plant

Starting pilot production in 2023



Key takeaways

The EV market is growing > 25% CAGR 2021-2026 and ST today is market leader in SiC MOSFETs. OEM ecosystem changes: **from buy to make model**

Silicon carbide is already driving car electrification: inverter, OBC, DC-DC converter... additional applications are ramping up

WBG semiconductor content in EV application grows in the coming years and lifetime requirement is being expanded continuously

DC Bus voltage converges to higher DC link voltages: around 2025-27 the majority of European OEM has an 800V system

Vertical integration is key to be competitive and to deliver high volumes

Our technology starts with You



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