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Silicon Carbide: a game changer in power electronics

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Agenda

Power electronics is increasingly the driver of our future world

- Key role of power conversion efficiency
- The central role of silicon carbide
- Market demand and ST strategy
- Focus on ST SiC technology
- Takeaways

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From combustion to conversion

535 nuclear power or coal plants →

Windmills 845 GW
Photovoltaic 942 GW installed in 2022

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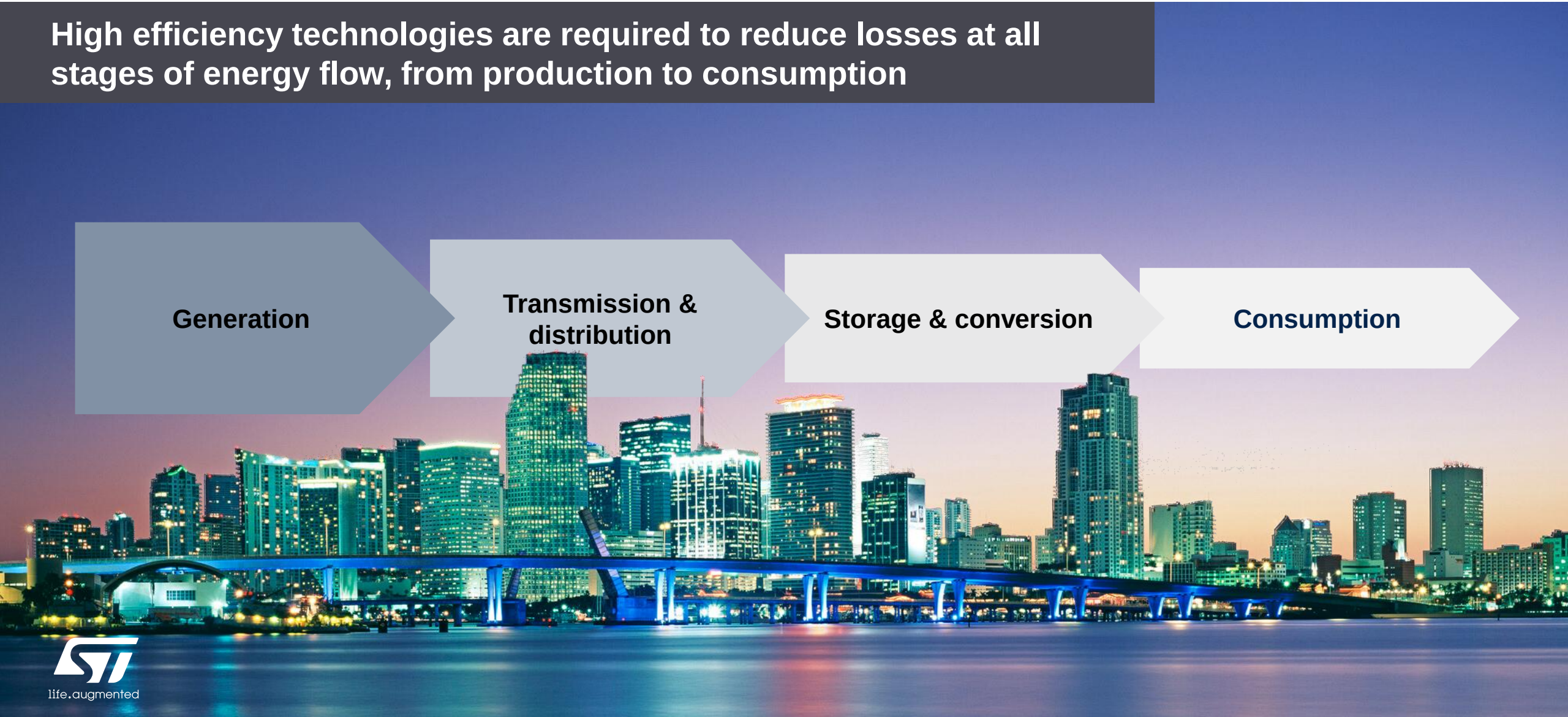
Efficiency and optimized power transfer

High efficiency technologies are required to reduce losses at all stages of energy flow, from production to consumption



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Megatrends driving adoption of SiC

	Electric vehicle	Charging station	Renewables	Power supplies
What?				
Where?	• Onboard chargers • DC-DC converters • Traction inverters • Other – PTC heater, e-compressor, etc.	• Industrial chargers • EV DC fast chargers • EV wireless chargers	• Solar inverters • Energy storage systems • Wind power	• AC/DC server power supplies • Telecom AC-DC rectifiers • UPS
Why?	Small size & weight, high efficiency, longer driving range	High efficiency, low cost, ease of thermal management	High efficiency, low system cost	High efficiency, high power density, lower energy costs

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ST SiC MOSFET focus applications and prospects

Focus applications

- Power supply
- UPS
- Solar Inverter
- Industrial Motors
- EV Charger
- Traction
- OBC, DC-DC

ST business prosects

>50%*
2022 Market share automotive & industrial

~$1.14B
SiC revenues in 2023

>155
projects in development

* SiC MOSFET + Full Module SiC based
Source: OMDIA - Power Discrete and Module Market Tracker V2

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More than 25 years of focus on SiC at ST

Catania: Power Electronics Competence Center

Ecosystem made of Academic, **Research Centers** and ST as a semiconductor leader, created a true “incubator”

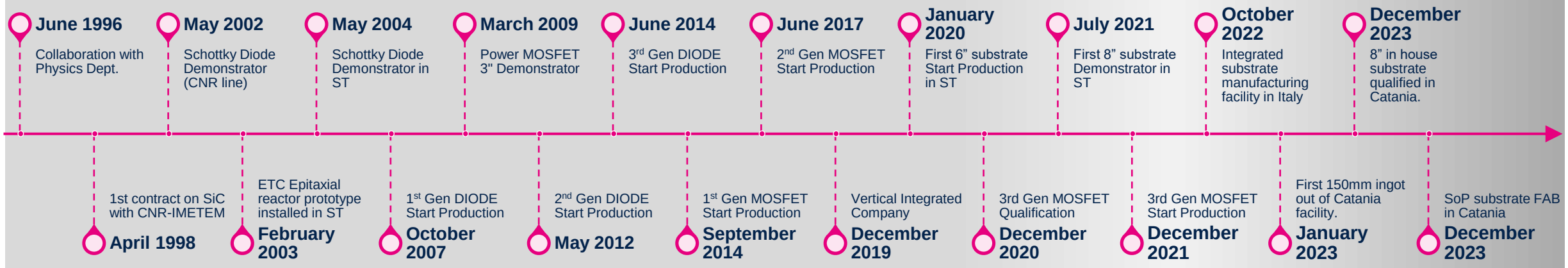
Everything started from 1-inch wafer

More than 110 patents and 650 technical documents

Leveraging on CNR on-site facilities at early stage

> 30 years of experience in power semiconductor

ST major milestones:



Vertically integrating for supply chain robustness

Improving process control and efficiency, from powder to final product

Raw material → SiC ingots & substrates → SiC dice manufacturing → design & manufacture → products

Norrköping SiC substrate R&D plant

- 150 mm production
- 200 mm with industrial quality and yields

Catania new integrated SiC plant

- Pilot production started in 2023*
- 150 mm substrates + epitaxy (converting to 200 mm)

* targeting > 40% substrate in-sourcing by 2024

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Silicon carbide substrate manufacturing facility in Italy

Increasing demand for SiC devices across automotive and industrial applications

A new integrated **silicon carbide (SiC)** substrate manufacturing **facility** in Italy

Unique in Europe to produce **150mm** SiC epitaxial substrates – to become **200mm** wafer in the near future

Volume production is expected to start in **2024**

700 additional jobs

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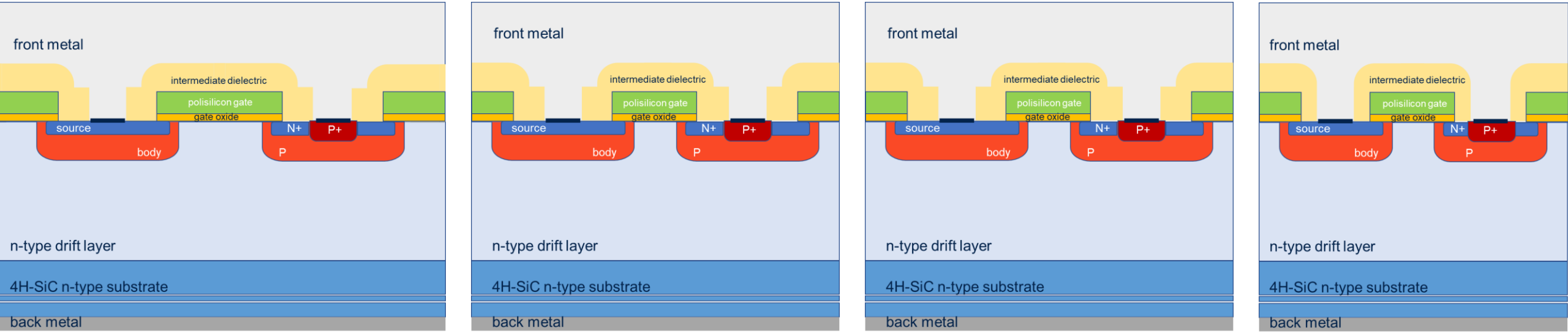
SiC planar MOSFET technology evolution



Gen2 → **Gen3** → **Gen4** → **Gen5**

same contact
same channel
reduced jfet
same edge
improved epi

same contact
same channel
same jfet
optimized egde
improved epi

reduced contact dimension
same channel
same jfet
same egde
same epi

same channel

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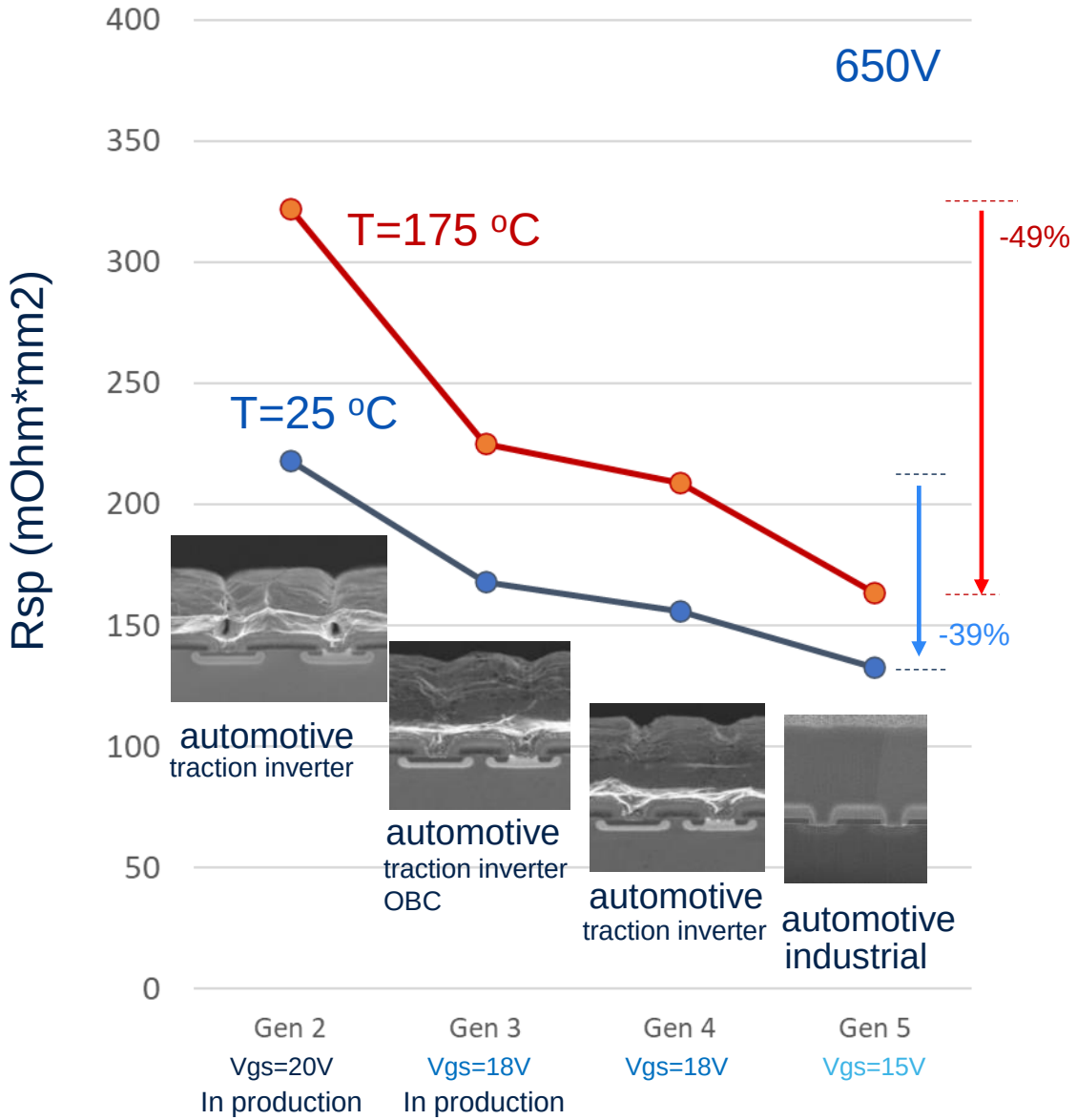
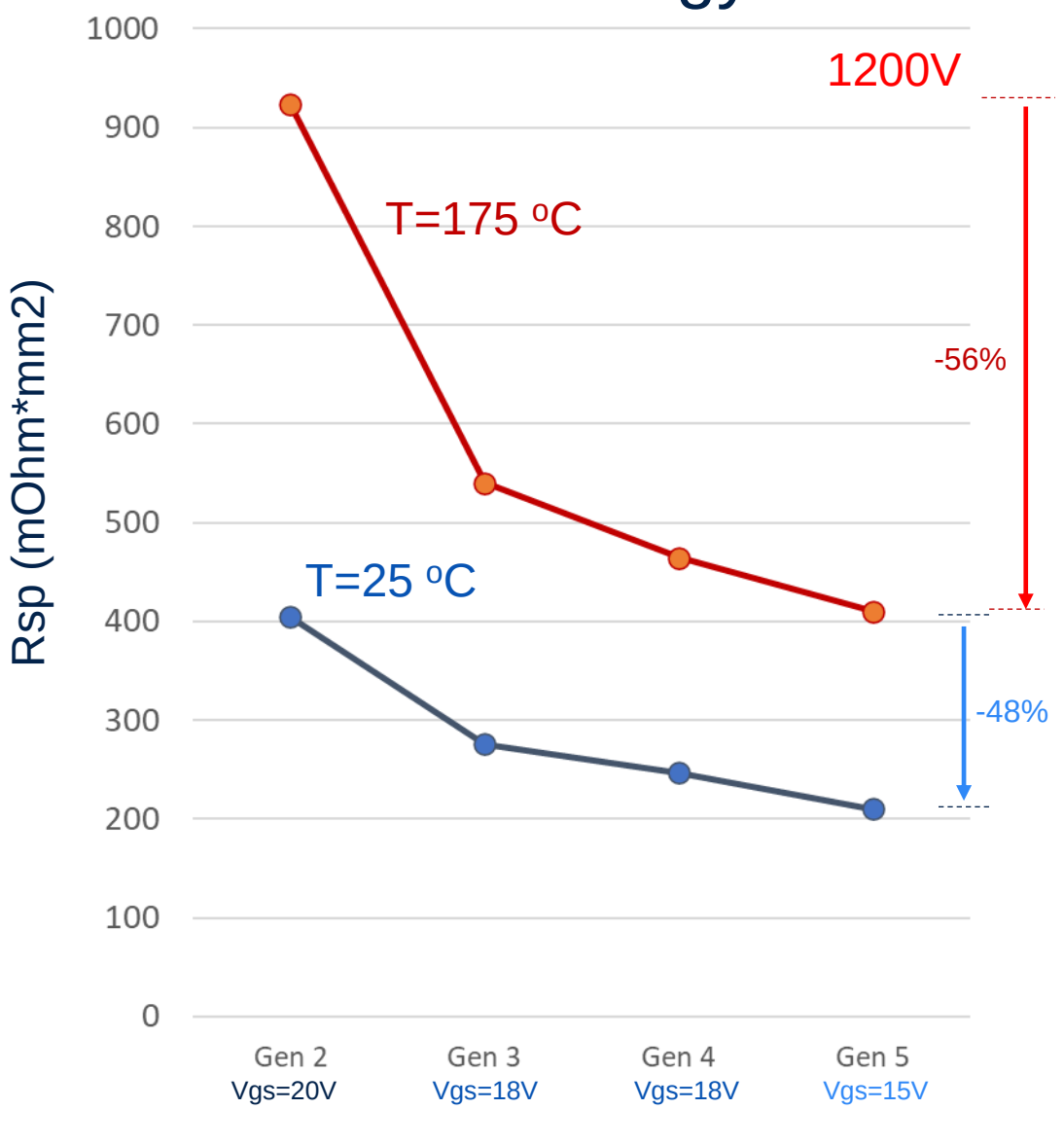
Designed in SiCily

SiC Planar MOSFET
technology evolution

experimental data





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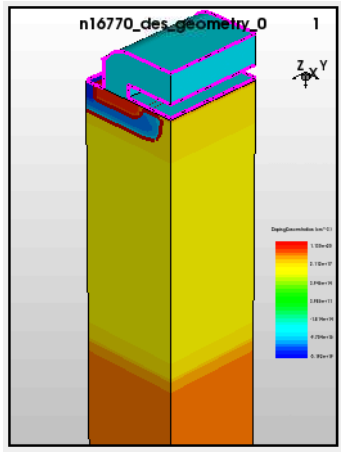
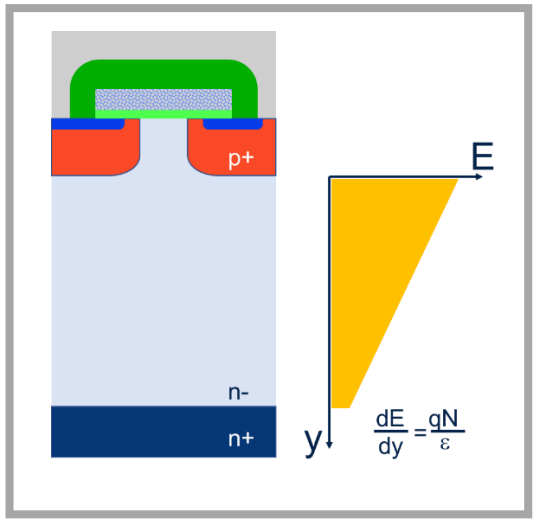
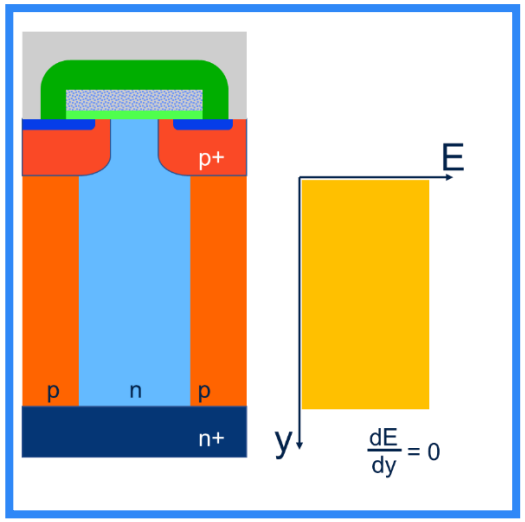
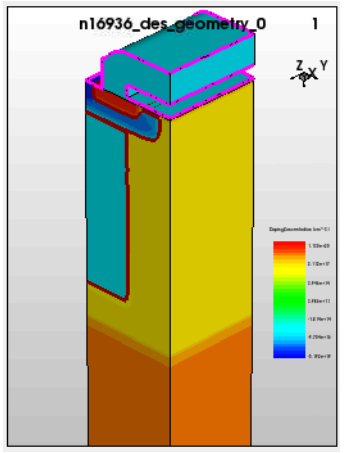
next? Superjunction advantage

Planar vs. Superjunction

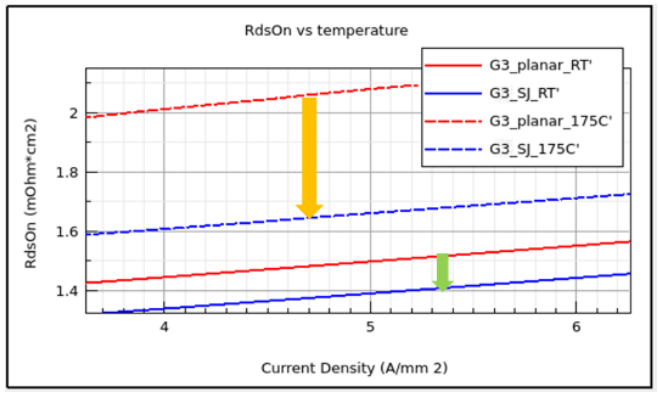








Charge balanced drain



IV simulation

	RT	175ºC
650V	- 7%	- 20%
1200V	- 34%	- 59%

Comparison done with same planar structure

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Innovation trend
power package technology evolution

Power module evolution towards discrete molded packages

750V IGBT & diode

Sixpack
Single side
direct cooling

750V, 1200V SiC MOSFET

Sixpack
Single side
direct cooling

750V, 1200 SiC MOSFET

Half-bridge
Single side
indirect cooling

750V, 1200 SiC MOSFET

Half-bridge
Single side
indirect cooling

750V, 1200 SiC MOSFET

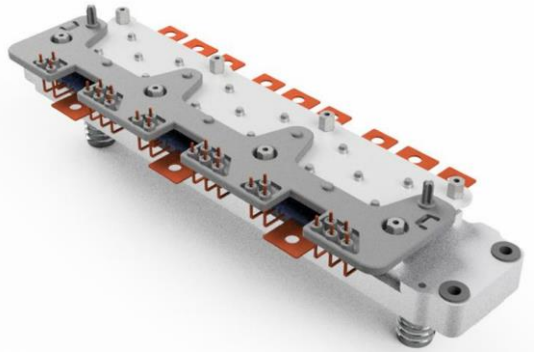
Half-bridge
Single side
indirect cooling

1200 SiC MOSFET

Half-bridge
Dual side
indirect cooling

Power pack

Power modules + cooler



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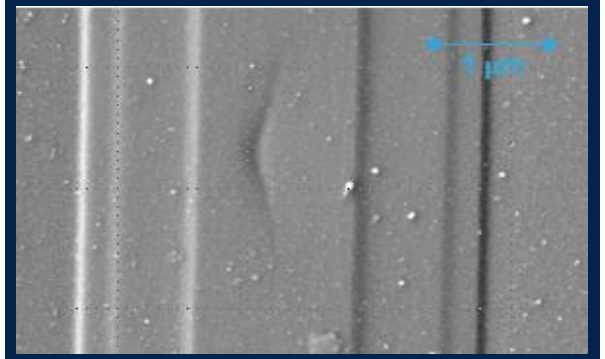
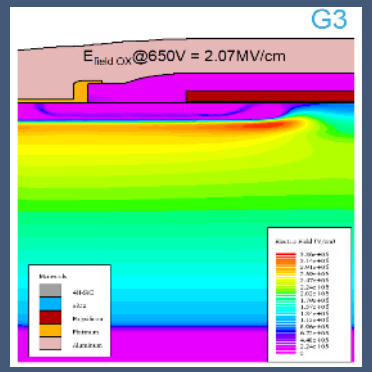
Four vectors for WBG deployment and validation

Failure analyses



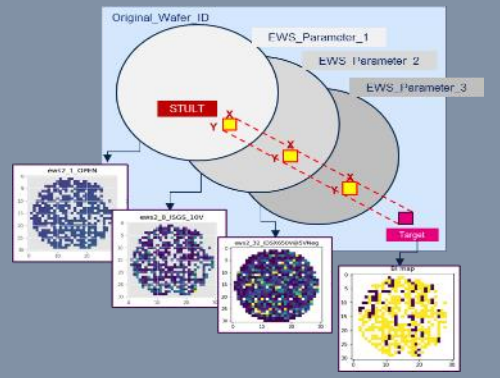
- Identification of new failure modes
- Effectiveness evaluation of screening methods
- Support for customer use in application
- New FA techniques

Design improvement



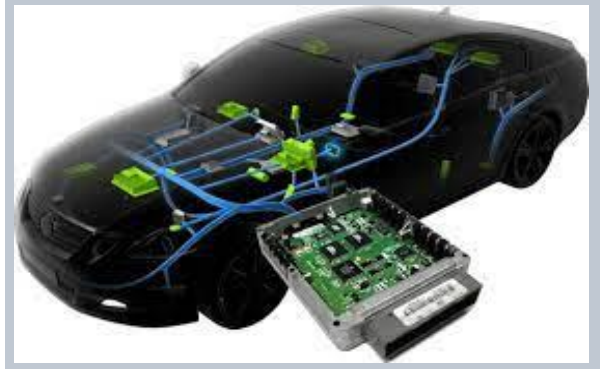
- Design fine tunings based on new failure mode
- Design for reliability and more margin
- Front-end & back-end new material and design solution evaluation

Testing improvement



- Fine tuning of testing in EWS and back-end
- Burn in testing for new technologies
- DOLI implementation for known defects

Mission profile assessment



- Analysis of customer specific mission profile
- Fine tuning of testing and reliability assessment
- Equivalent FIT evaluation

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FA = Failure Analysis, EWS = Electrical Wafer Sorting, DOLI = Defect Offline Inking, FIT = Failure in Time

Takeaways

Silicon carbide plays a key role in **power conversion efficiency**

Demand for SiC is growing fast to support the electrification of the automotive and industrial markets

ST is investing to support the market needs with a **vertical integration** manufacturing strategy

ST offers a wide range of **package solutions** according to customer needs

ST Planar SiC MOSFET technology is **state-of-the-art and best positioned** to support the growth today

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Our technology starts with You

Find out more at www.st.com/stpower

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