

> TURBOCHARGED TRANSISTORS

Silicon Carbide Shifting to Next Gear

Munich | November 14, 2024

Porsche Consulting

**SEMICON[®]
EUROPA**



Global mega trends

are shaping the
silicon carbide
ecosystem



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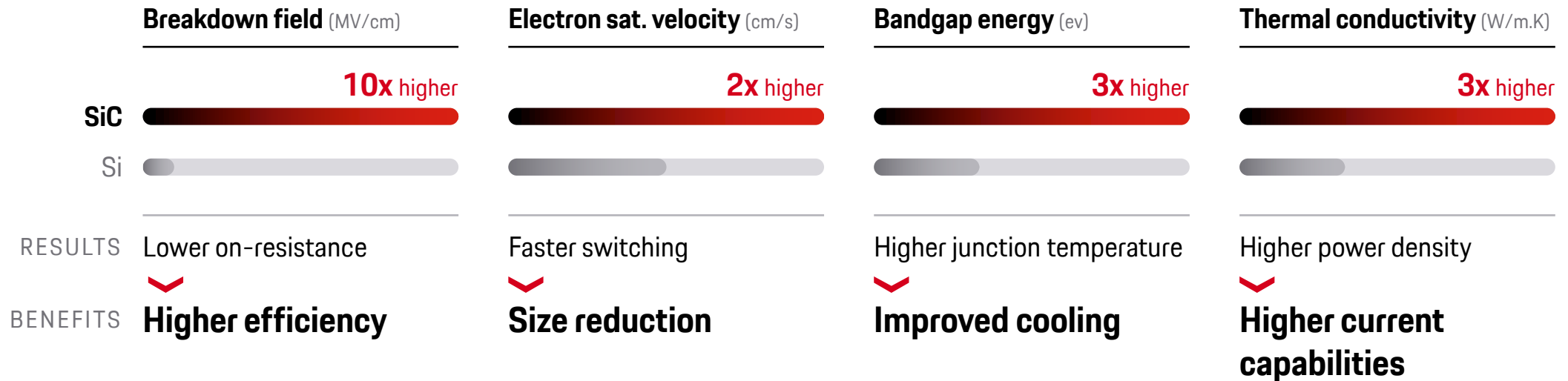
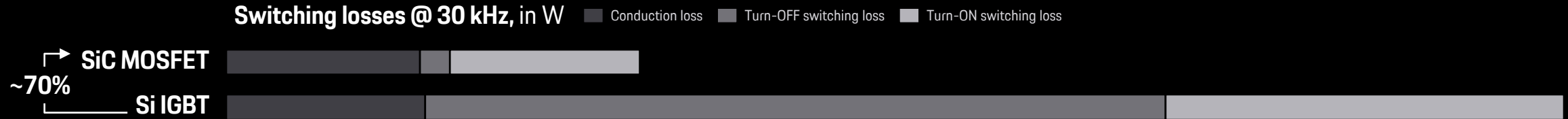


Global mega trends

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Silicone carbide offer significant technical benefits creating huge business potential across various applications



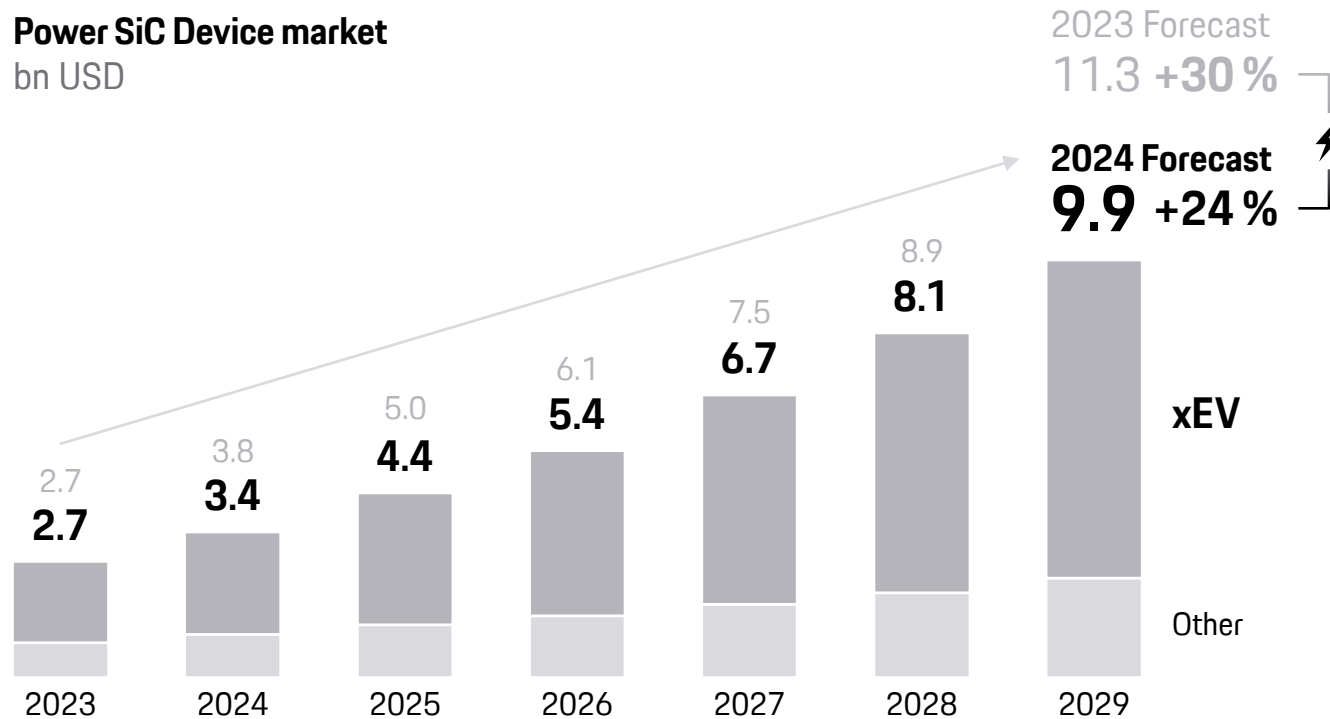
SiC applications

xEV Rail PV, Wind, ESS Charging infrastructure PFC/Power Supply & UPS Oil & Gas, Defense, R&D

The ambitious market forecast from last year is being revised downwards by analysts

Electrification is still the main driver,
despite the short-term slowdown

Power SiC Device market
bn USD



➤ Latest market projections

-6 % CAGR
vs. 2023

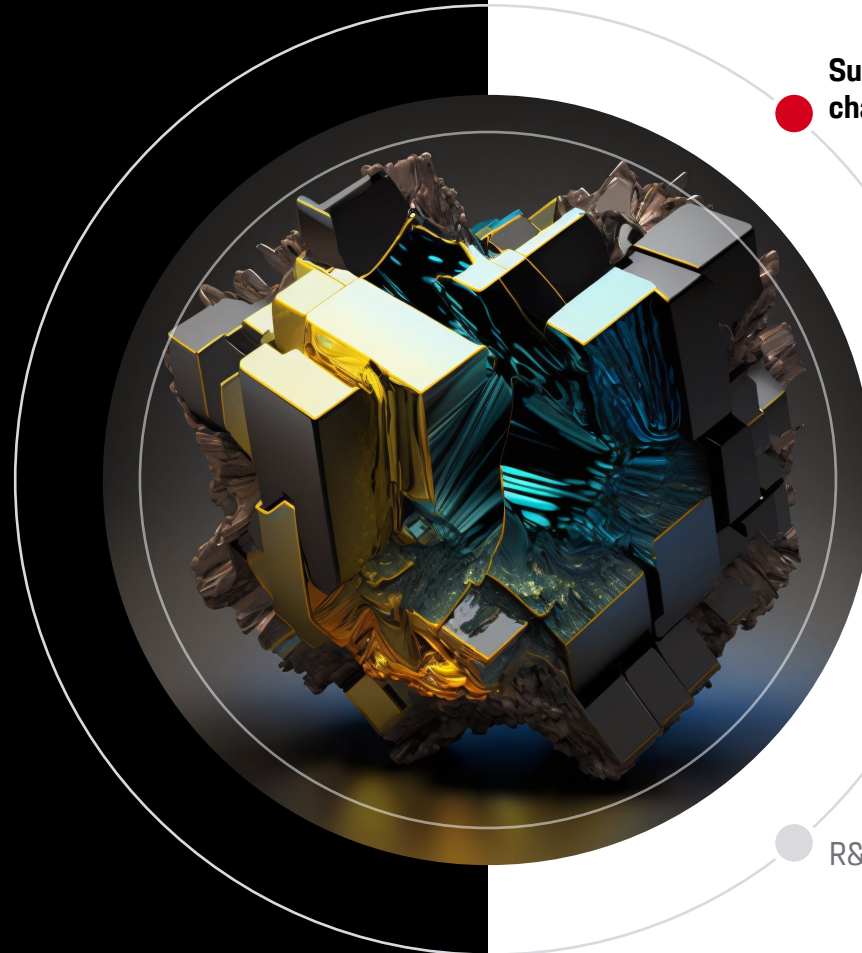
➤ Uncertainty regarding
BEV adoption as market
driver

➤ Cost pressure in particular
in mid-class segments

SEMICONDUCTOR INDUSTRY,
in close collaboration across the entire value chain

must act now

to avoid further SiC
adoption slowdown and
prove competitiveness
to other technologies



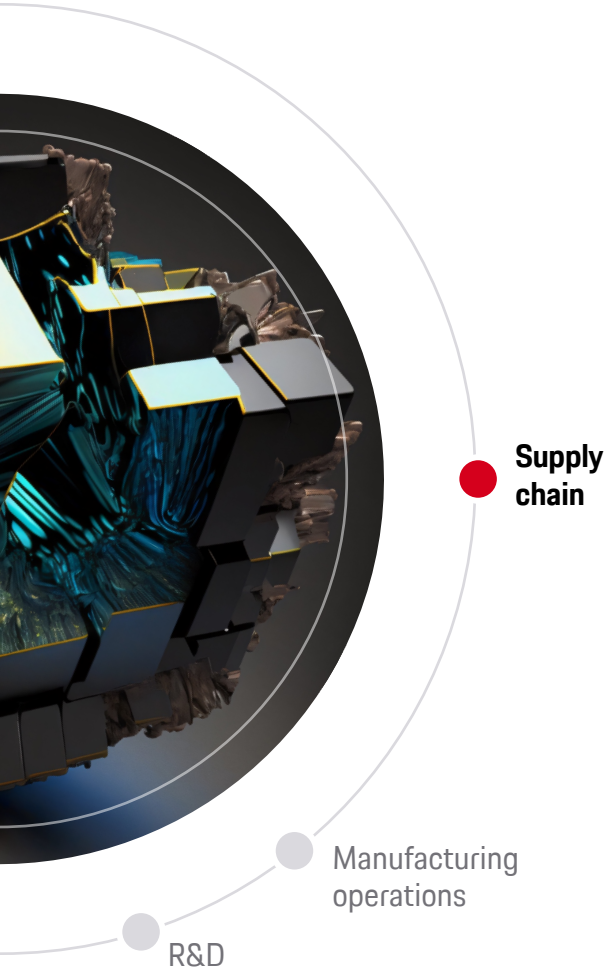
Supply
chain



Recalibration of
value chain towards
efficiency &
innovation

Manufacturing
operations

R&D



SUPPLY CHAIN TRENDS

The pathway to wide adoption of SiC leads through three main steps of supply chain reorganization

01

SLOW DOWN

Ramping up fab capacity continues despite demand decrease and first postponement of investments

02

CONSOLIDATION

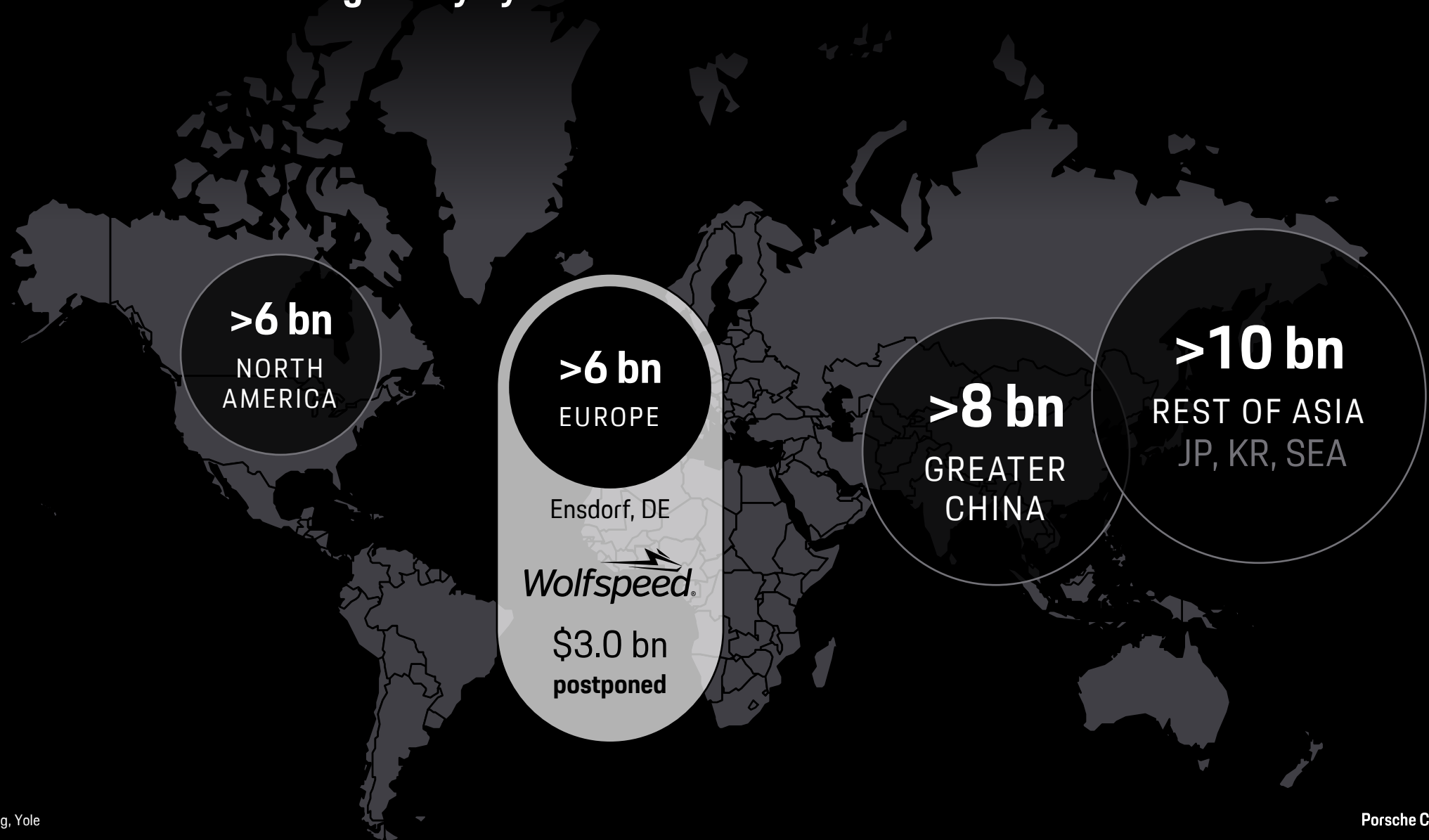
Steep increase in capacity exceeding current forecasted demand will lead to consolidated market and strategic reconsiderations

03

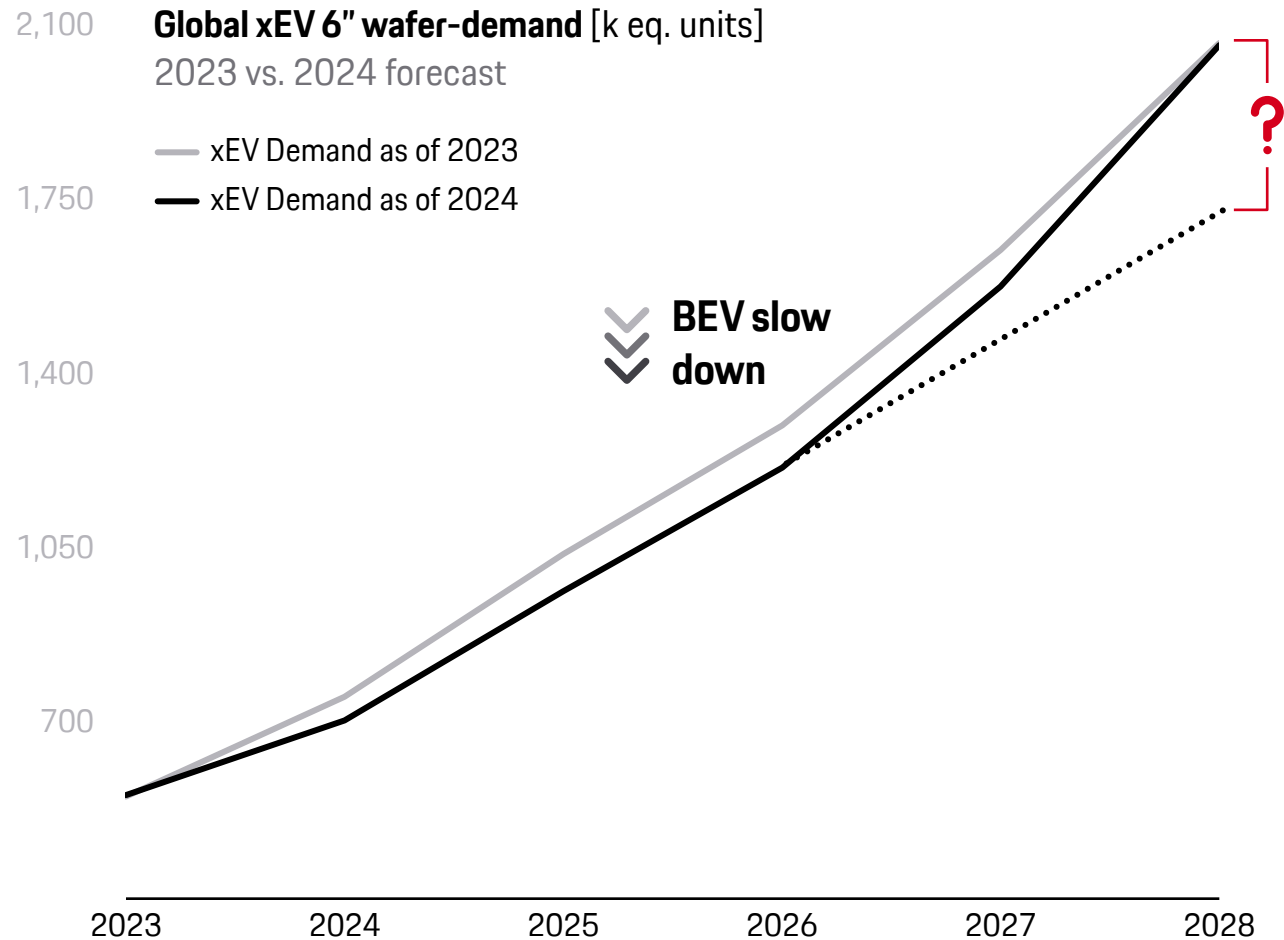
COOPERATIONS

Recalibration of value chain position and leveraging on collaboration among European players to aim for competitiveness

Long-term investments continue despite automotive slowdown – 30 bn USD investments in silicon carbide have been announced globally by Q3/24



However, the BEV slow down, and recent wafer capacity increases could cause a global wafer price war



CURRENT

CHALLENGES



EV demand
slow down



Wafer
Destocking



Price war in the
Chinese wafer market

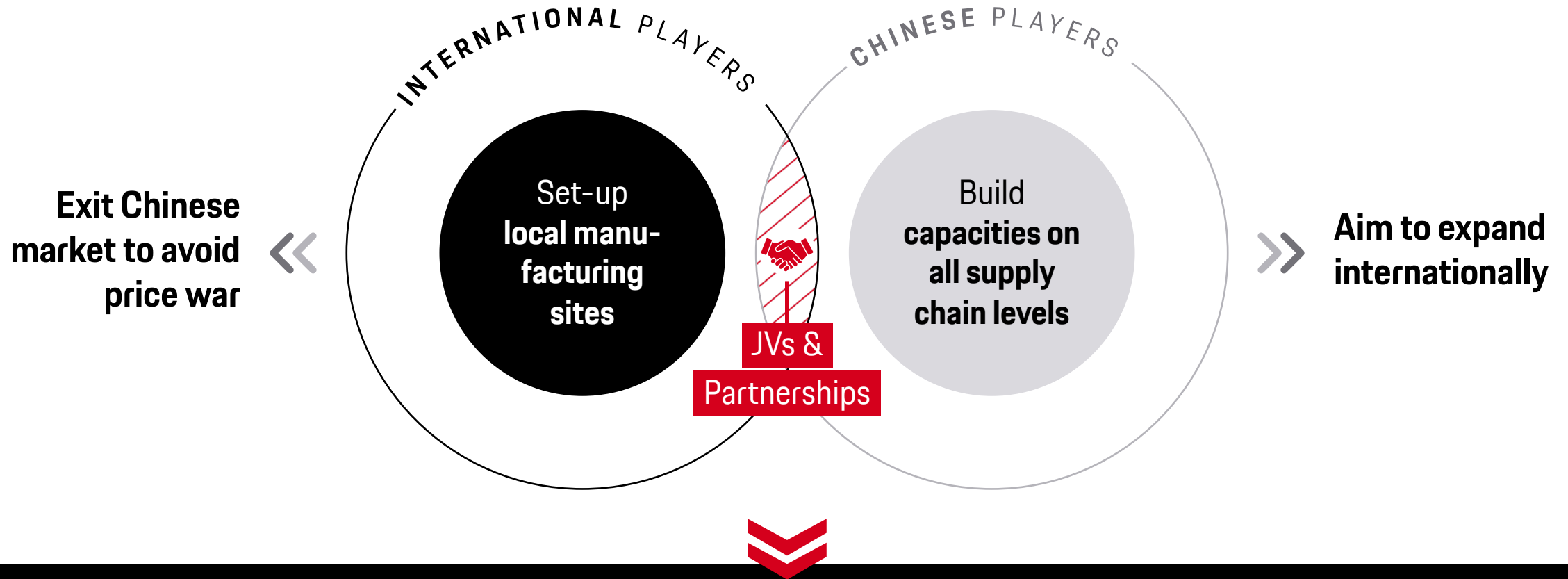


STRATEGIC IMPLICATIONS

Wafer manufacturers
must increase efficiency,
innovate to e.g., 8" or
integrate downstream

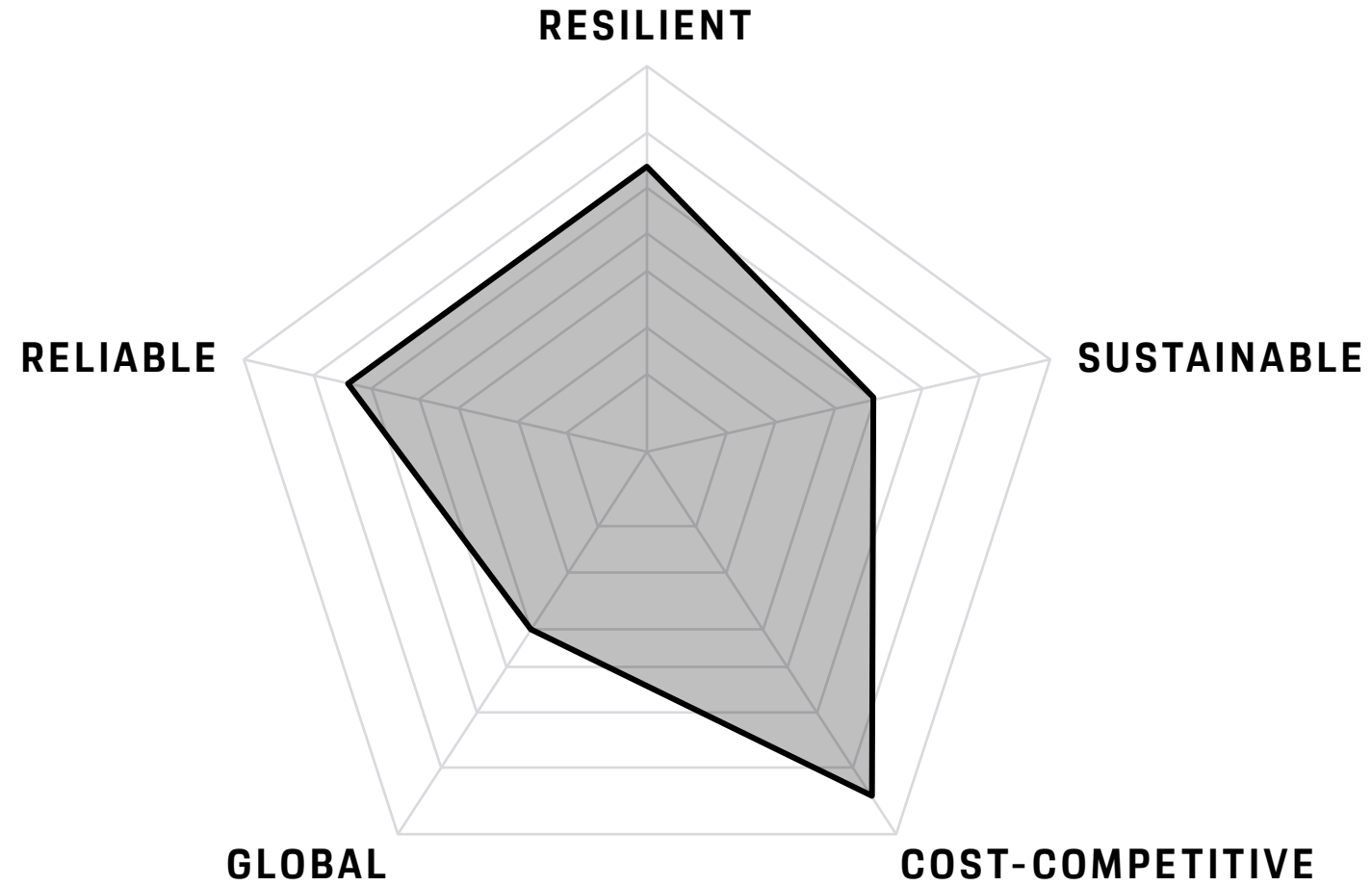
IDMs must reconsider
competitiveness of
inhouse wafer
production

Global tensions and a growing competition from China demand attention for supply chain design

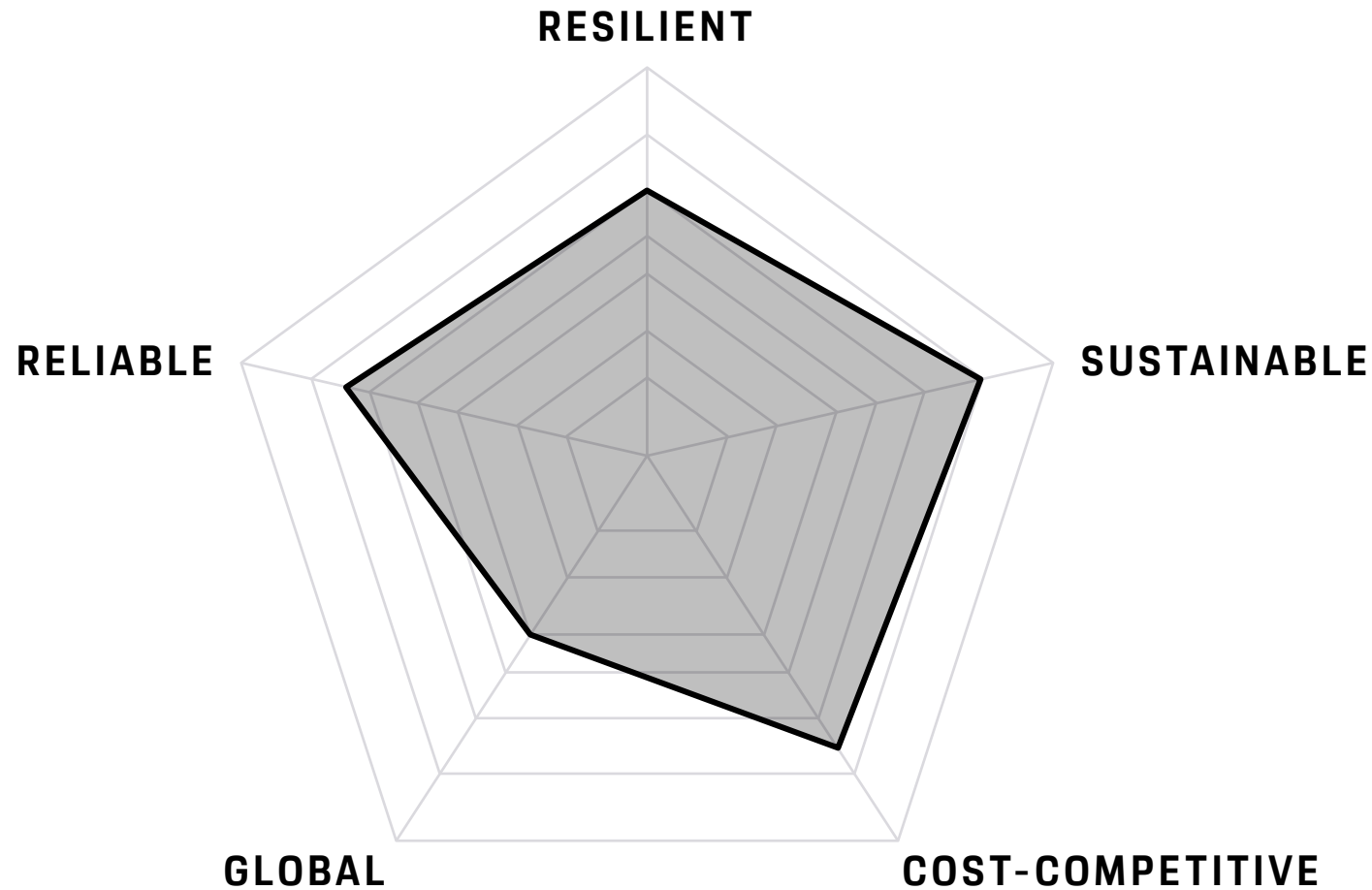


Should there be a Europe-first solution or do we need to think globally?

Imagining the perfect silicon carbide supply chain



Imagining the perfect silicon carbide supply chain



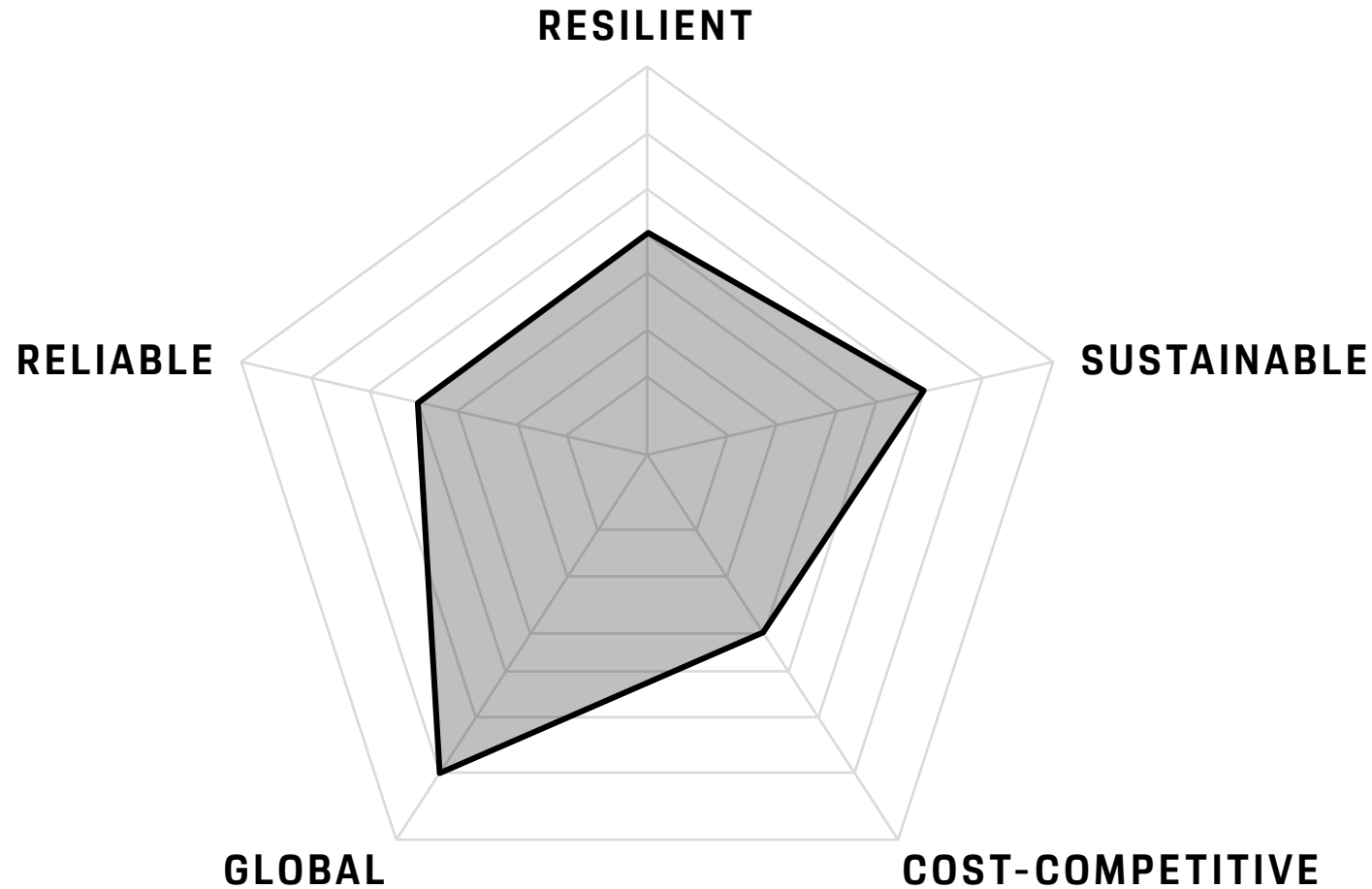
**Contradicting priorities
yield different options**

EXAMPLE SCENARIO 01

> European Mega Supplier

One major European IDM
takes it all from substrate
to module and scales its
business

Imagining the perfect silicon carbide supply chain



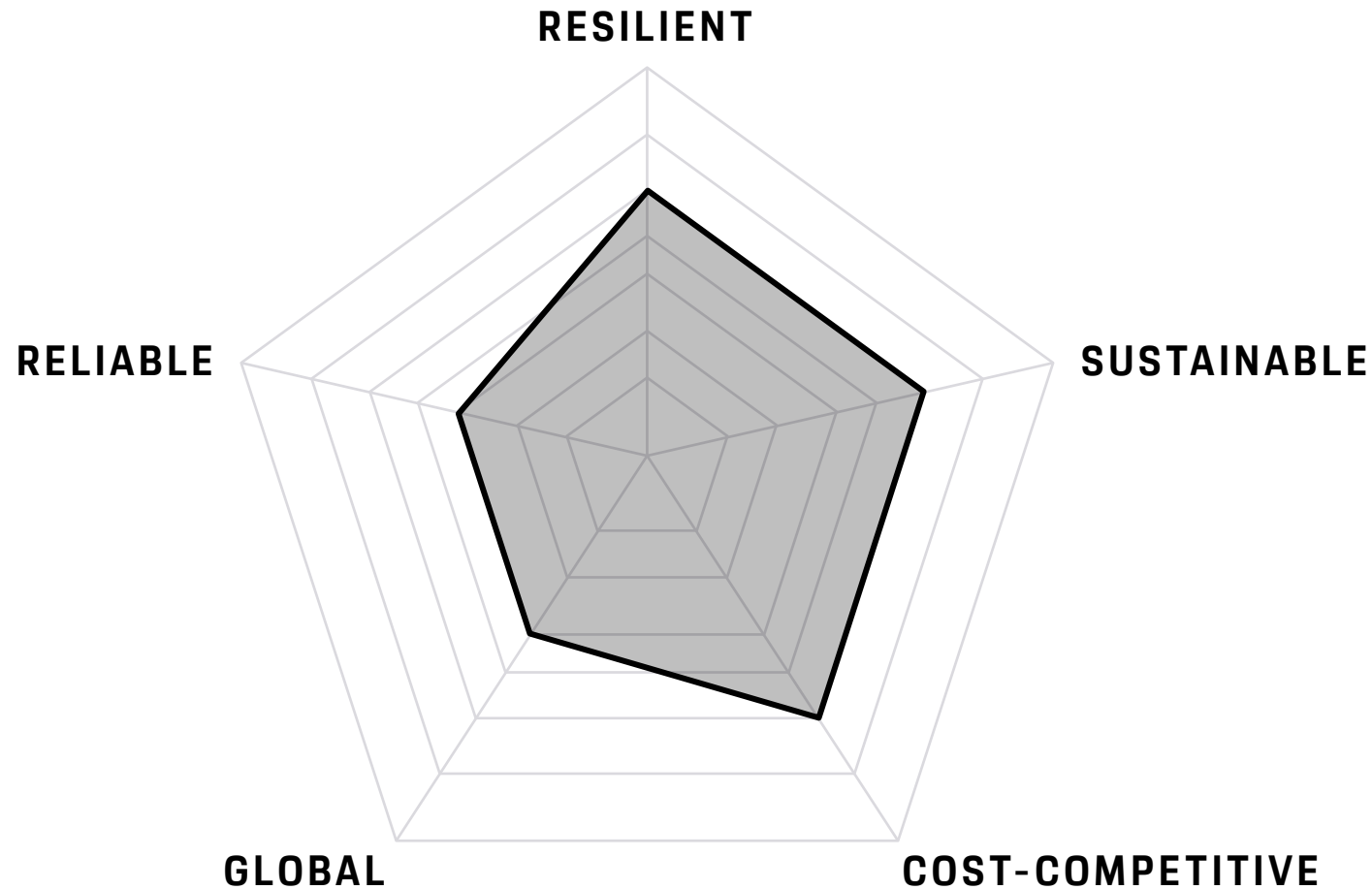
**Contradicting priorities
yield different options**

EXAMPLE SCENARIO 02

> Collaborative Network

Network of specialized
companies collaborate to
cover different segments
of the supply chain

Imagining the perfect silicon carbide supply chain

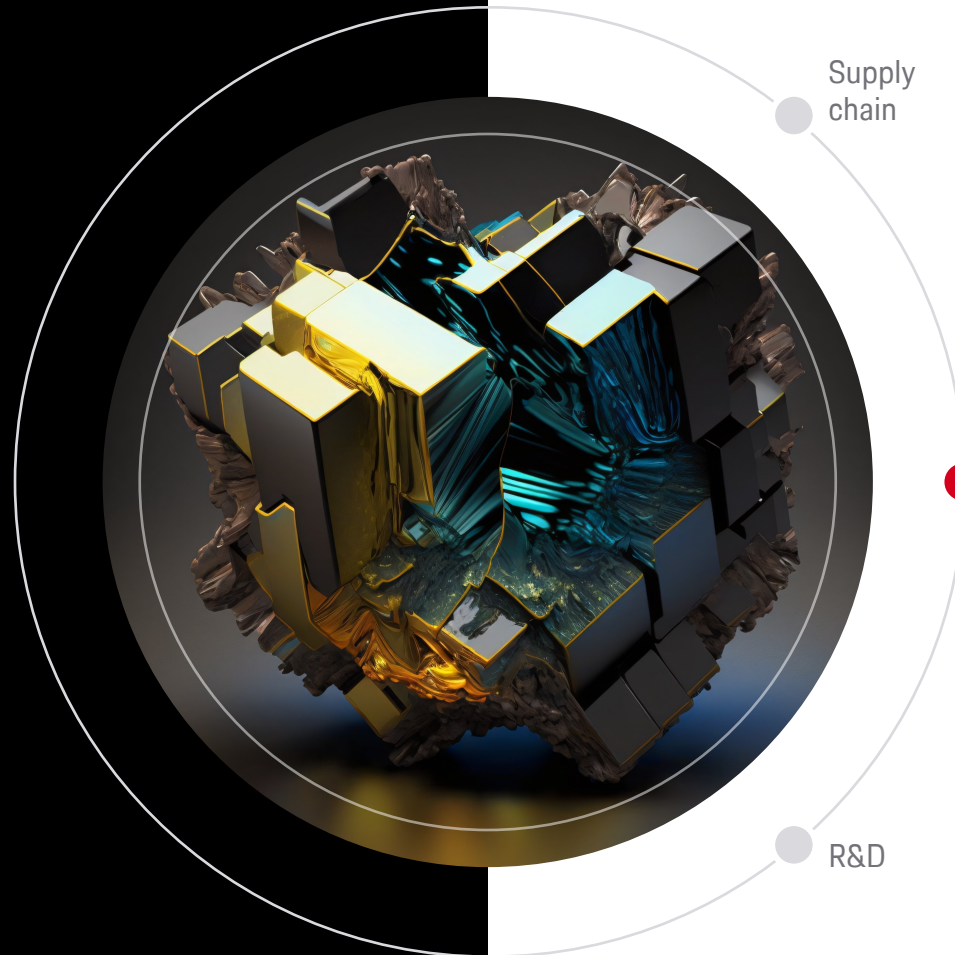


**Contradicting priorities
yield different options**

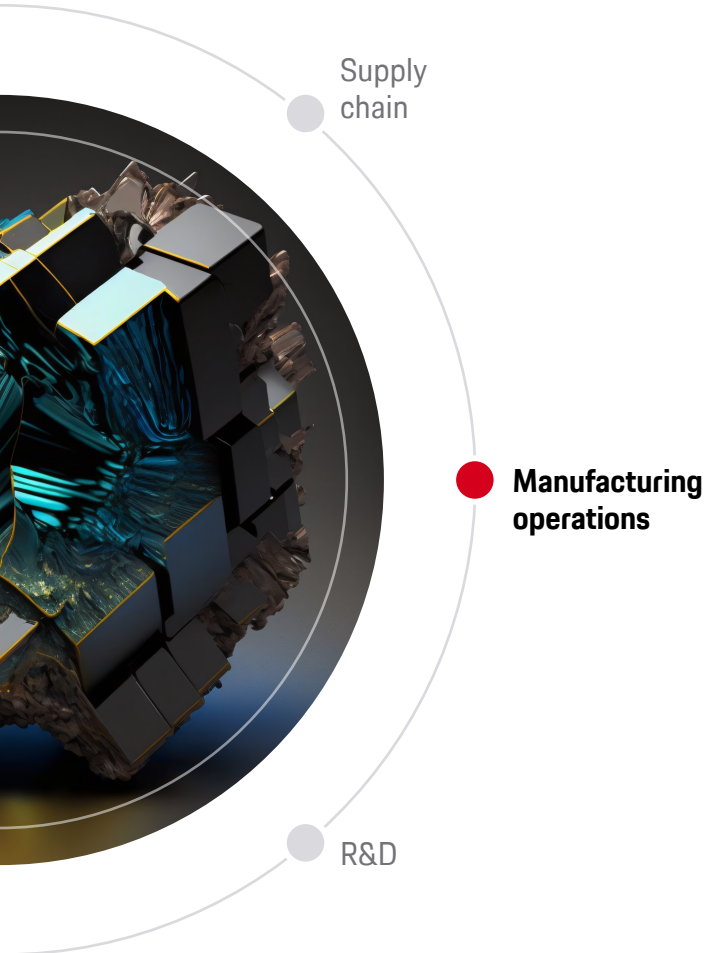
EXAMPLE SCENARIO **03**

> Fully Inte- grated OEMs

OEM integrate further
upstream and establish a
foundry-like business model
for silicon carbide



Boosting manufacturing efficiency at all levels



MANUFACTURING INNOVATIONS

The pathway to wide adoption of SiC leads through 3 main steps of manufacturing innovation

01

SPEED UP

Transition from 6" to 8"
Innovations in critical process steps, industrialization & ramp-up

02

IMPROVE

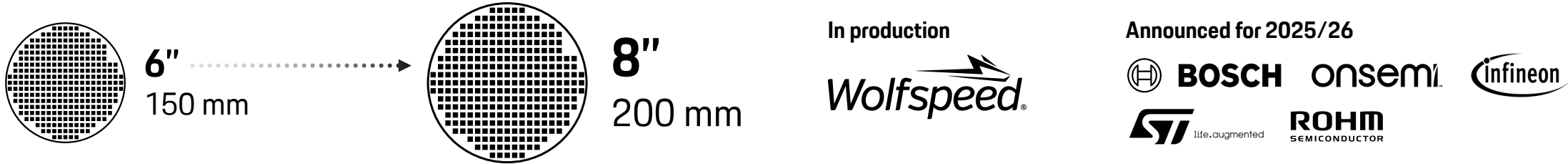
Improving growth process of Boules Reduced losses with new wafering technologies, material innovations

03

SUCCEED

Leveraging existing industry standards & Automation, AI + Digital twin capabilities to increase efficiency and get cost competitive

The transition from 6" to 8" wafer size comes with promising benefits for IDMs



MAINSTREAM

Will remain mainstream until end of decade

Getting commoditized: significant price decrease

Device manufacturers keep expanding

CURRENT CHALLENGES



Quality of crystal growth



Wafering process



Imperfect oxide layer/channel mobility



LONG-TERM OPPORTUNITIES



Leveraging on 200mm Si Infrastructure



Technological sweet spot for Fab performance



Cost competitiveness expected by 2030

Manufacturing **INNOVATION**

With three levers
losses can be reduced
and higher manu-
facturing performance
can be achieved



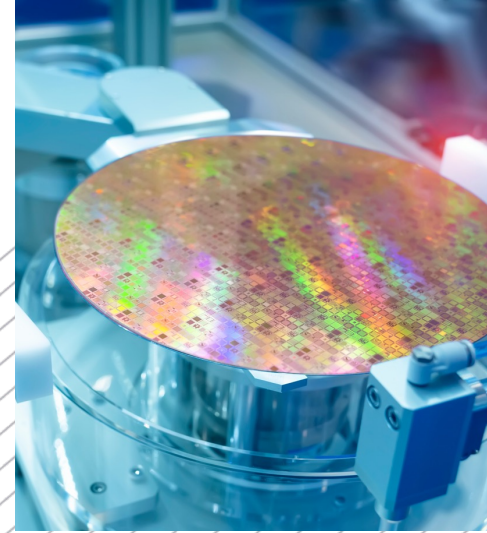
IMPROVEMENT LEVER 01

BOULE GROWTH

Increasing usable
thickness and growth
rate of SiC crystal



**Higher
yield**



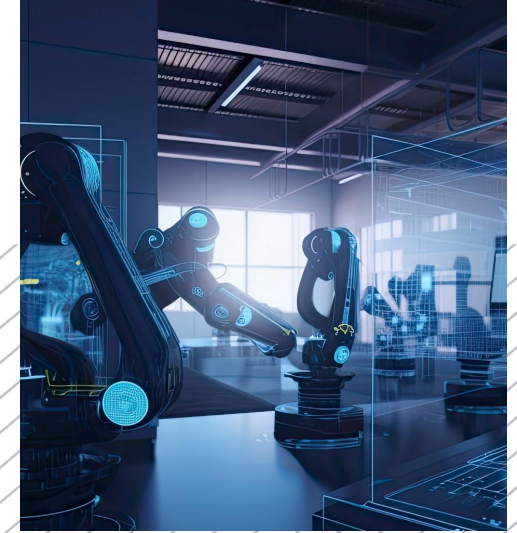
IMPROVEMENT LEVER 02

SUBSTRATE PROCESS

Improvements in
wafering technology and
subsequent processes



**Higher
performance**



IMPROVEMENT LEVER 03

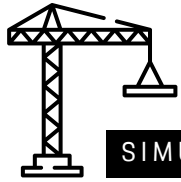
OVERALL MATURITY

Leveraging on standards
and increasing degree
of factory automation



**Increased
efficiency**

Both in fab planning and operation, data analytics and AI are taking silicon carbide to the next level



SIMULATION

Factory ramp up and capex saving

Multiple scenario analysis and fast decision making

End-to-end simulation models

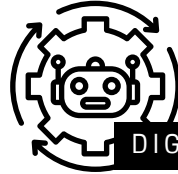
CapEx optimization and production debottlenecking

SAMPLE RESULTS

-10% 

CAPEX avoidance

Reduced WIP through what-if scenarios



DIGITAL TWIN AI

Realtime process control and optimization

Reveal latent patterns among process parameters to trigger production improvements

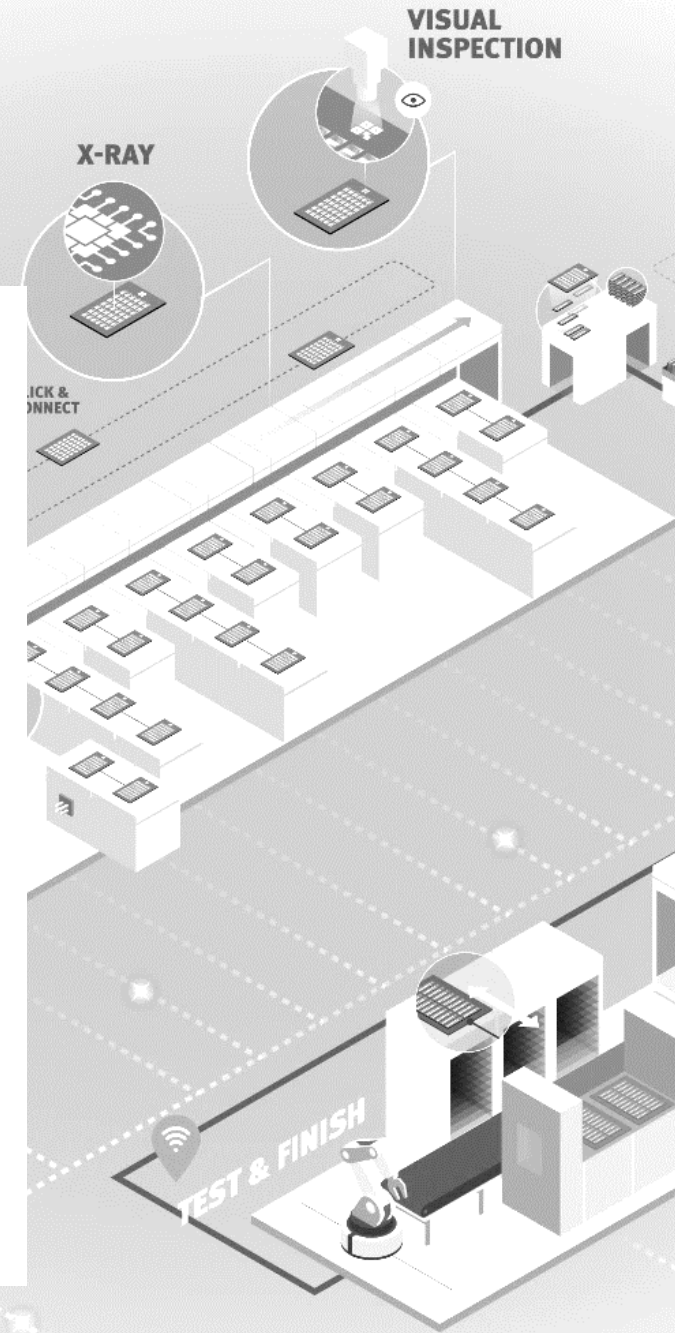
Predictive analytics through process-specific causal AI modelling

Creation of the AI Driven Fab based on state-of-the-art AI autonomous agents

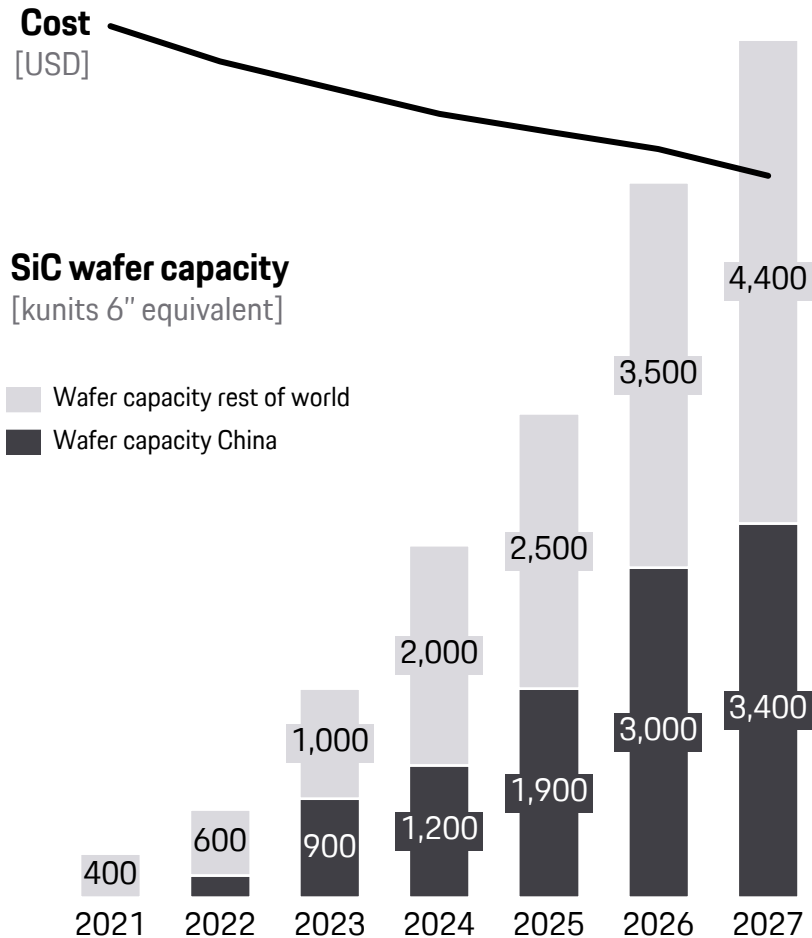
+5% 

Productivity increase

Less physical tests throughout the manufacturing process



Reducing cost per wafer and becoming cost competitive is crucial for market adoption of SiC



SUPPLY

Reduced cost/wafer through industrialized process (China repr. ≈40 % total capacity by 2027)

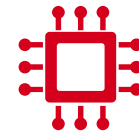
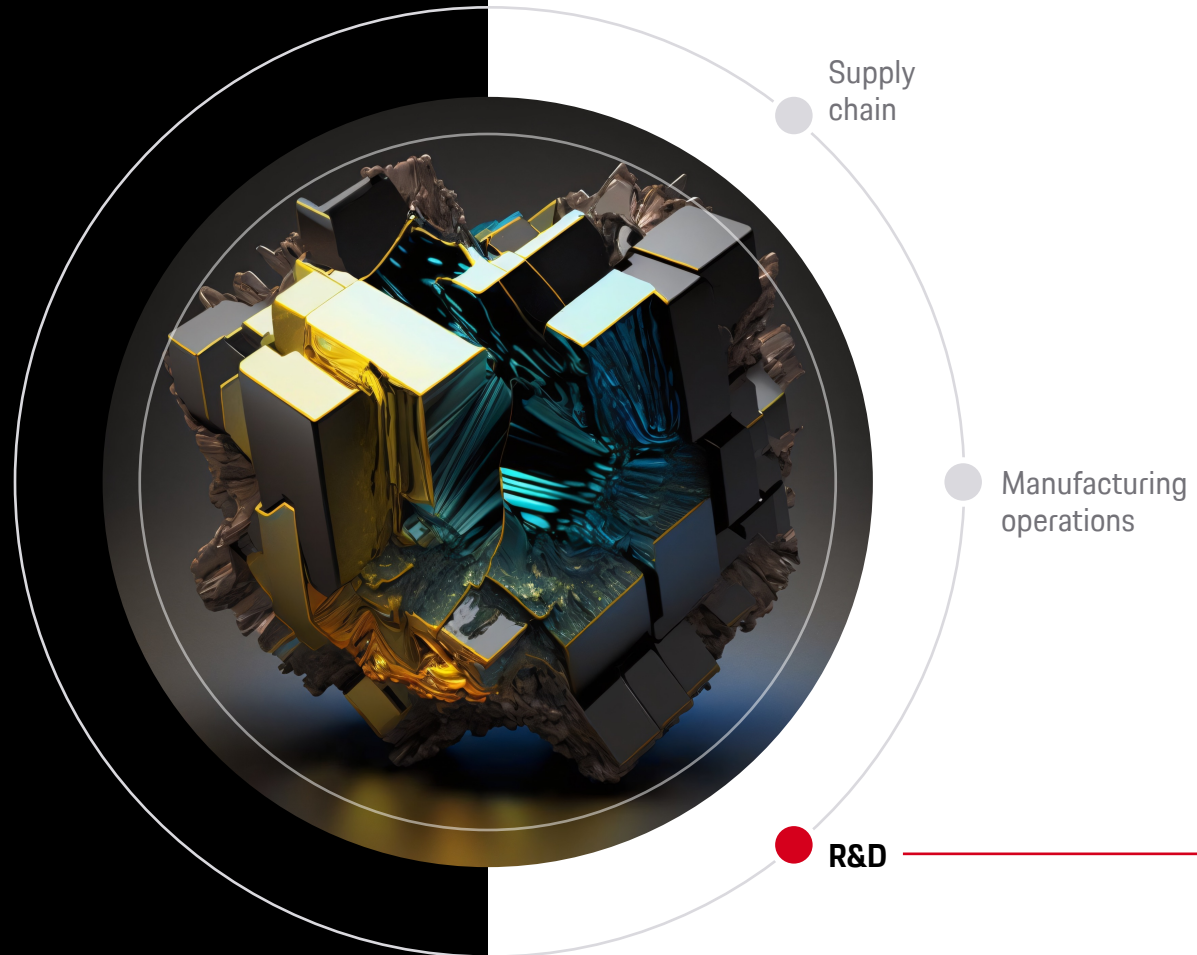
CAPEX

Industrialization through leveraging 200 mm standards reduces capex for new fab by approx. 30 % by 2027

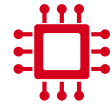
OPEX

High-yield production of power modules with 30 % reduction potential in scrap rates by 2028

Cost competitive manufacturing is key for fast adoption and increase in market share



System/device specification,
GaN & what's next



RESEARCH & DEVELOPMENT

While products in the market and manufacturing are ramping up & maturing, research and development must continue to provide stimuli for the future

01

INNOVATE

Innovation and new design on bare die-level
Package innovation bringing new possibilities
Finding the sweet-spot of innovation

02

INTEGRATE

Closing the cost-performance ratio-gap on the long-term and intercepting with an intermediary hybrid solution

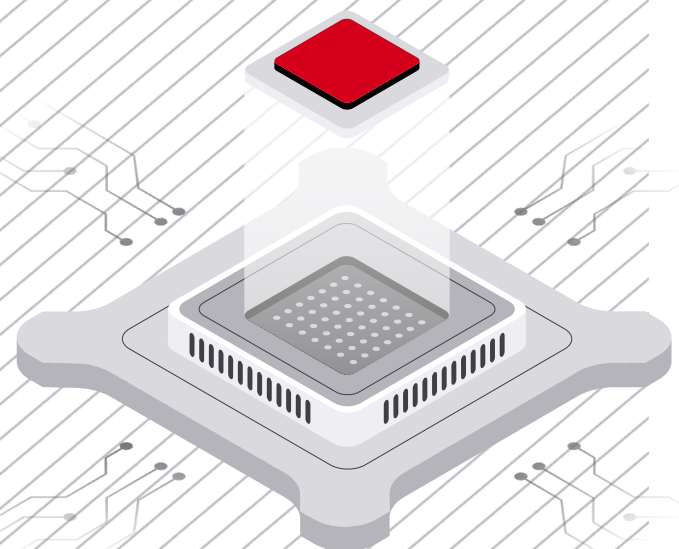
03

LEVEL-UP

GaN is following SiC in adoption and industrialization, while UWBG products are just getting started

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BARE-DIE-LEVEL



PACKAGE LEVEL

SiC stays at the forefront of innovation and keeps pushing boundaries, but finding the balance between performance, reliability & cost will be key

PLANAR OR TRENCH

Planar (DMOS) offers better cost efficiency & easier manufacturing

VS.

Trench (UMOS) enables device size reduction & higher eff. at lower BV*

SUPERJUNCTION

Unipolar devices are mature & offer cost efficiency at lower voltages

VS.

Superjunction open the door towards higher efficiency at high voltage

COOLING

Single-side cooling with cost & maturity benefits

VS.

Double-sided cooling further improves power density

PACKAGING SUBSTRATE

Al₂O₃ direct bonded copper (DBC) mainstream

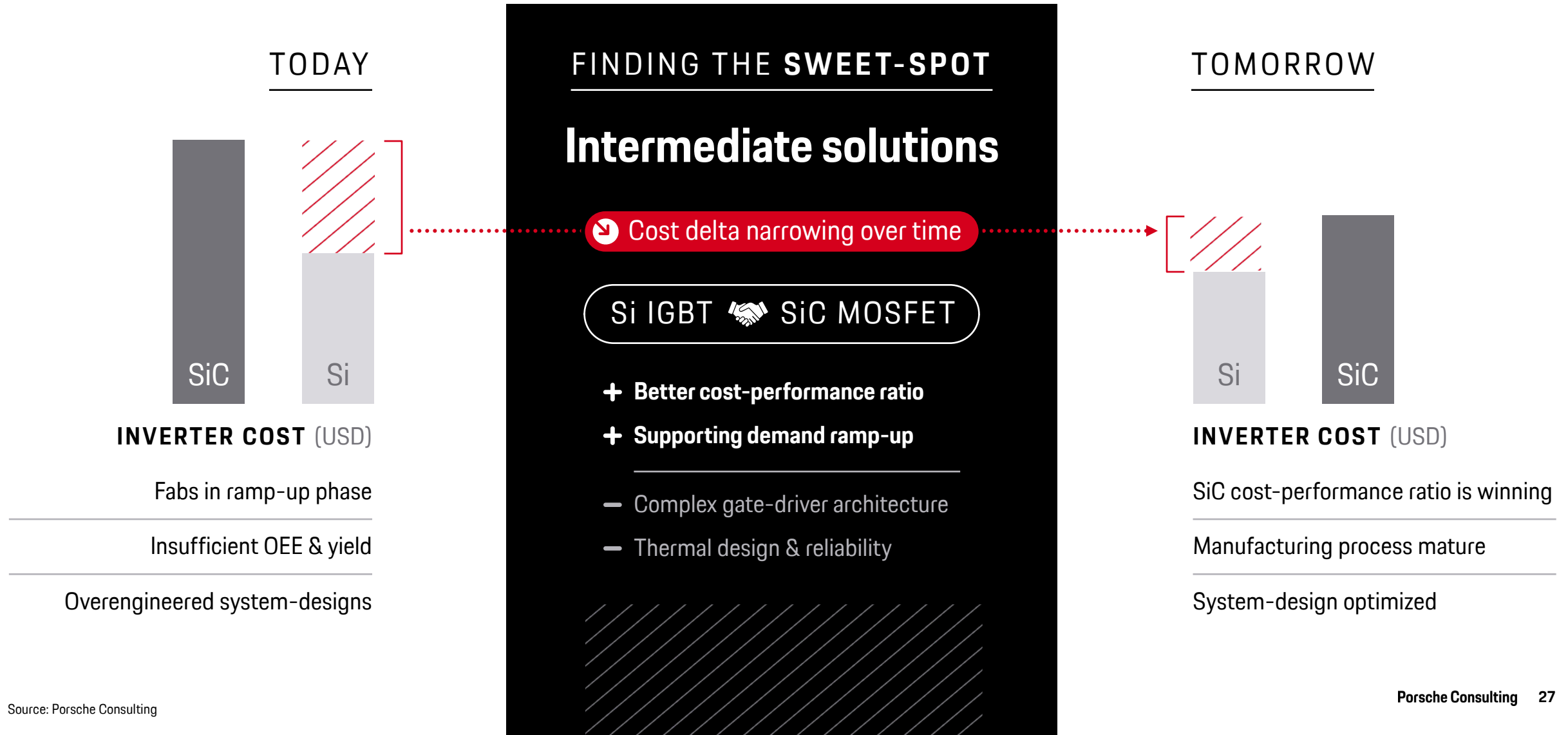
VS.

Active metal brazing (AMB) with better thermal conductivity

How does the industry find the sweet-spot between reliability, performance & efficiency as well as cost reduction?

> Collaboration will be essential!

While manufacturing & technology are maturing, closing the competitive gap to silicon might take more time and short-term intermediary solutions

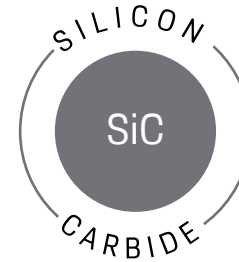


Besides silicon carbide, power semiconductor industry is repeatedly proving what's possible

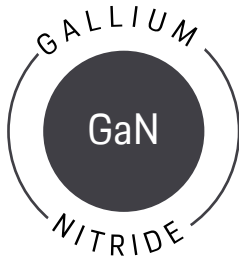
Continuous innovation to target application-specific challenges



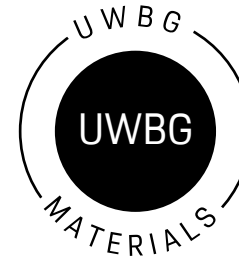
Main driver for mass consumer applications and highest maturity in process, manufacturing and supply chain



Industrialization and establishment of supply chain to enable energy efficient transition to CO₂-neutral technologies



Ramping up capacity and overcoming manufacturing challenges (e.g. Infineon with first 300mm wafer)

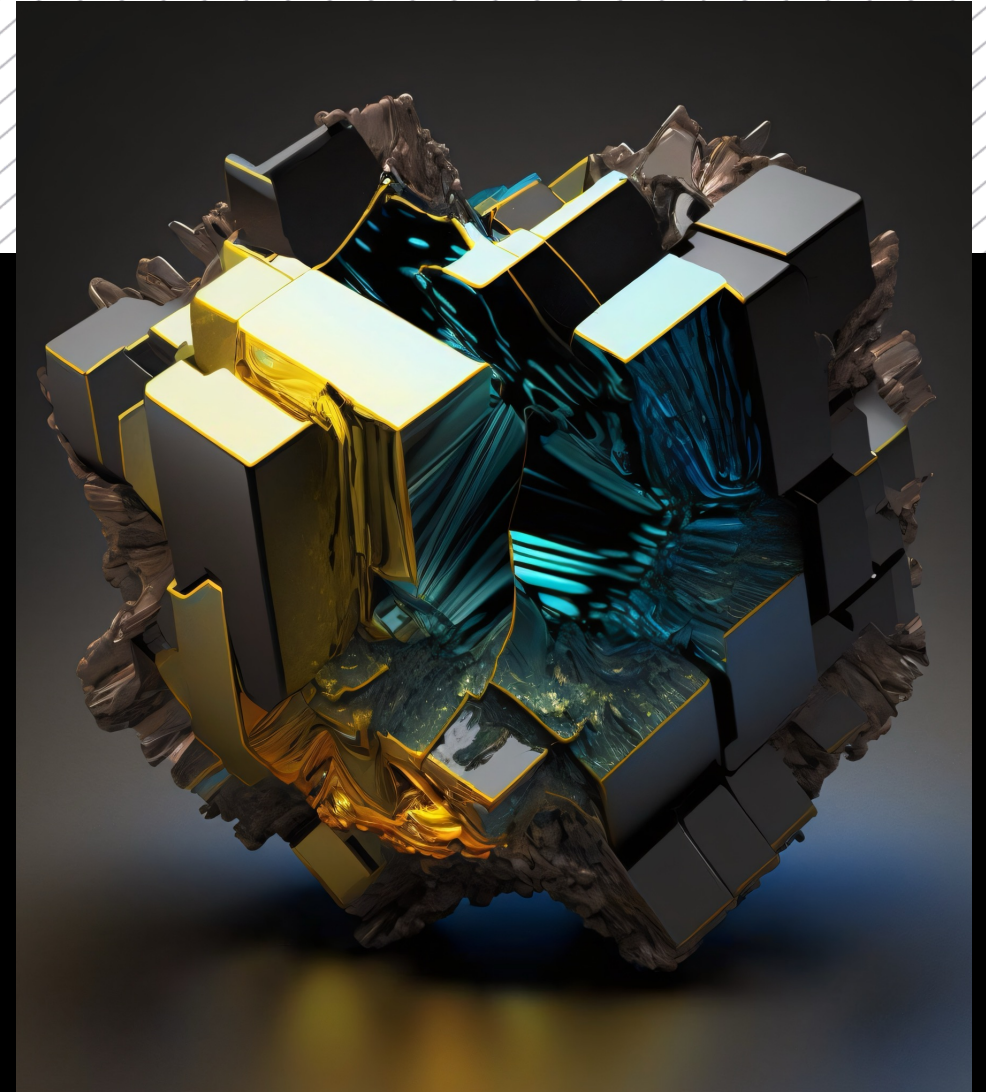


Multiple promising technologies ready to reach critical mass with specific capabilities

WRAP-UP

Substantial technical
benefits make silicon
carbide highly relevant to
decarbonize many sectors

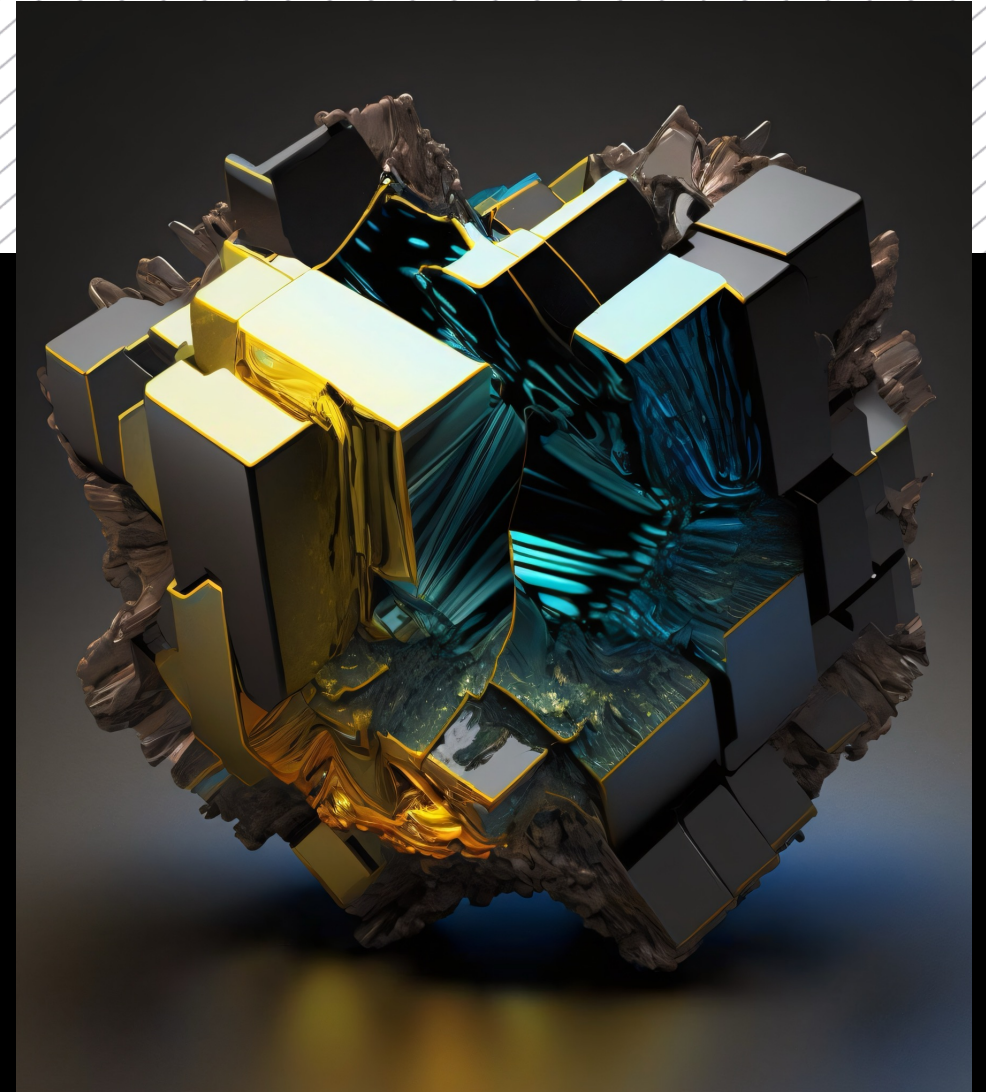
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WRAP-UP

**Automotive xEV platforms
will be the main driver,
but global adoption rate
remains uncertain**

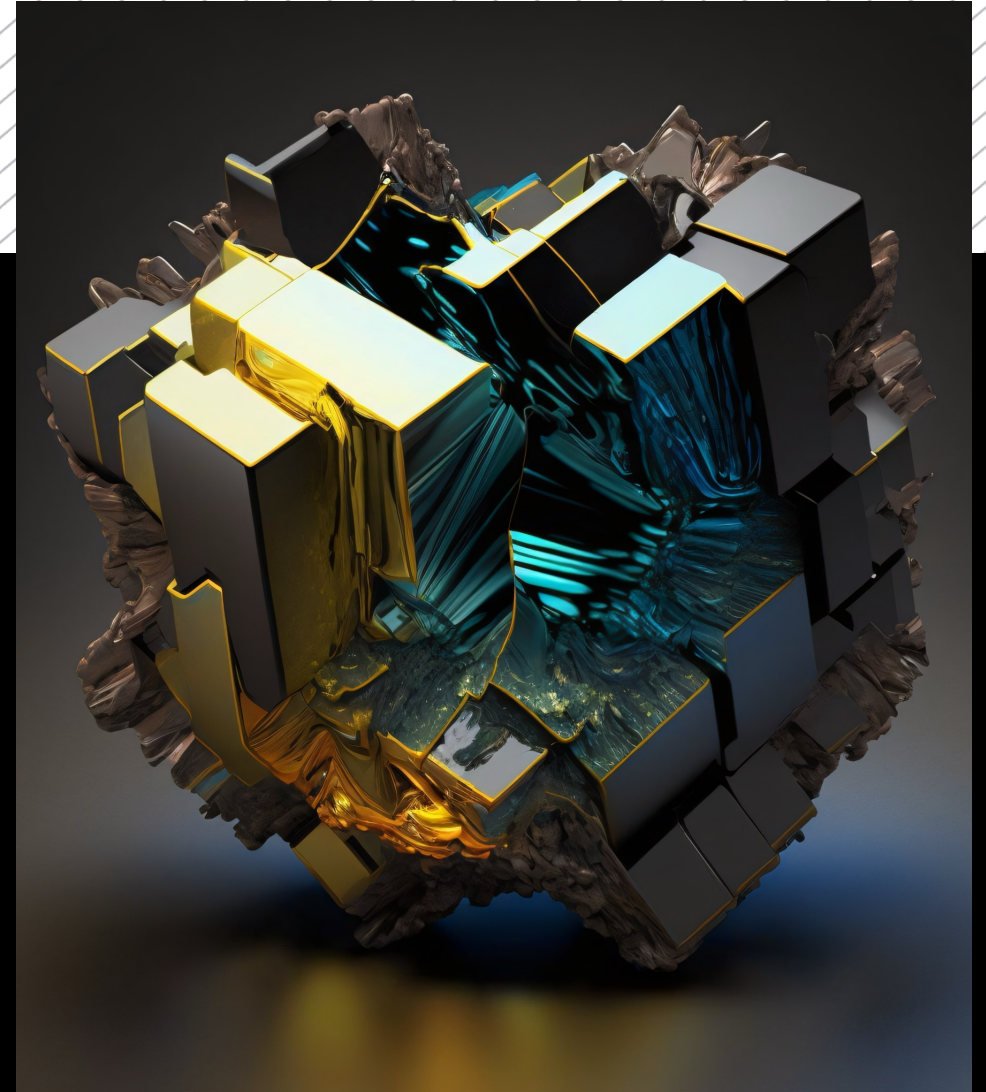
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WRAP-UP

Capacity ramp-up and price erosion have brought first investments to a halt: Need for efficiency & innovation

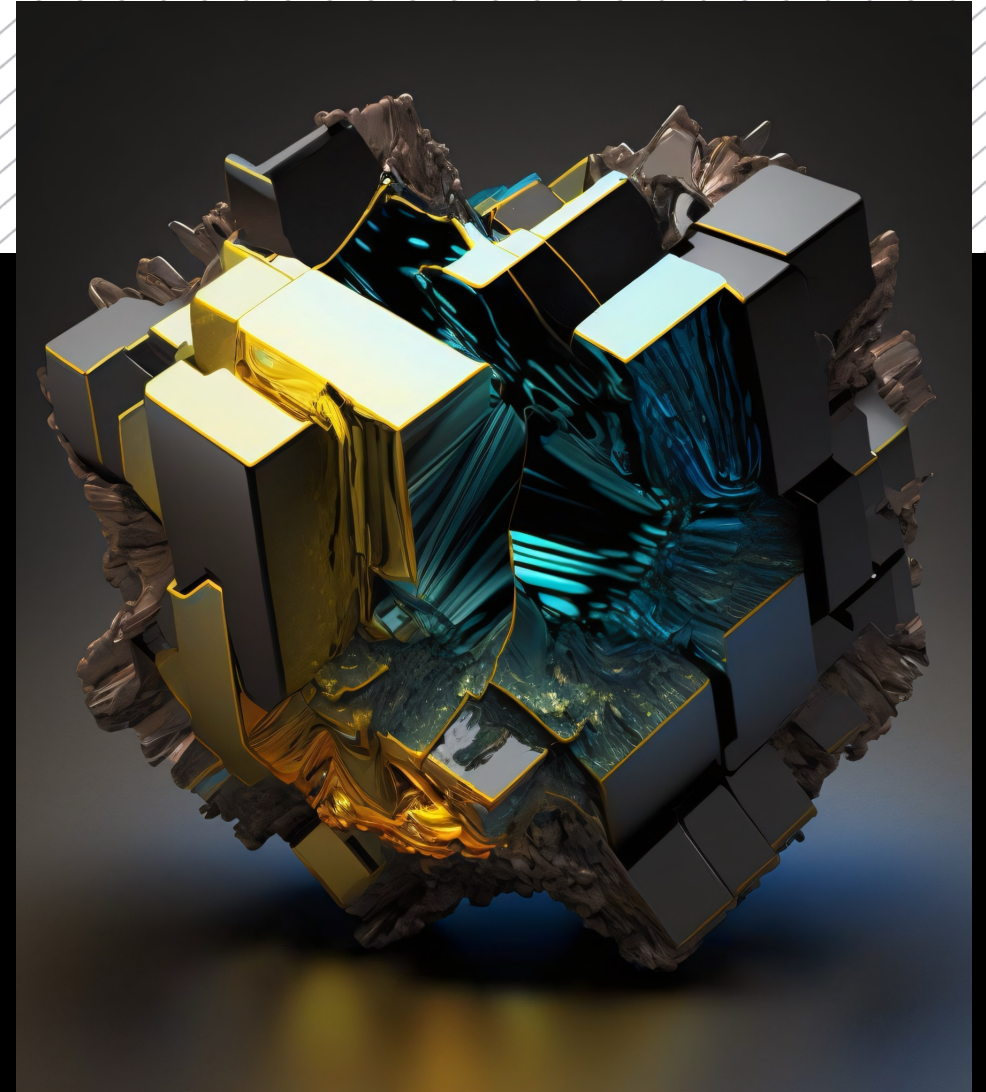
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WRAP-UP

**Standardization, automation
and AI will play a crucial role
in creating a **dynamic**
manufacturing ecosystem**

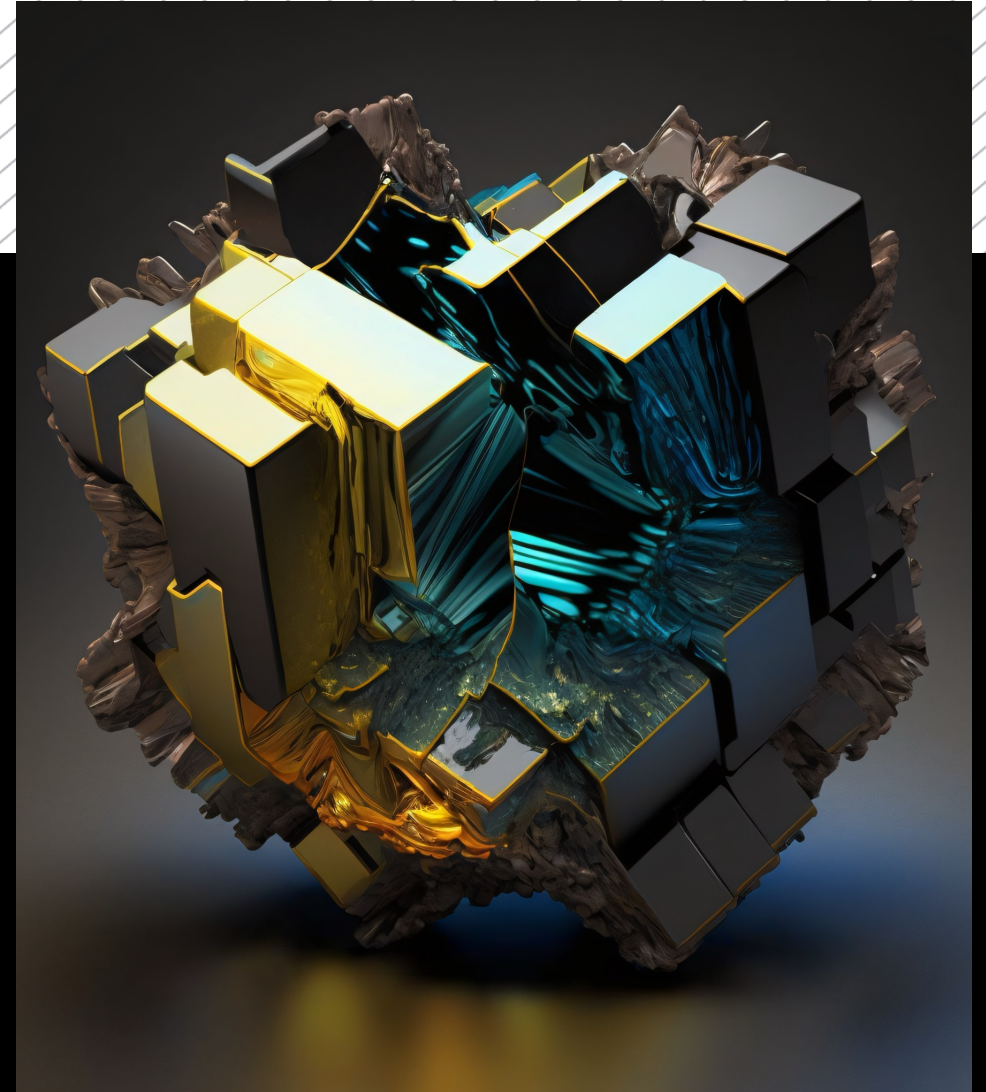
01 02 03 04 05



WRAP-UP

Balancing technological advancement and system design contributes to improved competitiveness

01 02 03 04 05



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