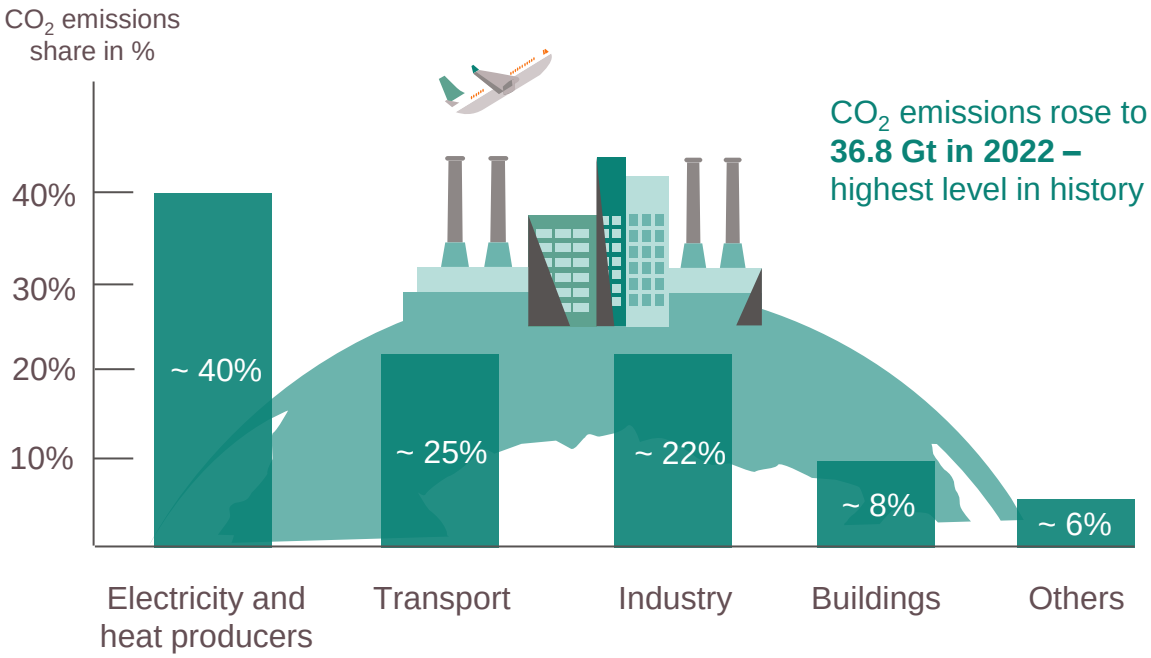
The grid of the future and how SiC power devices will enable the transition towards zero CO_2

Dr. Peter Friedrichs, Infineon Technologies AG
Fellow SiC Innovation & Industrialization

Electrification and CO_2 emission reduction are key for our future

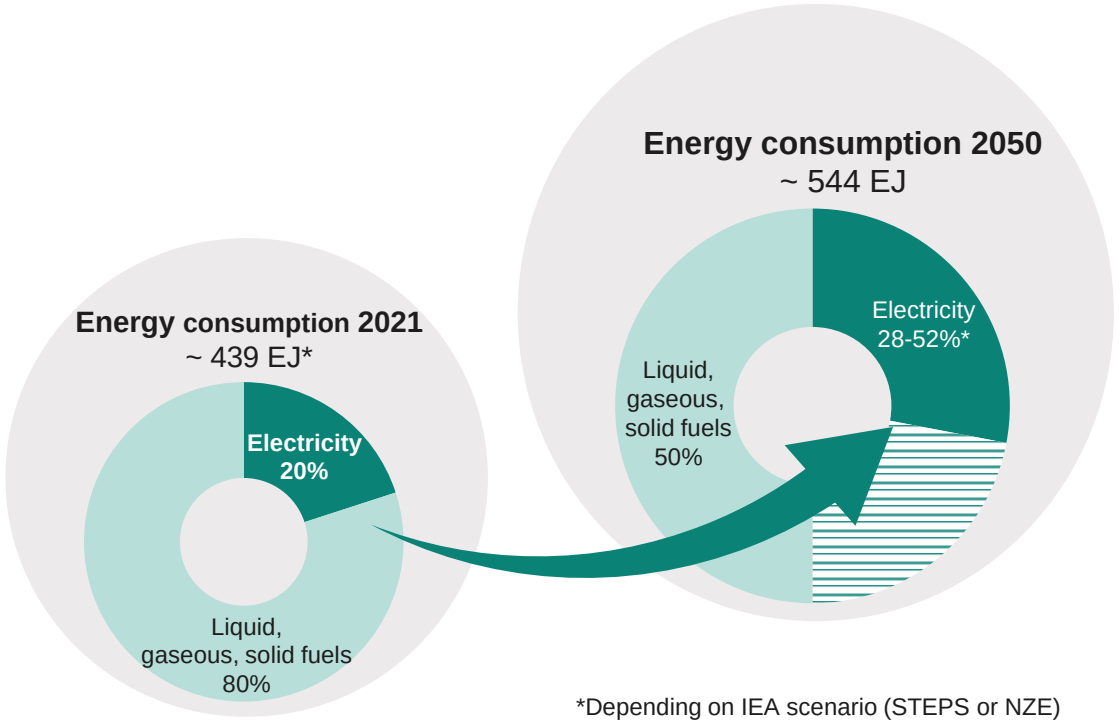
Cutting CO_2 emissions in all sectors



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

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)

Increasing electricity demand

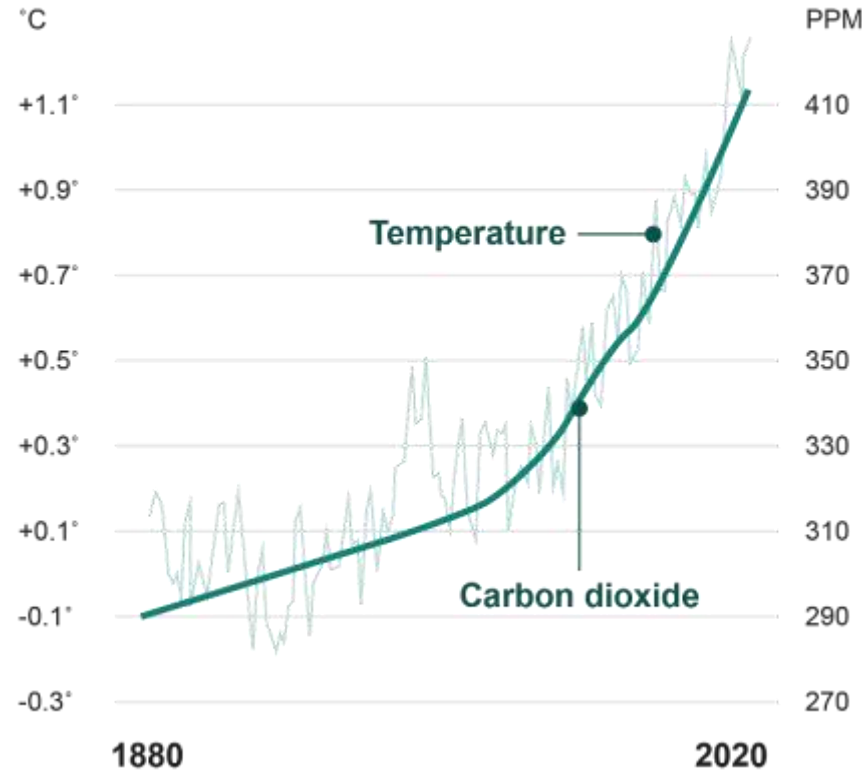


*Depending on IEA scenario (STEPS or NZE)

* 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.

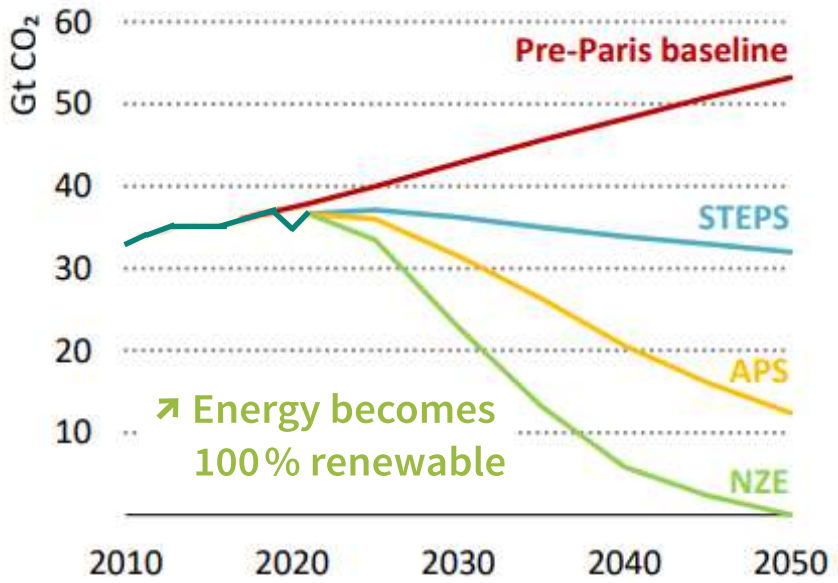
Massive and timely reductions of CO_2 emissions are essential to limit Earth's temperature increase to 1,5°C

Earth temperature & CO_2 development



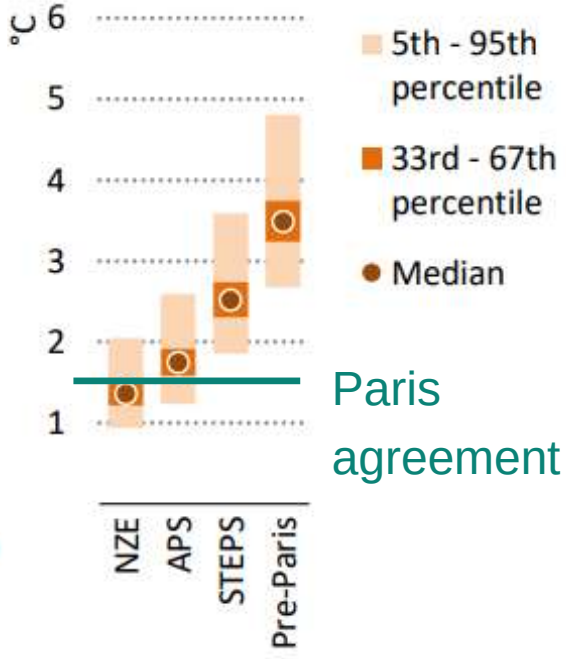
Source: NASA GISS, NOAA NCEI, ESRL

Annual global CO2 emissions



Source: IEA World Energy Outlook 2022.

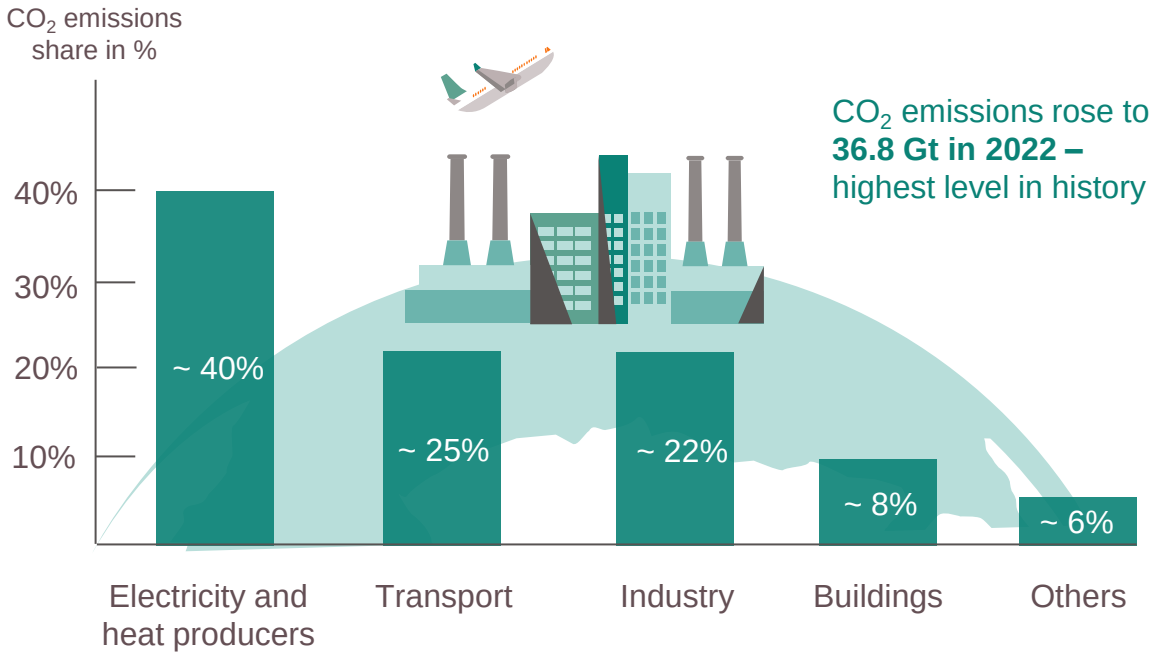
Delta T in year 2100



Paris agreement

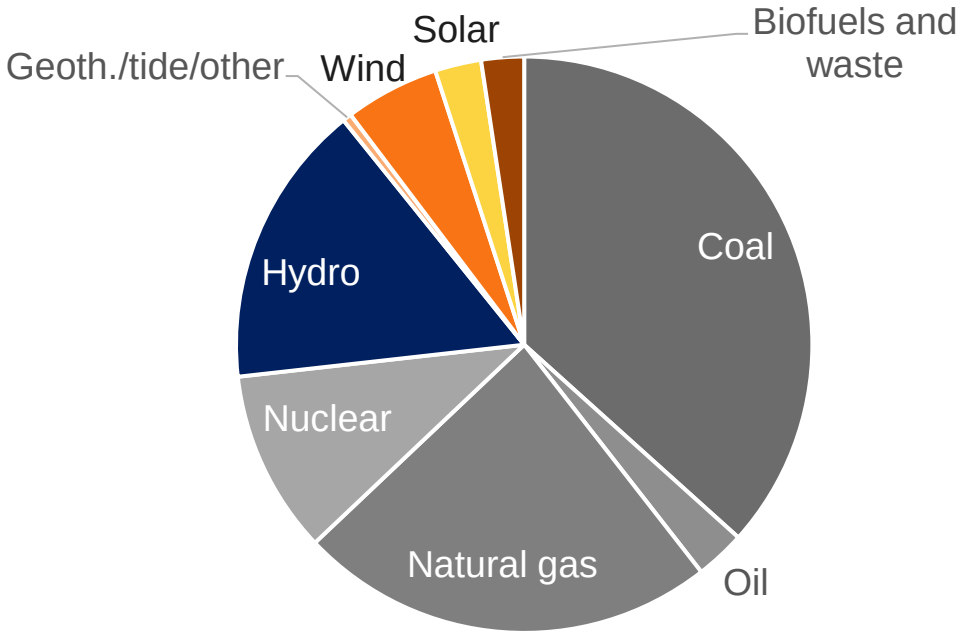
Only the aggressive NZE (Net ZEro) scenario can achieve the Paris 1,5°C objective!

Biggest chunk of CO_2 emissions stems from electricity generation
2022: 36.8 Gt total emissions – thereof 14.65 Gt from power generation



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

Global gross electricity generation in 2022

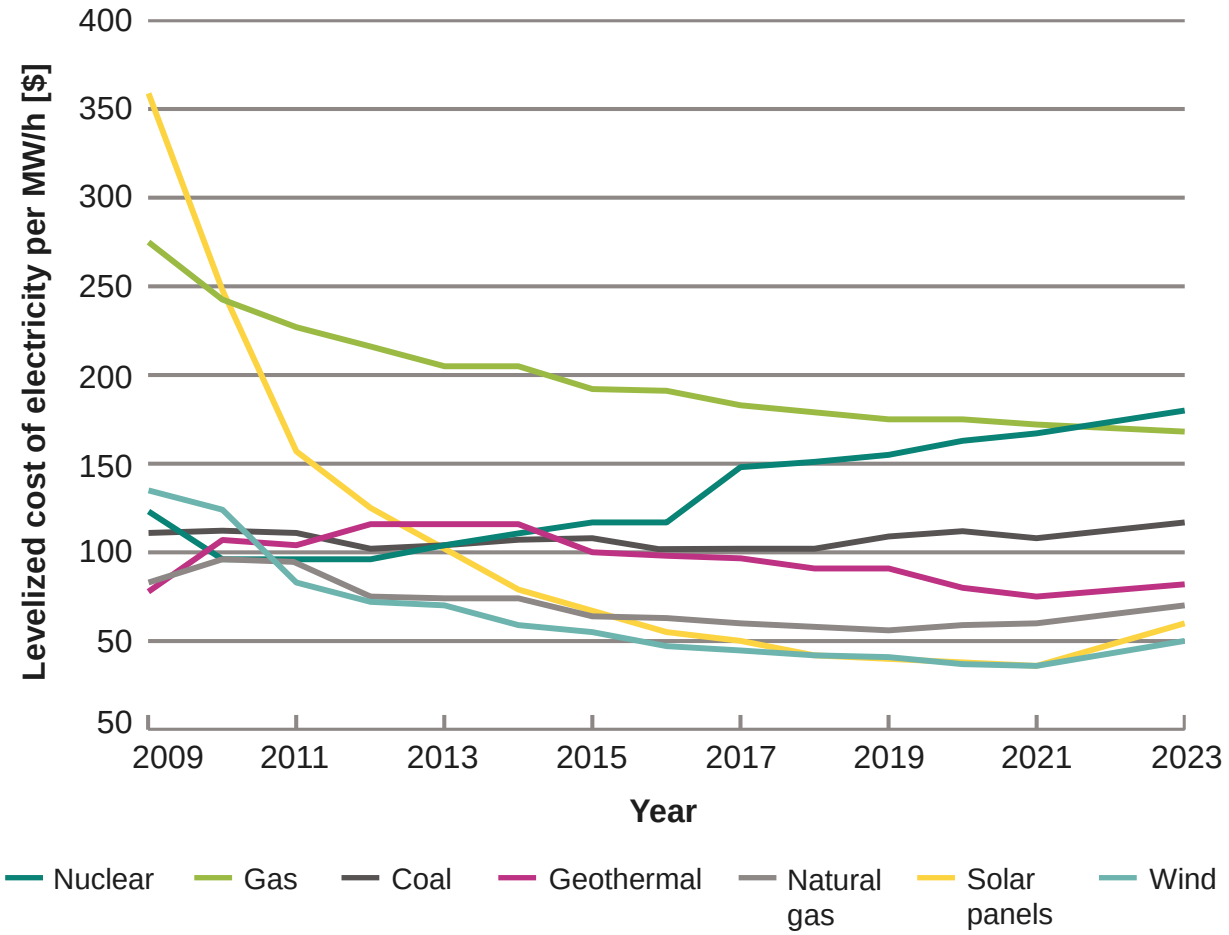


~29,000 TWh

IEA (2023), CO2 Emissions in 2022, IEA, Paris https://www.iea.org/reports/co2-emissions-in-2022, License: CC BY 4.0
https://www.iea.org/data-and-statistics/charts/global-co2-emissions-by-sector-2019-2022

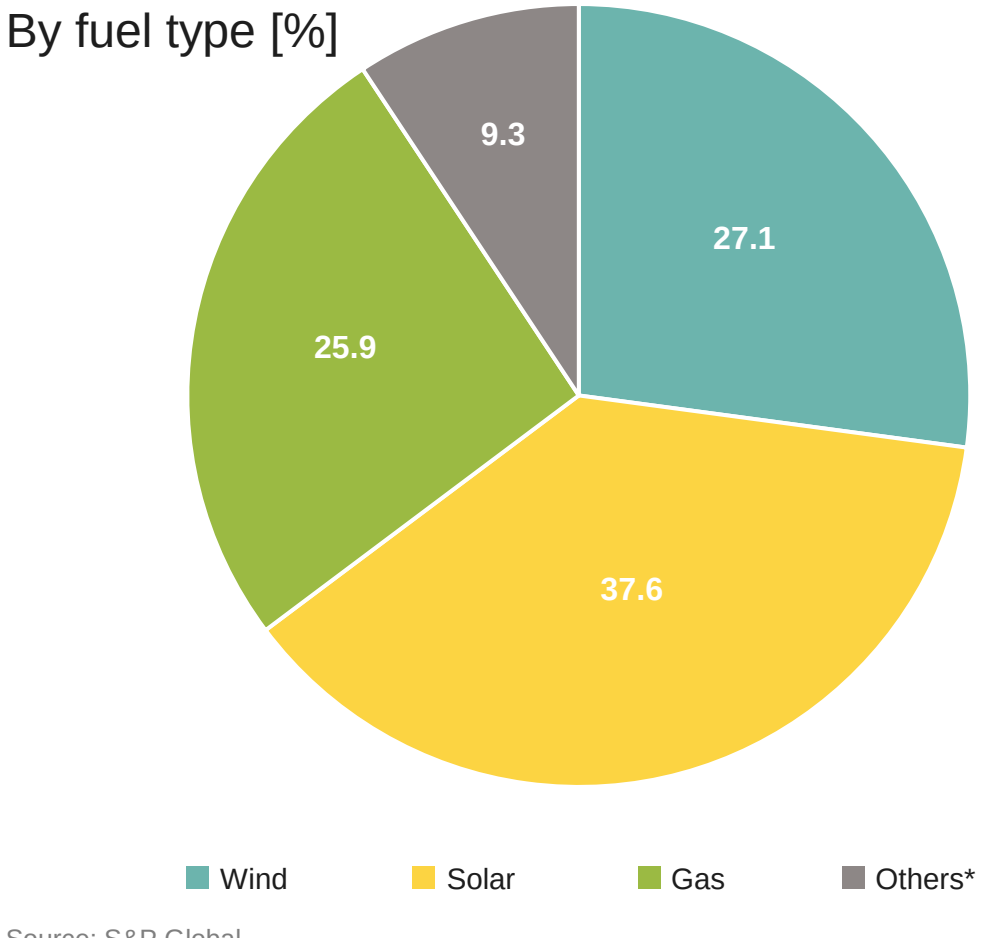
Decarbonization pays off – renewable energies have become the cheapest source of electricity

Trend of electricity cost



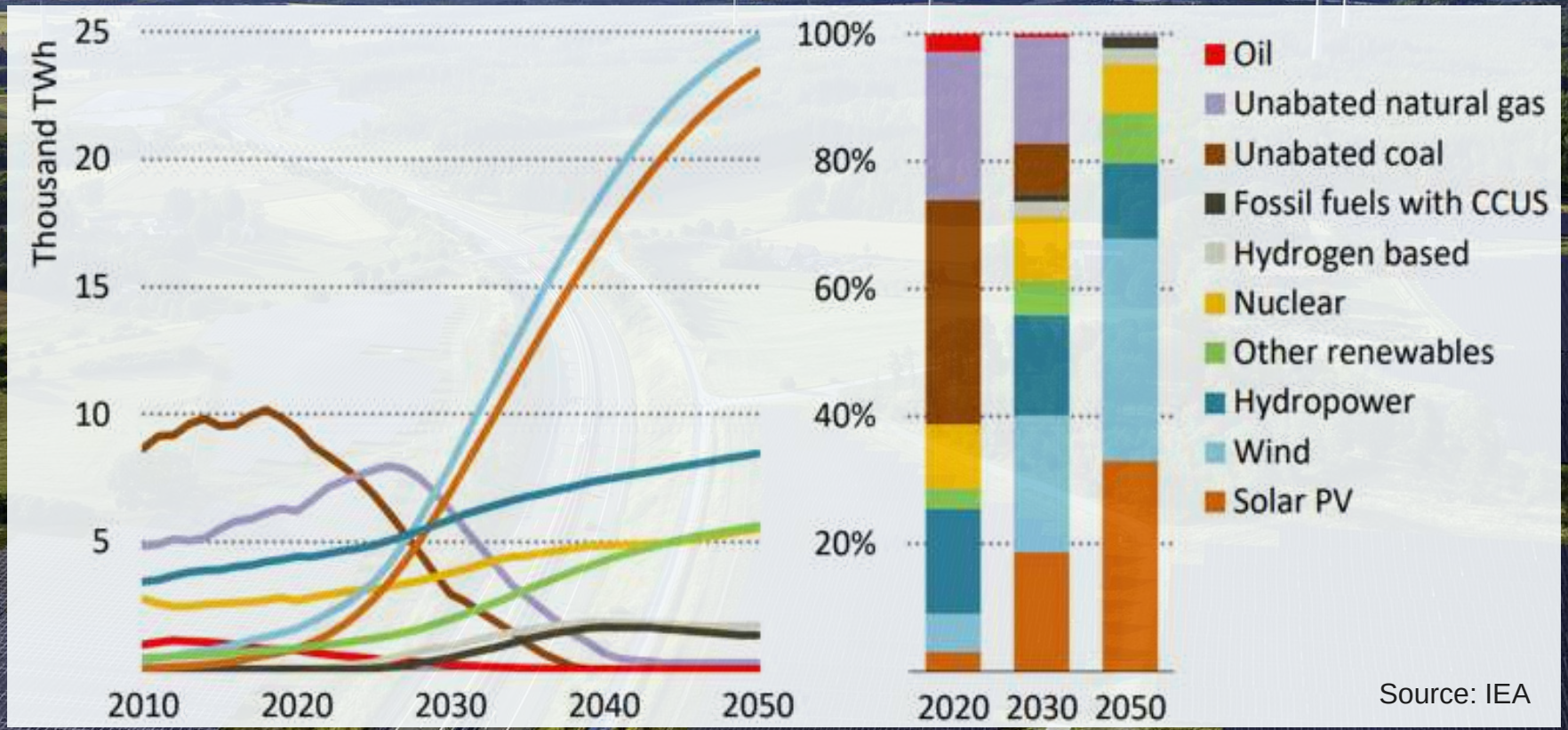
Source: Lazard

Electricity generation additions in US 2022 – total 24.7 GW

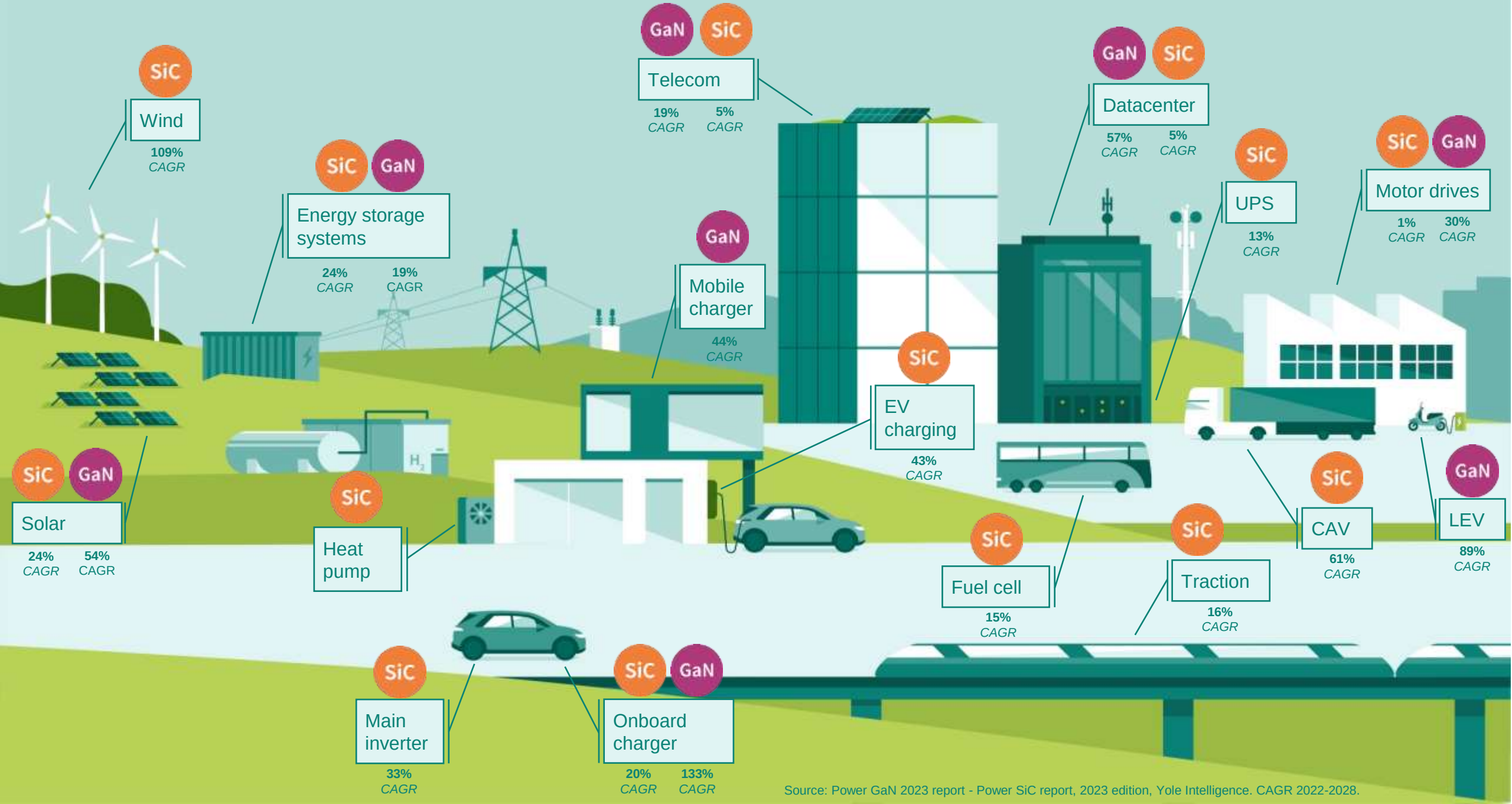


Source: S&P Global

Global electricity generation by source until 2050

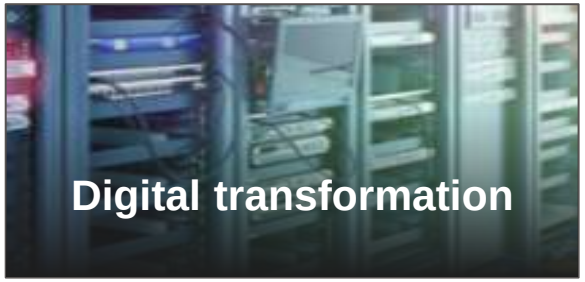


Source: IEA

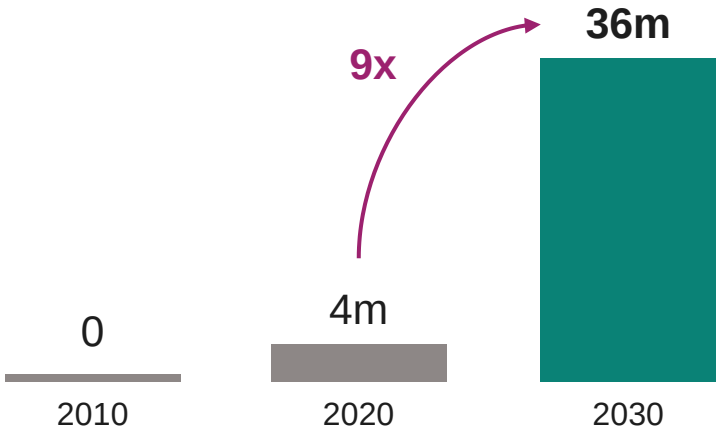


Source: Power GaN 2023 report - Power SiC report, 2023 edition, Yole Intelligence. CAGR 2022-2028.

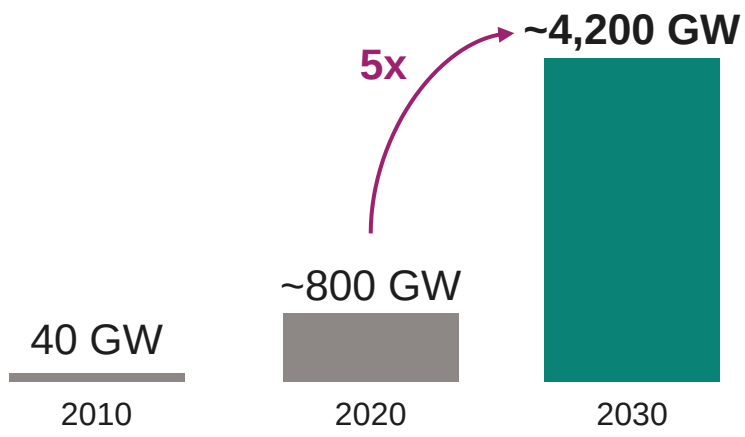
Global megatrends lead to tectonic technology shifts; examples: xEV and renewable energies



Number of BEV + PHEV sales[1]

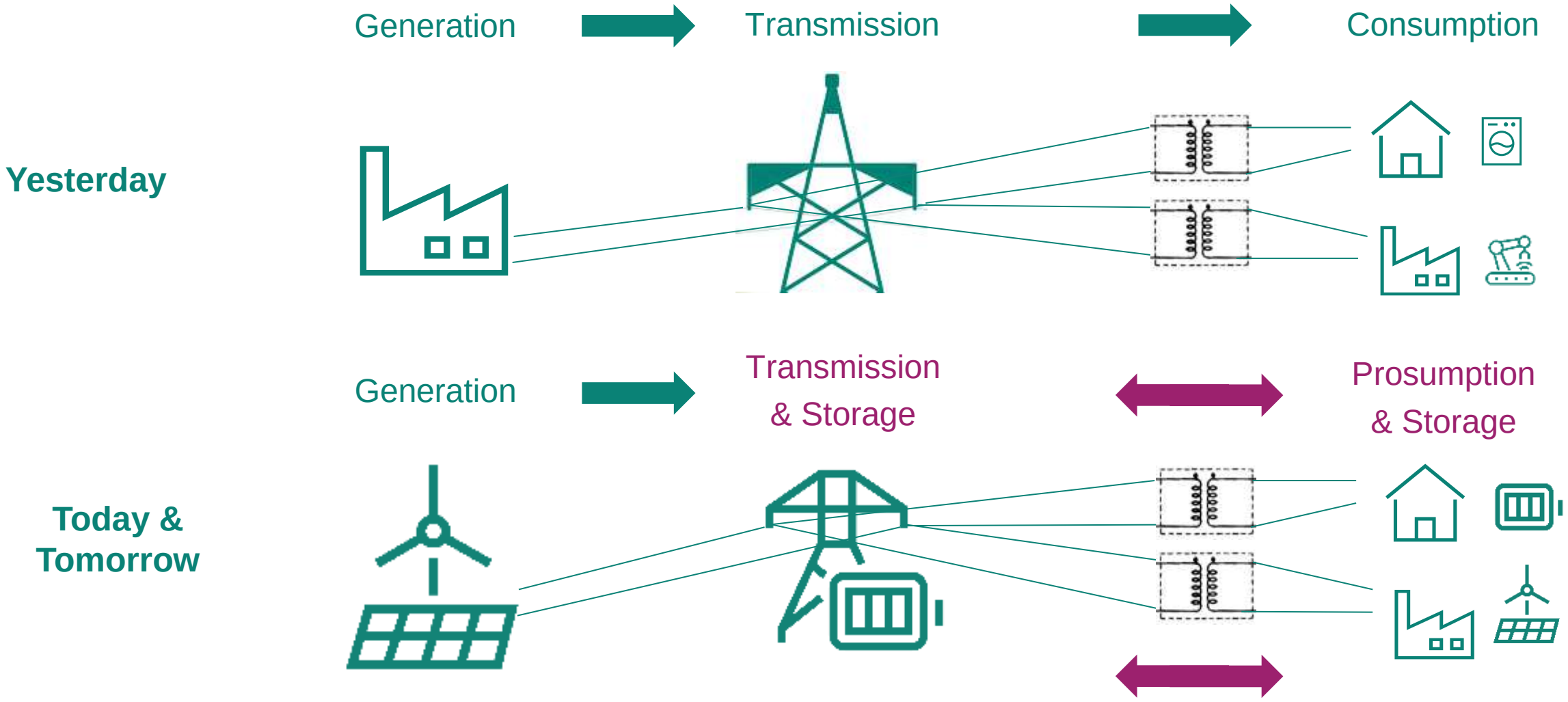


Installed PV power[2]

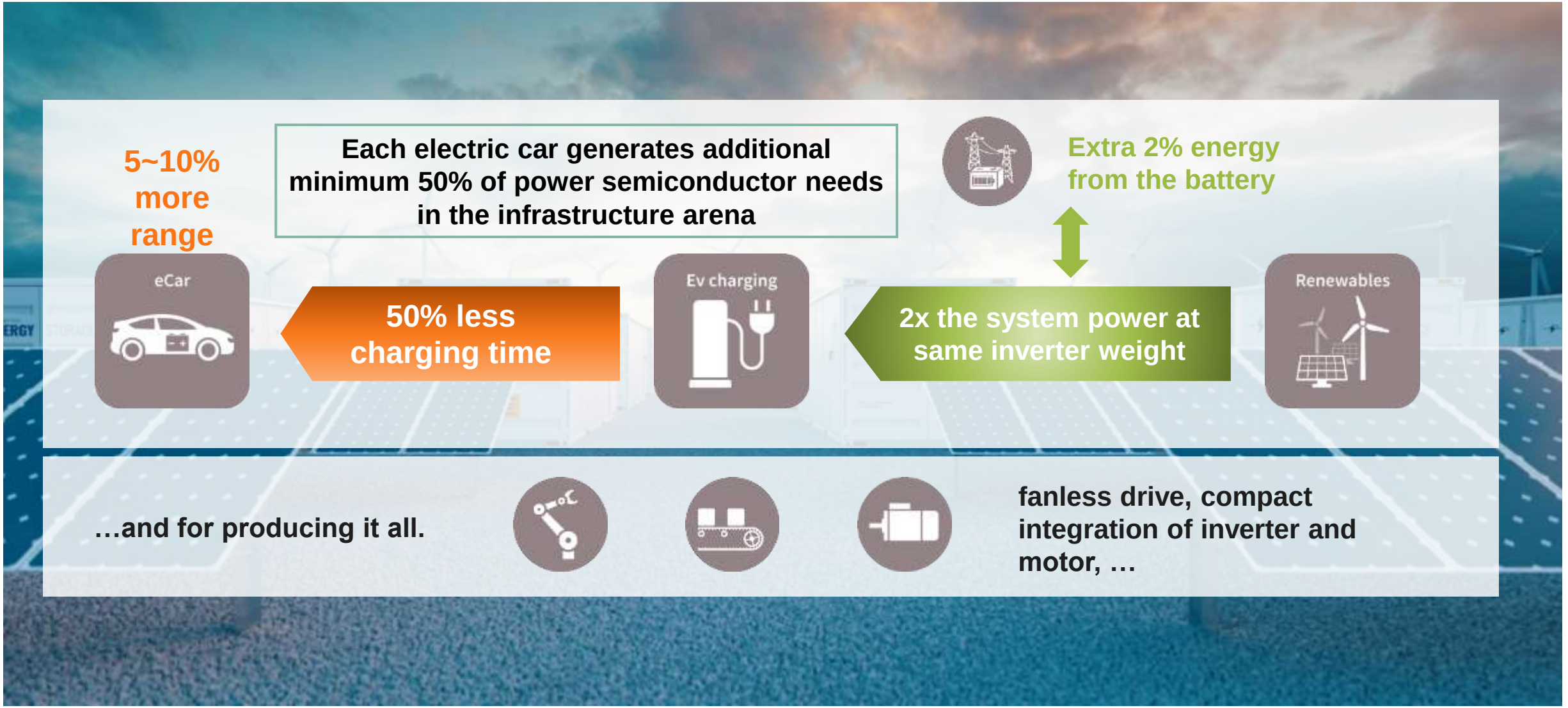


1 Based on or includes content supplied by IHS Markit Automotive: *Light Vehicle Alternative Propulsion Forecast.* August 2021 | **2** IEA: *Net Zero by 2050 - A Roadmap for the Global Energy Sector*. May 2021

The grid & storage opportunity - From unidirectional to bidirectional energy flow ...

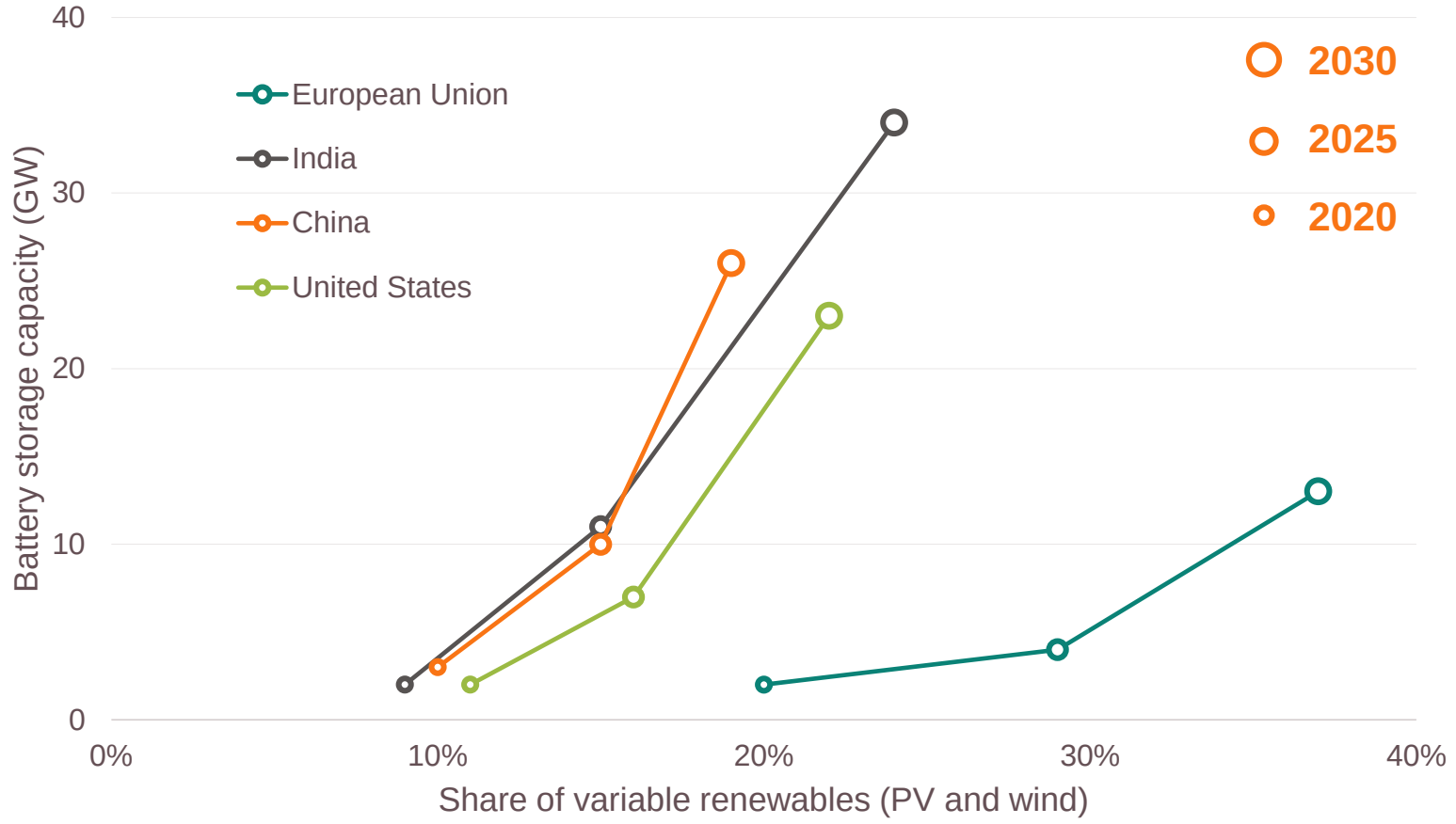


Green energy solutions enable e-mobility ➔ decisive role of renewable sources and storage to enable clean driving



Today renewable power conversion is combined with energy storage - essential to further deploy decentral and green energy generation

Battery storage capacity and share of variable renewables[1)]



Key drivers

- **Decentralization** of power generation
- **Peak shaving** of energy generation and energy consumption
- **Limited capacity** and flexibility of today's grids
- **Reduction of standby cost** of fossil power plants

~€3,200 of power semiconductor content per MW of installed energy storage capacity[2)]

Efficiency improvement by SiC solutions drives the penetration speed – <u>it counts double !</u>

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

SiC MOSFETs helps to reduce energy losses leading to some extra energy, available when needed

Advantages of SiC

As the battery bank makes up the major portion of the total system costs for Energy Storage Systems (ESS), a change from super-junction MOSFET to 1200V CoolSiC™ MOSFET can lead to approx. 2% extra energy without increasing battery size

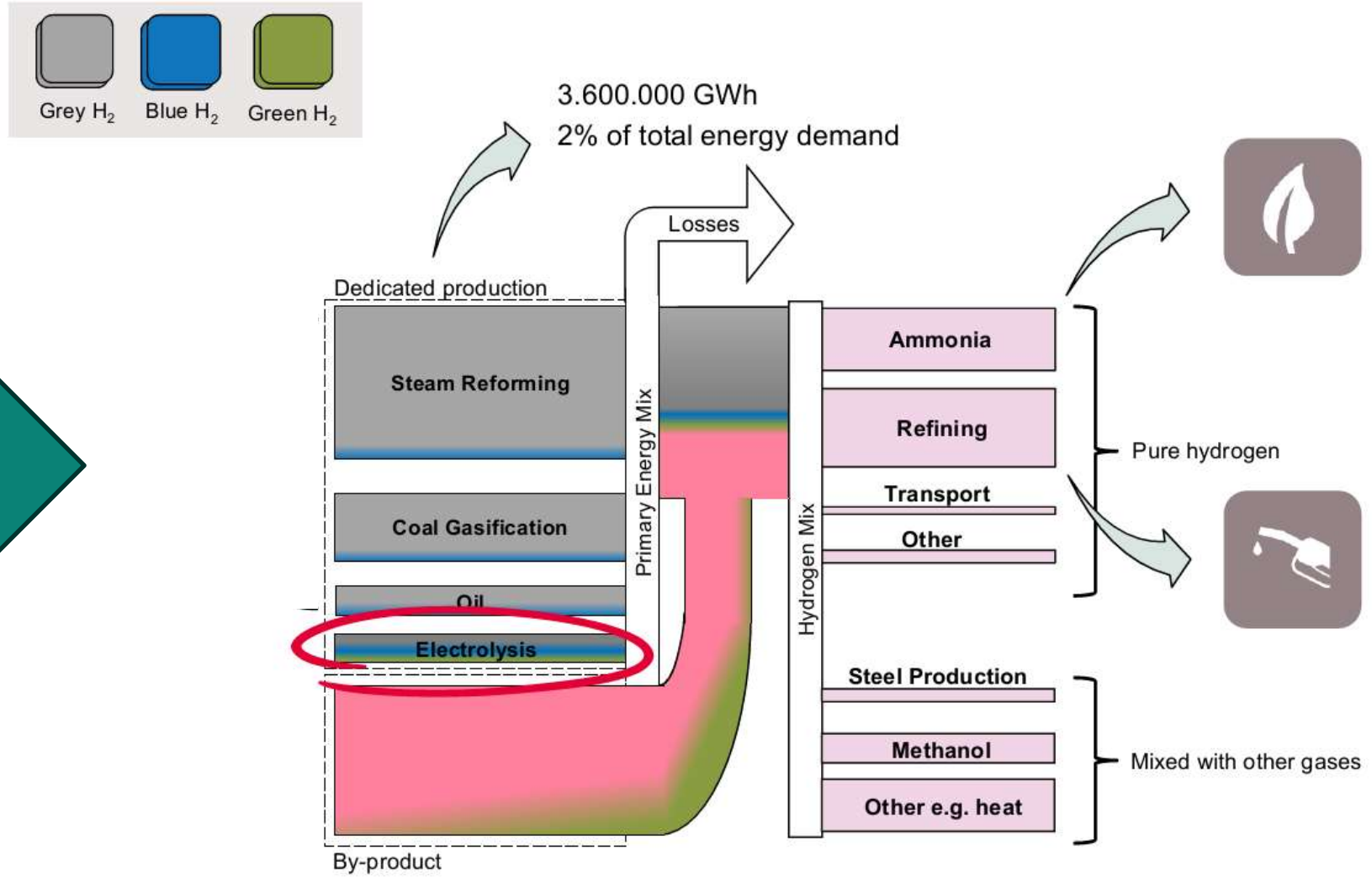
CoolSiC™ MOSFET 1200V cutting losses by 50% for extra energy

Cooperation with PIONIERKRAFT

- Infineon and PIONIERKRAFT cooperation enables energy sharing among neighbors with demand-oriented distribution for self-produced solar energy
- Several Infineon components make this possible: The discrete CoolSiC™ MOSFET, the EiceDRIVER™ Compact Gate Driver and the CoolMOS™ Power-MOSFET

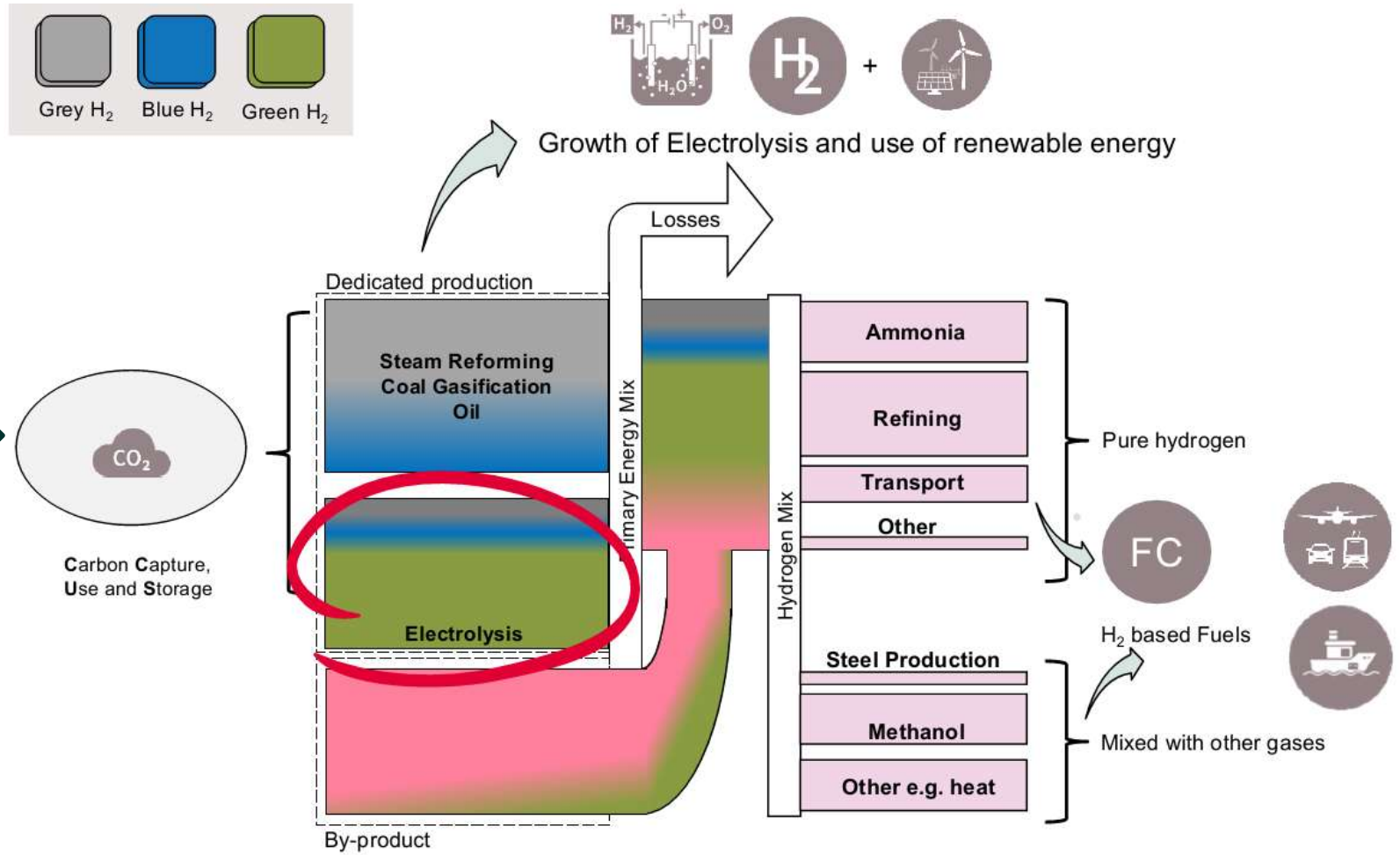
Further need for highly efficient power semiconductors – green hydrogen generation

Today

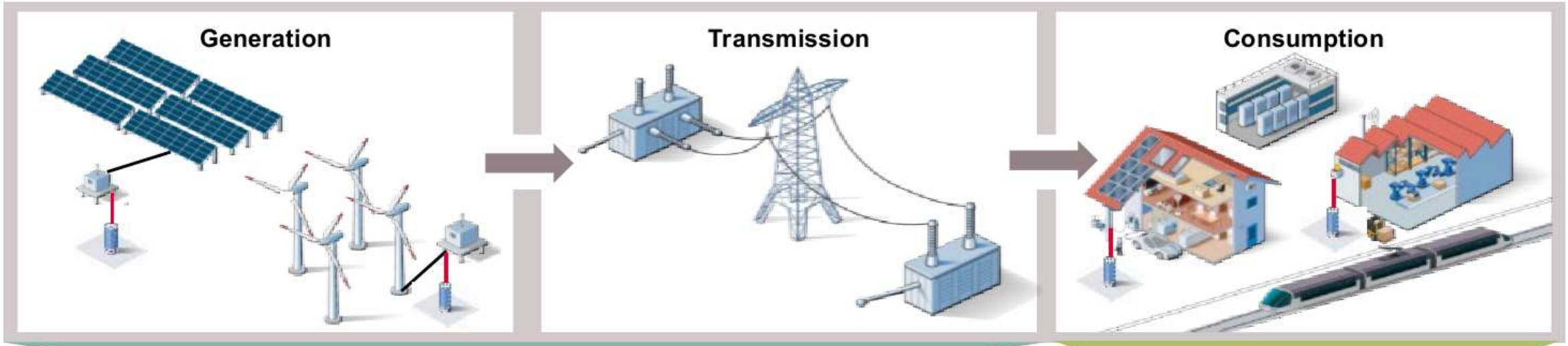


Further need for highly efficient power semiconductors – green hydrogen generation

Future

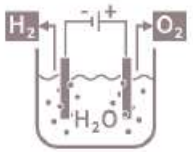


Further need for highly efficient power semiconductors – green hydrogen generation



Generation & Storage

› Electrolysis AC or DC coupled



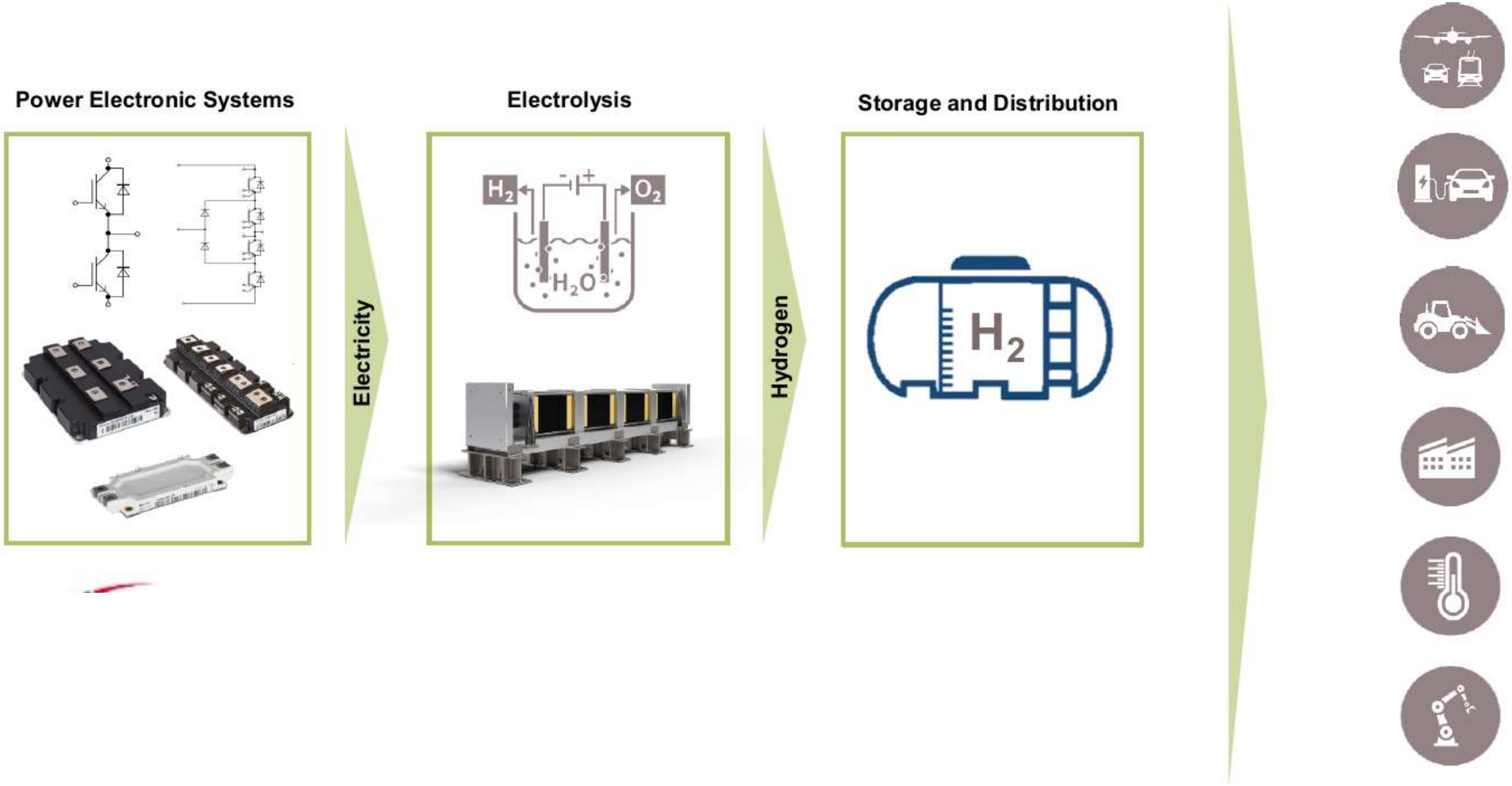
Consumption

› Pure and synthesized H2

› Fuel cell, gas network, industrial production

System power 1 kW up to > 50 MW

Further need for highly efficient pwoer semiconductors – green hydrogen generation



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 higher efficiency

Si: 93-94% → SiC: 96-97%

Volume / power density / weight

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

Si: 0,66kW/l → SiC: 1kW/l

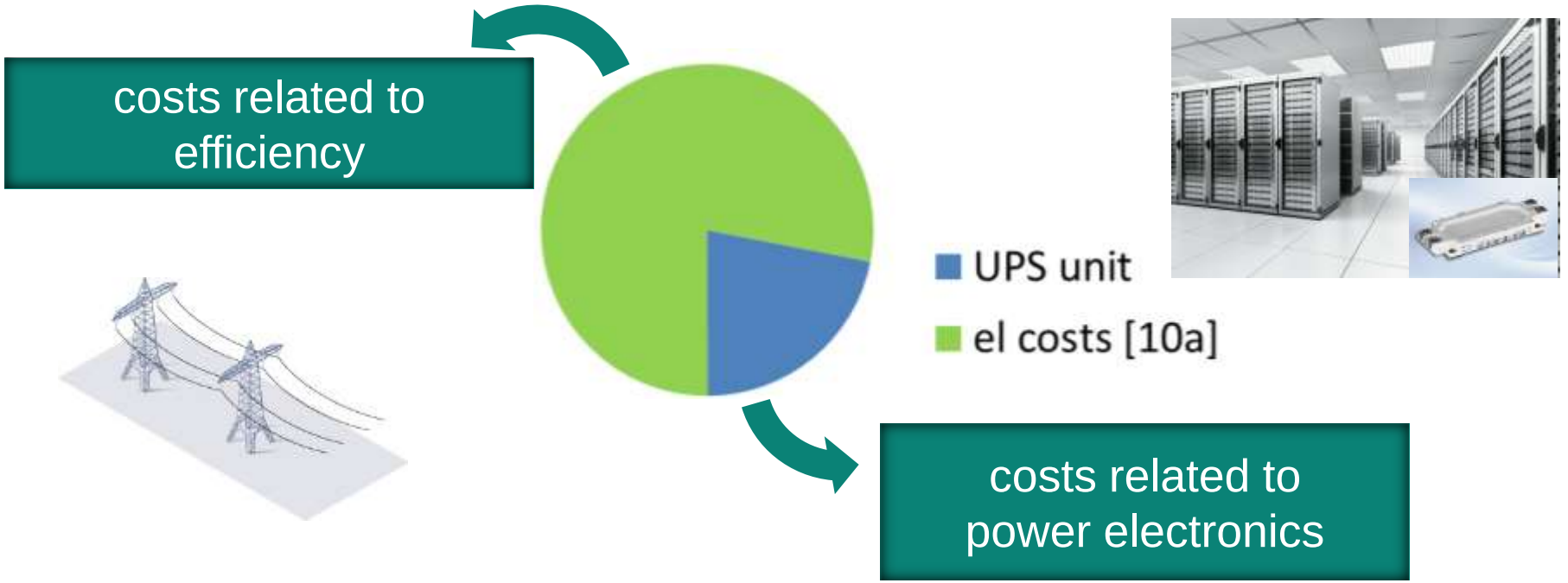
Noise

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

Si: 65 dB(A) → SiC: 50 dB(A)

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

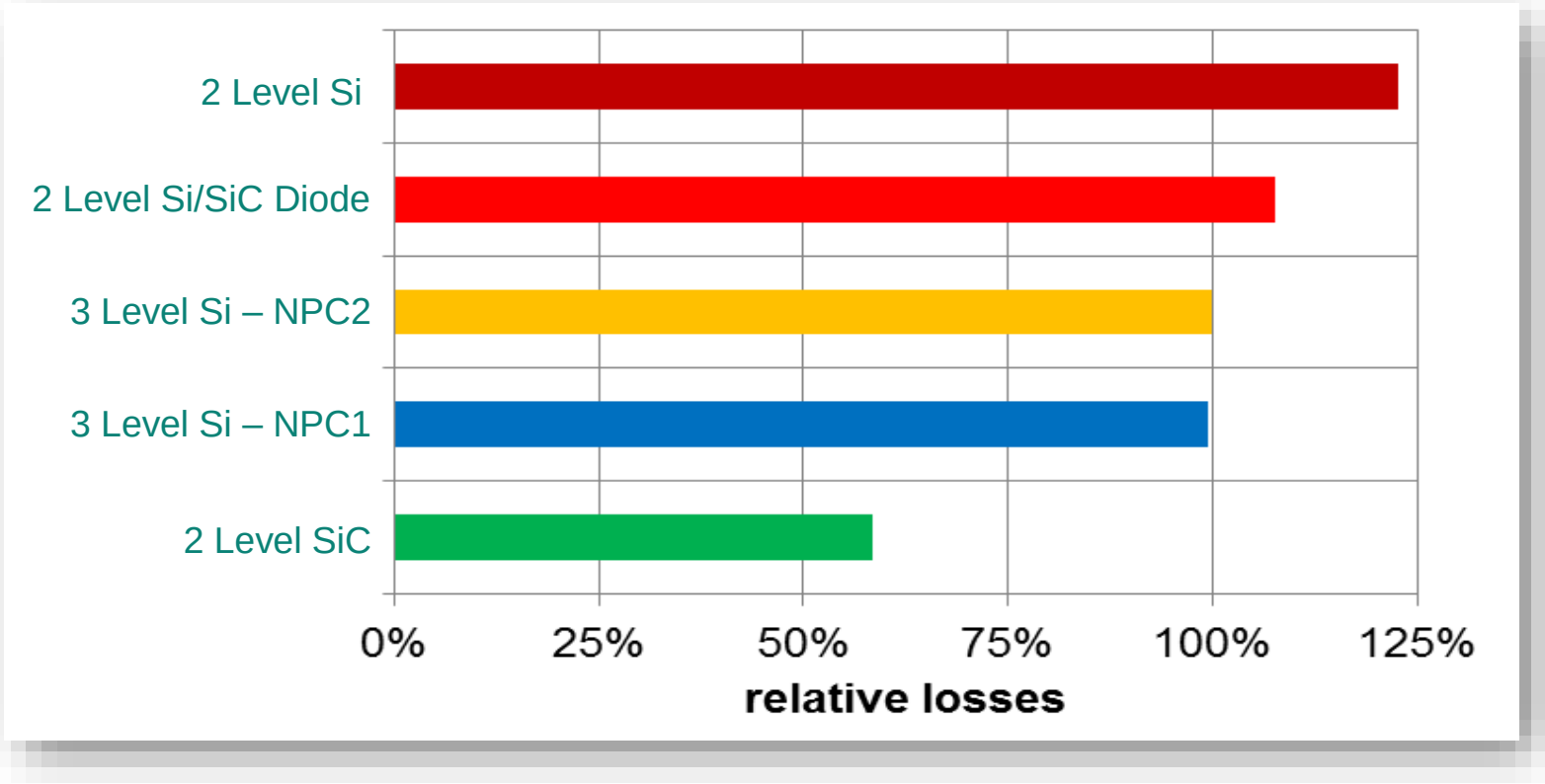


– Power electronics are very small portion of overall costs
– Improved efficiency is main goal!

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

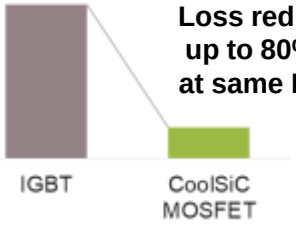
UPS systems – efficiency counts !

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



Power losses are reduced by more than 40%!

CoolSiC™ MOSFET:
Next generation of servo drives



Loss reduction in all operating modes - up to 80% system loss reduction even at same EMC level as for IGBT solution

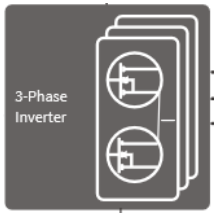
CoolSiC™ MOSFETs

- **Enhance pulse current capability**
- **Current rating jump**
- **Passive cooling**
- **Inverter motor integration**

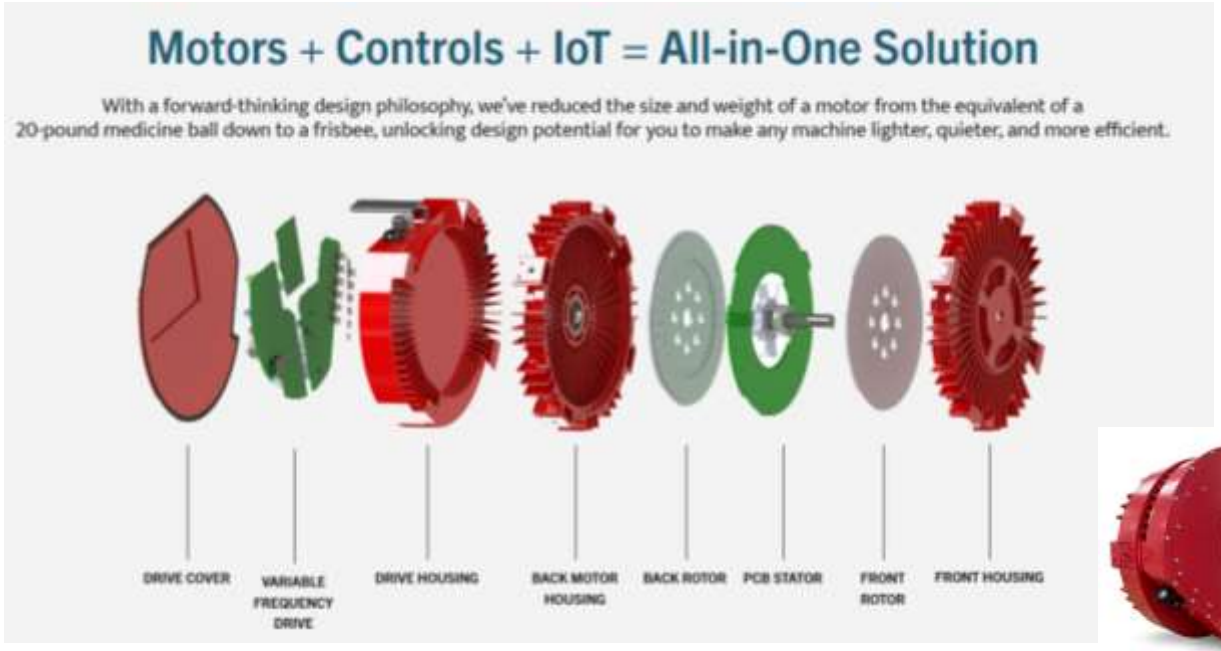
IGBT

CoolSiC™ MOSFET

Same frame extra current



Completely new motor solutions enabled by SiC



Industrial drive

SiC

Precise control saving energy

10% energy savings	**50%** less Size & weight	**30%** CO_2 reduction

- Infinitum's Air Core uses 66% less copper than traditional motors
- Powered by SiC MOSFETs

www.infinitumelectric.com

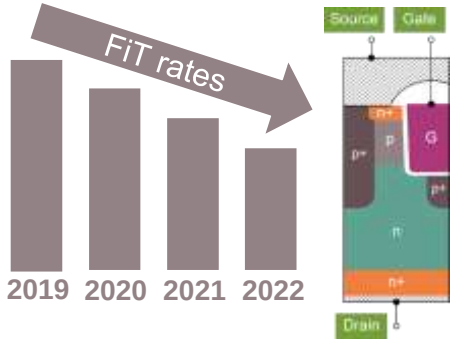
Very low inductance → Very high switching speed required, but no limit for dv/dt → SiC is an enabling element

Mastering the WBG key success factors is at the core of our roadmap from product development to mass manufacturing

Chip, package & control technology

Deep system understanding

Quality standards



Mastering supply stability and scaling


Infineon