



GaN

SiC

Si

Si, SiC and GaN – the three essentials for power



Dorothea Werber

Vice President Automotive High Voltage Development
Infineon Technologies AG



Si, SiC and GaN – the three essentials for power

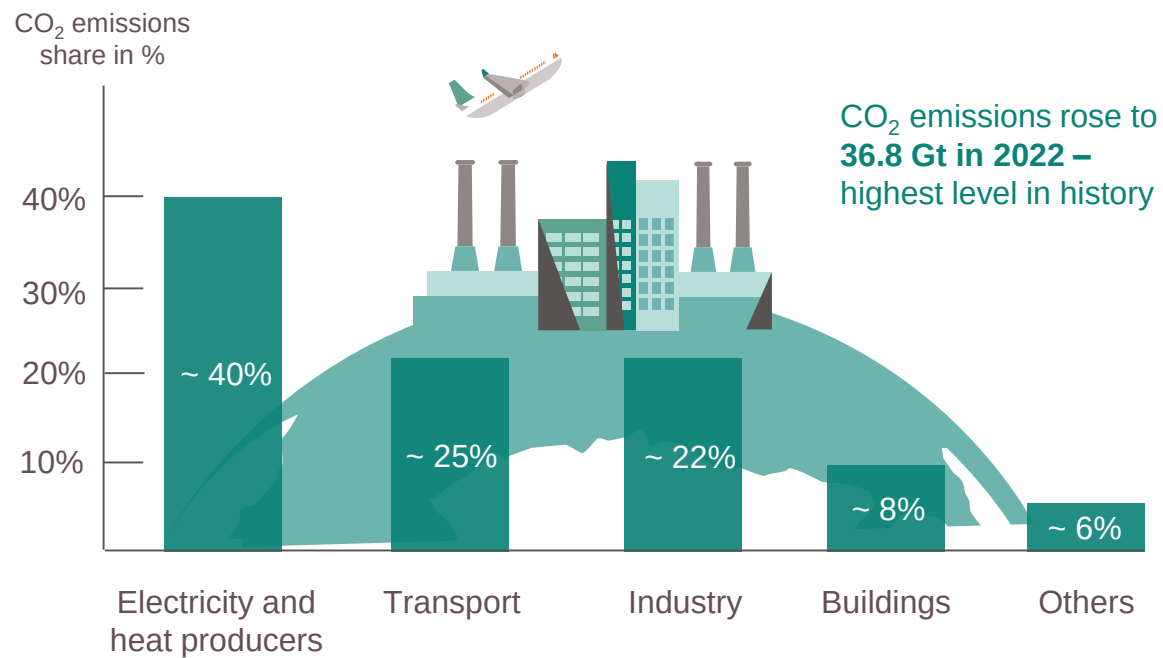
1	Power semiconductors - key technology for decarbonization	3
2	Si, SiC and GaN - three essential power semiconductors materials	7
3	Technology fusion - creating added value by combination	14
4	Summary	17

Si, SiC and GaN – the three essentials for power

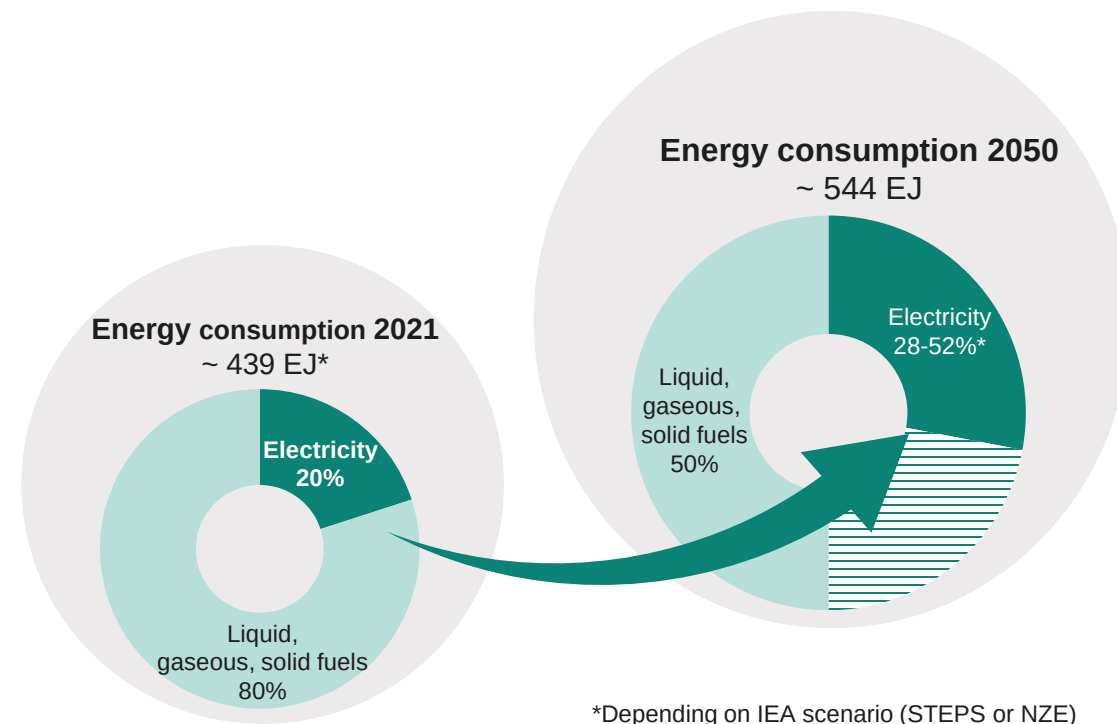
1	Power semiconductors - key technology for decarbonization	3
2	Si, SiC and GaN - three essential power semiconductors materials	7
3	Technology fusion - creating added value by combination	14
4	Summary	17

Decarbonization & Digitalization are the driving forces for

Cutting CO₂ emissions in all sectors



Increasing electricity demand

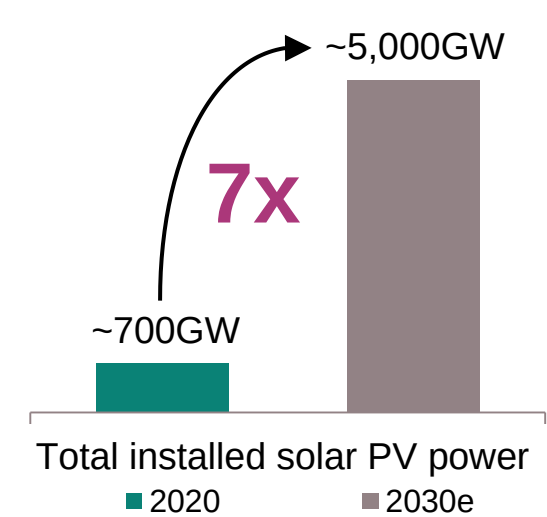


*Depending on IEA scenario (STEPS or NZE)

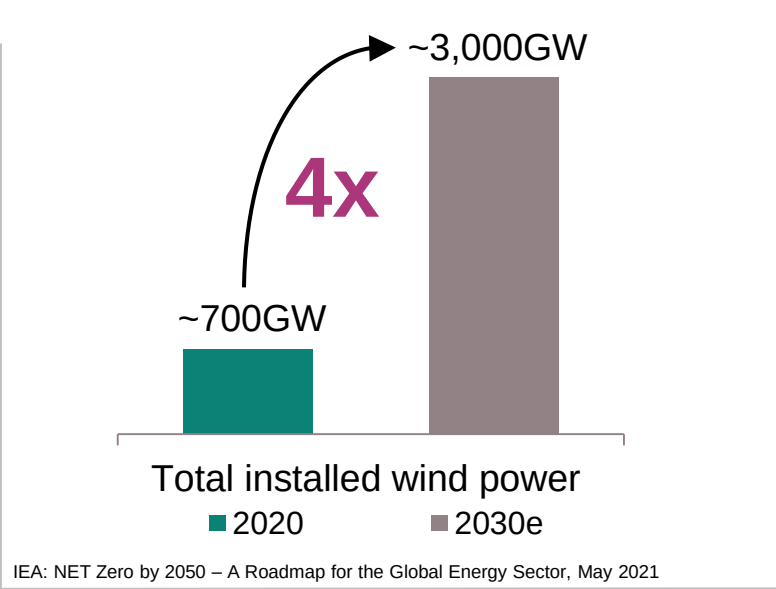
IEA, Global energy-related CO₂ emissions by sector, IEA, Paris
<https://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-by-sector>, IEA.
 License: CC BY 4.0 (Status: 26 October 2022), <https://www.iea.org/news/global-co2-emissions-rose-less-than-initially-feared-in-2022-as-clean-energy-growth-offset-much-of-the-impact-of-greater-coal-and-oil-use>
 (Status: 2 March 2023)

* EJ (Exajoule) = 278 TWh
 IEA (2022), World Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/world-energy-outlook-2022>, p 414 for STEPS and p 447 for NZE by 2050 scenario.

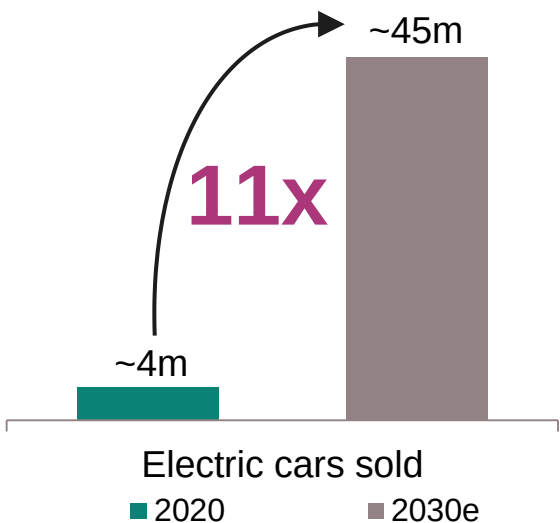
Decarbonization & Digitalization will strongly drive growth in many of our key markets



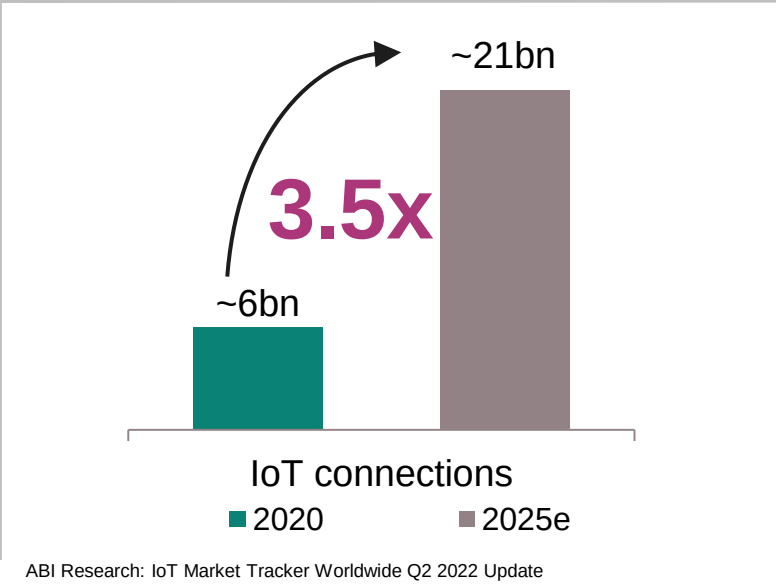
IEA: NET Zero by 2050 – A Roadmap for the Global Energy Sector, May 2021



IEA: NET Zero by 2050 – A Roadmap for the Global Energy Sector, May 2021

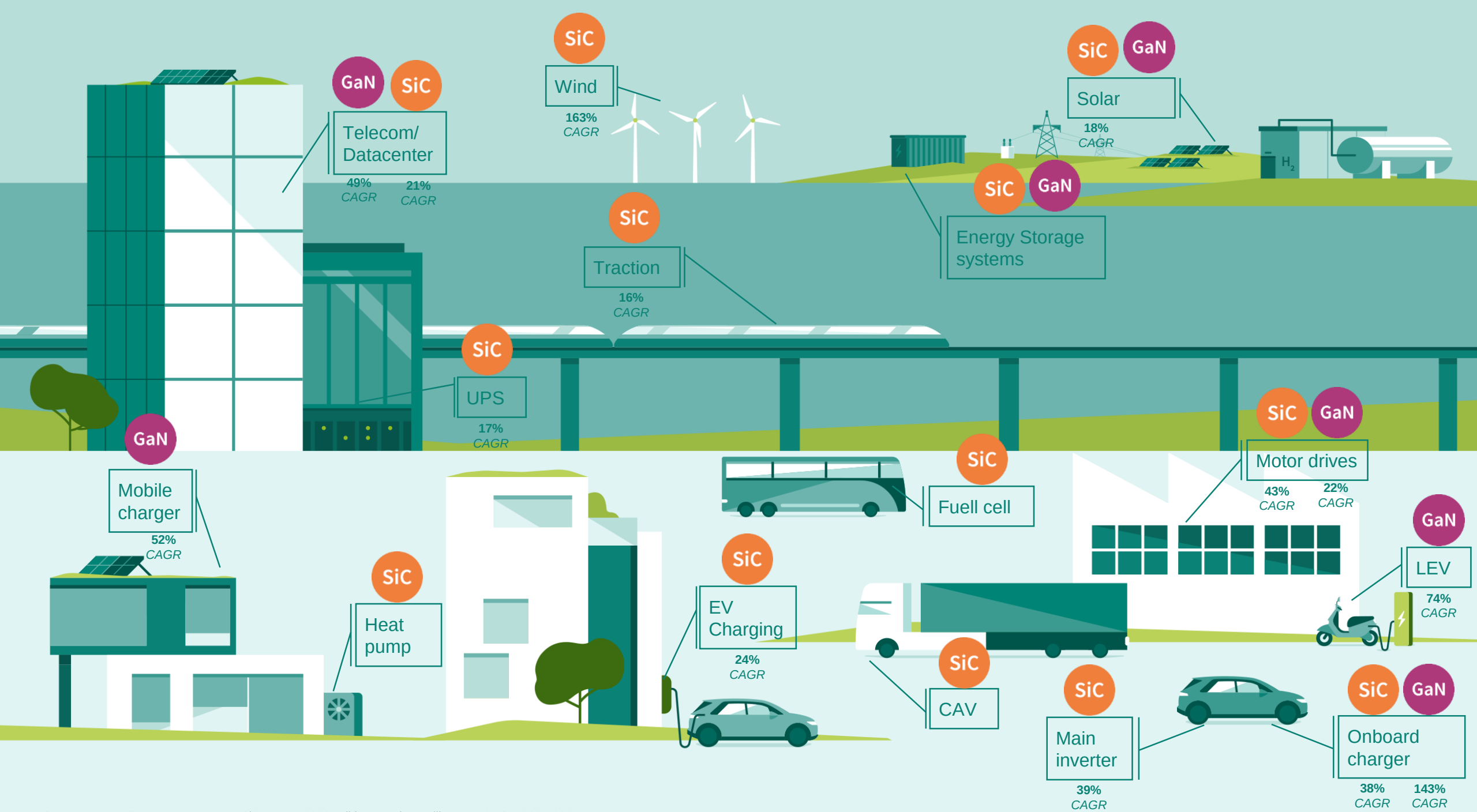


Based on or includes content supplied by S&P Global (former IHS Markit Automotive) September 2022



ABI Research: IoT Market Tracker Worldwide Q2 2022 Update





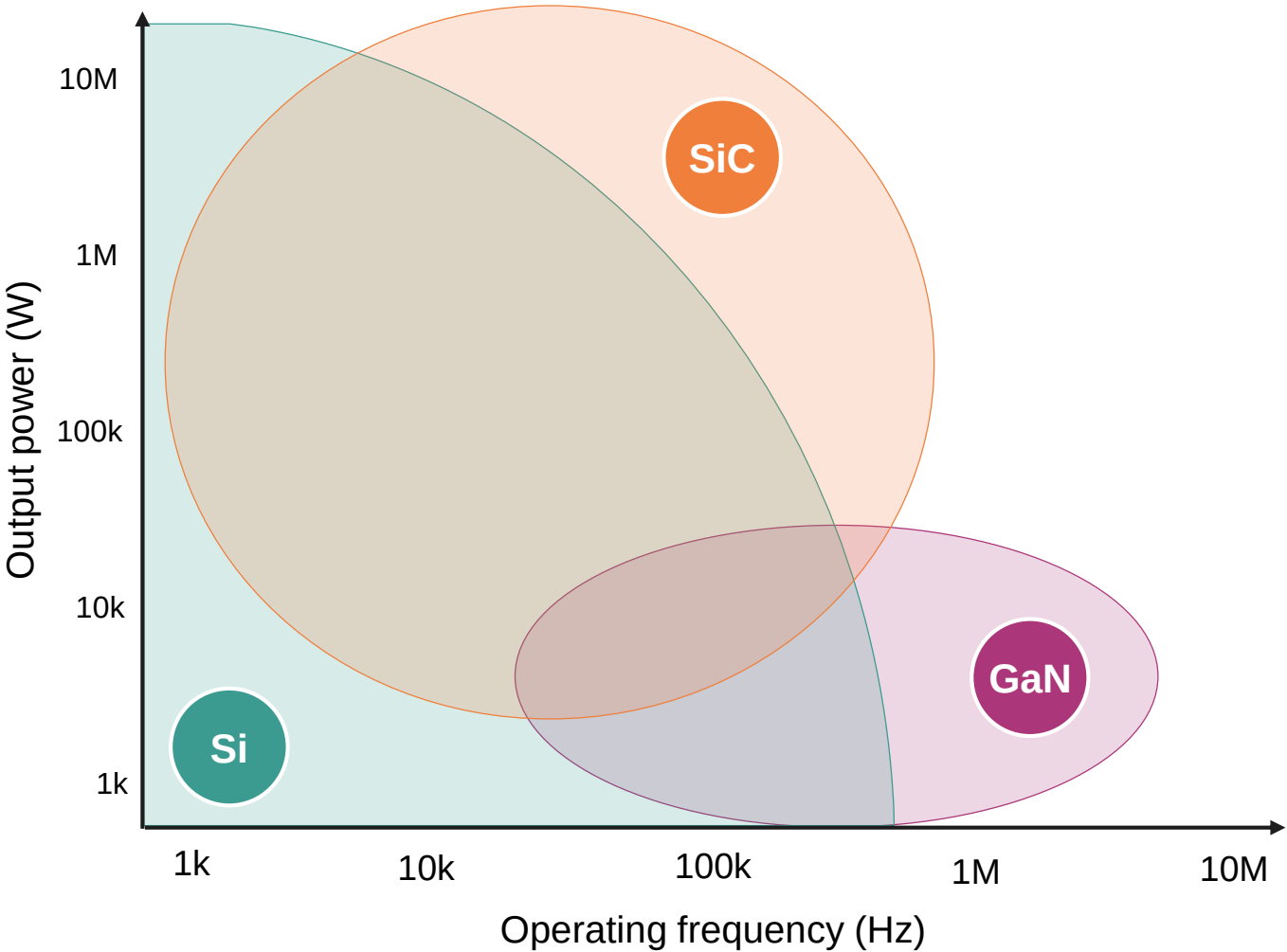
Source: Power GaN report – Power SiC report, 2022 editions, Yole Intelligence. CAGR 2021-2027.

Si, SiC and GaN – the three essentials for power

1	Power semiconductors - key technology for decarbonization	3
2	Si, SiC and GaN - three essential power semiconductors materials	7
3	Technology fusion - creating added value by combination	14
4	Summary	17

The right power semiconductor material depends on the target application and its requirements, all THREE are very relevant

Power device market development		
	Market size (today)	Market growth (predicted)
Si		
SiC		
GaN		

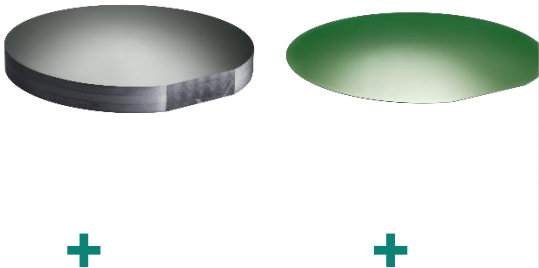


Source: Karminski, State of the Art and Future of Wide band-Gap Devices, Proceedings of the EPE 2009

Differentiation will shift towards device technology, packaging and application know how, substrates will become a commodity



Differentiation



Wafer diameters & defect density define not only productivity, but have a direct influence on device design and use case



Silicon
Diode – MOSFET – IGBT – Driver – Controller



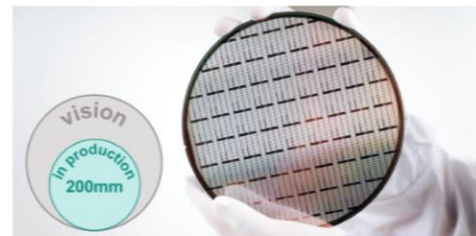
Commoditized substrates with high quality

Silicon carbide
Diode – MOSFET

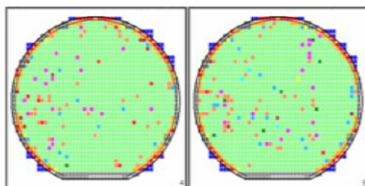
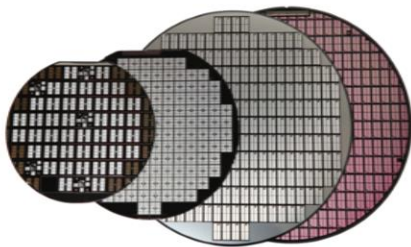


Substrate market evolving at similar quality EPI growth critical for quality & performance

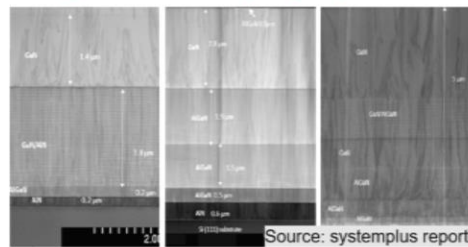
Gallium nitride
HEMT – Driver



Commoditized substrates with high quality EPI growth vital for quality & performance



Low-cost vs. high-cost wafer same number of defects



Source: systemplus report

18 Okt 2023 restricted

Copyright © Infineon Technologies AG 2023. All rights reserved.

Entegris semi 20



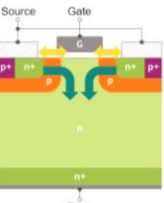
Differentiation will shift towards device technology, packaging and application know how, substrates will become a commodity



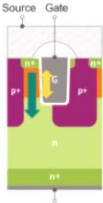
Differentiation

Trench vs. Planar most effective area utilization enabled by Trench

Classical planar MOSFET
Due to critical dimensions in lateral direction, planar MOSFETs come along with a lot of non-used area for current flow
→ shrink limited



Infineon's superior trench design
Trench allows rigid quality controls (electric stress testing) sifting out devices with undetected defects



Major cost disadvantage in addition to SiC specific drawbacks of planar concepts, history in silicon proved trench as long-term winner

Infineon's device with performance benchmark and outstanding stability → not a single failure in the field in a wide range of applications

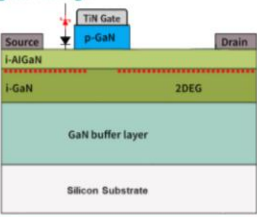
» Trench needs less wafer surface.
The gap will widen, better shrink potential in trench.

18 Oct 2023 restricted Copyright © Infineon Technologies AG 2023. All rights reserved. 21

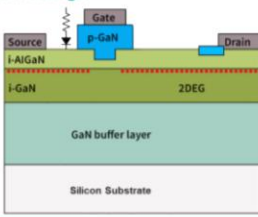


Hybrid drain GIT vs. Schottky Gate ruggedness and reliability for e-mode HEMT

Classical Schottky gate design
Simple structure for implementing normally off HEMT enabling sufficient performance for resonant topologies.



Infineon's robust GIT design
GIT offers inherent self protection and high peak currents. Hybrid drain design helps during hard switching, as it omits dynamic R_{DSon} drifts.



To overcome the normally on characteristic of a lateral GaN on Si HEMT, a gate metal is chosen which creates a Schottky contact.

Infineon's device enhances the device characteristics by introducing a recess structure and a resistive gate contact.

» Normally off characteristic is enabled by both e-mode HEMT devices
Ruggedness and reliability is increased by applying GIT structure

18 Oct 2023 restricted Copyright © Infineon Technologies AG 2023. All rights reserved. 22



Differentiation will shift towards device technology, packaging and application know how, substrates will become a commodity



Differentiation

Comprehensive product offering of automotive semiconductors based on dedicated technologies

Software, Tools and Services

Sense

Radar (24 GHz, 60 GHz, 77 GHz)

3D Image/ToF Camera REAL3™

Pressure

Magnetic

Current

Compute and Store

SEMPER™ NOR Flash

HYPERRAM™ 2.0

TRAVEO™ T2G

AURIX™

EXCELON™ F-RAM

PSoC™ Automotive

TriCore™

Connectivity ICs

Transceivers

System Basis Chips

XENSIV™ MEMS microphone

Bluetooth

WiFi

MERUS™ audio amplifier

AURIX™ 2nd generation

TRAVEO™ T2G

Automotive Power ICs

Power Semiconductors, MOSFETs, Intelligent Power Devices PROFET™, SPOC™

MOTIX™ Motor Control

LITIX™ LED

BMS IC

Power Supply ICs

OPTIGA™ TPM

SLI37 SLS37 V2X

SEMPER™ Secure NOR Flash

Sense

Compute

Store

Connect

Power

Secured

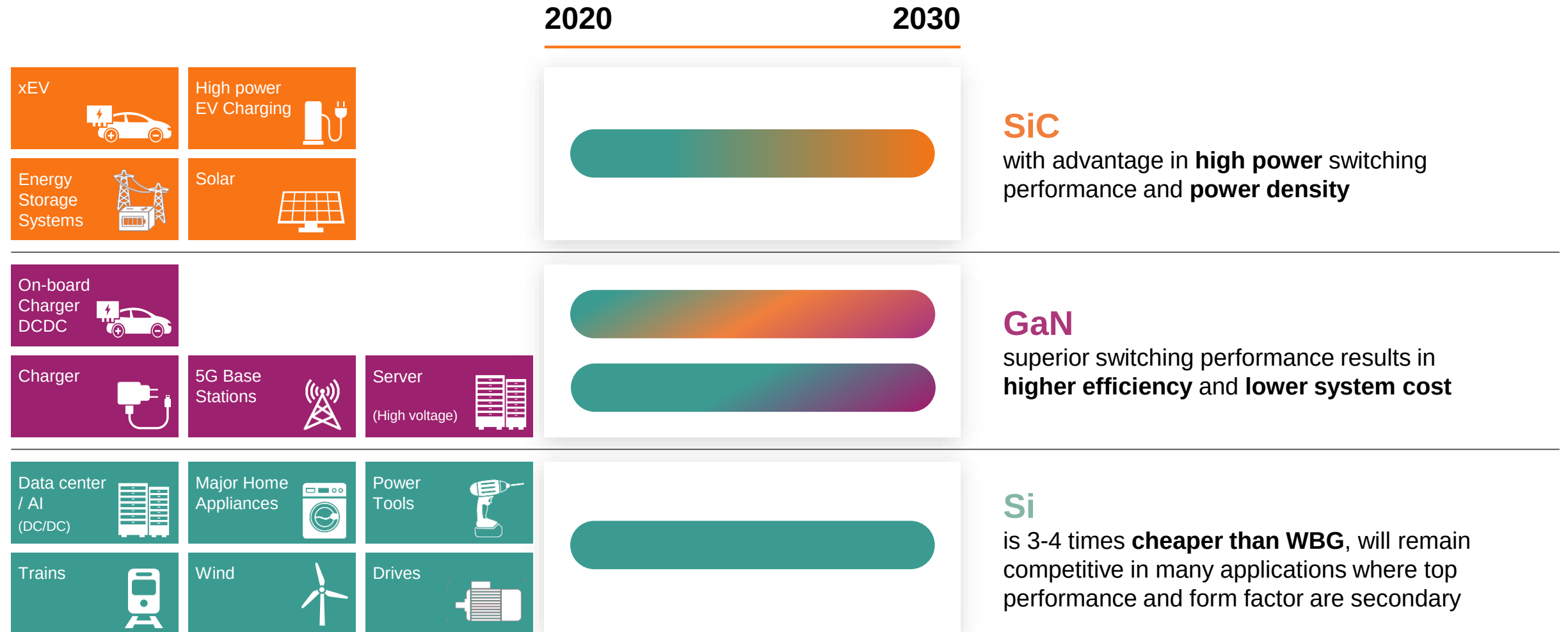
Software

18 Okt 2023 restricted Copyright © Infineon Technologies AG 2023. All rights reserved. Entegris semi 23

16 Nov 2023 restricted Copyright © Infineon Technologies AG 2023. All rights reserved. Entegris semi 33

Entegris semi 11

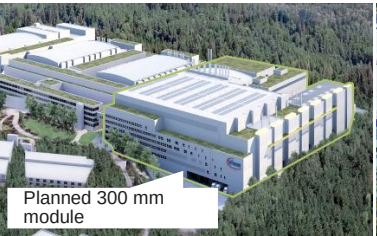
Transition to WBG will vastly differ by application with Si expected to remain technology of choice for many of them



■ Si ■ SiC ■ GaN

We follow a ambitious growth plan: Latest investments into Infineon's capacity



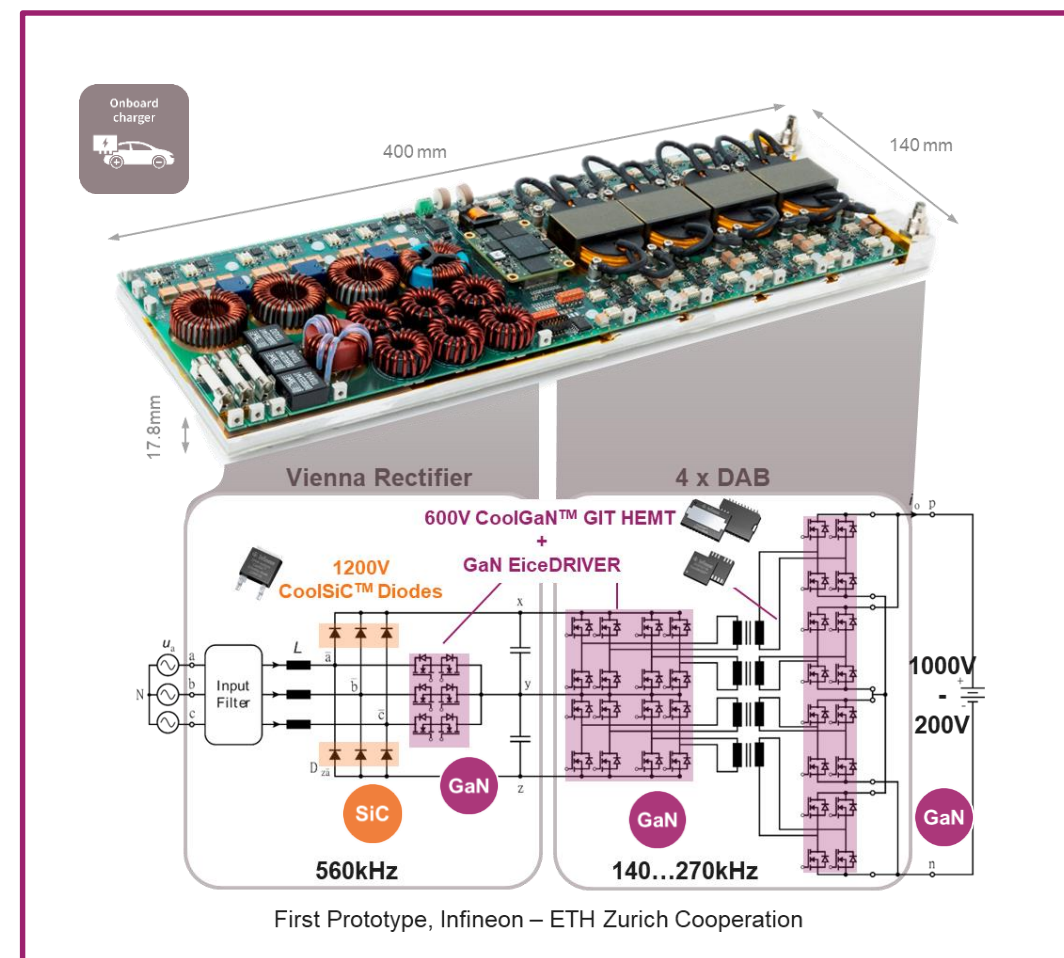
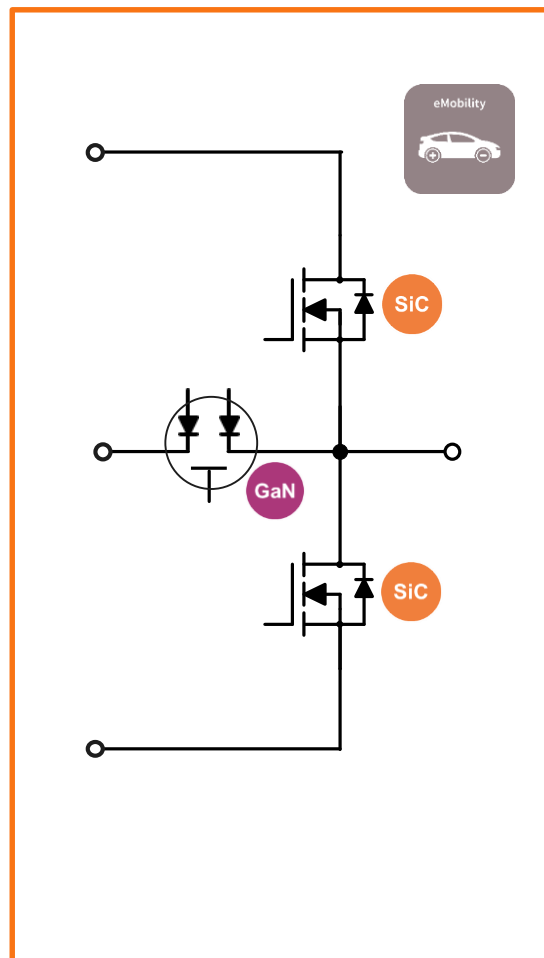
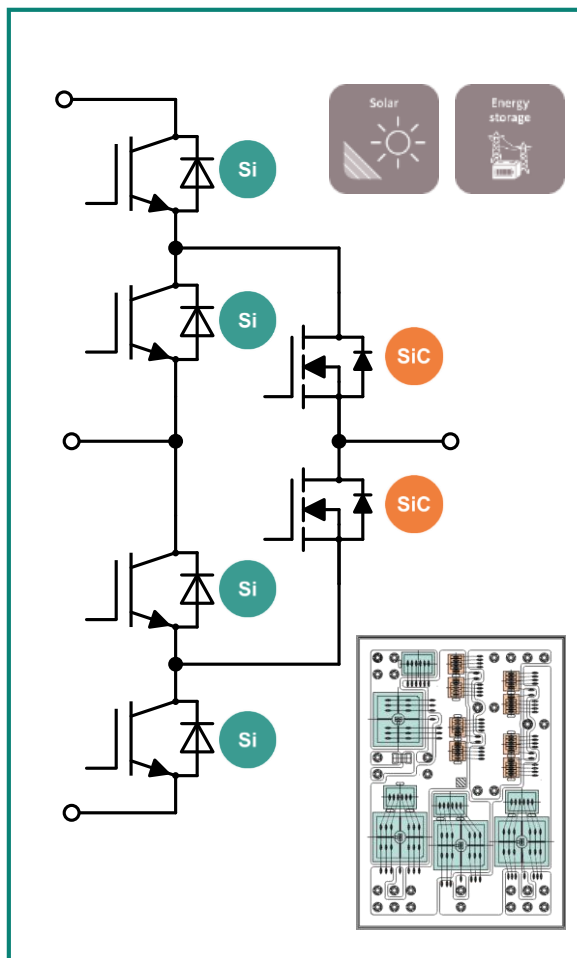
Kulim, Malaysia	Batam, Indonesia	Cegléd, Hungary	Dresden, Germany	Kulim, Malaysia	Dresden, Germany
					
Expansion of SiC and GaN capacity in a 3 rd module benefitting from the economies of scale for 200mm manufacturing in Kulim Announced in Feb. 2022	Extension of Backend manufacturing capacities, doubling the production Announced in Apr. 2022	Expansion of assembly and testing capacity, opened with focus on high-power semiconductor modules for electro mobility vehicles & green energy Opened Oct. 2022	Largest investment in company history, expanding with a “Smart Power Fab” for analog/mixed signal technologies and power semis Announced in Nov. 2022	Building the world's largest 200-millimeter SiC Power Fab with a second construction phase for Module Three at the Kulim site Announced in Aug. 2023	Joint investment with TSMC, Bosch, and NXP to provide advanced semiconductor manufacturing services Announced in Aug. 2023
					
Frontend	Backend	Backend	Frontend	Frontend	Frontend
Revenue potential ¹ ~€7 bn per year ²	–	–	~€5 bn per year	~€7 bn per year ²	–
Ready for production Second half of calendar year 2024	2024	February 2022	Fall 2026	Summer 2027	End of 2027

Note: 1) once fully equipped | 2) Total SiC revenue potential end of decade: Total revenue potential comprises Villach, Kulim 3 phase 1 and phase 2 incl. 200-millimeter conversion

Si, SiC and GaN – the three essentials for power

1	Power semiconductors - key technology for decarbonization	3
2	Si, SiC and GaN - three essential power semiconductors materials	7
3	Technology fusion - creating added value by combination	14
4	Summary	17

Technology fusion - creating added value by combination



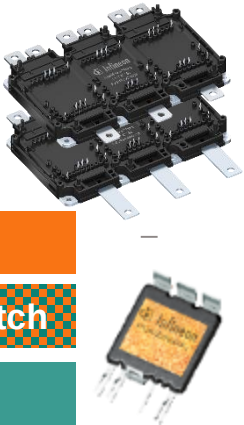
Combination of power semiconductor technologies in one system is state of the art (e.g. traction inverter)



HybridPACK™ CoolSiC™
for primary axle

Focus on

- Range: SiC
- Cost
 - Large battery: SiC
 - SiC/IGBT fusion switch
 - Small battery: IGBT



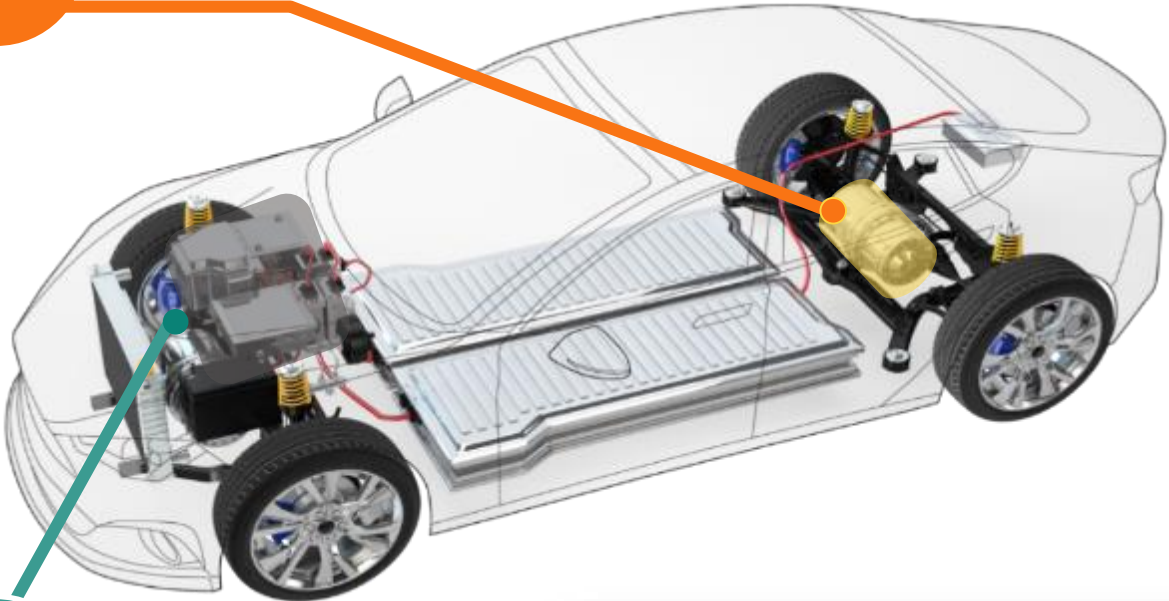
HybridPACK™ IGBT
for secondary axle

Focus on cost : IGBT



SiC

Si



Si, SiC and GaN – the three essentials for power

1	Power semiconductors - key technology for decarbonization	3
2	Si, SiC and GaN - three essential power semiconductors materials	7
3	Technology fusion - creating added value by combination	14
4	Summary	17

Si, SiC and GaN - the three essentials for power

- *Decarbonization & Digitalization drive power semiconductor demand*
- *Mastering all value chain aspects creates superior power solutions*
- *GaN, SiC and Si are complementing power technologies*
- *Technology fusion can lead to better performance*

