



SiC Power Technologies and business – empower a greener future

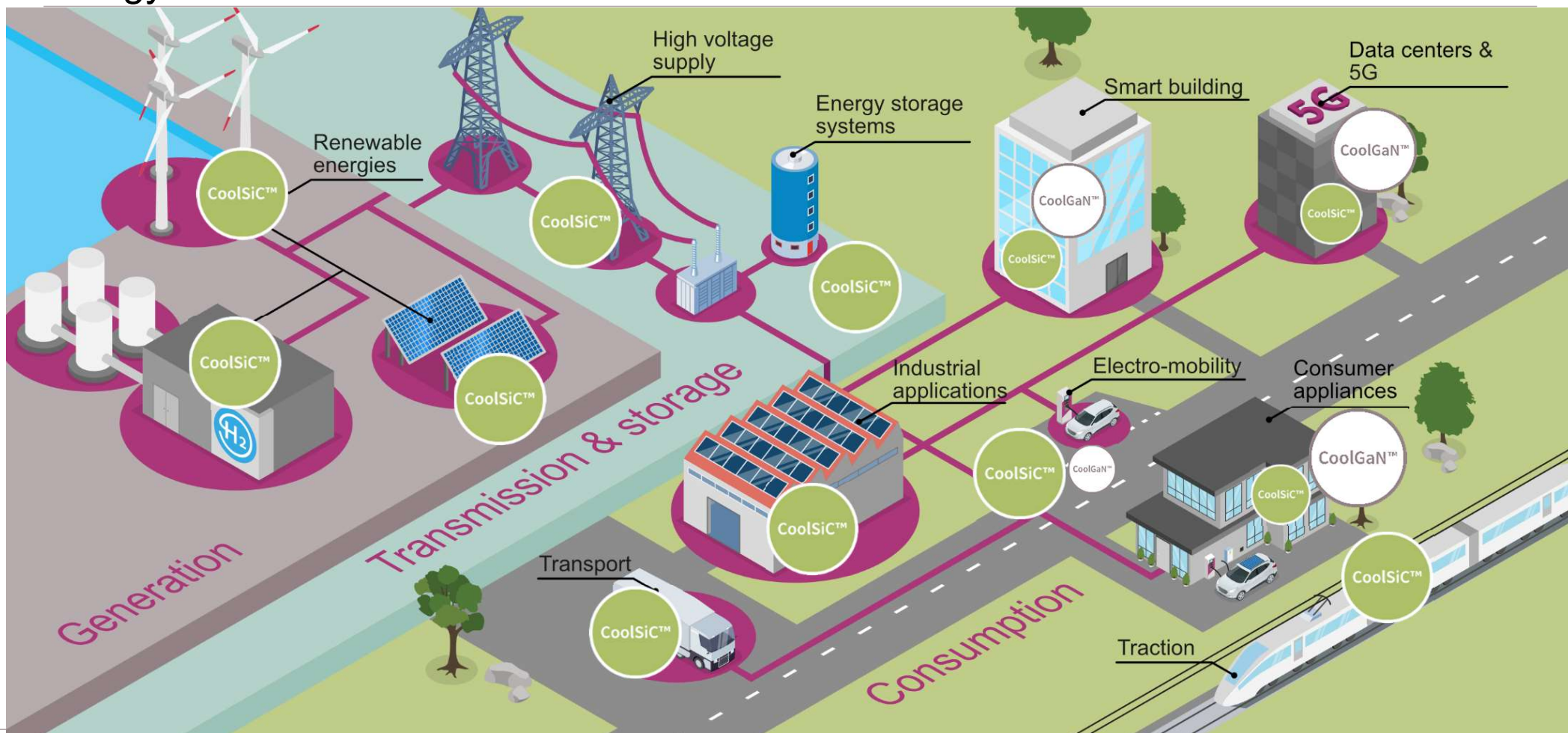
Dr. Peter Friedrichs, Infineon Technologies AG
IFAG IPC T, VP SiC
November 2022



Setting the stage...



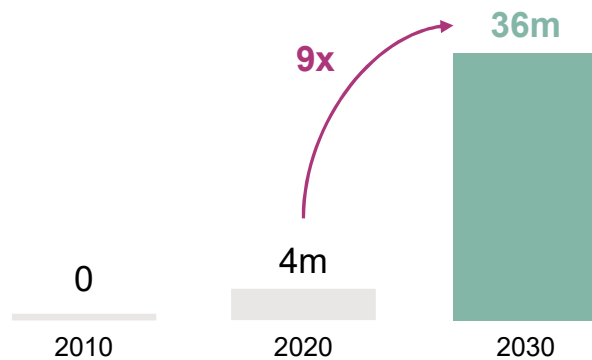
Wide band gap technologies will re-shape the megatrends along the energy conversion chain



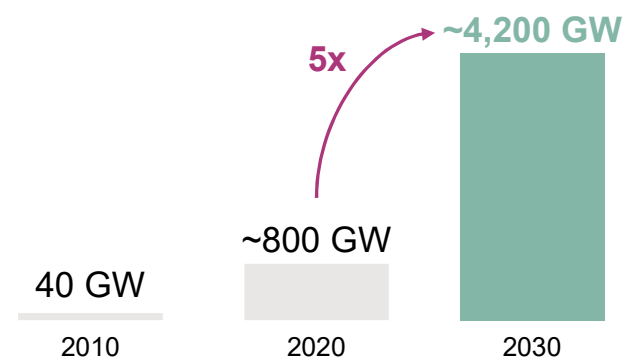
Global megatrends lead to tectonic technology shifts; examples: xEV and renewable energies



Number of BEV + PHEV sales¹



Installed PV power²



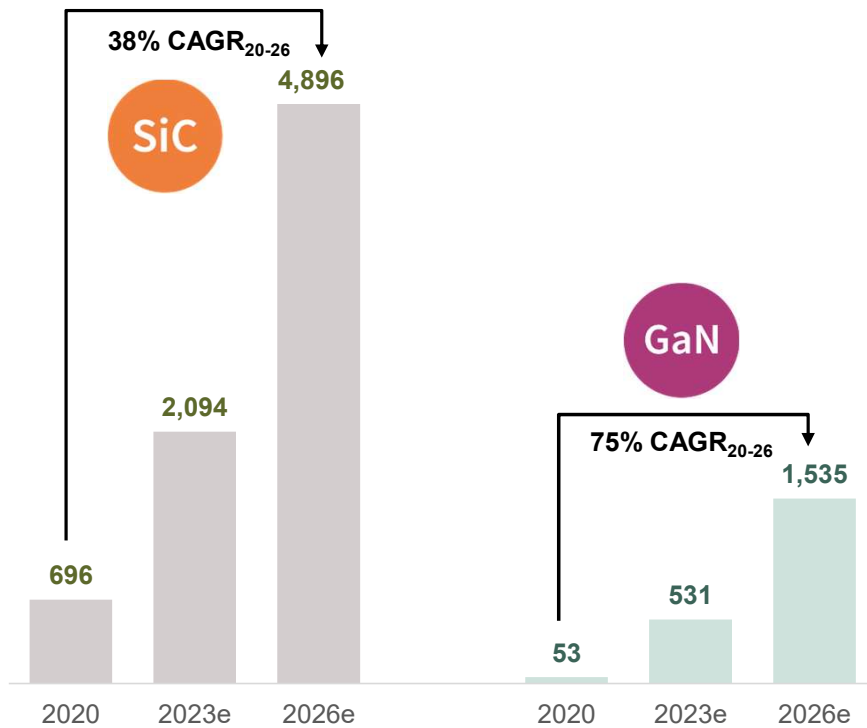
¹ Based on or includes content supplied by IHS Markit Automotive: *Light Vehicle Alternative Propulsion Forecast*. August 2021 | ² IEA: *Net Zero by 2050 - A Roadmap for the Global Energy Sector*. May 2021

Infineon is excellently positioned to leverage its wide bandgap - WBG portfolio to provide additional value for its customers



WBG market development¹

Total market [in million USD]



E-mobility infrastructure



Renewable energy



Chargers & adapters



Data centers



¹ Yole Développement: Compound Semiconductor Quarterly Market Monitor. Q1 2022

EV booming and its meaning to industry

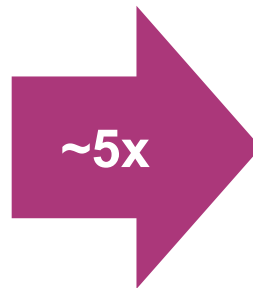
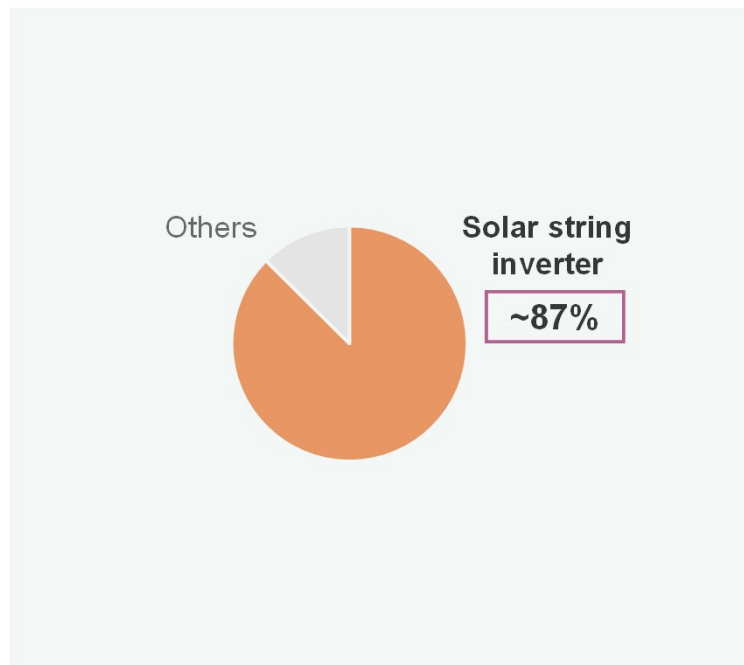


Industry market will grow proportionally to EV market

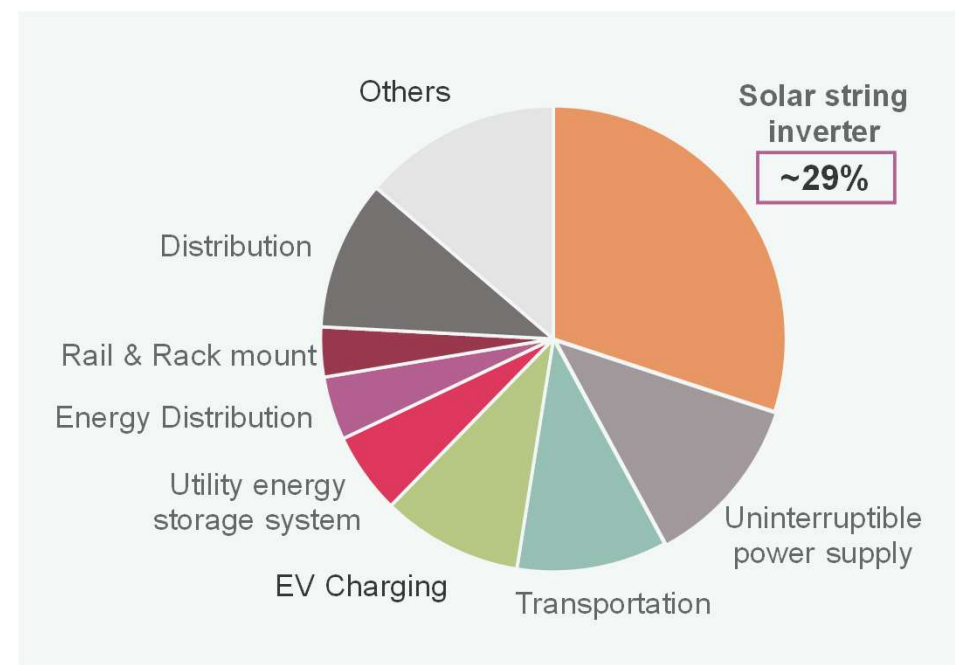
SiC grows continues and gains wide spread adoption in industrial and automotive applications



Infineon's industrial SiC design wins FY17

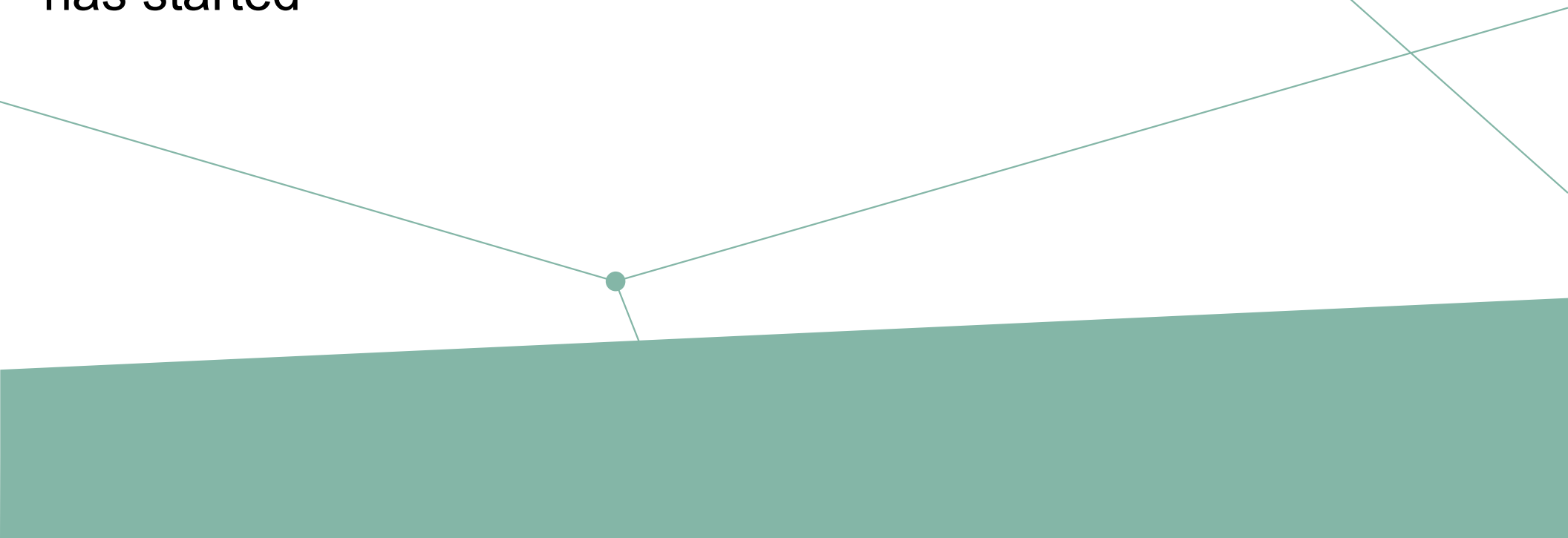


Infineon's industrial SiC design wins FY21



Starting as a key success factor in solar, SiC becomes designed-in into more and more applications

SiC in the real world – mainstream adoption
has started



SiC will add significant value to a broad variety of systems across many applications



Photovoltaic

- › reduction of system cost
- › reduction of system size



EV charging

- › faster charging cycles



Industrial power supplies/ UPS

- › higher efficiency
- › reduced total cost of ownership



eMobility

- › higher reach per charge
- › more compact main inverter

tipping point reached



Traction

- › energy savings of ~10%
- › reduction of motor noise



Drives

- › reduced system size
- › reduced total cost of ownership



Energy storage system

- › higher efficiency (extra energy of ~2% at same battery size)

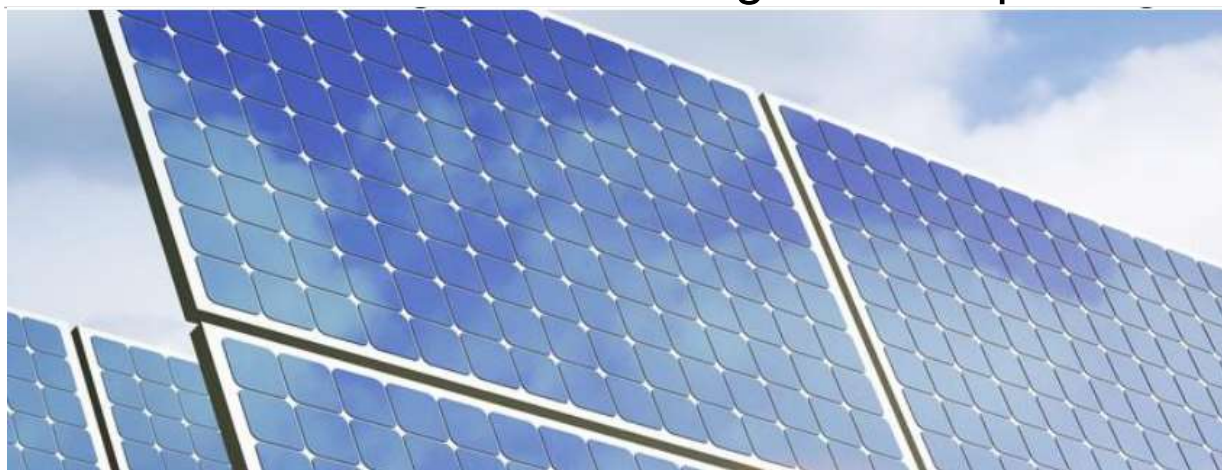


Commercial HVAC

- › higher efficiency, reduced system size
- › reduction of noise

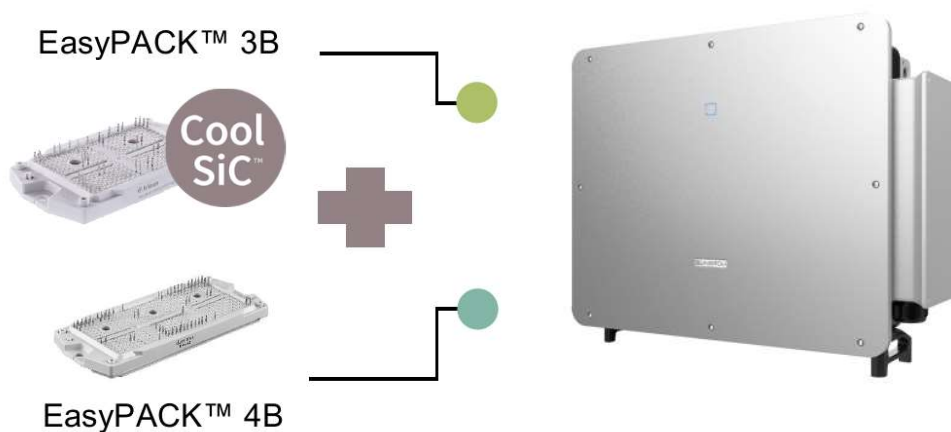
future tipping points

New world record for solar string inverters powered by SiC MOSFETs



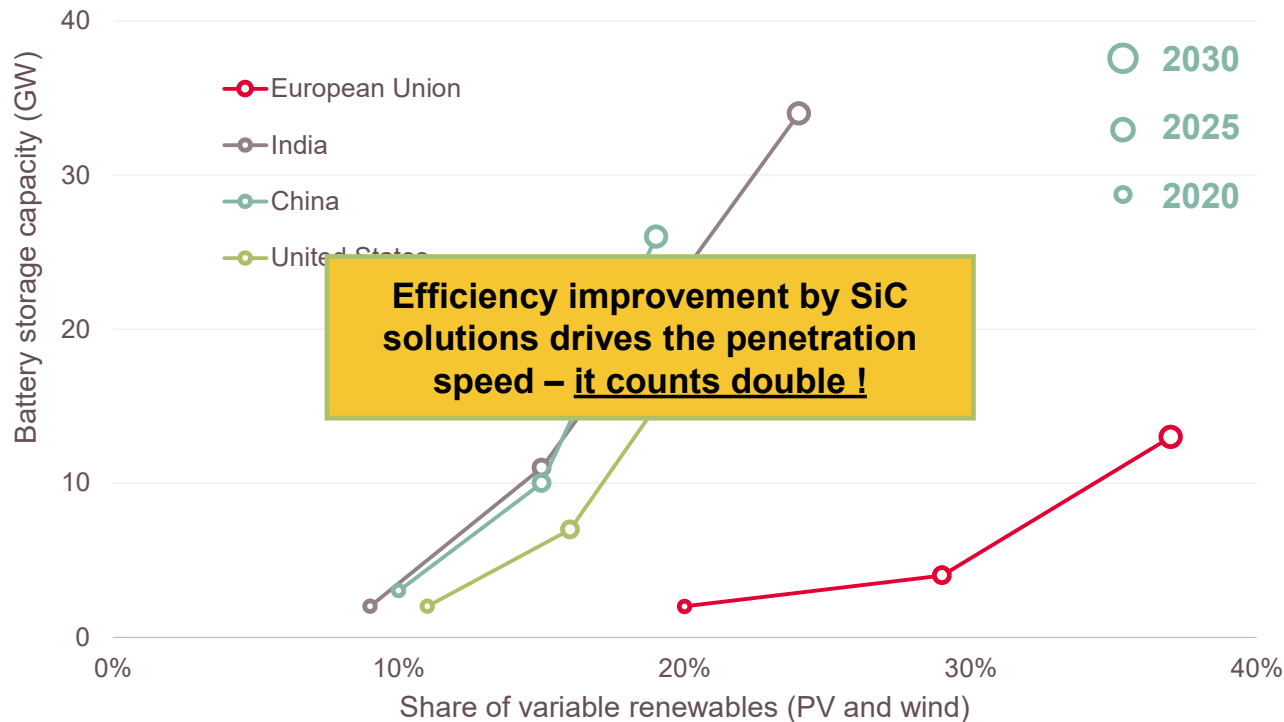
› Sungrow_SG350HX solar string inverter for 1500V panels

- › 352 kW
- › 110 kg weight
- › New high voltage SiC MOSFET and diode technology
- › New press fit package platform for high power introduced



Renewable energy generation will be combined with energy storage - essential to further deploy decentral and stable grids

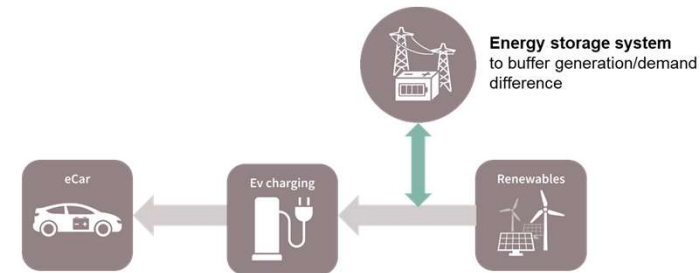
Battery storage capacity and share of variable renewables¹⁾



1) International Energy Agency: "World Energy Outlook 2020", p. 248; variable renewables consist of solar and wind energy.
2) Infineon estimate

Key drivers

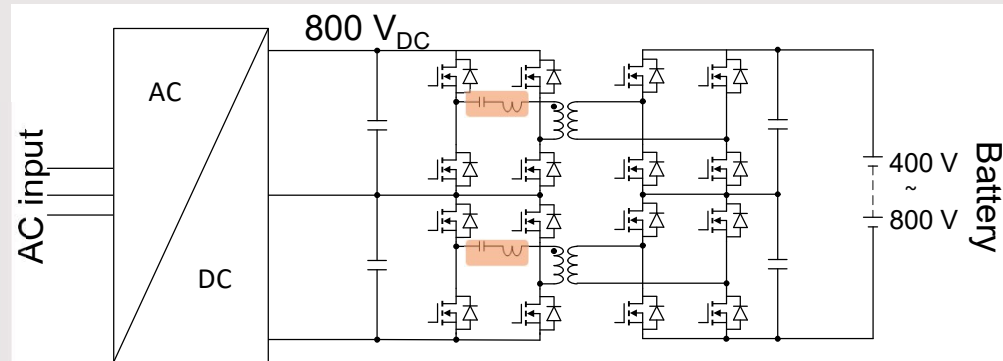
- > **Decentralization** of power generation
- > **Peak shaving** of energy generation and energy consumption
- > **Reduction of standby cost** of fossil power plants



~€3,200 of power semiconductor content per MW of installed energy storage capacity²⁾

CoolSiC™ MOSFET for EV fast Charging

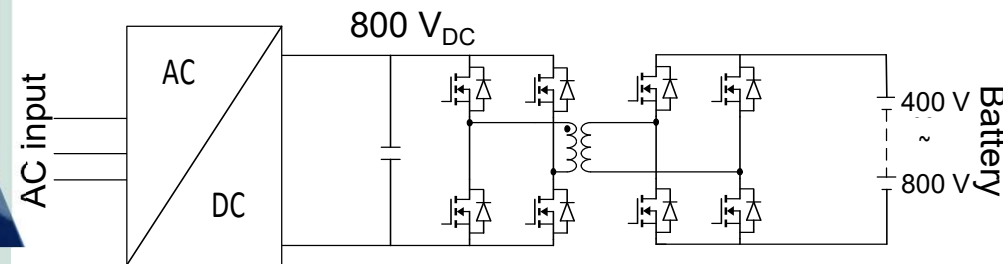
Enables simpler hard-switching solution



650 V Si SJ MOSFET in
DC/DC stage:
2x full-bridge LLC



Si to
SiC



1200 V SiC MOSFET
DC/DC:

- › Simple hard-switching topology
- › Less control effort
- › Reduced part count by 50%
- › Especially attractive for bidirectional charging

Benefits enabled by SiC vs. Si for a 75kW fast charger

› Efficiency

- as semiconductors account for ~2/3 of total losses → need to reduce their losses when aiming for higher efficiency



› Volume / power density / weight

- Higher switching frequencies are advantageous for the design of the magnetics.
- Save volume/weight for cooling system

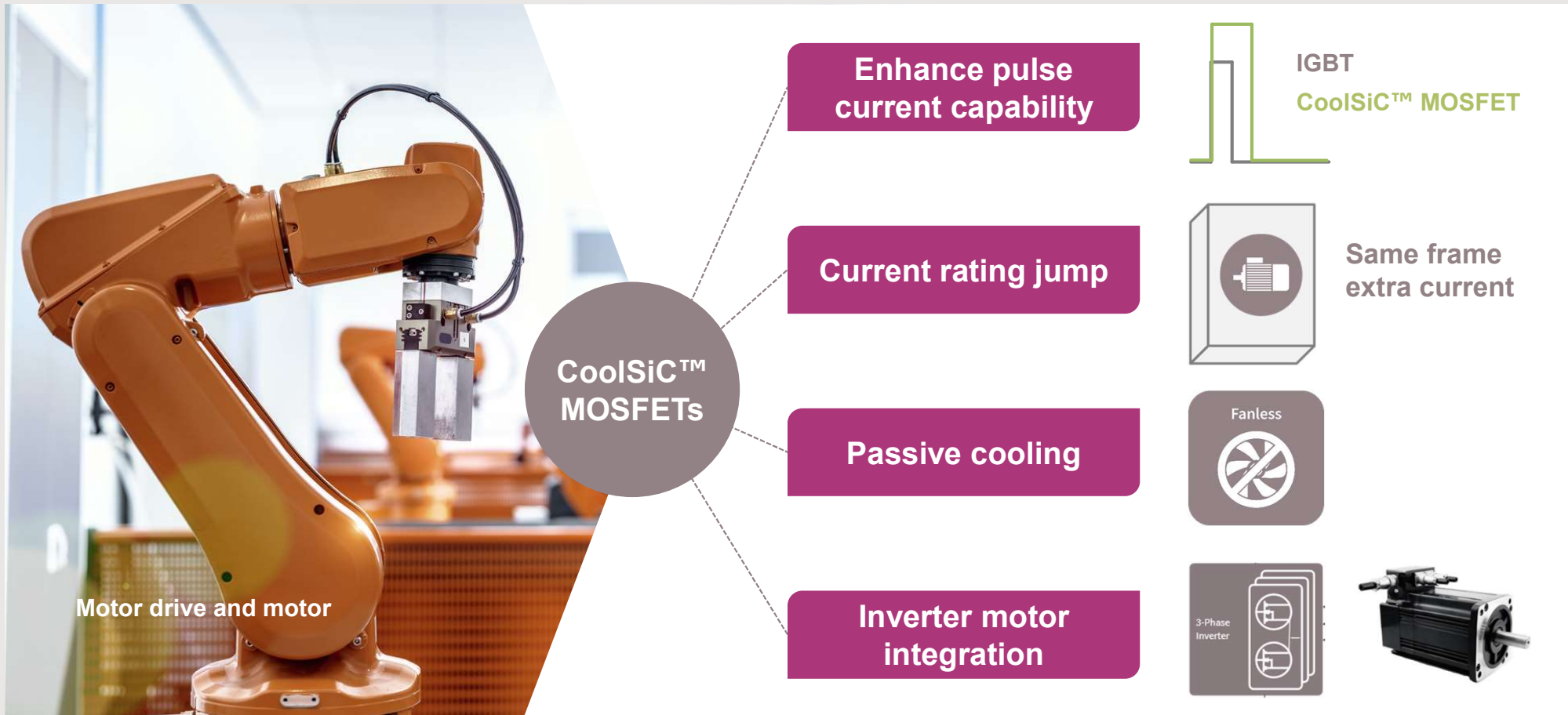


› Noise

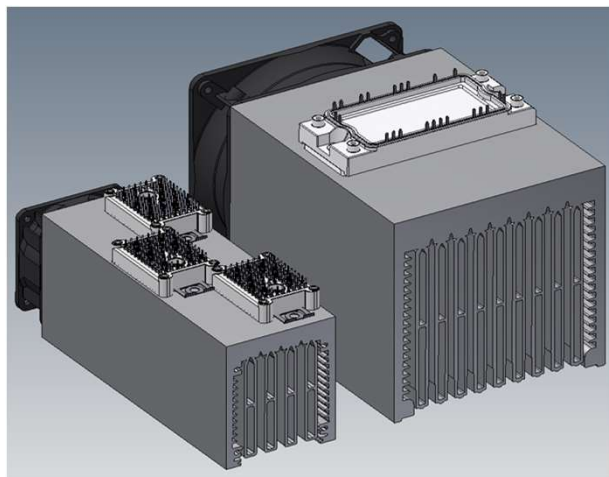
- reduced number of fans (according to reduction of losses → factor 2)
- reduced noise



CoolSiC™ MOSFET: Next generation of servo drives

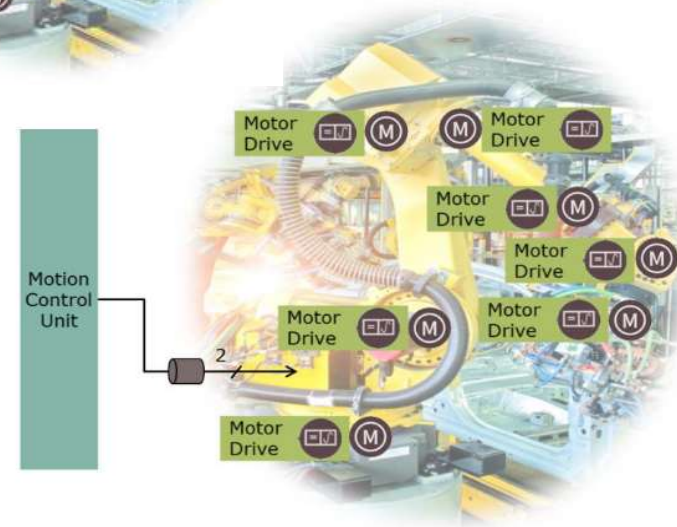
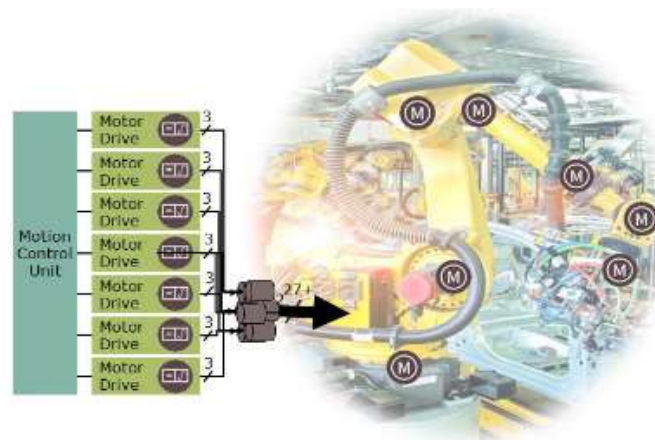


Lower losses equates to lower weight



60% size and weight reduction

For some applications weight & size are key design parameters.



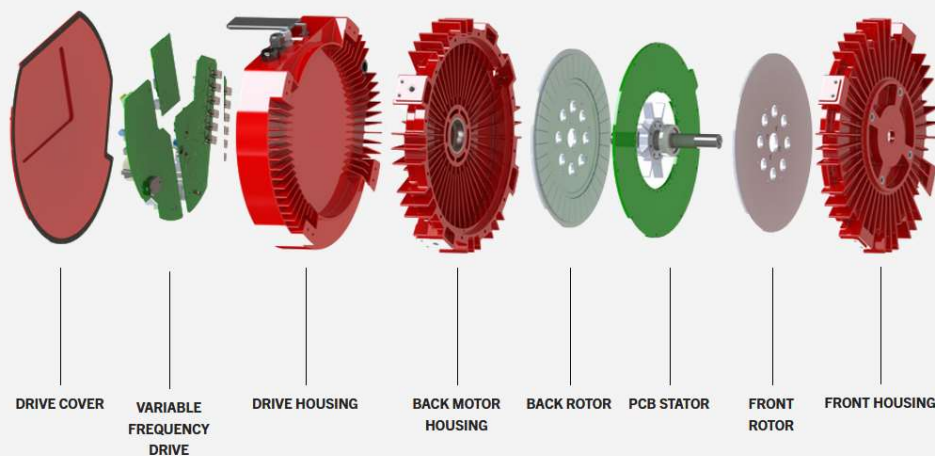
Among others - SiC enables new motor concepts

Completely new motor solutions enabled by SiC

Motors + Controls + IoT = All-in-One Solution

With a forward-thinking design philosophy, we've reduced the size and weight of a motor from the equivalent of a 20-pound medicine ball down to a frisbee, unlocking design potential for you to make any machine lighter, quieter, and more efficient.

www.infinitumelectric.com



Iron less motor with PE integration

Requirements:

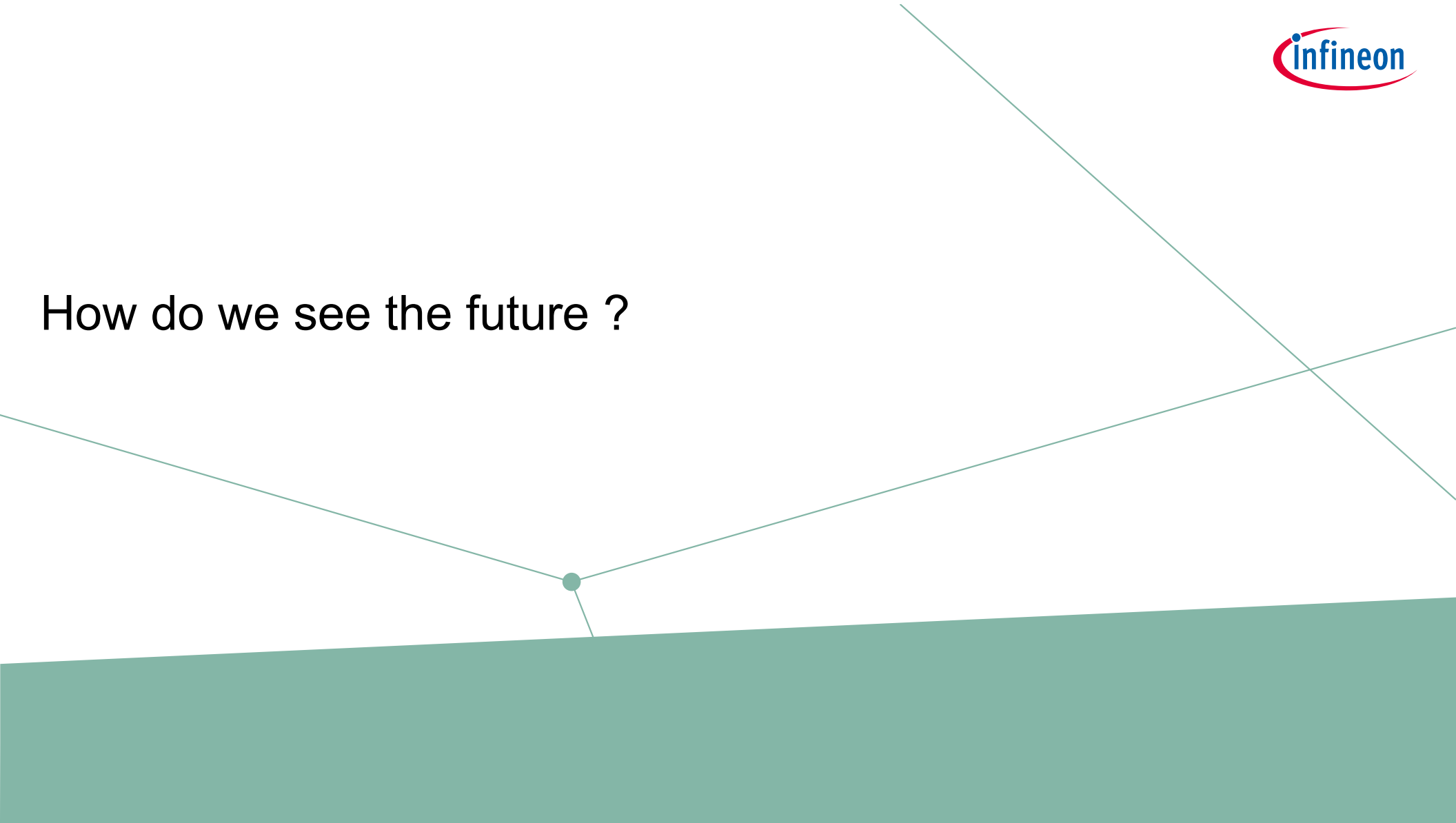
- efficiency
- high switching frequency
- passive cooling

Very low inductance

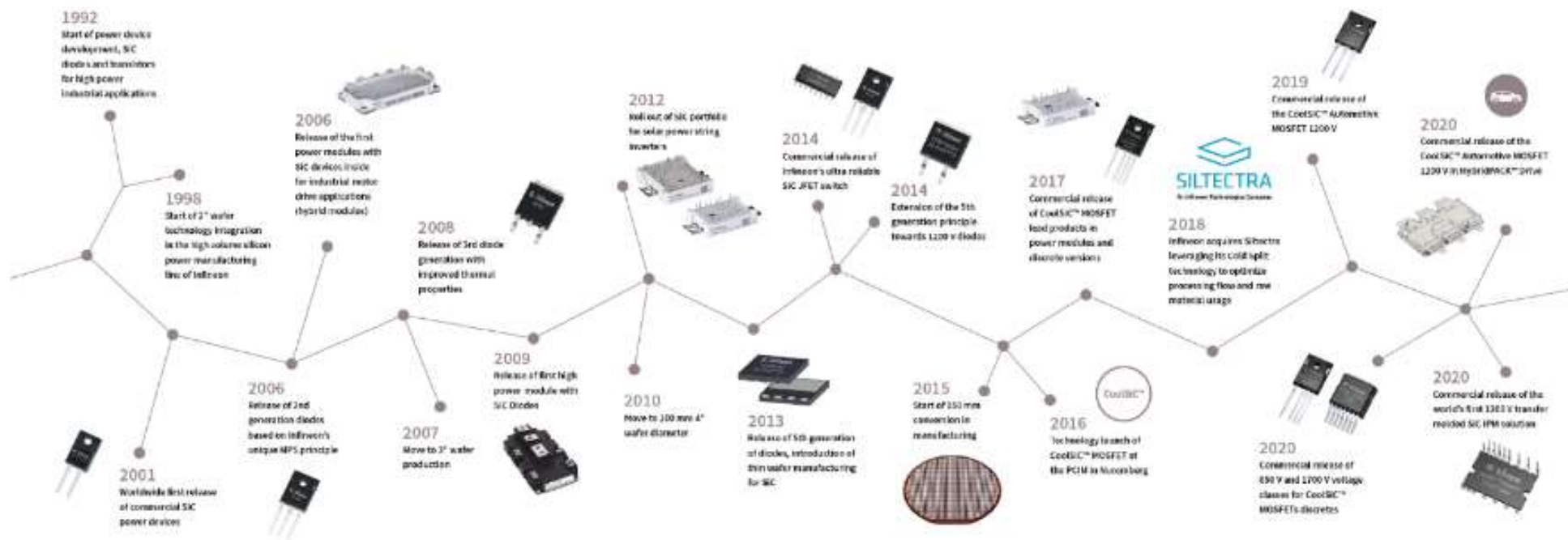
Very high switching speed required, but
no limit for dv/dt

SiC is an enabling element

How do we see the future ?



Infineon builds up on 25+ years of experience in SiC technology



2022 Infineon CoolSiC™ Portfolio – broadest offering among all SiC power device suppliers today (catalogue products only, customer specific modules not counted)



Package options voltages	Industrial – CoolSiC™								Automotive CoolSiC™					
	Diode		Hybrid		MOSFET				Diode	Hybrid	MOSFET			
	Discrete	Bare die	Discrete	Module	Discrete	IPM	LMP Module	Bare die	Discrete	Discrete	Discrete	Frame Module	Molded Module	Bare die
600 V														
650 V														
750 V														
1200 V														
1700 V														
2 kV	2022				2022									

Status July 2022

mass production

in development Gen 1

in development or planned Gen 2



Complement the vast portfolio of CoolSiC™ MOSFETs with the EiceDRIVER™ gate driver ICs.

Key success factor – wide portfolio also beyond the power device



1 **Controller**
AURIX™ microcontroller



2 **EiceDRIVER™ gate driver ICs**
EiceDRIVER™ enhanced



3 **CoolSiC™ switches**
650 V/ 1200 V CoolSiC™ MOSFETs



1200 V in EasyPACK™



System solution enables...



> Fastest charging cycles



> More compact designs with up to **+30% power density**

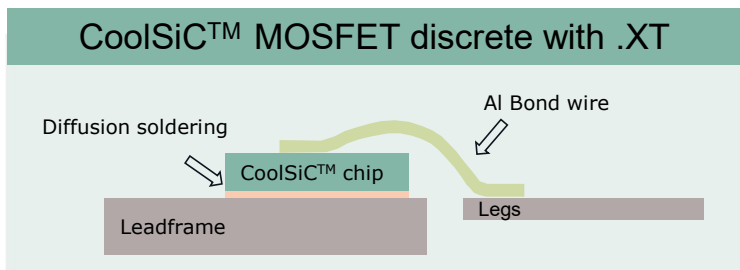


> Highest lifetime and reliability

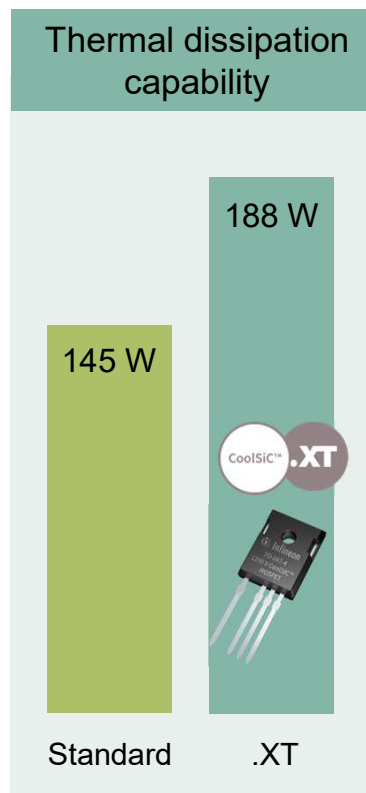
Packaging technology needs to follow the chip performance - Diffusion solder in our .XT technology enables higher power density



.XT technology



- › New die attach process enables a significant improvement of the thermal impedance
- › Compensates for the drawback of small die due to low area specific resistance if nominally identical devices are compared
- › Simplification of assembly process due to lack of solder layer



Award presentation ceremony

Der Deutsche Innovationspreis



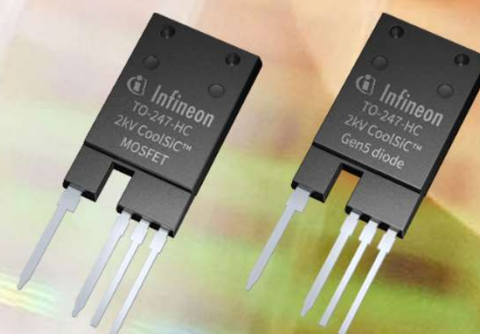
› Foto: Marc-Steffen Unger

Device definition needs to follow the wider application requirements – a new voltage class with SiC 2 kV MOSFET and diode introduced in 2022

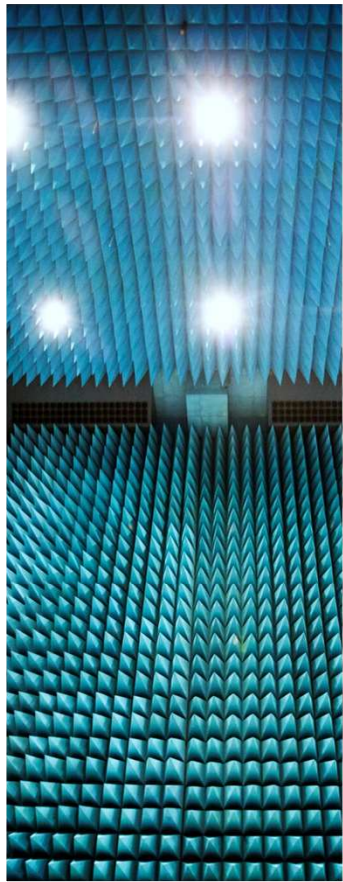
Technology designed to have both low $R_{DS(on)} \cdot A$ and low FiT rate at 1500 V DC



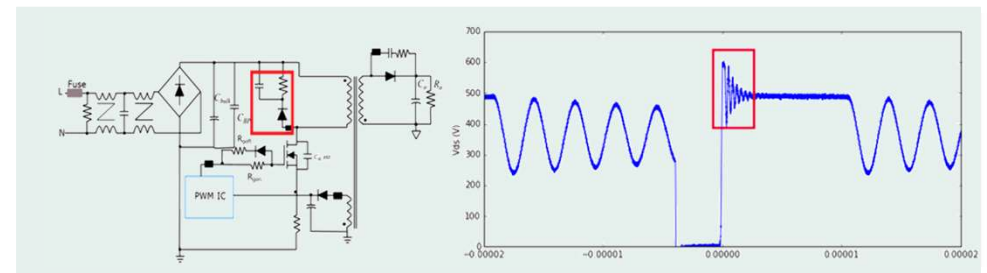
New package including .XT die attach and with higher creepage and clearance distance for this new voltage class



EMI topics are often more significant in modern power conversion system designs – identification of root-causes requires special expertise



- › Faster rise & fall times for voltage and current waveforms
 - greater spikes with significant energy at high frequencies cause conducted & radiated noise
- › Root cause often very complex and cumbersome to identify
 - **measurements** (far/near-fields): **ensure quality and correct interpretations**
 - effects not appearing on schematics: **parasitics, low-qual. groundings, etc.**
 - **common-mode noises, resonances, “hidden” transients & current loops in PCBs (i.p. multi-layer), etc.**
 - cut-and-try like approaches requiring **multiple hardware prototypes**



As an industry leader we gained broad knowledge to tackle increasing challenges with high-frequency-related EMI

In-depth knowledge of power semiconductors

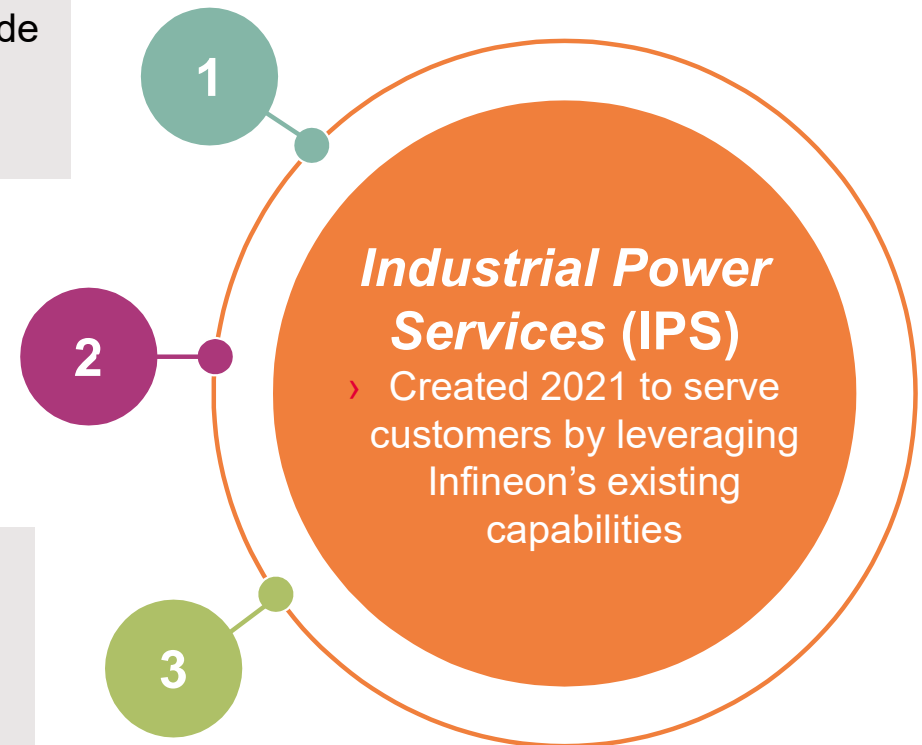
- › Infineon is Top-10 Semiconductor company worldwide
- › *Industrial Power Control* (IPC) designs innovative power modules for >30 years

Development of Power Conversion Reference Designs

- › Experience in dvmnt of 50+ reference designs
- › Systemic understanding on applying modern IGBT & SiC modules on system level

Network of Experts

- › Development of simulation skills in dedicated teams
- › Individual experts in global network who work on system design incl. EMI topics

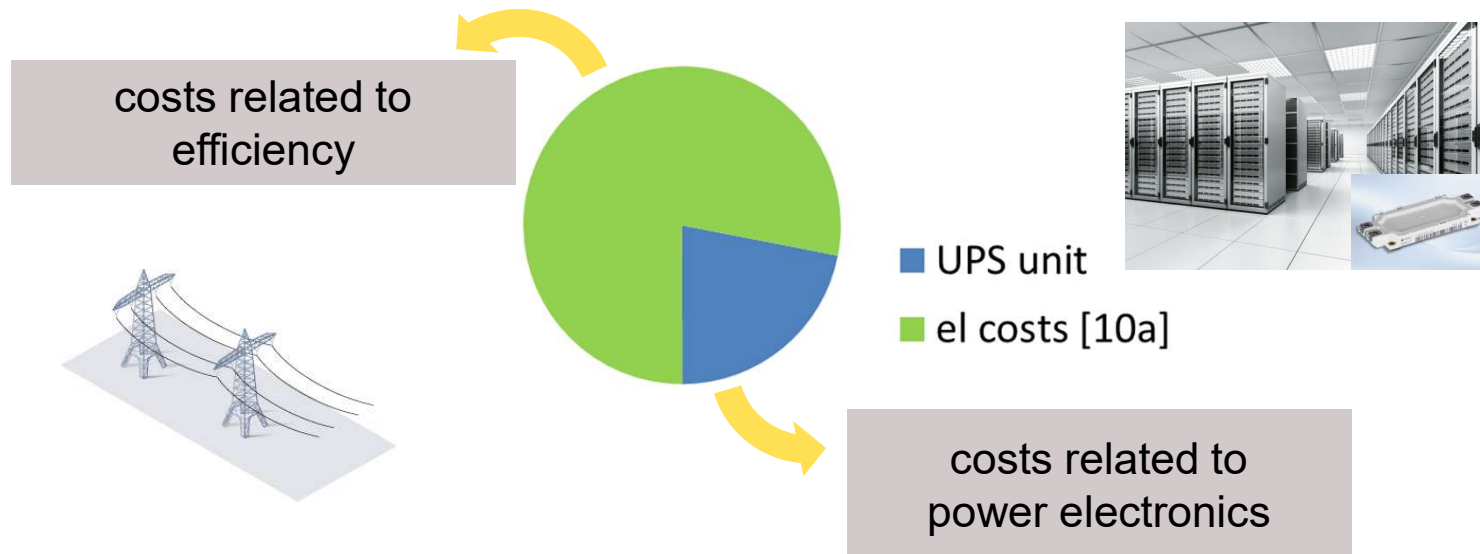




Part of your life. Part of tomorrow.

Are we able to compensate the higher cost of SiC transistors by energy saving ?– UPS and CoO

- › Costs of a UPS (uninterruptable power supply) unit need to include operation (cost of ownership - CoO) as well

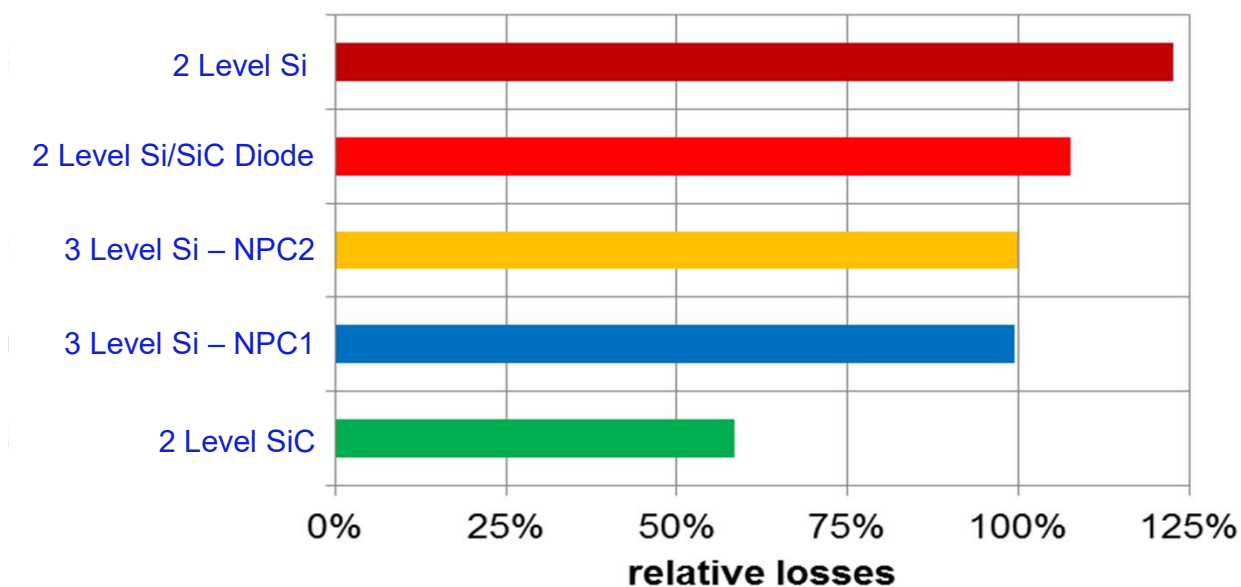


- › Improved efficiency is main goal!

U. Schwarzer, SB, K. Vogel, PCIM Europe 2014

UPS systems – efficiency counts !

- › Significant improvement for 3-Level Si and 2-Level SiC solutions



Power losses are reduced by more than 40%!

Calculating the energy losses for a 1MW UPS operating at 50% load for 5 years

500kWhrs x 24 hours x 365 days x 5 years = 22 million kWhrs processed power through UPS

› **Ancient Si 2-Level at 3.2% loss** = 700,000 kWhrs x 1.2 factor* = 840,000 kWhrs

– At \$.10 per kWhr = **\$84,000**

› **State of the art Si 3-Level at 2.9% loss** = 700,000 kWhrs x 1.2 factor* = 760,000 kWhrs

– At \$.10 per kWhr = **\$76,000**



› **Disruptive SiC 2-Level at 1.7% loss** = 374,000 kWhrs x 1.2 factor* = 450,000 kWhrs

– At \$.10 per kWhr = **\$45,000**



*1.2 factor reflects the energy used for air conditioning to extract heat from a building with UPS installed