Green Industrial Power – Driving decarbonization

GIP call at PCIM

May 11, 2023

Table of contents

1	Green Industrial Power	4
2	Business update	9
3	Wide bandgap strategy	12
4	Q&A	31

Copyright © Infineon Technologies AG 2023. All rights reserved.

Speakers

Dr. Peter Wawer

Division President GIP

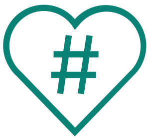
Dr. Peter Friedrichs

Vice President SiC

Our purpose

We empower a world of unlimited Green Energy

Emphasizes our contribution to **energy transition**



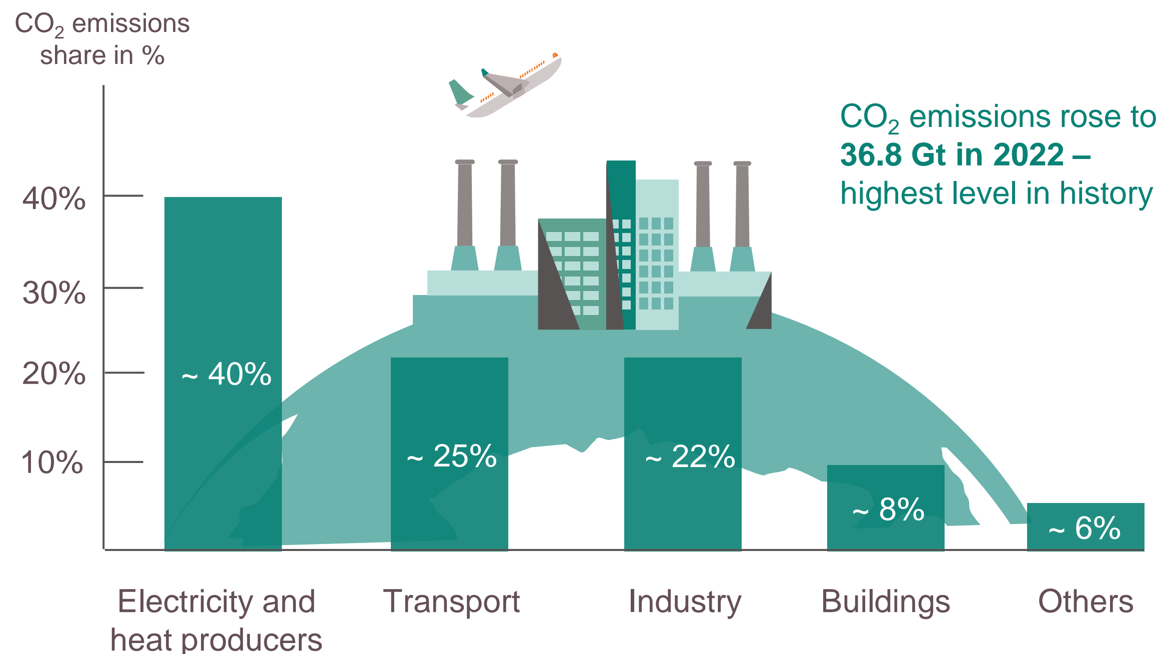
Fosters **pride** and engages **external stakeholders**

Sets a mark for the **paradigm shift** towards rapid growth and highly dynamic applications

The new name for the division demonstrates our transformation.

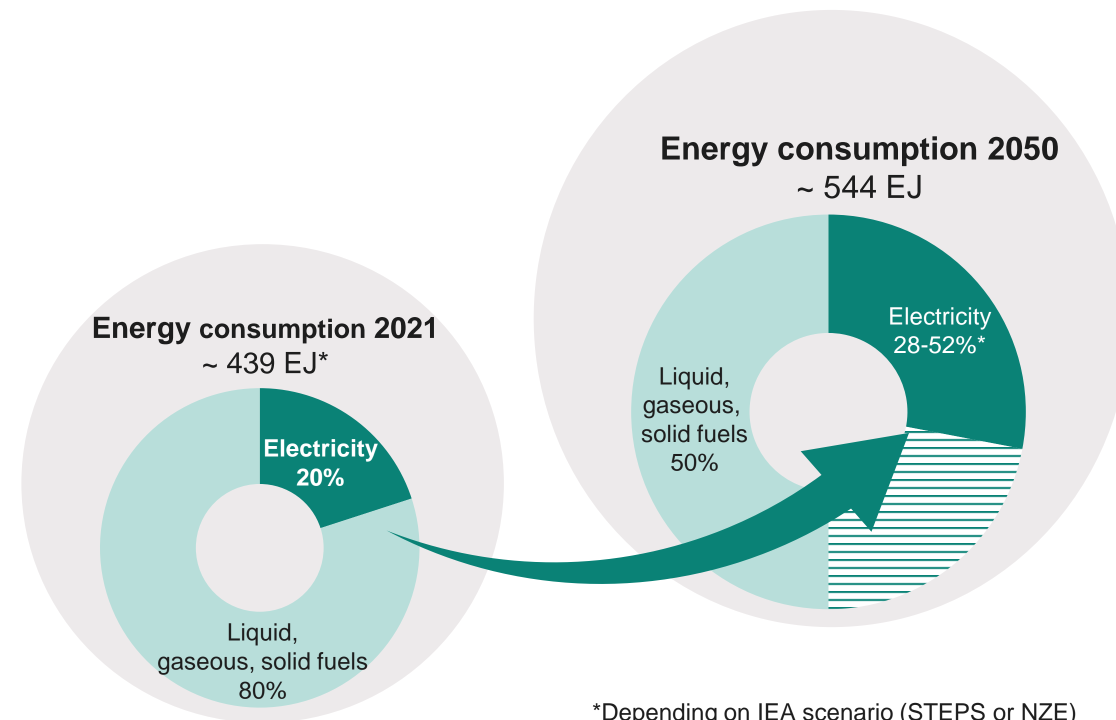
Decarbonization & Digitalization are the driving forces for

Cutting CO_2 emissions in all sectors



CO_2 emissions rose to **36.8 Gt in 2022 –** highest level in history

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)

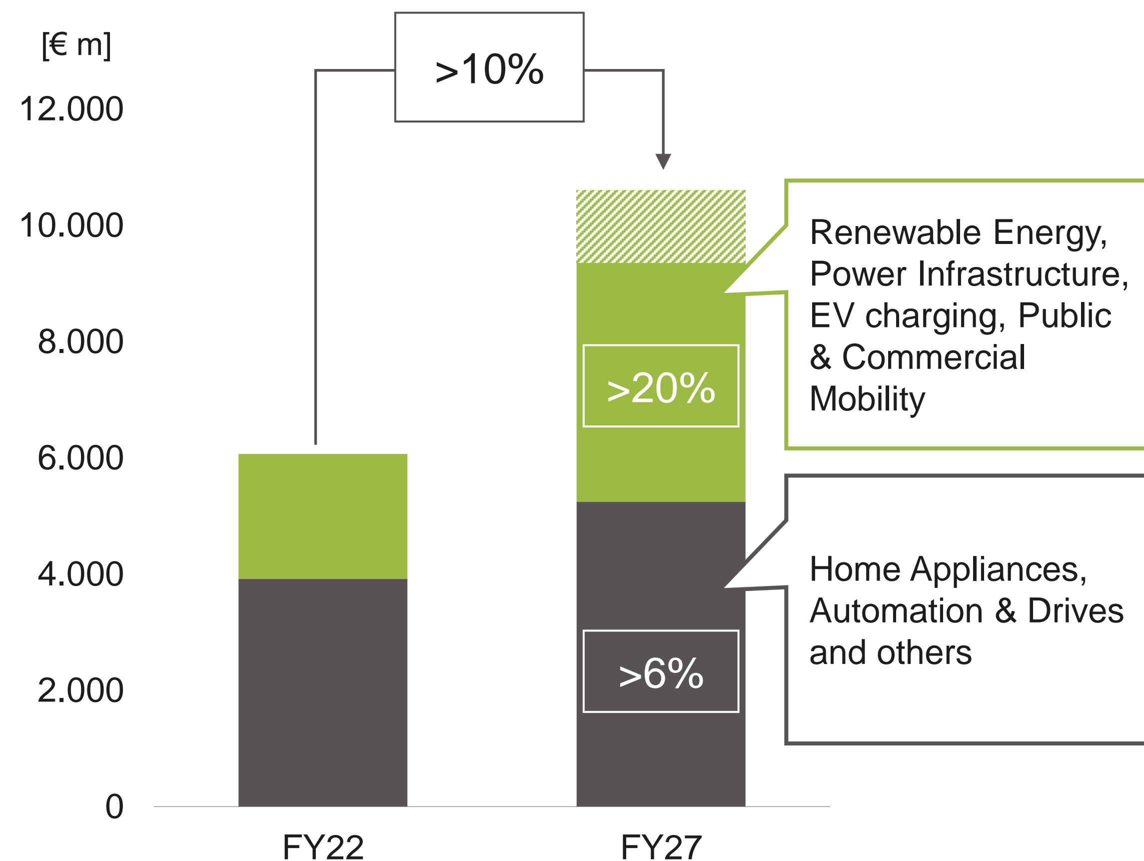
* EJ (Exajoule) = 278 TWh
IEA (2022), World Energy Outlook 2021, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2022, p 414 for STEPS and p 447 for NZE by 2050 scenario.

Copyright © Infineon Technologies AG 2023. All rights reserved.

GIP markets accelerate growth – Enabling green energy and driving decarbonization

Key facts

- The **acceleration of the energy transition** drives GIP markets
- **SiC penetration accelerates**
- **SiC** is a key point of **differentiation** and drives GIP **profitability**



Infineon analysis

x% CAGR FY22–27e

Copyright © Infineon Technologies AG 2023. All rights reserved.

Decarbonization of heating

Heat pump

- Heat pumps play a crucial role in the decarbonization of heating. EU objective: 60m heat pumps by 2030 (15m current installed base). This translates to a **22% CAGR**.

- Infineon offers full solution
  Power: Modules, discretes, IPMs Si and SiC
  Control: MCU, sensors
  Usability: HMI
  Connectivity and Security

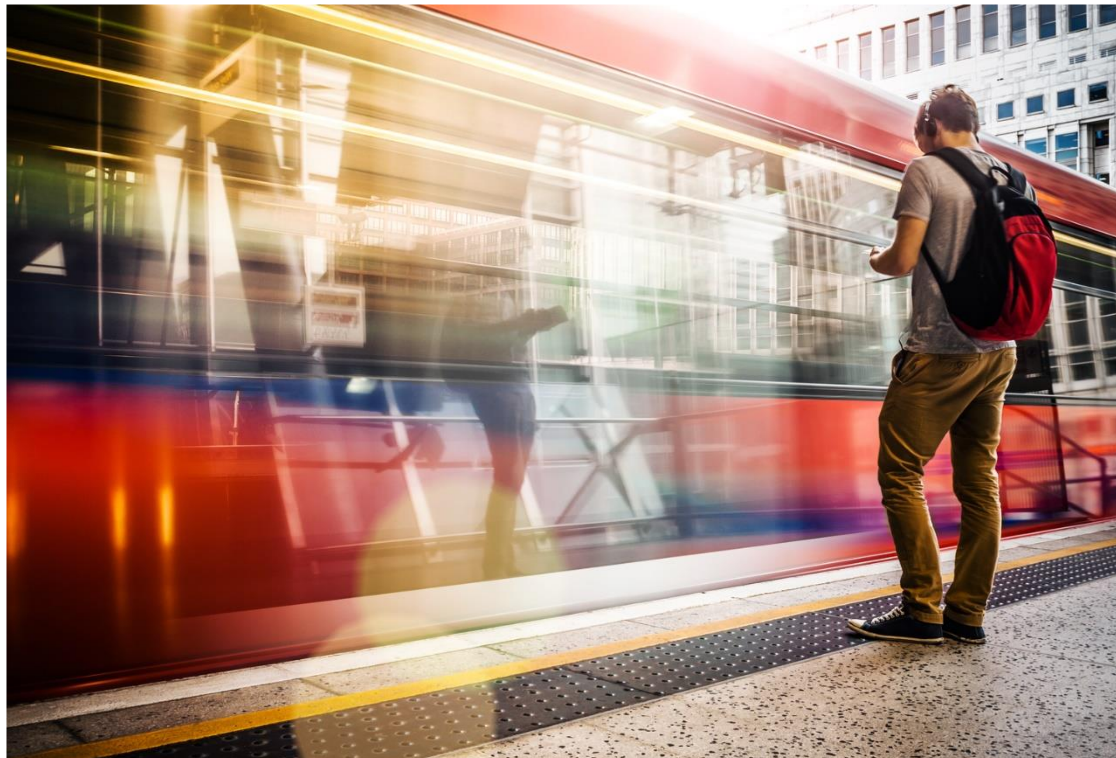
Major design-win in Europe:
Low-power modules using SiC and IGBT8 for different power classes.

Copyright © Infineon Technologies AG 2023. All rights reserved.

Energy efficient and reliable rail transport is key to reducing the greenhouse gas emissions

Traction application – Key requirements

- Energy efficiency
- High power density
- Long lifetime (> 30 years) with demanding mission profiles



3.3 kV CoolSiC™ MOSFET XHP™ 2

- 10% overall losses reduction
- 10% to 25% system volume reduction
- Robust modules with high cycling capabilities
- Less noise

.XT

SiC

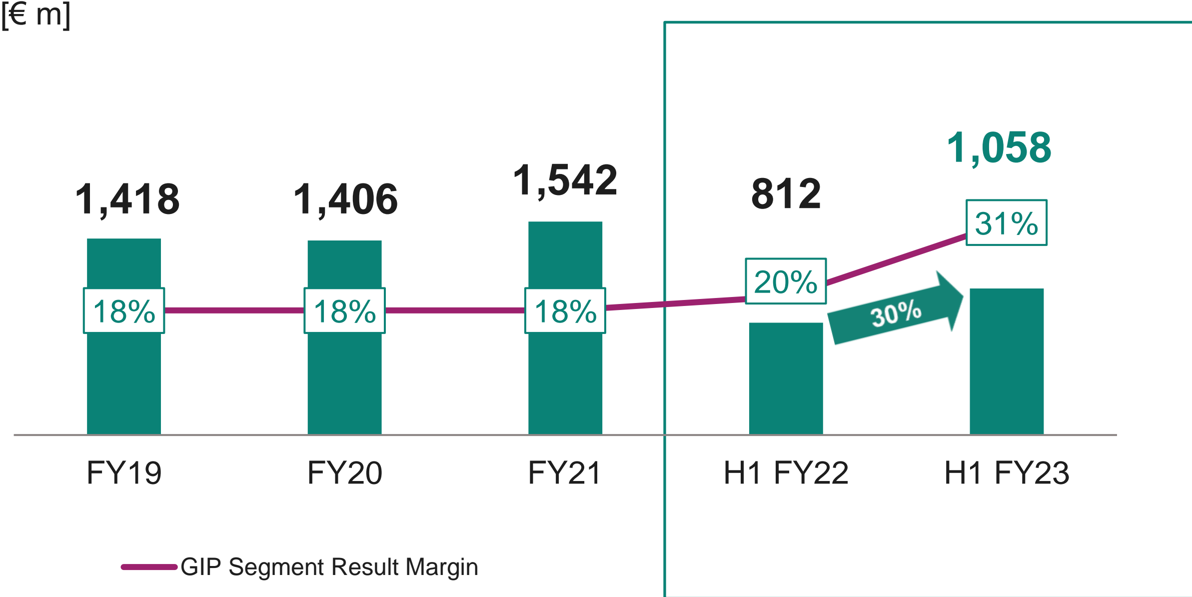
Enjoy the silence

Copyright © Infineon Technologies AG 2023. All rights reserved.

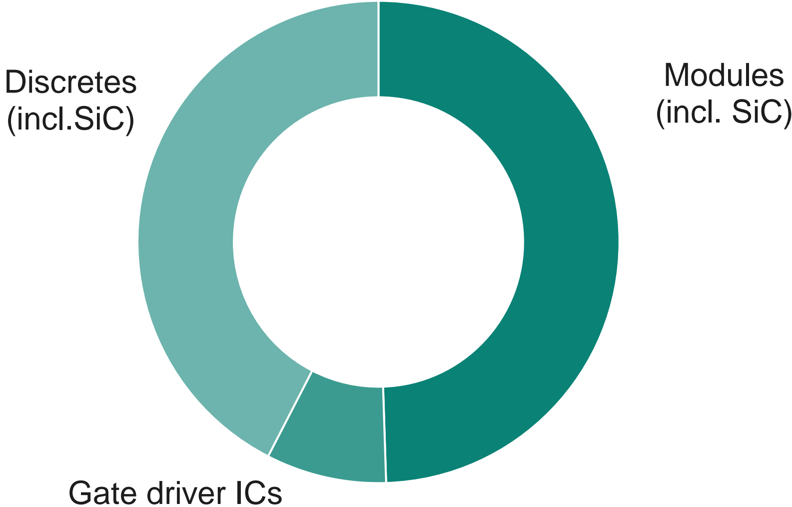
Business update

Excellent start into FY23
Another record quarter in March with a SR-Margin of 32%

GIP revenue and Segment Result Margin



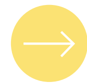
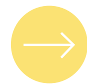
FY22 revenue split by product group



Key customers

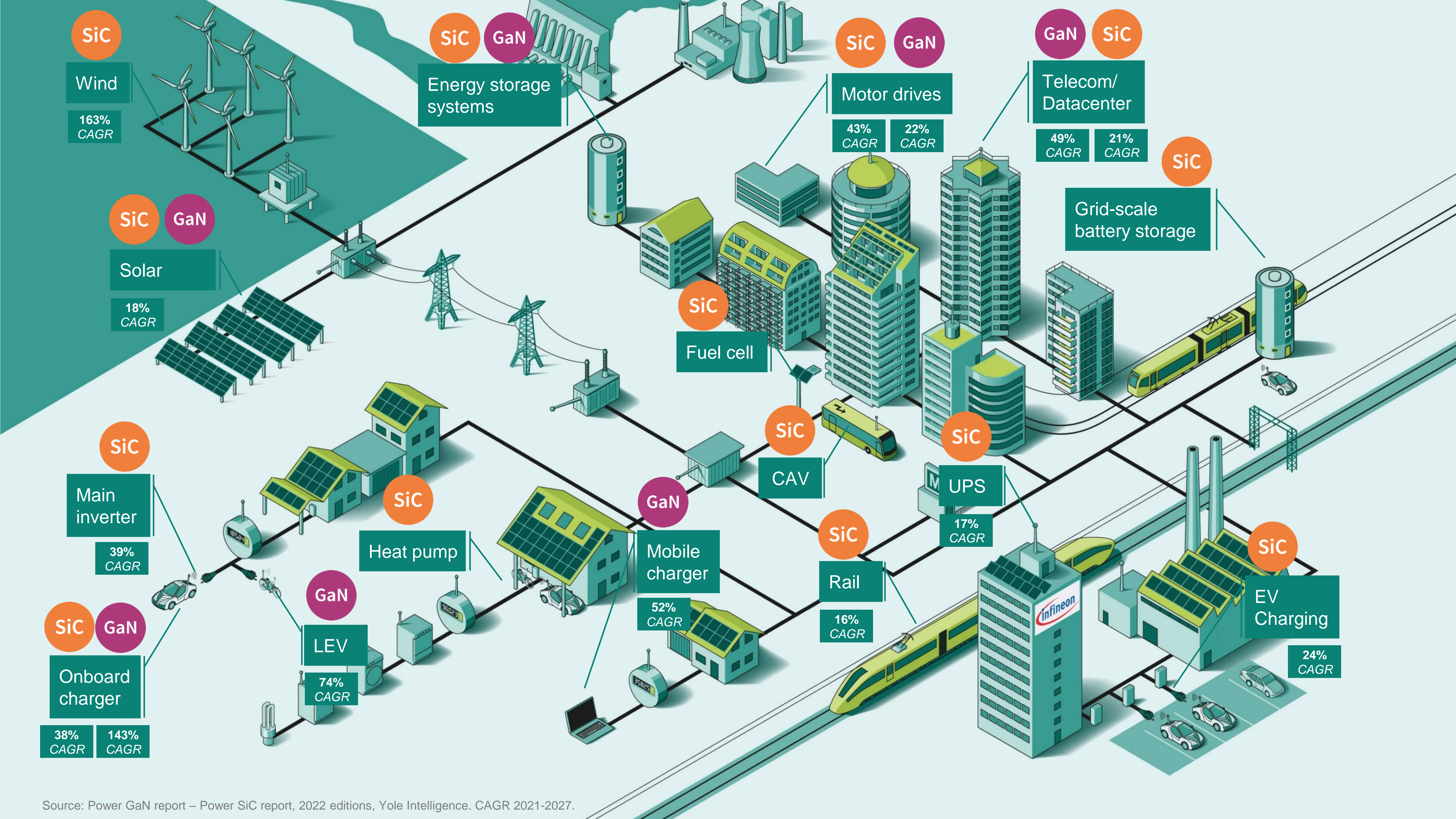
Copyright © Infineon Technologies AG 2023. All rights reserved.

Despite weak macro sentiment, GIP market outlook remains positive. Strong demand in decarbonization related applications

Applications % of FY22 segment revenue		Market Outlook for CY23	
	~35% Automation and Drives		– Analysts expect market pullback in 2H/2023 due to decline in demand, but no contraction due to ongoing energy transition and energy efficiency trends – Customers see still strong demand overall, for China demand seems to slow down (increased stock levels)
	~26% Renewable Energy Generation		– Growth rates remain strong for global PV installations (43% YoY); demand for green hydrogen boost outlook – Wind project delays in China pushed demand from 2022 to 2023 (51% YoY growth of global wind installations), project push outs in Europe into 2024/2025 impair growth in 2023
	~10% Power Infrastructure		– Growth in EV charging infrastructure is expected to remain strong supported by government push programs – Further growth of ESS (34% YoY) and T&D required to capture renewable energy generated
	~17% Home Appliance		– Overall market is weak, semiconductor demand more stable in areas linked to progressing inverterization – Residential AirCon demand slowed down, China government measures expected to induce stabilization in 2H/2023; heat pump demand remains strong
	~5% Transportation		– Strong growth opportunities for CAV and OBC (electrification) – Traction: growth for locomotives & metro to stay flat, demand for high-speed trains still weak, but slightly ramps
	~7% Others		– Long-term positive outlook driven by general trend of electrification in emerging applications (e.g. e-aviation, e-marine)

Copyright © Infineon Technologies AG 2023. All rights reserved.

Wide bandgap strategy



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

The benefits of using WBG are evident in a variety of end applications – thus contributing to a greener future

Industrial drive

SiC

Precise control saving energy

- Infinitum's Air Core uses 66% less copper than traditional motors
- Powered with CoolSiC™ MOSFETs

10% energy savings	50% less size & weight	30% CO_2 reduction

Electric car

SiC

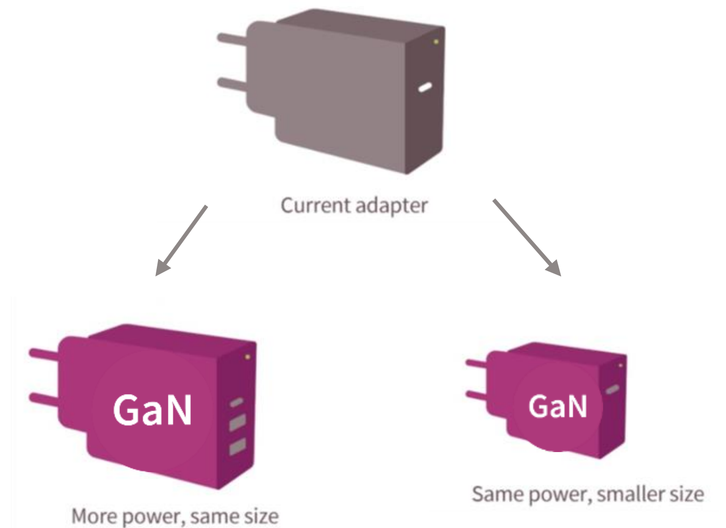
Increasing power density – OBC

2 kW/L 2020	4 kW/L 2024	>6 kW/L > 2025

Mobile charger

GaN

Saving weight and energy

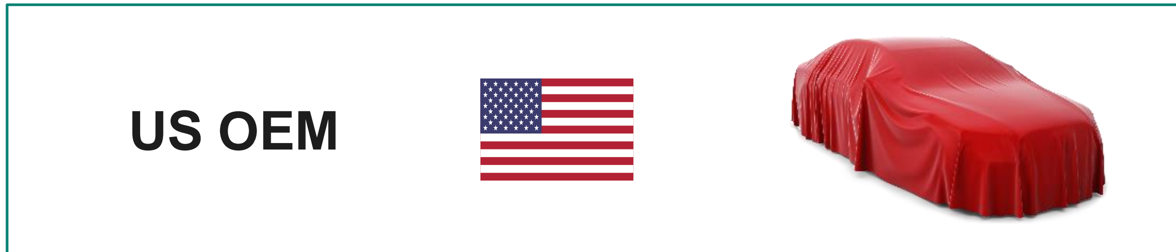


>30% energy savings	2x less size & weight	20% lower system cost

Copyright © Infineon Technologies AG 2023. All rights reserved.

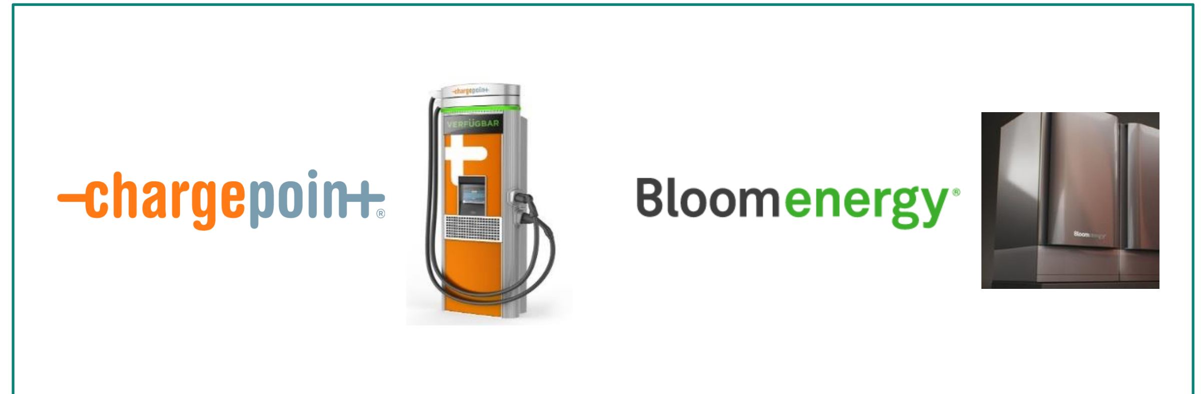
SiC momentum further accelerating: Significant new design-wins in auto, continuous leadership in industrial applications

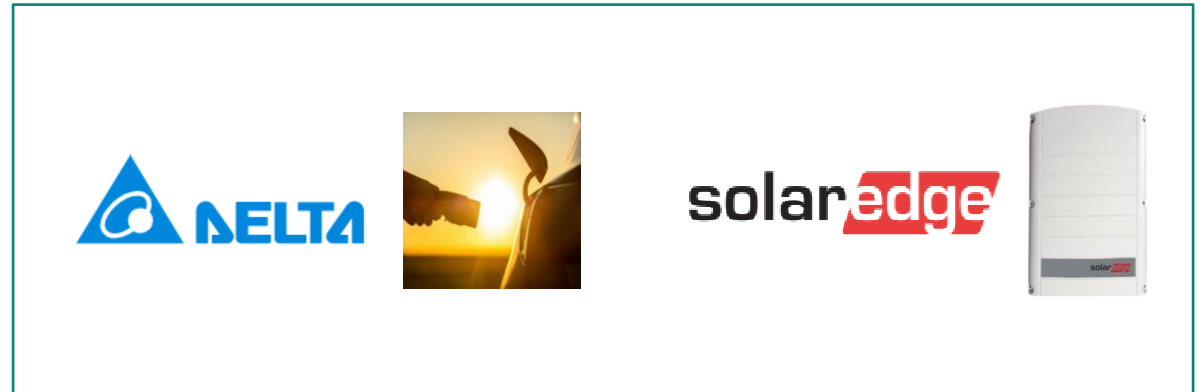
Most recent automotive SiC design-wins



In addition, ~20 OEMs and ~10 Tier-1s already won

Most recent industrial SiC design-wins



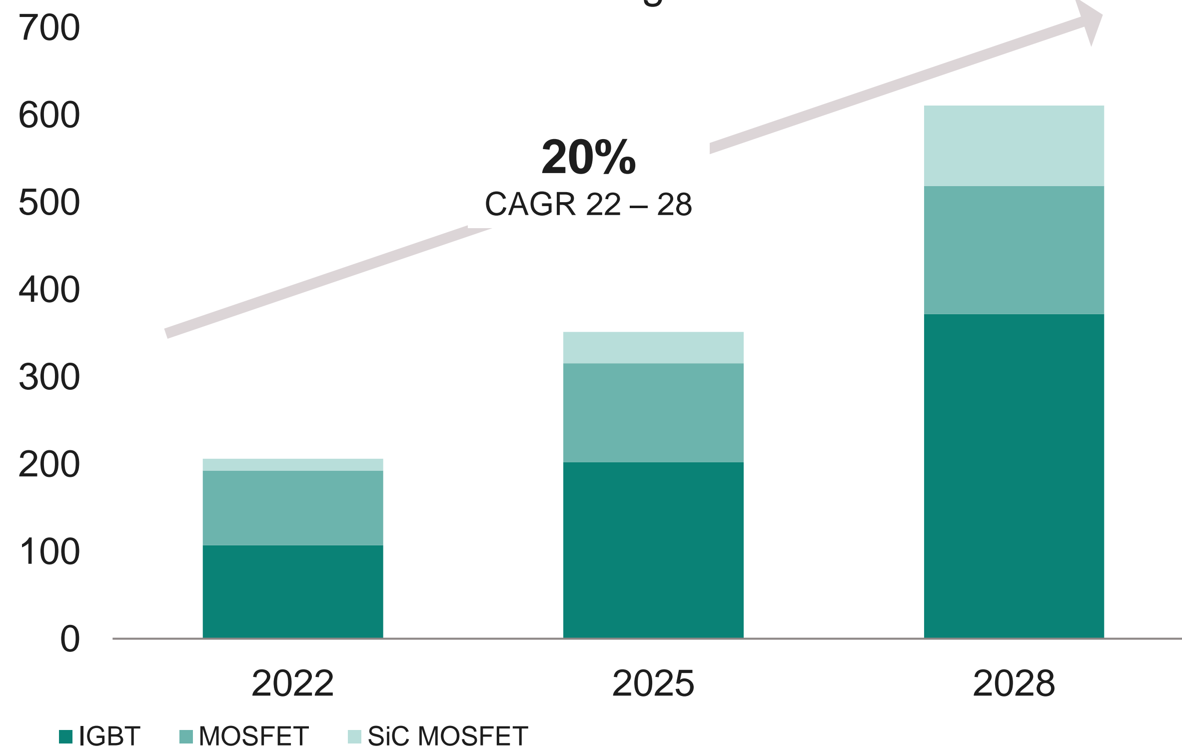


More than 3,600 active customers being served

Copyright © Infineon Technologies AG 2023. All rights reserved.

Chargepoint will become one of our leading customers in the fast growing EV Charger market

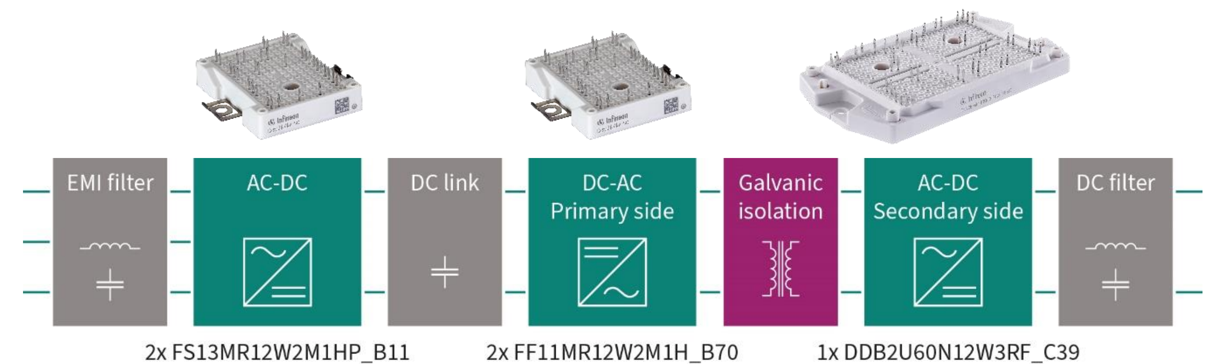
EV charging is an attractive business opportunity



Yole, DC Charging for Automotive 2023

Infineon extends its market leadership

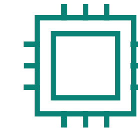
- Significant CRA signed for EASY 3B SiC-modules
- Chargepoint runs an EV charging network with an integrated portfolio of hardware, cloud services and support



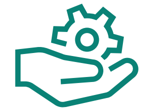
Copyright © Infineon Technologies AG 2023. All rights reserved.

Overview of key investment highlights

Strengthening GaN portfolio, reinforcing global leadership in Power Systems



Addressing fast-growth applications with **highly complementary strengths** in IP, application understanding, customer access and project pipeline

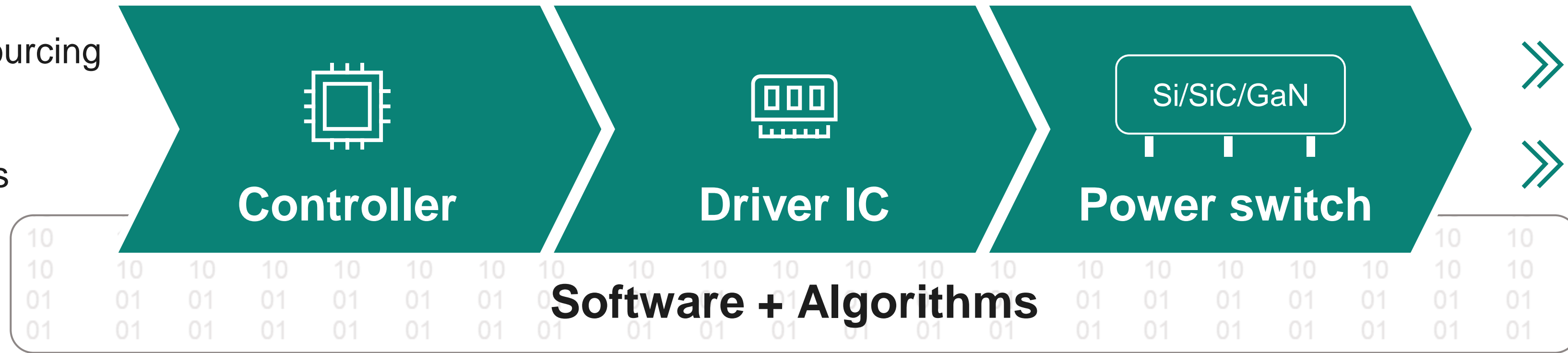


Significant **roadmap acceleration** through unmatched R&D resources and application expertise

Leadership in Power Systems through mastery of all relevant power technologies – Si, SiC, GaN

Undisputed power systems leadership mastering all three key materials

- Reliable multi sourcing of raw materials
- World-scale fabs



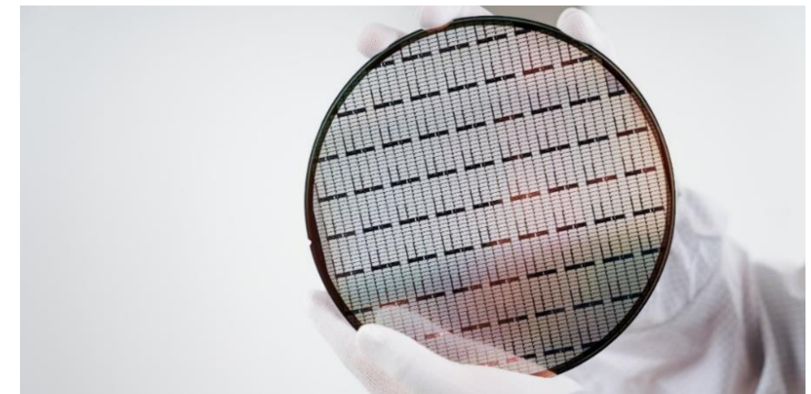
- Application understanding
- Packaging know-how and hybridization competence

Leadership in Power Systems across all materials and technologies

Silicon
Diode – MOSFET – IGBT – Driver – Controller

Silicon carbide
Diode – MOSFET

Gallium nitride
HEMT – Driver



Copyright © Infineon Technologies AG 2023. All rights reserved.

Infineon leveraging Si leadership, strengthening position in wide bandgap

Market size (2022 vs. 2028)

Si CAGR 2022-2028 4%

Si

SiC CAGR 30%

SiC

GaN CAGR 53%

GaN

- **Different applications require different solutions**
- Infineon offers the broadest portfolio in silicon, silicon carbide and gallium nitride
- **Leadership in Power Systems across all materials and technologies**

The boxes' area represents 2022 (solid) and 2028 (shaded) market revenues;
Yole Intelligence: Compound Semiconductor Market Monitor-Module 1 Q1 2023.

Copyright © Infineon Technologies AG 2023. All rights reserved.

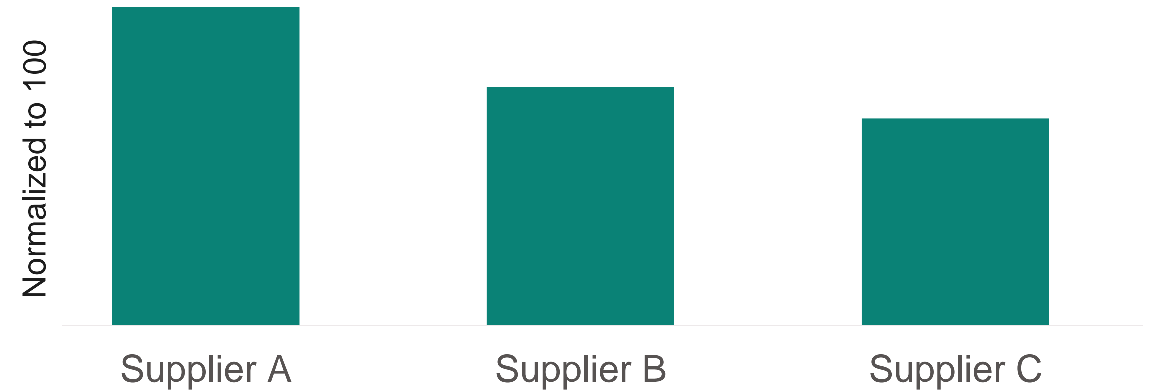
Expanding our SiC substrate supplier base

Well diversified regional supply

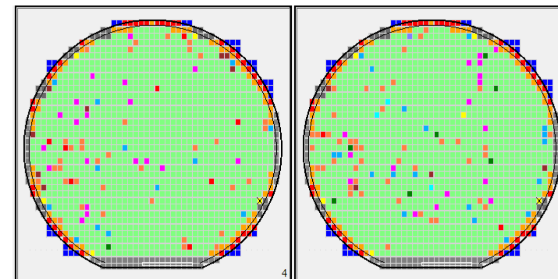
- Resilient substrate sourcing from Europe, USA, Japan and China
- **New supply contract with SICC and TanKeBlue** from China adding to Resonac, Coherent and Wolfspeed
- 5 material supply contracts in place
- Further suppliers qualified or in qualification
- Contracts cover boules and wafers
- Roadmap for 200mm transition

» **Infineon secured sufficient wafer supply for planned growth**

Price quotation per SiC bare wafer (150 mm)



Significant delta between high- and low-price suppliers, low-price suppliers with excellent performance



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

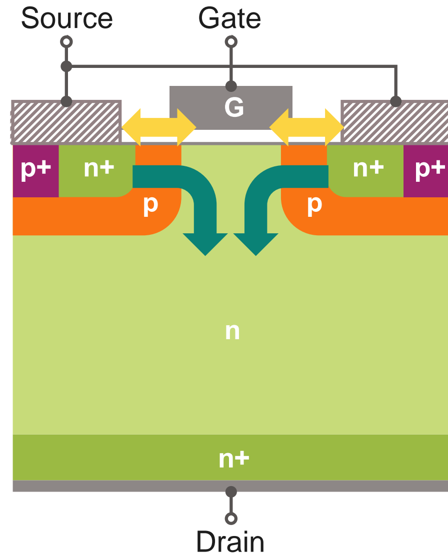
» **Pricing gets competetive**

Copyright © Infineon Technologies AG 2023. All rights reserved.

Trench vs. Planar
most effective area utilization enabled by Trench

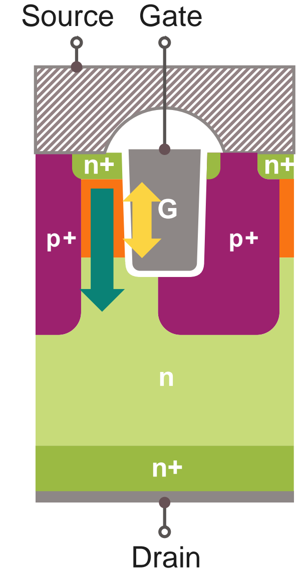
Classical planar MOSFET

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) selecting 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

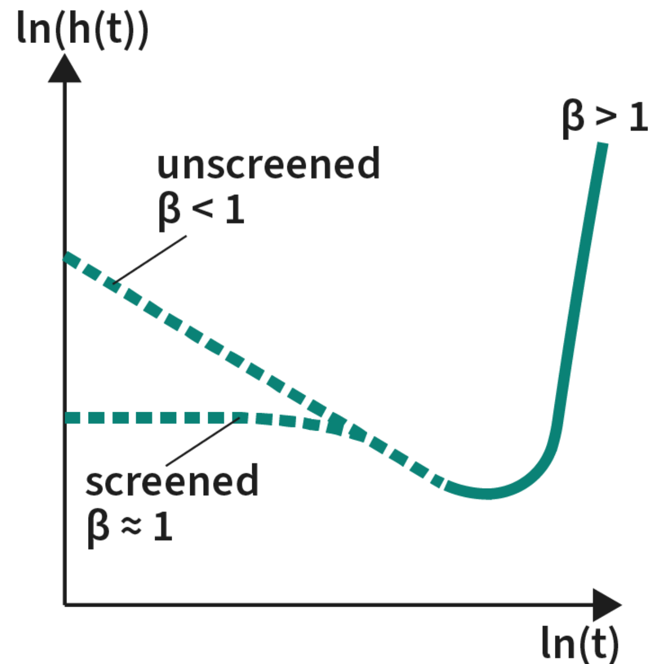
Trench needs less wafer surface.
The gap will widen, better shrink potential in trench.

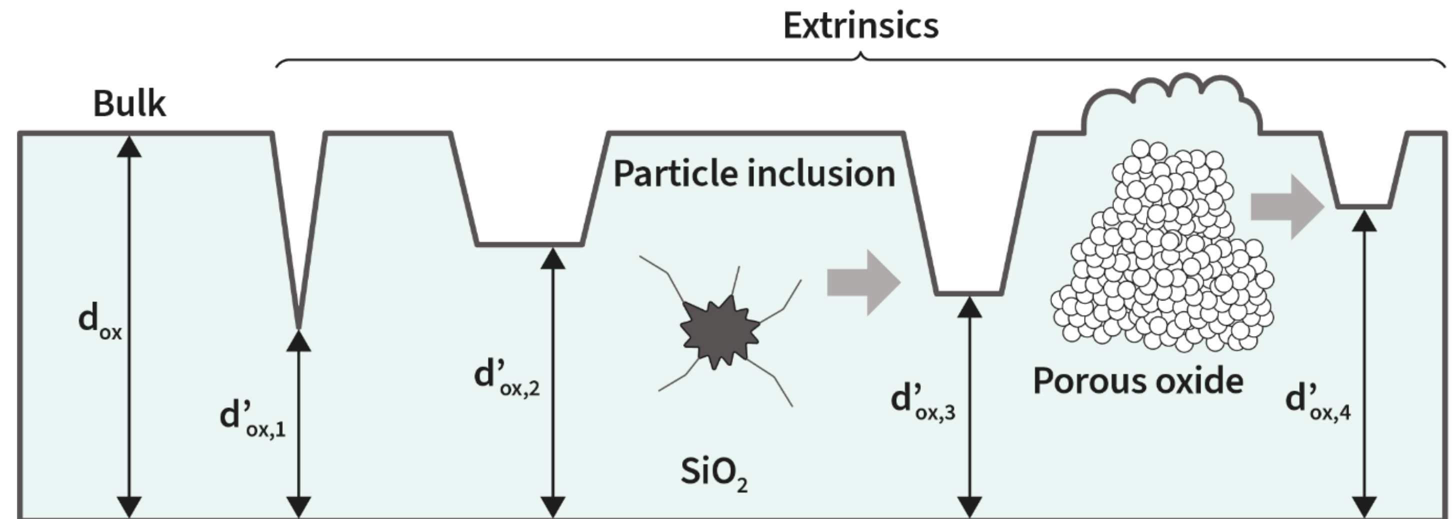
Copyright © Infineon Technologies AG 2023. All rights reserved.

Reliability is building the fundament for every power-device development of Infineon

Extrinsics can be regarded as localized oxide thinning

- Extrinsics lead to early failures (β < 1)
- Screening improves the use life time period (β = 1) and reduces the quantity of early field failures
- SiC has a higher extrinsic failure probability compared to Si





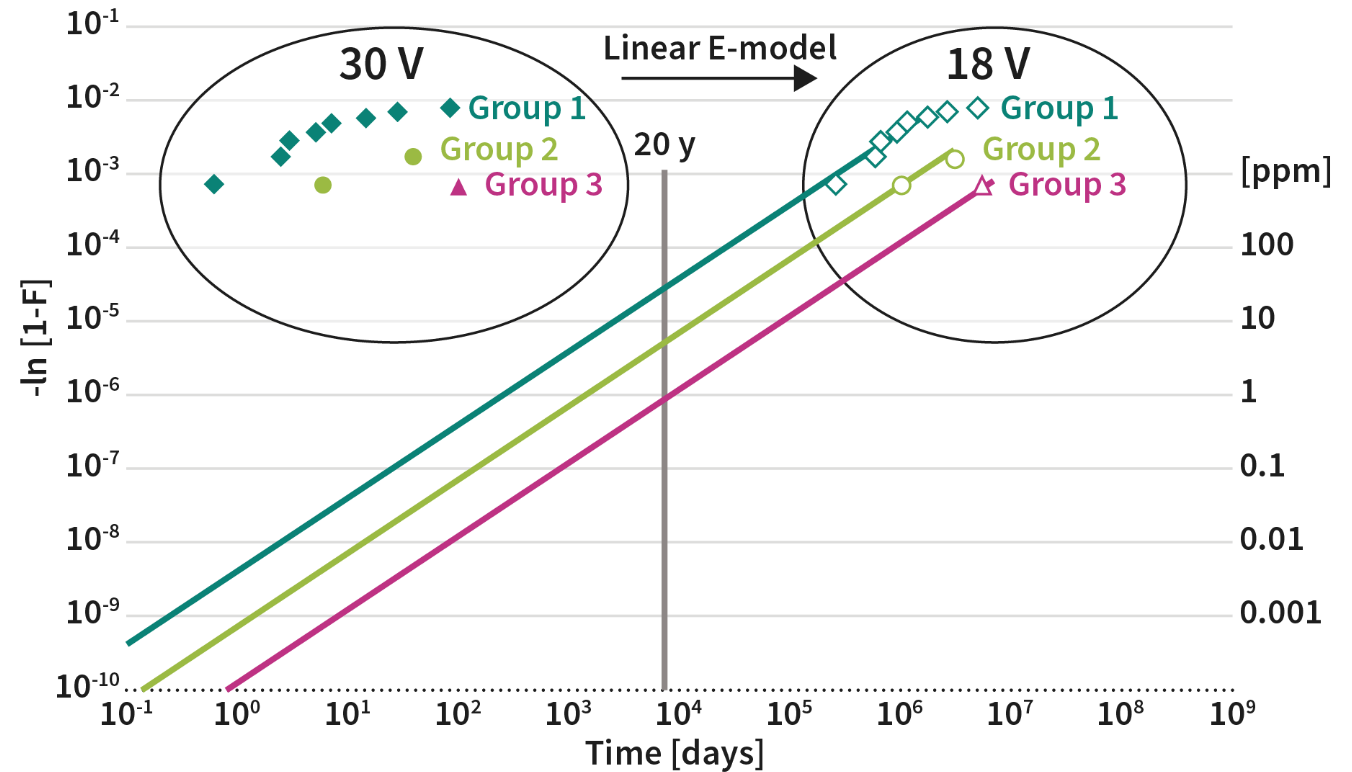
Copyright © Infineon Technologies AG 2023. All rights reserved.

Reliability is building the fundament for every power-device development of Infineon

Marathon test to setup the model

A straightforward electrical method to determine screening capability of gate-oxide extrinsics in arbitrary, commercially available SiC MOSFETs

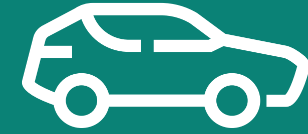
Gate-oxide reliability and failure-rate reduction of industrial SiC MOSFETs



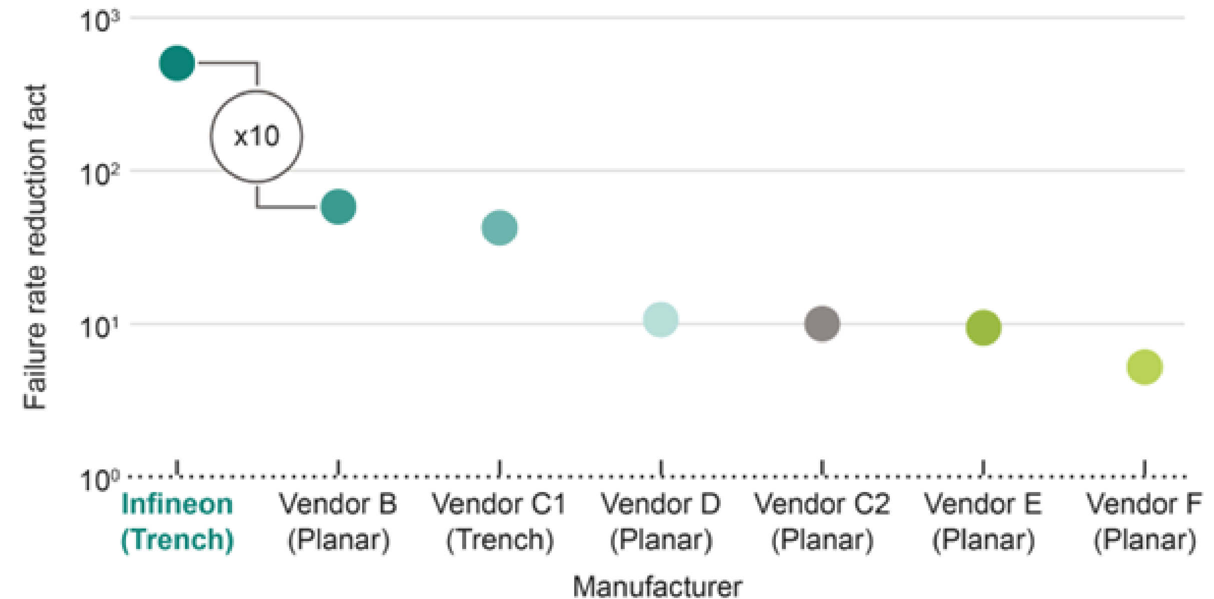
Copyright © Infineon Technologies AG 2023. All rights reserved.

Defect Density Screening made by Infineon: Keeping the Promise of low FiT-Rates[1]

Potential Field Failures based on 100,000 sold cars



- Valid for base material but higher defect density in planar vs. trench (due to add. horizontal plane)
- Same defect density level assumed
- Worst case boundary conditions used
- V_{GS} = 18 V ; T_J = 150°C; 8,000 h use life (50% duty cycle)
- Package: HybridPACK™ Drive assembled with 24 SiCMOS



The FiT rate after voltage screening ($FiT_{post,scr}$) is then defined as the original FiT rate at the end of processing (FiT_{EoP}) divided by the failure reduction factor H_{scr}:

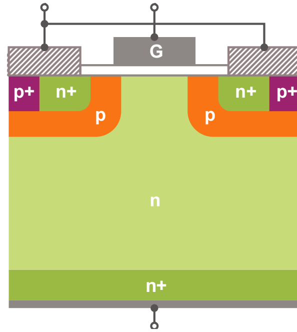
$$FiT_{post,scr} = \frac{FiT_{EoP}}{H_{scr}}$$

1) FiT = Failure in Time (1bn hours)

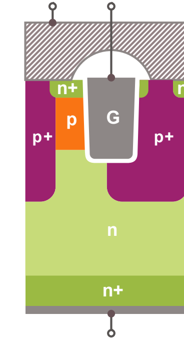
Copyright © Infineon Technologies AG 2023. All rights reserved.

Defect Density Screening made by Infineon: Keeping the Promise of low FIT-Rates

Planar



Gate-oxide thickness optimization



Trench

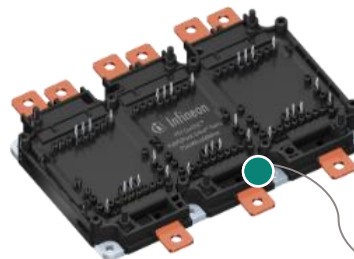
x10

FIT	PPM
0.6	4.8

FIT	PPM
0.06	0.48

x10

14.4	115.2



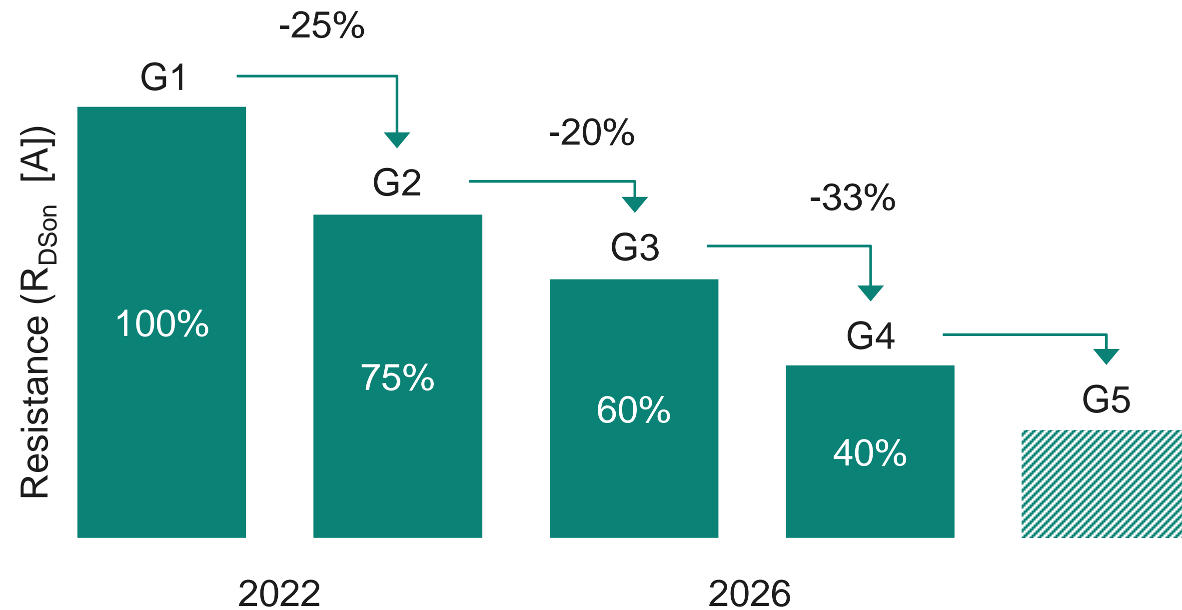
1.4	11.5

CoolSiC™ G2

Copyright © Infineon Technologies AG 2023. All rights reserved.

Superior trench technology drives sustainable competitiveness in cost and performance

Infineon's trench roadmap



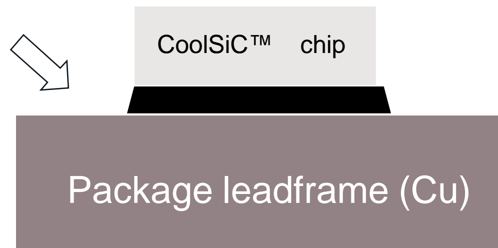
Reduction of the resistance and shrink of the device go hand in hand

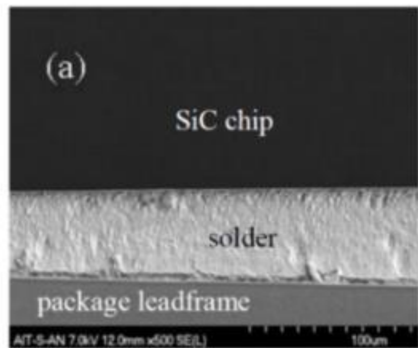
Copyright © Infineon Technologies AG 2023. All rights reserved.

.XT interconnection for discretes solves thermal challenges in small form factor ➔ smaller chips require innovative assembly technologies

Standard interconnection widely used in discrete package

Standard soldering

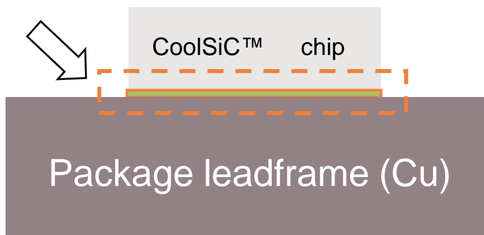


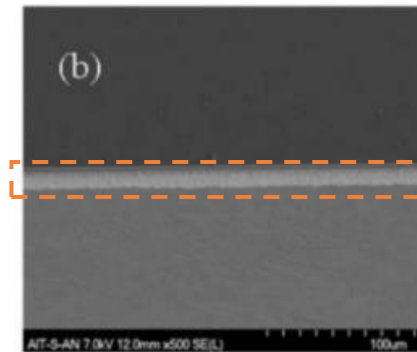


Standard soldering

.XT interconnection by Infineon

Diffusion soldering

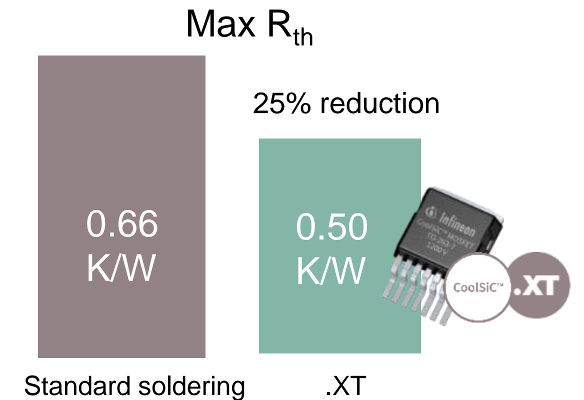




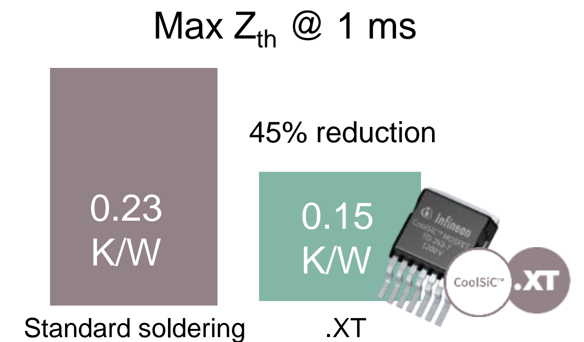
Elimination of solder joint drawbacks by diffusion soldering

Enhanced thermal performance in small form factor

Max R_{th}



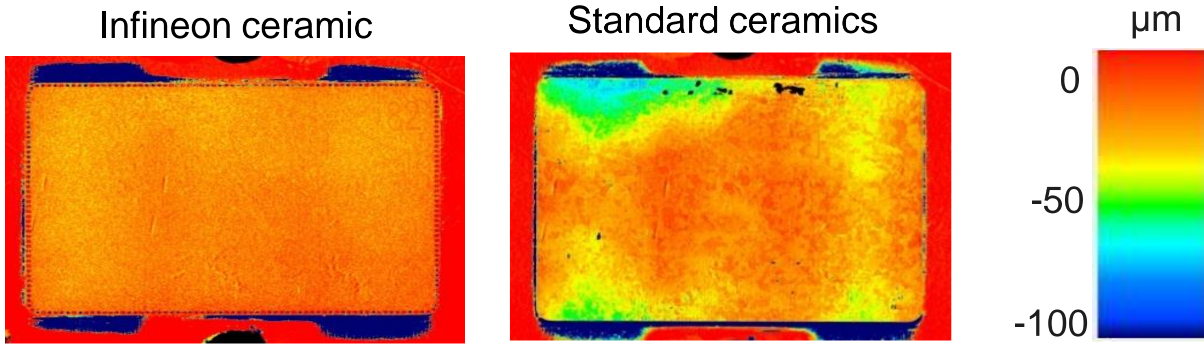
Max Z_{th} @ 1 ms



Copyright © Infineon Technologies AG 2023. All rights reserved.

High performance ceramics for modules – driven by assessment of the actual system pain

High performance ceramics for modules – comparison of backside flatness with standard material

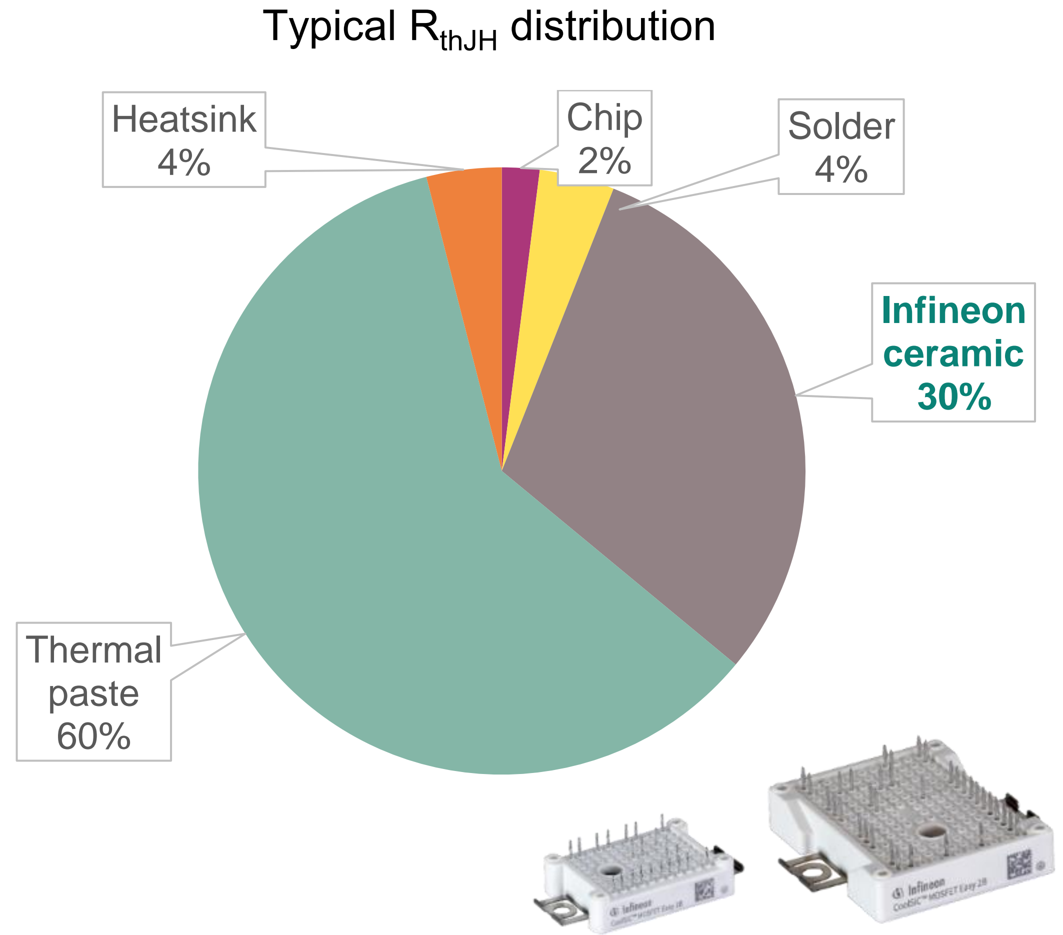


Significantly better cavity situation and superior thermal conductivity

Impact of new ceramics on system performance:

- Minimization of the cavity between module and heat sink enabled by superior ceramics allows much thinner thermal grease layers ➔ in total significant better thermal performance
- Chip power handling capability increased by 30% for typical applications

Impact of Infineon ceramics on total thermal resistance

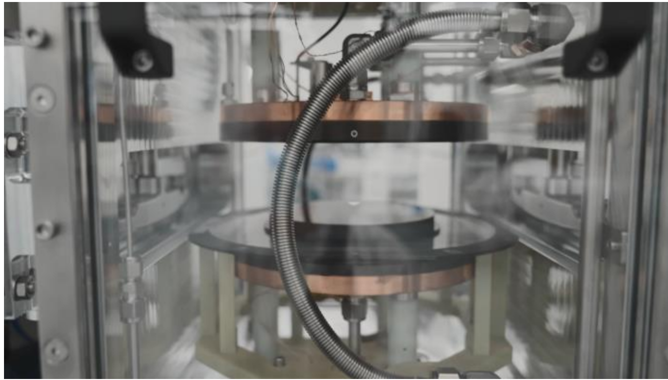


Copyright © Infineon Technologies AG 2023. All rights reserved.

Cold split successfully established in production environment, roll-out to Kulim in progress

Laser based SiC splitting as important productivity lever

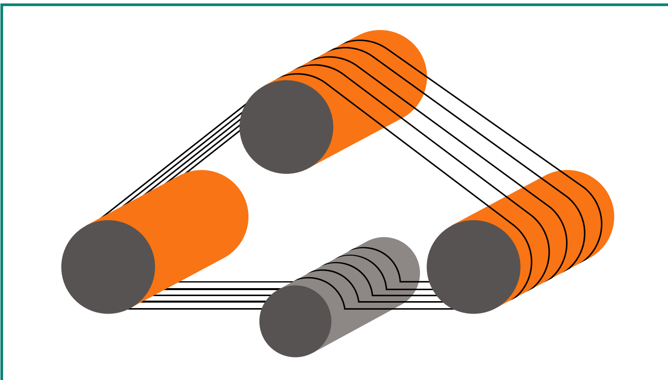
Cold split

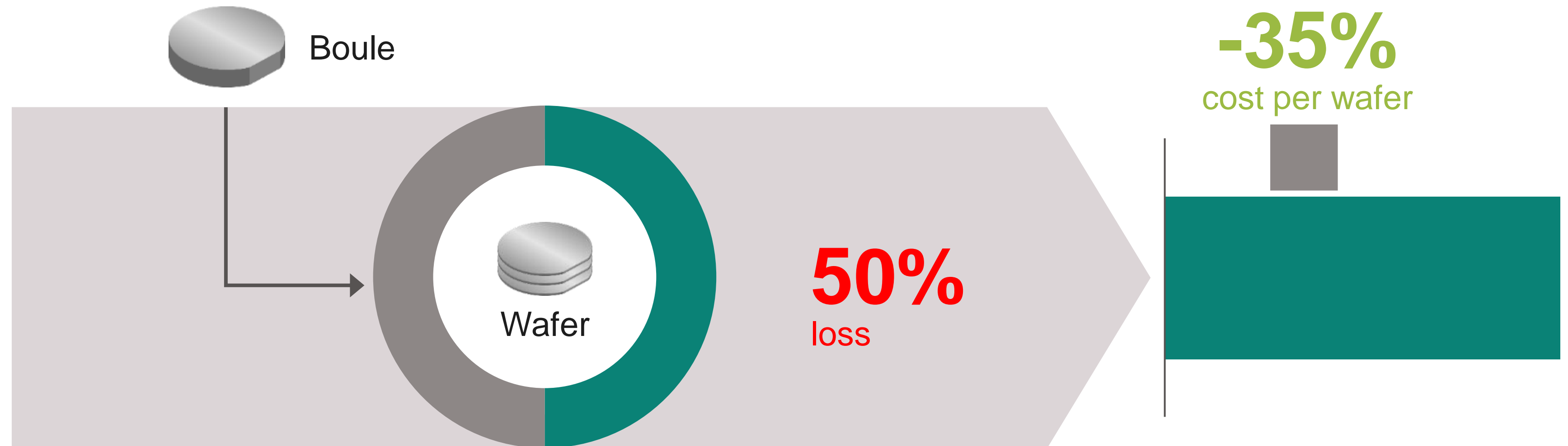


Boule

-35%
cost per wafer

Wire sawing

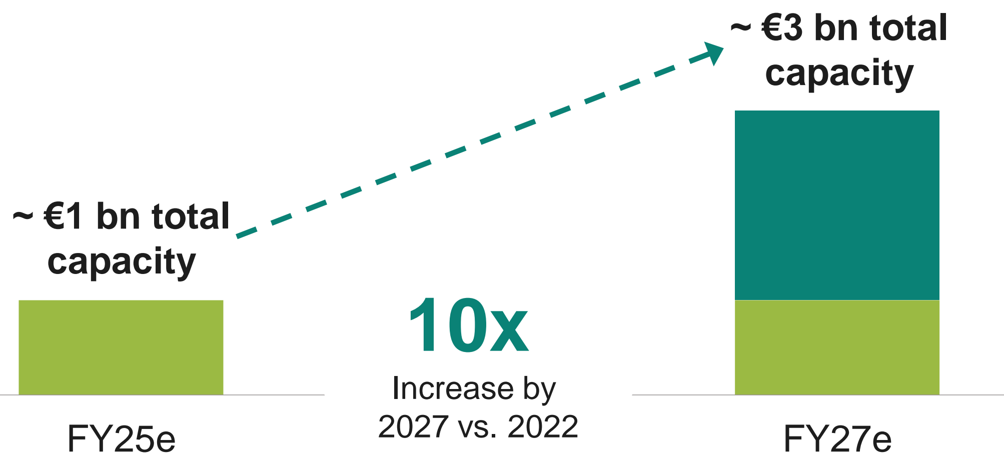




Copyright © Infineon Technologies AG 2023. All rights reserved.

30% market share target in SiC by end of decade underpinned by significant capacity expansion

Well positioned for strong SiC market growth



Infineon is executing

- Revenue growth of >60% in FY23
- Ramp in Villach on schedule
- Construction in Kulim according to plan.
  Production will start in H2 2024
- Setup of cold split production in existing facilities in Kulim
  Start of volume production in H2 2024
- Training of Kulim staff in Villach/Dresden has started

We rock the ramp

Copyright © Infineon Technologies AG 2023. All rights reserved.

Questions & answers

infineon