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SiC: Paving the way for sustainable mobility

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Porsche Consulting

**ADVANCED
PRODUCTS AND
TECHNOLOGIES**

Sustainability, new mobility and decoupling are megatrends shaping the SiC market



Silicon carbide is an important technical lever to improve performance, efficiency, package and weight in automotive electric drivetrains – cost potentials on a system level can be captured, too

Automotive

- Traction inverter
- On-board charger
- DC/DC converter

Charging infrastructure

- Fast DC charging
- Wireless charging
- Industrial charger

IT infrastructure

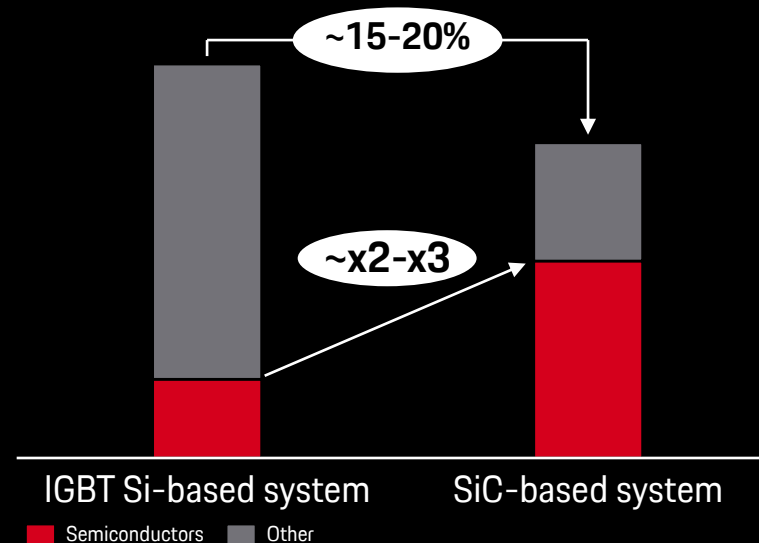
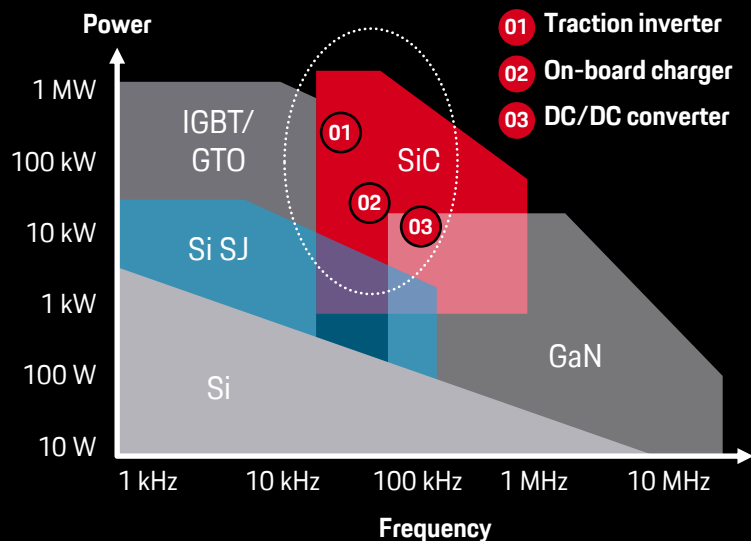
- PFC
- DC/DC converter

Renewables

- Solar inverter
- Energy storage
- Wind

Circuit protection

- AC/DC circuit breaker
- MV circuit breaker
- SV circuit breaker



SiC benefits



~50%

Shorter charging time 800V



~5-10%

Increased battery range



~15-20%

Reduced system costs

To reach maturity and make SiC technology widely accessible, three main challenges need to be overcome by all players along the value chain

01

CAPACITY

Sufficient fab capacity
to keep up with global
demand

Drivers and inhibitors
of capacity ramp-up

02

COST

Cost drivers and **reduction potentials** on raw material
and device level

System integration costs
and **design advancements**

03

QUALITY

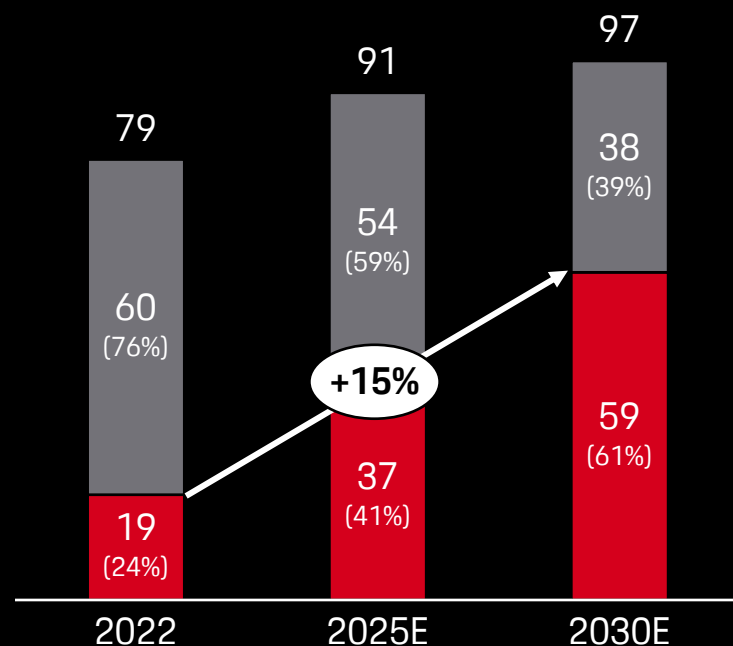
Quality levers along the
value chain, e.g. in wafer
processing

Common understanding
of future vehicle **use cases**

The global xEV market drives the demand for power electronics

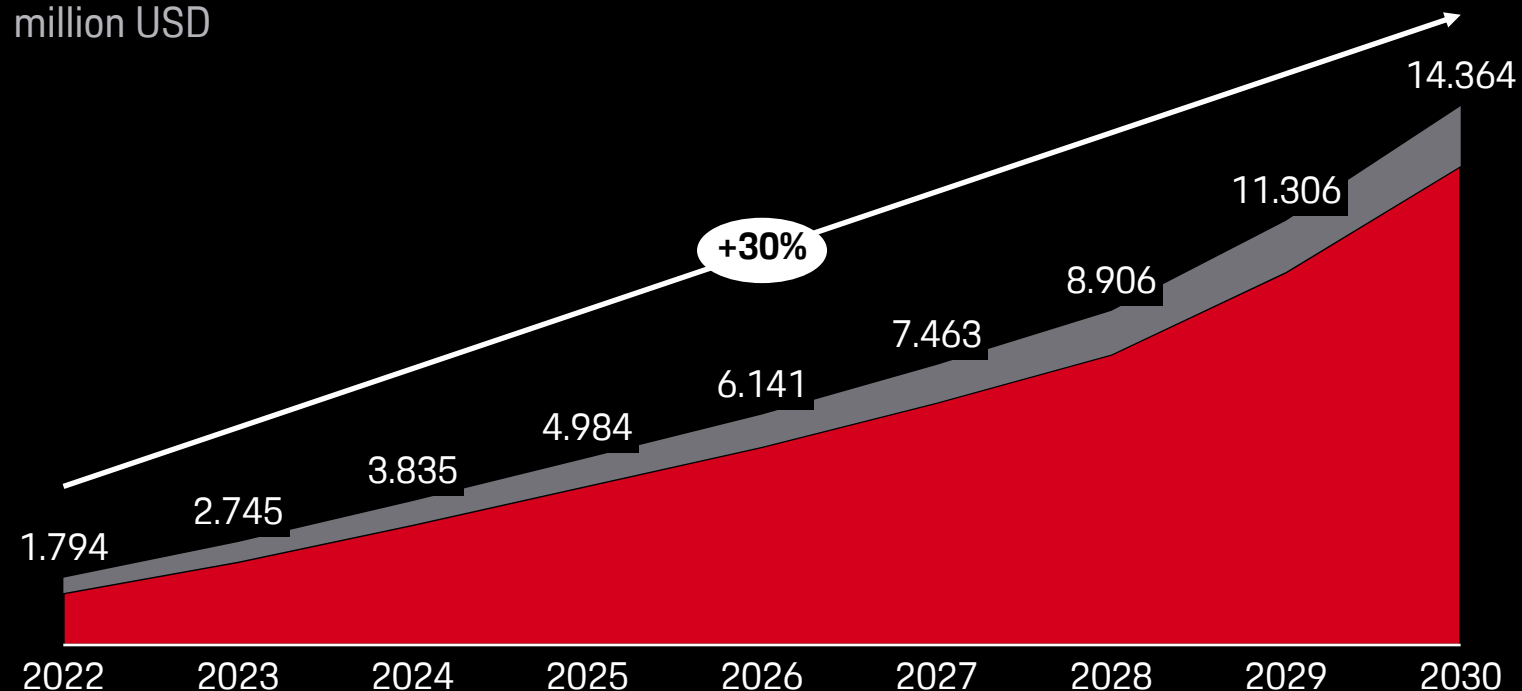
Global light vehicle market

million units



SiC device market outlook

million USD



■ xEV (BEV, MHEV, FHEV, PHEV, FCEV, EREV)

■ ICE

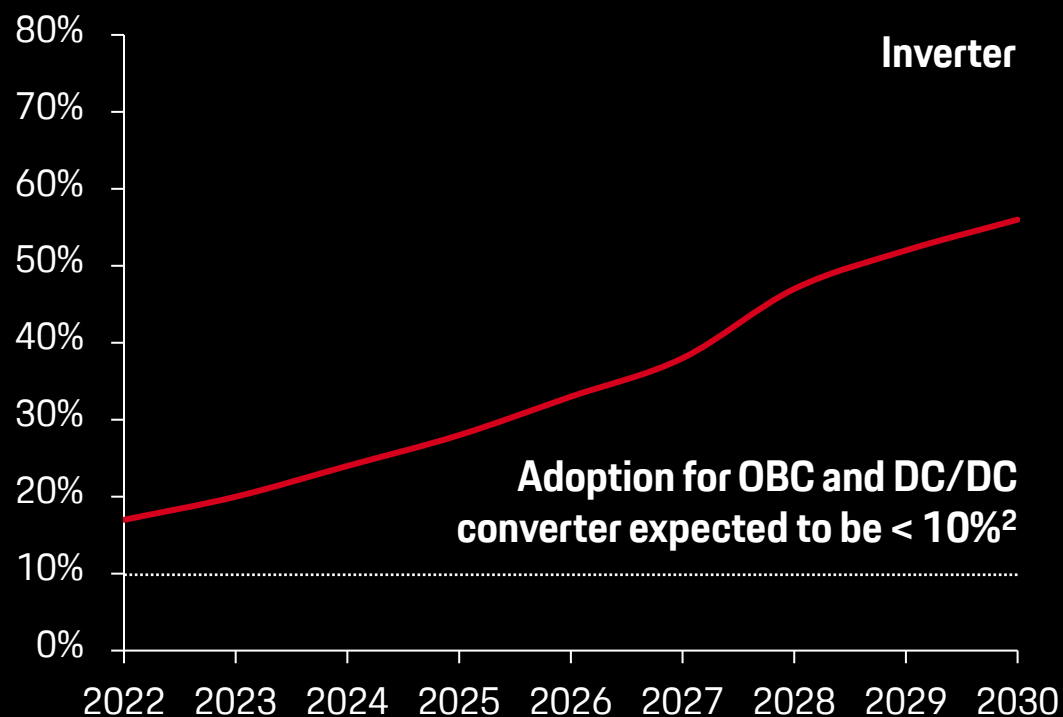
+X%

CAGR

■ Automotive ■ Non-automotive

Penetration of SiC-based inverter design to reach S-curve inflection around 2027, highest with 800V BEVs – low penetration expected for PHEVs and volume-oriented OEMs as well as OBC and DC/DC

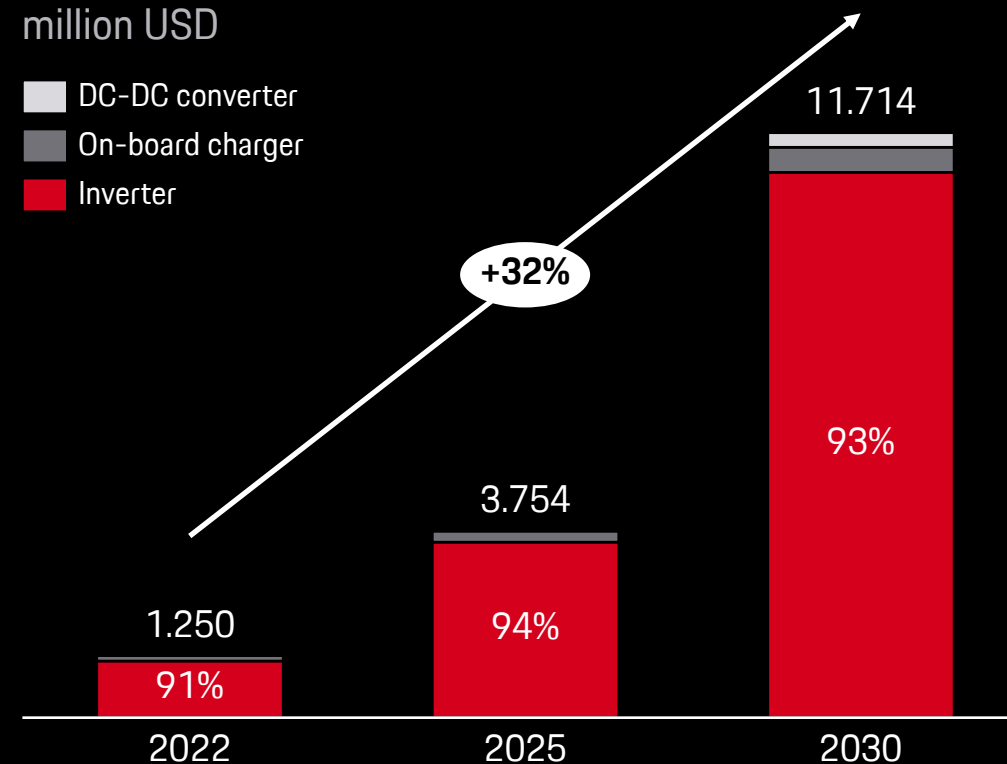
Share of power electronics using SiC-based design¹



Power SiC device market for electric vehicles

million USD

- DC-DC converter
- On-board charger
- Inverter



¹ Weighted average of HEV and BEV adoption | ² First adopted in niche, high-end vehicles

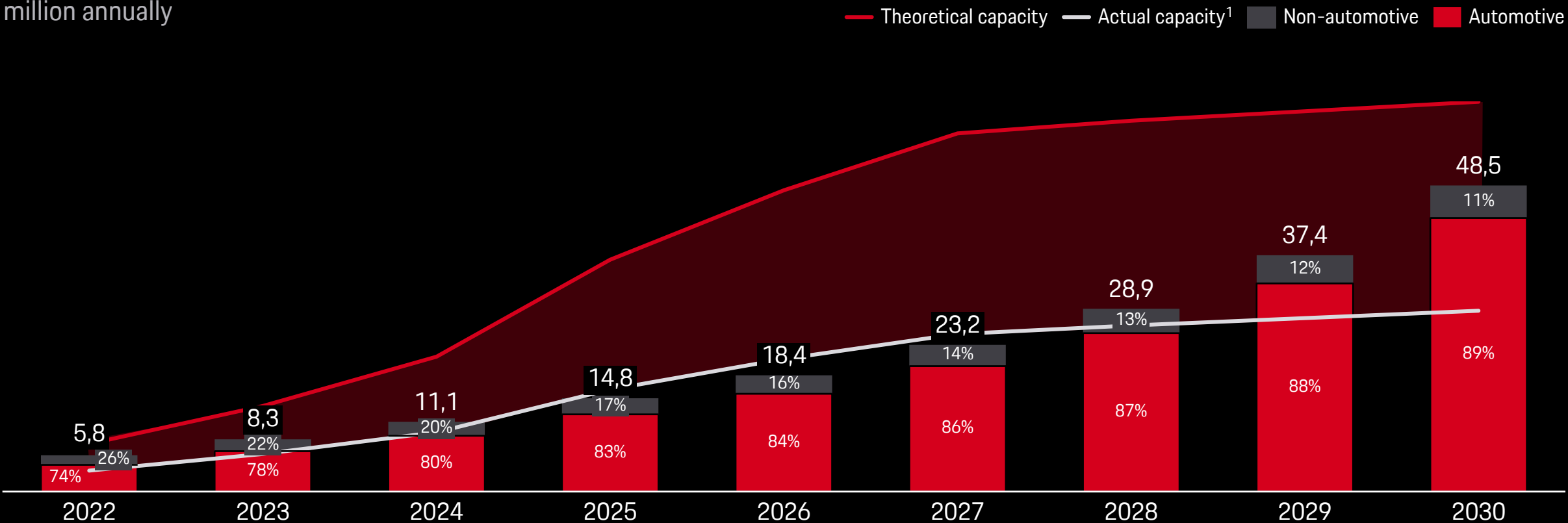
Source: Porsche Consulting, Yole

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Available capacity is subject to investment financials (e.g. government incentives), equipment availability and, particularly for emerging players, to achieve automotive grade qualification

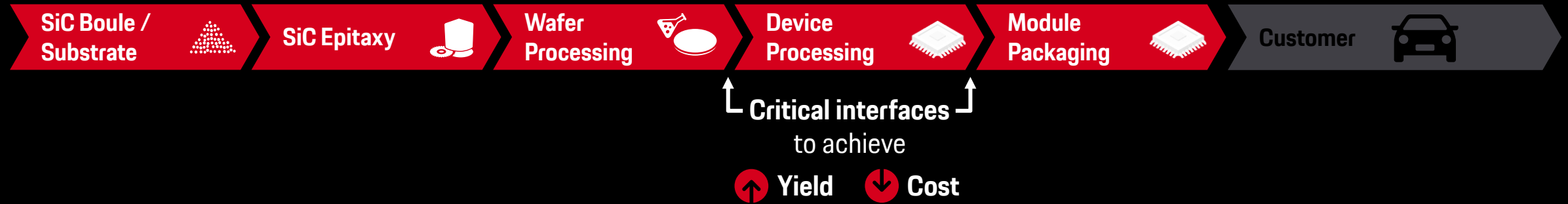
SiC supply-demand balance, 6" equivalent substrate units per year

million annually



¹ Actual capacity considers 80% fab utilization and 55% boule yield through 2027, increasing to 60% by 2030
Source: Porsche Consulting, Yole
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Managing interfaces between the wafer, device and module level is crucial to achieve cost reduction, technical optimization as well as fast time-to-market



Vertical integration

- +** Critical interfaces all in one hand
 - Margin stacking eliminated
 - Resilient inhouse supply
-
- CAPEX intensive

Cooperation

- Shared CAPEX
 - Focus on individual strengths, no doubling of experts
-
- Project management more complex
 - Higher level of standardization required

Interface management

- ✓ Joint requirements management
- ✓ AIT¹ interface between die and power module
- ✓ Transparent cost structures
- ✓ Integrated demand and risk management

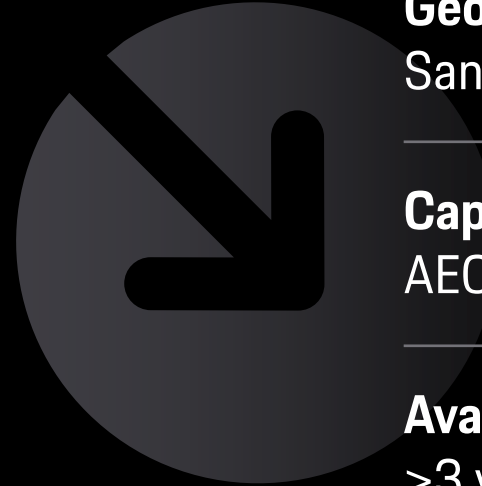
Most important drivers and inhibitors will influence the global capacity ramp-up



New players across the value chain
Especially from China

Higher levels of automation
Shift to 200 mm wafers

Technological advancements
Laser splitting, splitting-bonding

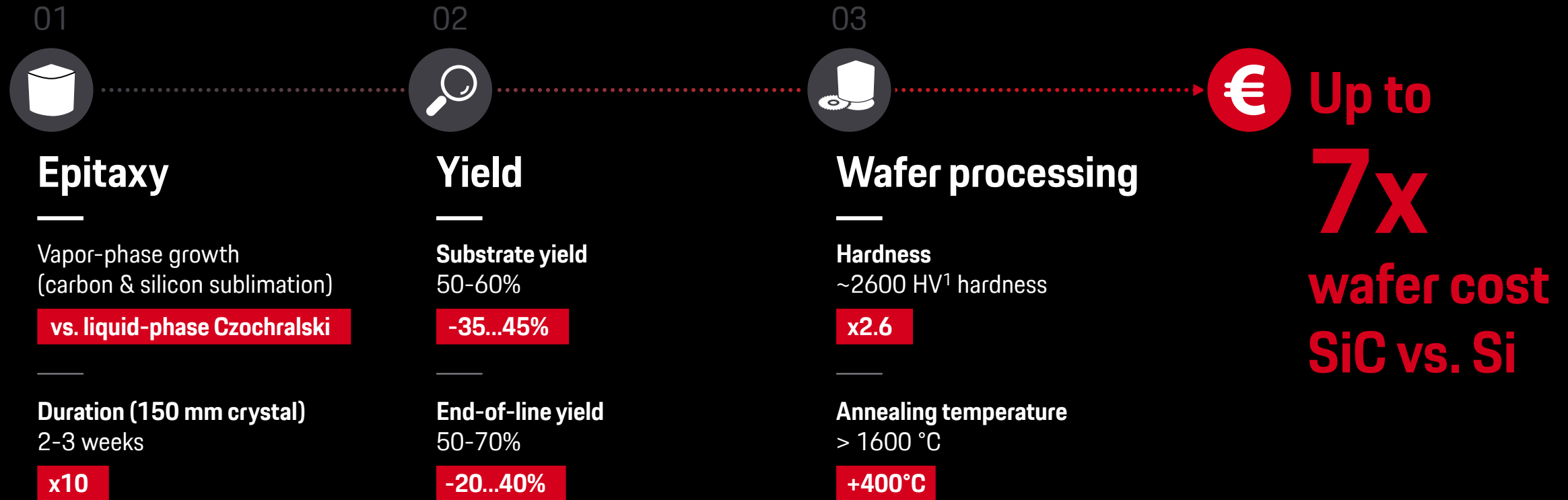


Geopolitical unbalance
Sanctions or additional tariffs

Capacity and quality delivery
AEC-Q100 certification

Availability of equipment and tools
>3 years lead time

Compared to Si, SiC manufacturing is more complex and requires special equipment



Compared to Si

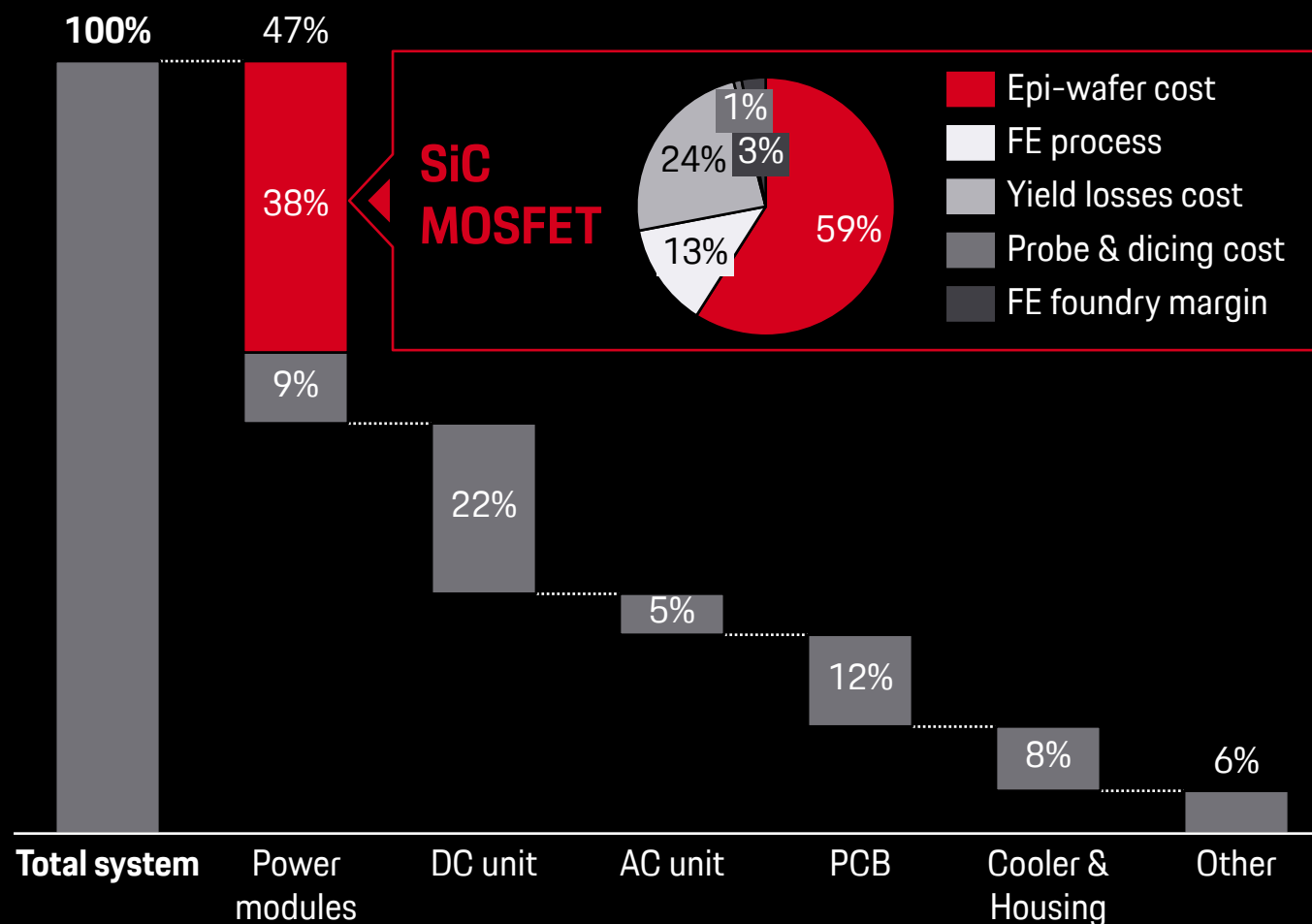
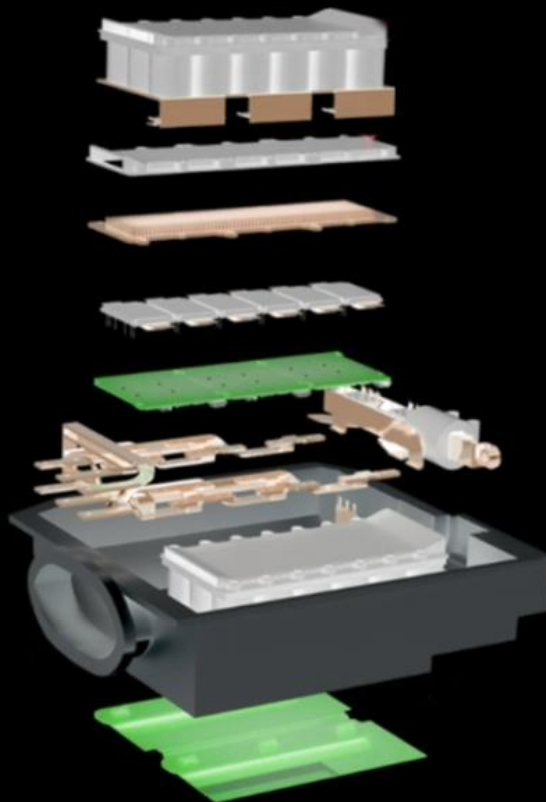
1) Vicker's hardness
Source: Porsche Consulting

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Device costs account for ca. 40% of inverter system costs, of which ca. 60% are wafer cost – system integration and associated costs need to emphasize thermal management due to higher power density

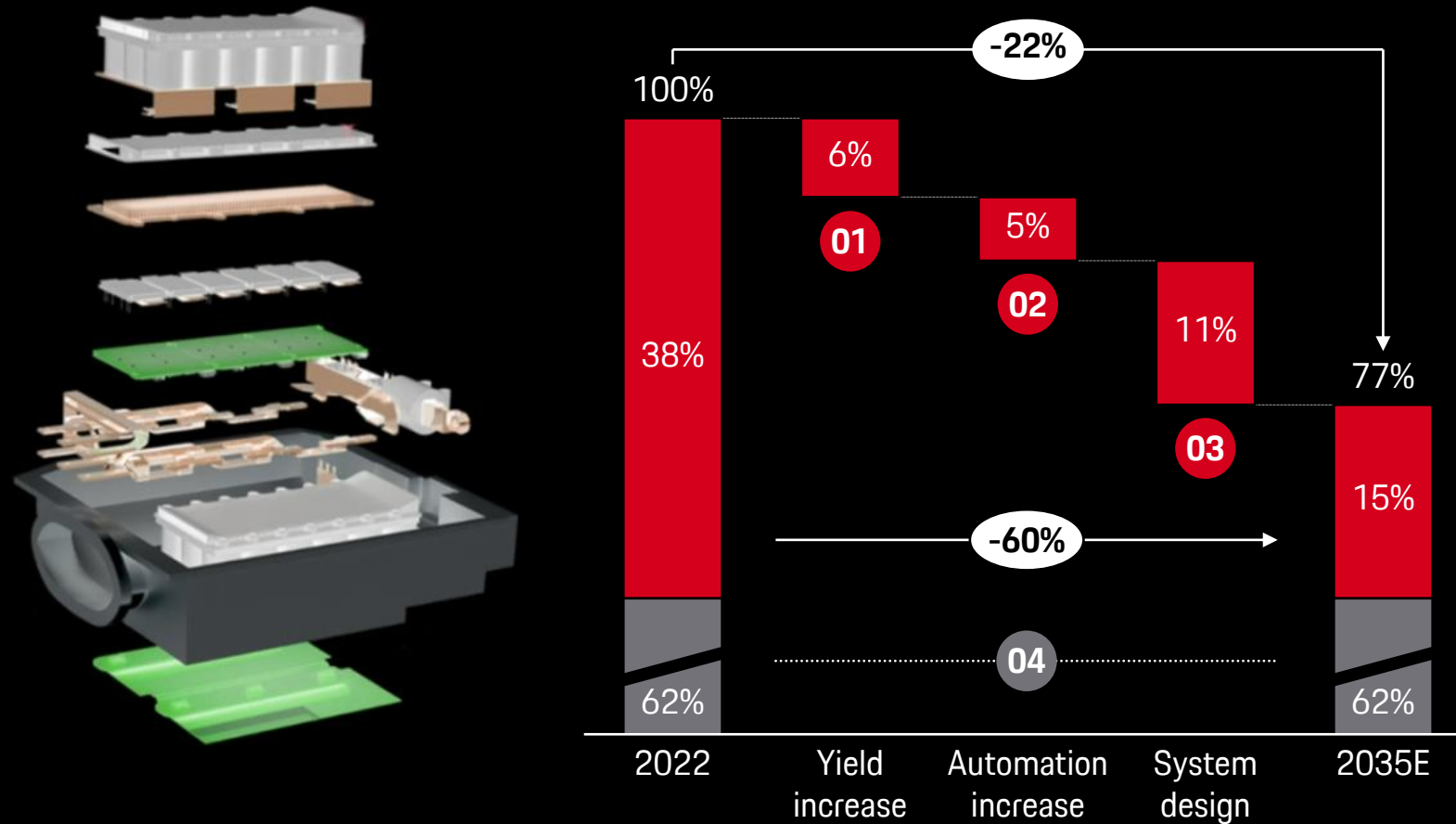
Compared to Si-based designs, SiC-based require emphasis on:

- ▶ Advanced thermal management
- ▶ High-voltage isolation
- ▶ Low parasitic inductances to manage high di/dt



We expect a cost degradation of ca. 60% for applied semiconductors on a system level by 2035

System cost degradation (2022–2030E)



Premises

01 Yield increase

- 55% boule yield through 2027
- Increasing to 75% by 2035

02 Automation increase

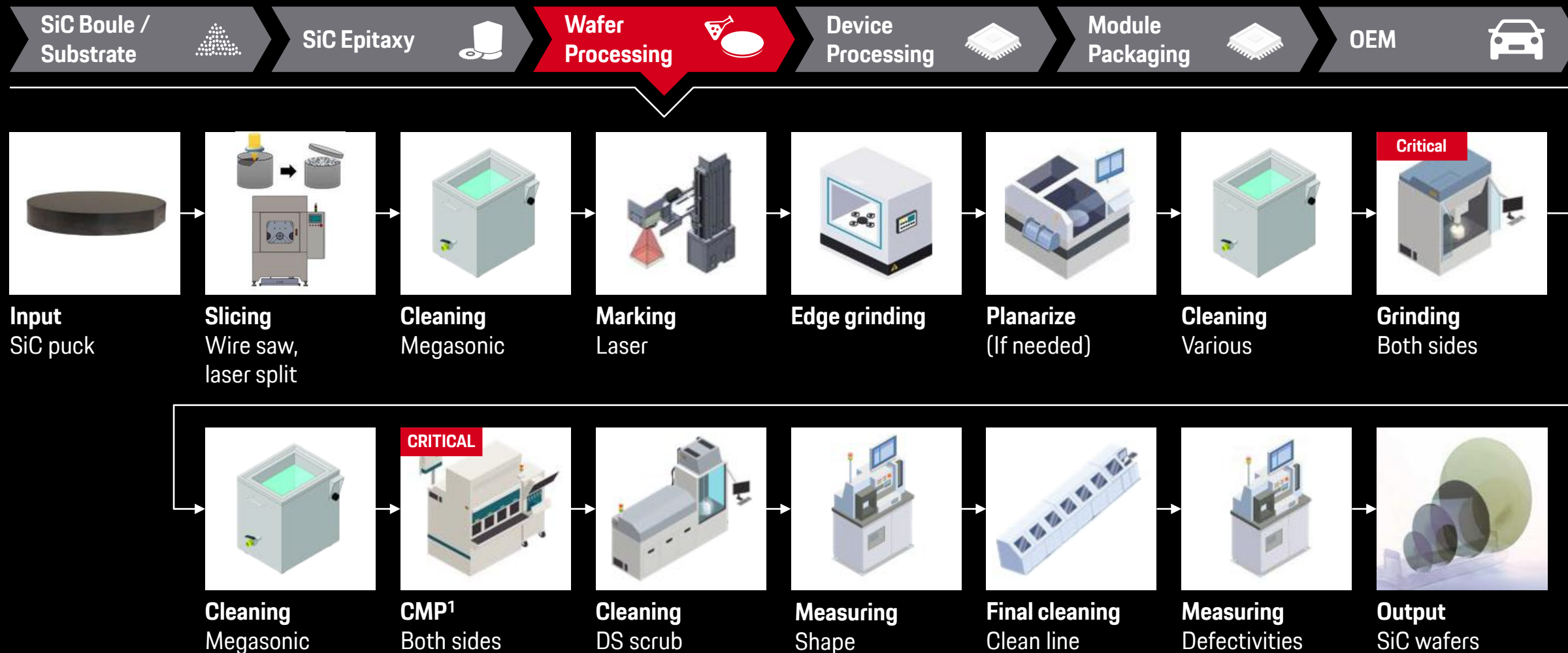
- Driven by shift to 200 mm and continuously higher level of automation

03 System design optimization

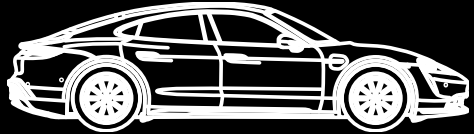
- Current safety factor of 2 based on lifetime requirements
- Reduced 1.4 in 2030

04 No cost degradation for commodity parts

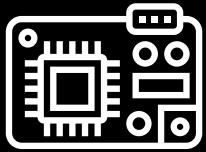
Intense quality management along the whole value chain is required – especially the wafer processing is most demanding due to material properties



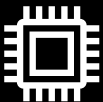
Strategic development trends on a system and entire vehicle level are pushing for higher efficiency and synergies across the vehicle portfolio



Inverter



SiC device



From range to efficiency

- Focus on holistic efficiency improvement in drive and energy system
- Reduction of electric and mechanical losses
- Improved thermal management

Modular platforms

- Scalable drive and energy systems
- Commonality across segments and brands
- Enabling technology platforms

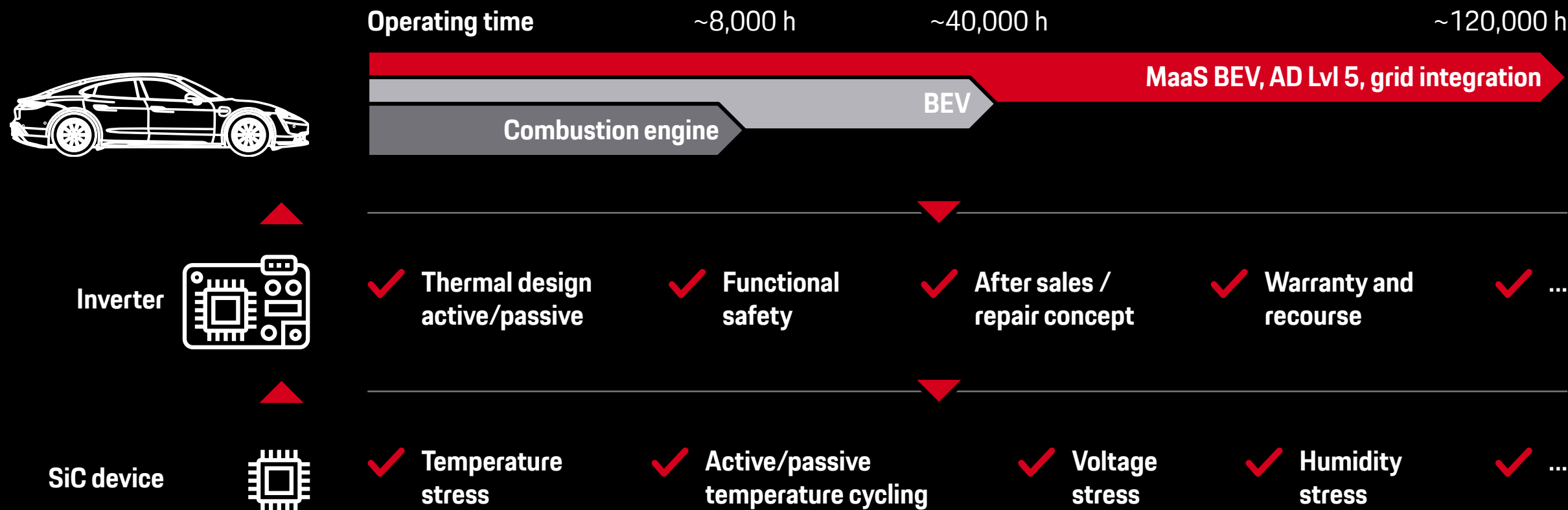
Higher system integration

- Integrated e-axle (e-motor, inverter, gearbox), power units (DC/DC, OBC, PDU)
- Package optimization
- Faster time-to-market

Advanced packaging

- Innovative designs to manage heat and power
- Improve long-term reliability and scalability

New mission profiles on an entire vehicle and ecosystem level directly impact the requirements on a material and device level



Conclusion

01

CAPACITY

Create **demand transparency** across the value chain to enable strategic **decision making**

Cooperation & vertical integration will be key to **manage critical interfaces** across the value chain

02

COST

Increasing **yield rate** and **higher automation** will drive bare die cost degression

Requirements transparency and **optimized system design** will lead to reduced SiC die demand

03

QUALITY

Improving **wafer processing** is the main quality lever in the value chain to achieve **higher reliability**

In a **joint approach** across the value chain, **common mission profiles** need to be defined

Let's connect!



Frank Seuster
Partner



Dr. Arnaud de Vries
Associate Partner



Marius Ruhnau
Manager



Marvin Müller
Consultant

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