

INTELLIGENCE TO SHAPE YOUR TOMORROW

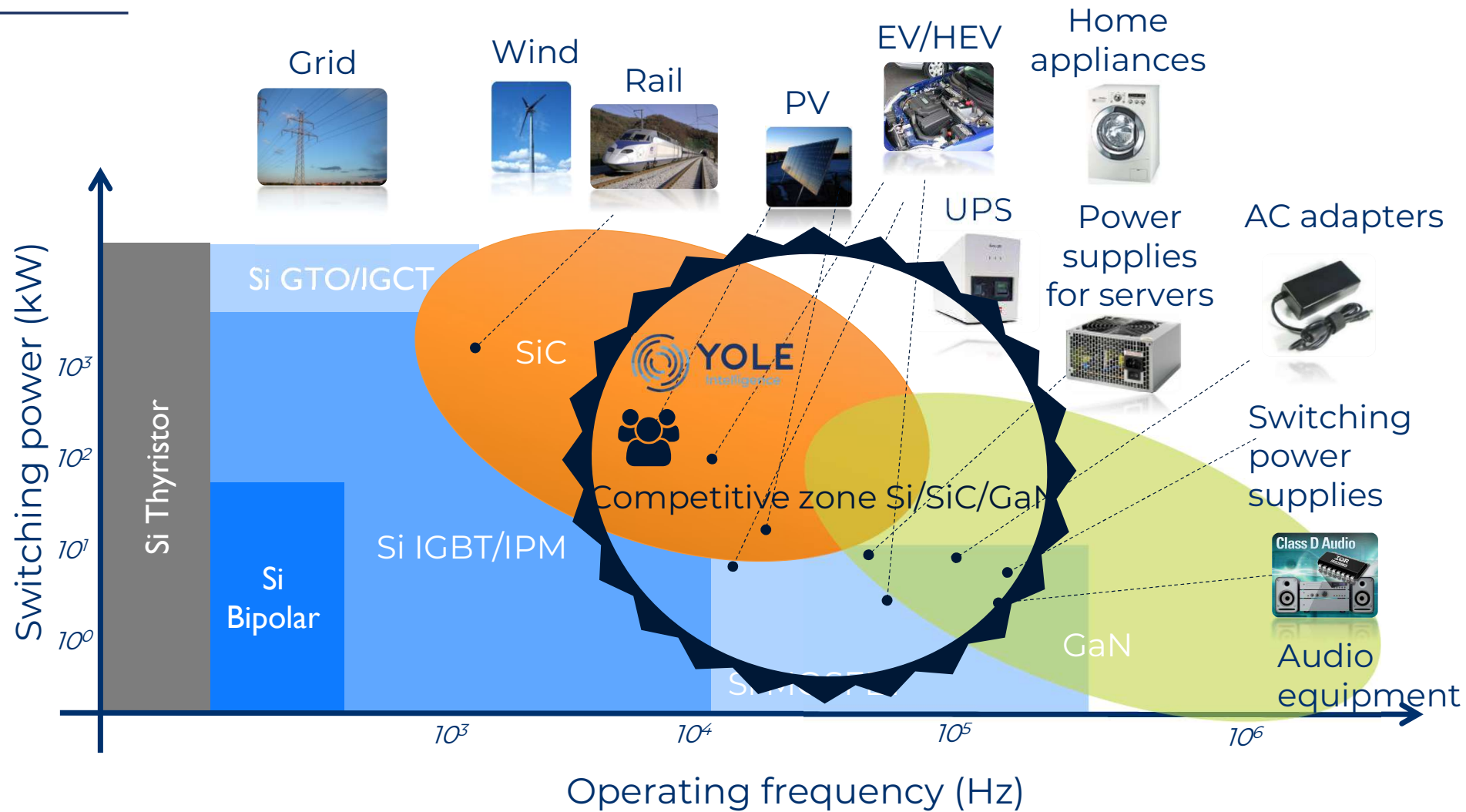
Power SiC/GaN market update

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POWER DEVICE POSITIONING AS A FUNCTION OF POWER AND FREQUENCY

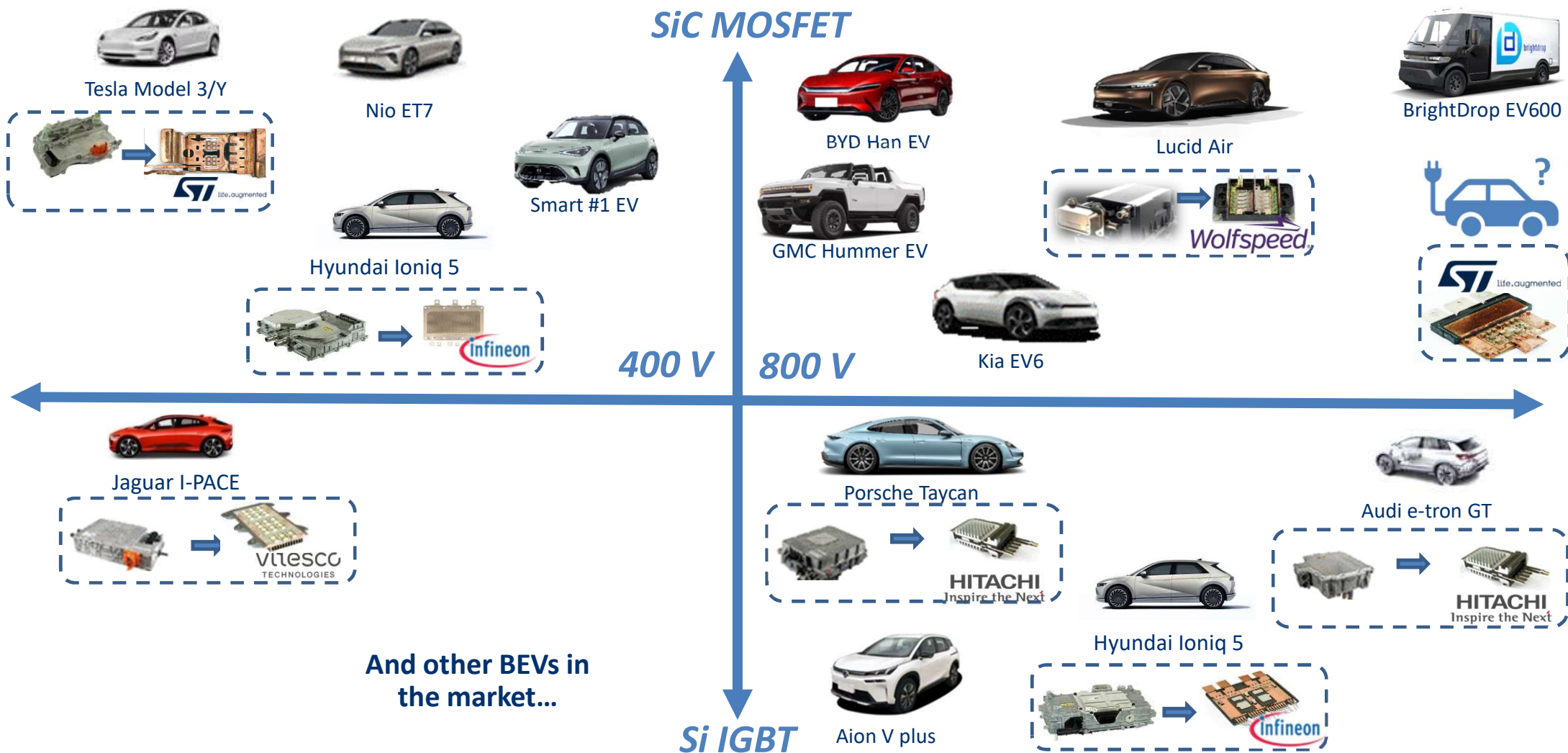


Power SiC Market Overview

SiC modules in Automotive




















Roadmap of BEV With System Voltage & Power Semiconductor Choice





SIC DESIGN-WIN MATRIX AS OF Q1-2023

Leading SiC device players' volume production at OEMs (non exhaustive list)

OEM SiC device												
	✓	✓ ✓										
		✓	✓							✓		
	✓			✓	✓	✓ ✓			✓			✓
				✓	✓	✓	✓	✓			✓	
											✓	

Non-exhaustive list

- As of 2023, major OEMs are looking for double-sourcing SiC devices for their current and future models to be released.
- It's a non-exhaustive list.
- The information is based on Yole's understanding, sources from press releases and industry feedback.
- In Mar-23, Tesla stated the cost reduction on their next generation powertrain, which included 75% reduction on SiC. However, the ODM didn't share more details. Please refer to the slide for the scenario and analysis based on currently available information. [Link](#)

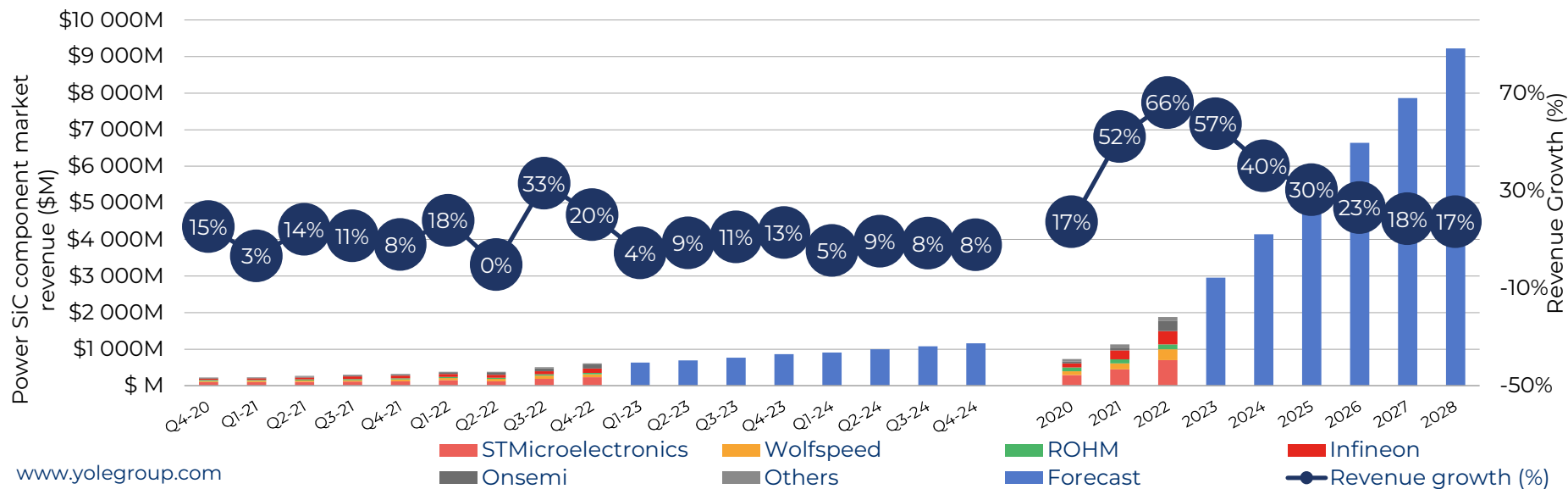


Inverter

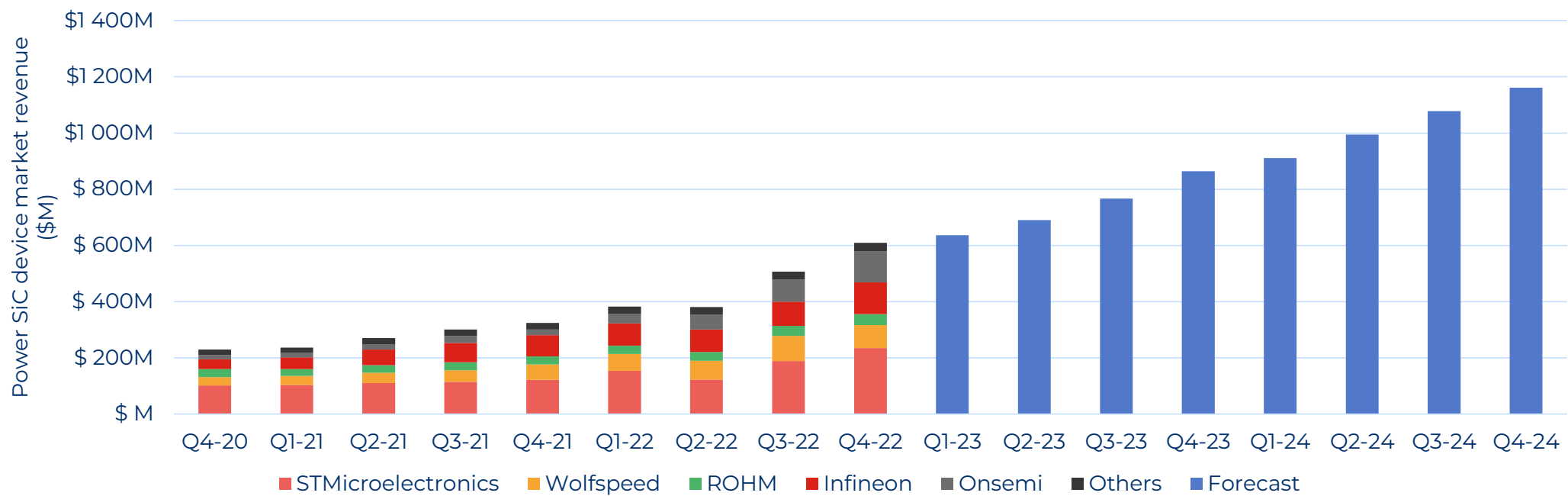


OBC & DC-DC

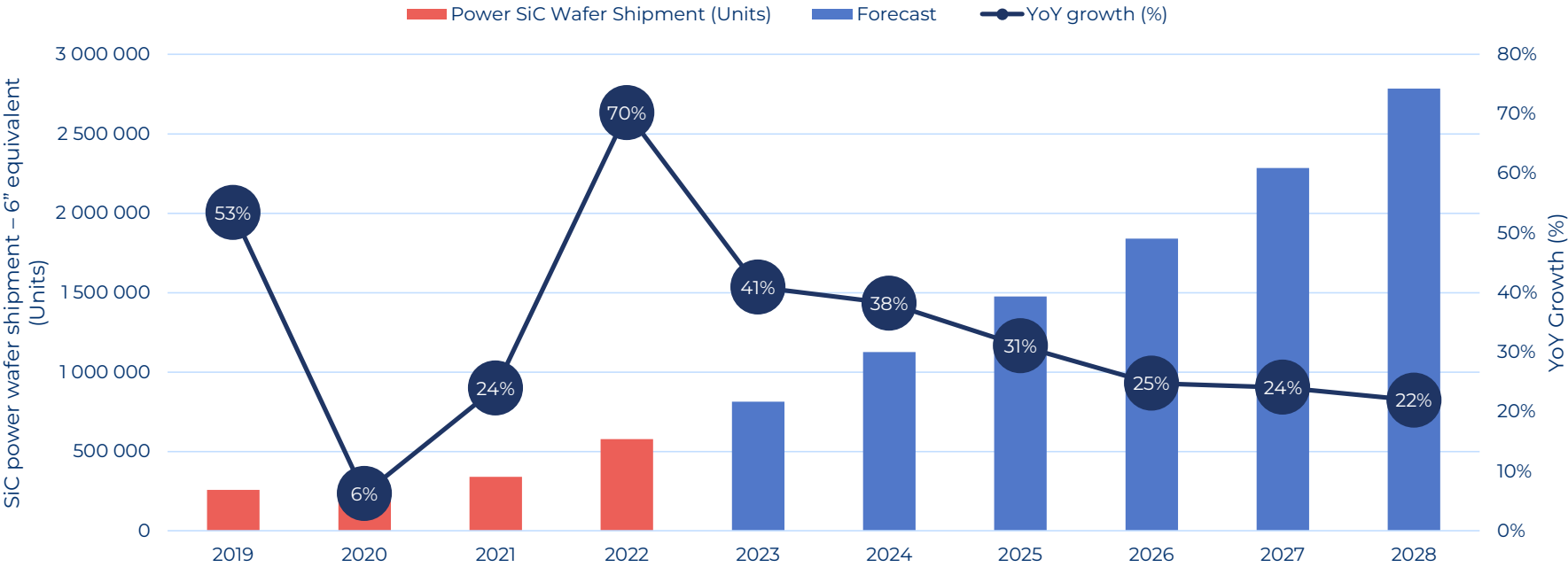
POWER SiC DEVICE REVENUES - MARKET DYNAMICS



QUARTERLY POWER SiC COMPONENT REVENUE



POWER SiC SUBSTRATE SHIPMENTS – 6” INCH EQUIVALENT





TESLA'S NEW APPROACH TO USE 75% LESS SiC?

Yole's scenarios

Tesla stated the cost reduction on their next generation powertrain, which included 75% reduction on SiC, but what does that mean?

With limited details in the presentation, there are scenario and potential impacted provide in this slide.



Scenario 1: less device count

Tesla is the first OEM implemented SiC in EV, the solution is based on most innovative technology available in 2017. This 2-in-1 mini module, with 48 bare dies in the inverter is the design almost 10 years ago. From today's perspective, the level of integration is low and the performance of SiC is also limited.

Meanwhile, 800V is the enabler for higher efficiency and fast charging, SiC is the best candidate.

Therefore, a full-SiC module with a lower bare die count, e.g., a reduction from 48 to 12 to replace the current solution with a more advanced design in terms of integration for a more compact solution, could be a better option from cost and scalability perspectives.

Scenario 2: smaller vehicle not requiring high power

Tesla wants to create more accessible vehicle for growing the car sales in volume, for example the new Model 2 or Model Q to be launched in the coming years will need the maximum scalability with a lower cost to support the massive shipment. Therefore, a less powerful car requires less SiC content. However, it's unlikely implanted in current Model 3.

Scenario 3: replacing SiC by other materials

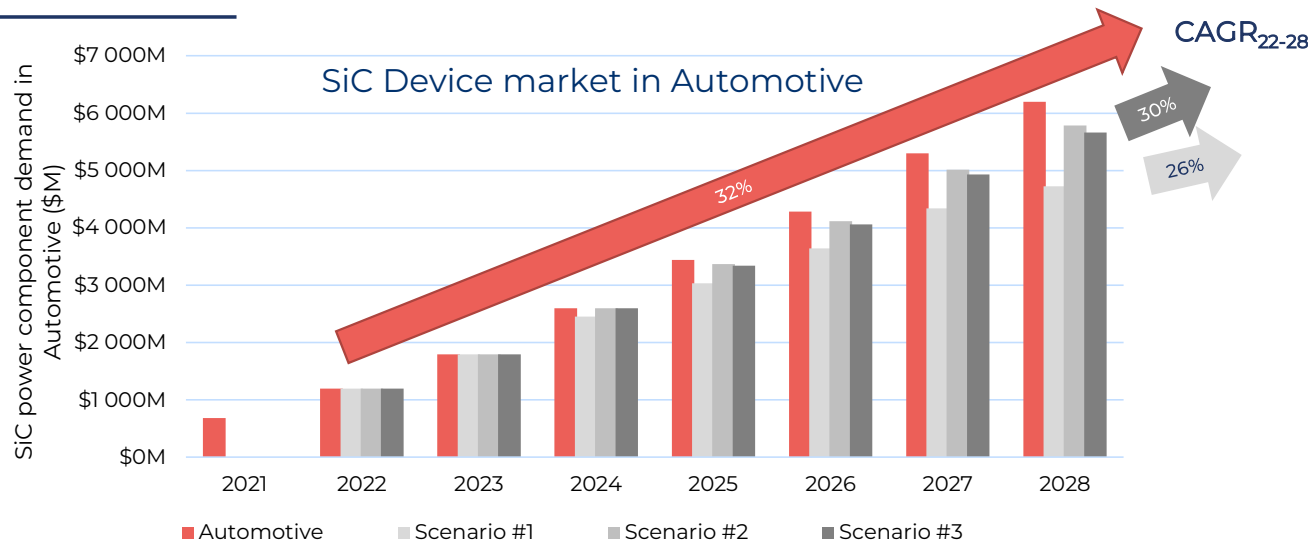
Both SiC and Si-IGBT are already the case for dual-motor models. Does it refer to the opportunity for GaN-on-Si? In our estimation, GaN-on-Si in main inverter is in a 10-year timeframe.

Impacts:

- No short-term impacts on SiC penetration for OEMs, especially for the coming 800V vehicles.
- The trend is in line with our view of transition of the focus, from raw materials to device and system integration.
- Pressure on SiC IDMs to launch more performance and cost competitive solutions, the requirements will arrive with other OEMs.
- Potential negative impacts on the wafer shipment, if a more compact module design is taken.
- Minor impacts on SiC device market, 1200V-rating SiC device and power module have higher price.
- Opportunities for new technologies to penetrate the market, e.g. trench SiC MOSFET for higher power density and new materials. Power GaN could be the option in a long-term perspective.
- Some SiC companies' valuations are also affected. It could lead to some M&A as SiC technology is still not fully accessible to all end-system players.

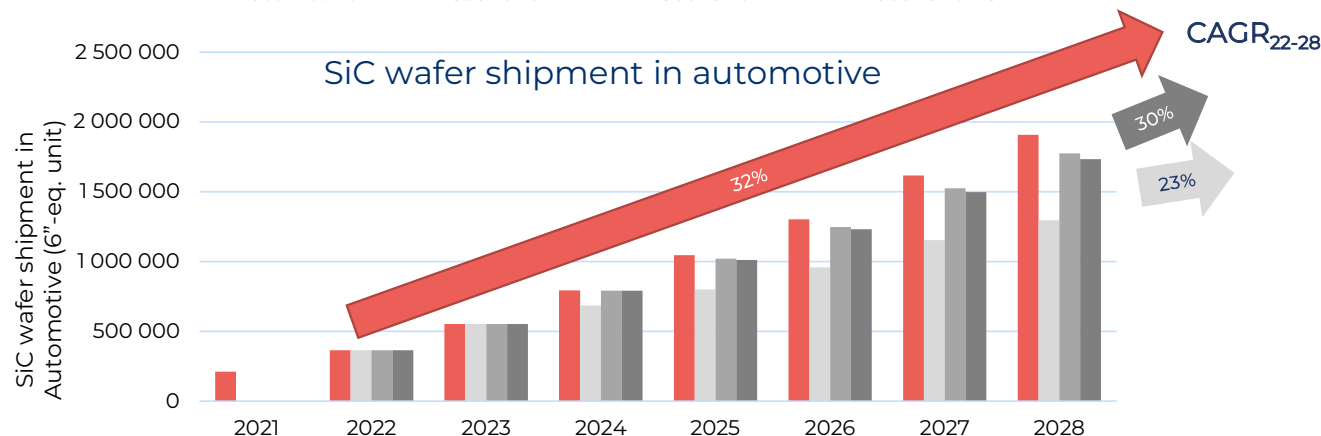
TESLA'S NEW APPROACH TO USE 75% LESS SiC?

Scenario analysis on the forecasts of SiC device market (\$M) and wafer shipment



Scenario 1 is expected to impact more the wafer shipment, than device market. Less bare die count, from 48 to 12, directly leads to less wafer demand. However, larger die size to carry high power is needed to remain the performance and reliability.

At device level, larger die size and higher level of integration make the device price not decreasing as for wafer shipment. The benefit is to have lower cost at system level, in the inverter. It's expected to remain the growth rate at 26% in the timeframe of 2022-2028.

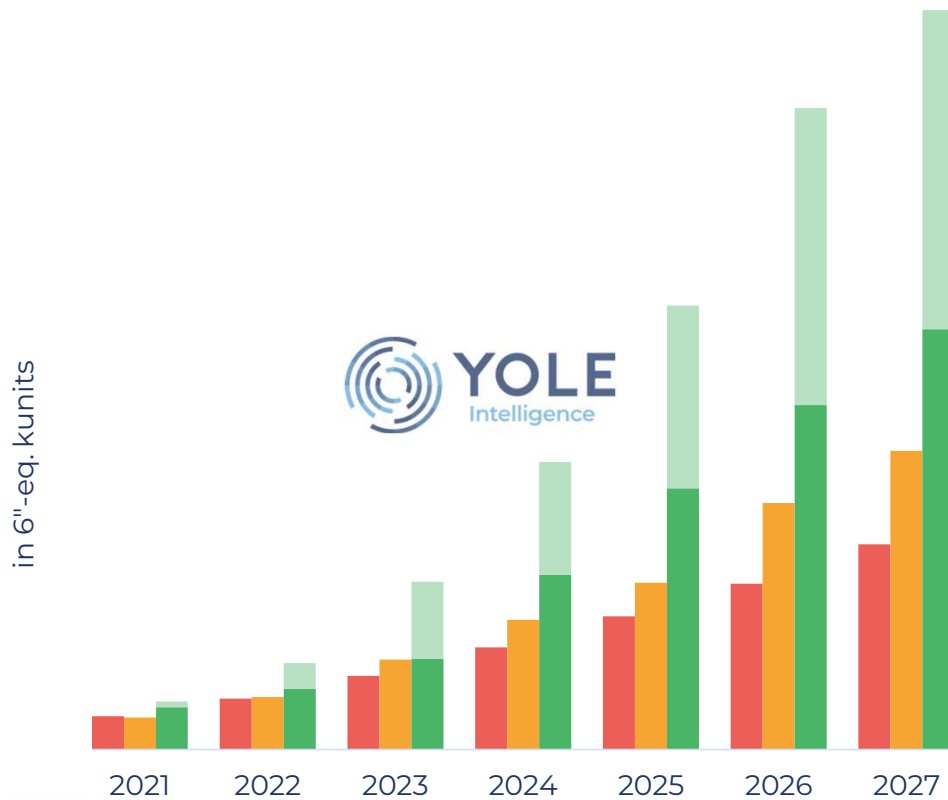


Scenario 2 & 3 depends on how quick the time-to-market of Model 2. This model is expected to be shipped in high volume in long-term, in order to supply to majority of customers. However, the ramp-up also depends on how the OEM allocate the production in different facilities. It's expected to reach more than 7% of Tesla's total volume.



DEMAND VS CAPACITY

The massive building-up in wafer capacity, especially the new entrants in China



Strong wafer capacity expansion likely to lead to price reduction of SiC wafers and devices

Actual volume of SiC wafer production in units do not take into account the quality and yield, especially for new entrants

In the near future, vertical integration may not be so important (4" and 6" compared to 8")

■ wafer capacity of Chinese players

■ wafer capacity (leading US&EU players)

■ Front-end capacity (top 5 players)

■ wafer demand based on Yole's forecast (yield is taken into account)



SiC N-TYPE SUBSTRATE/BOULE CAPACITY FORECAST (6"-EQUIVALENT PER YEAR)



In our understanding, the supply matched the demand in 2022, and more volume will be delivered according to the expansion. Please note, **capacity doesn't equal production**; utilization rate, yield, and quality are critical in SiC substrate production. Looking into the coming years, the demand for high-quality substrate and 8" substrate will also grow quickly. Therefore, the supply chain could still be tight.

^[1] The capacity can also be used for semi-insulating SiC growth used for RF GaN applications. Overall, most (80%) of the total capacity is estimated to be used for power SiC applications.

^[2] Based on the industry feedback and estimation, non exhaustive list

^[3] onsemi acquired GTAT for \$415M in Q4-2021.

^[4] Resonac, formerly Showa Denko, acquired the SiC substrate business of Nippon Steel in 2018.

Current capacity

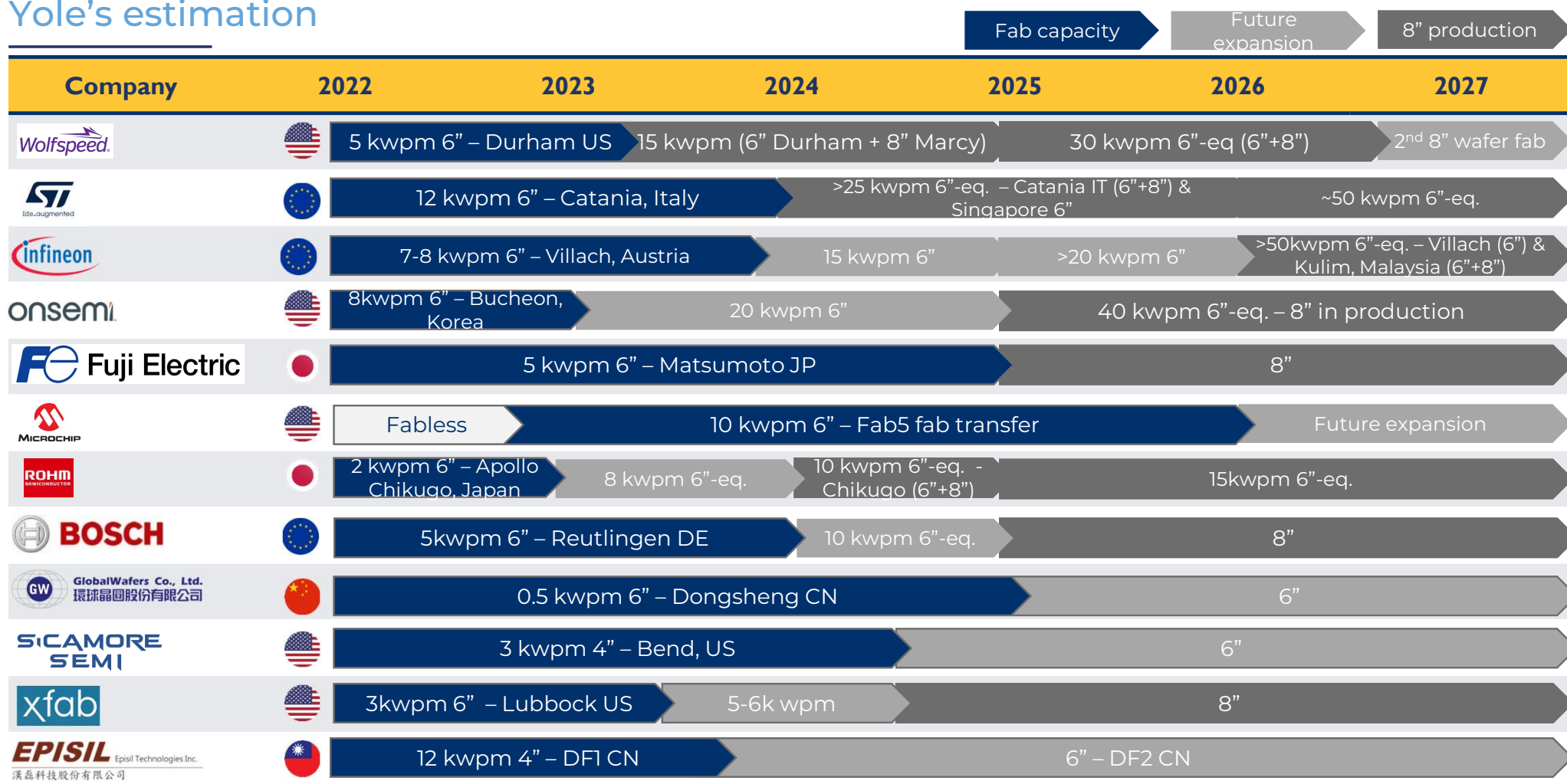
Future capacity

S.C. + S.I. substrates ^[1]



LEADING POWER SiC DEVICE SUPPLIERS' CAPACITY FORECAST

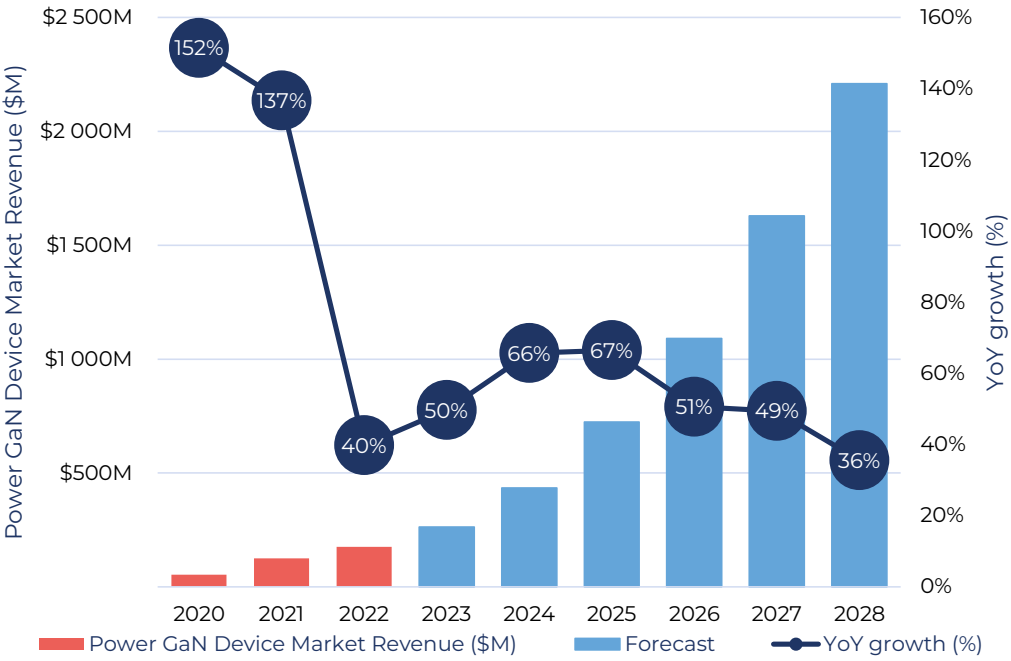
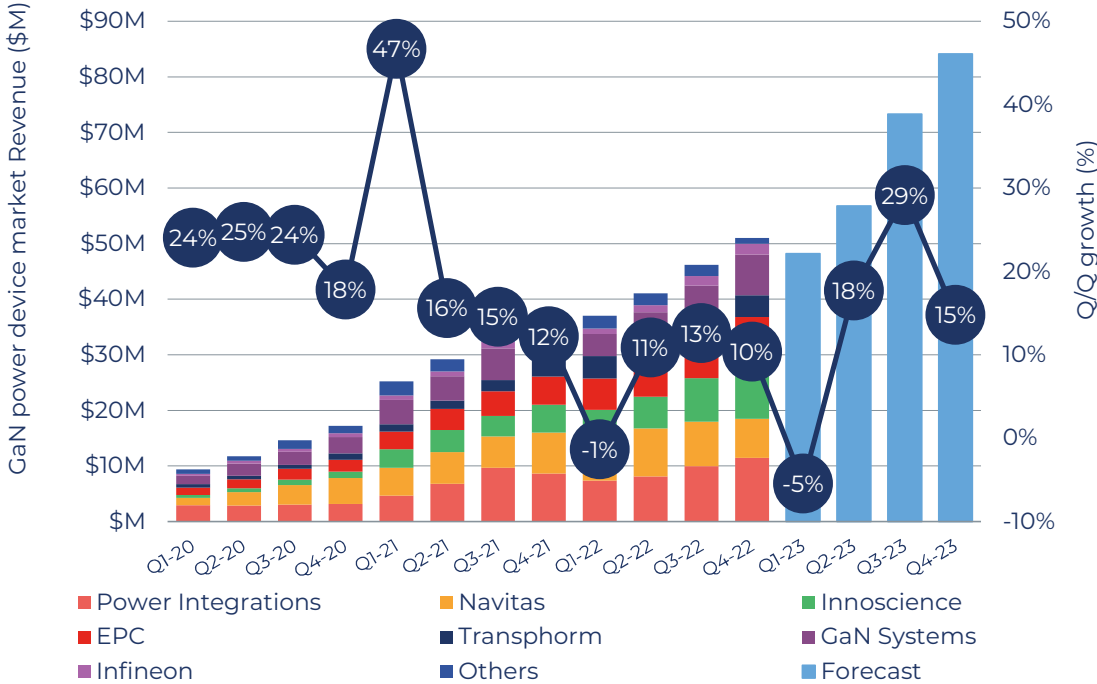
Yole's estimation



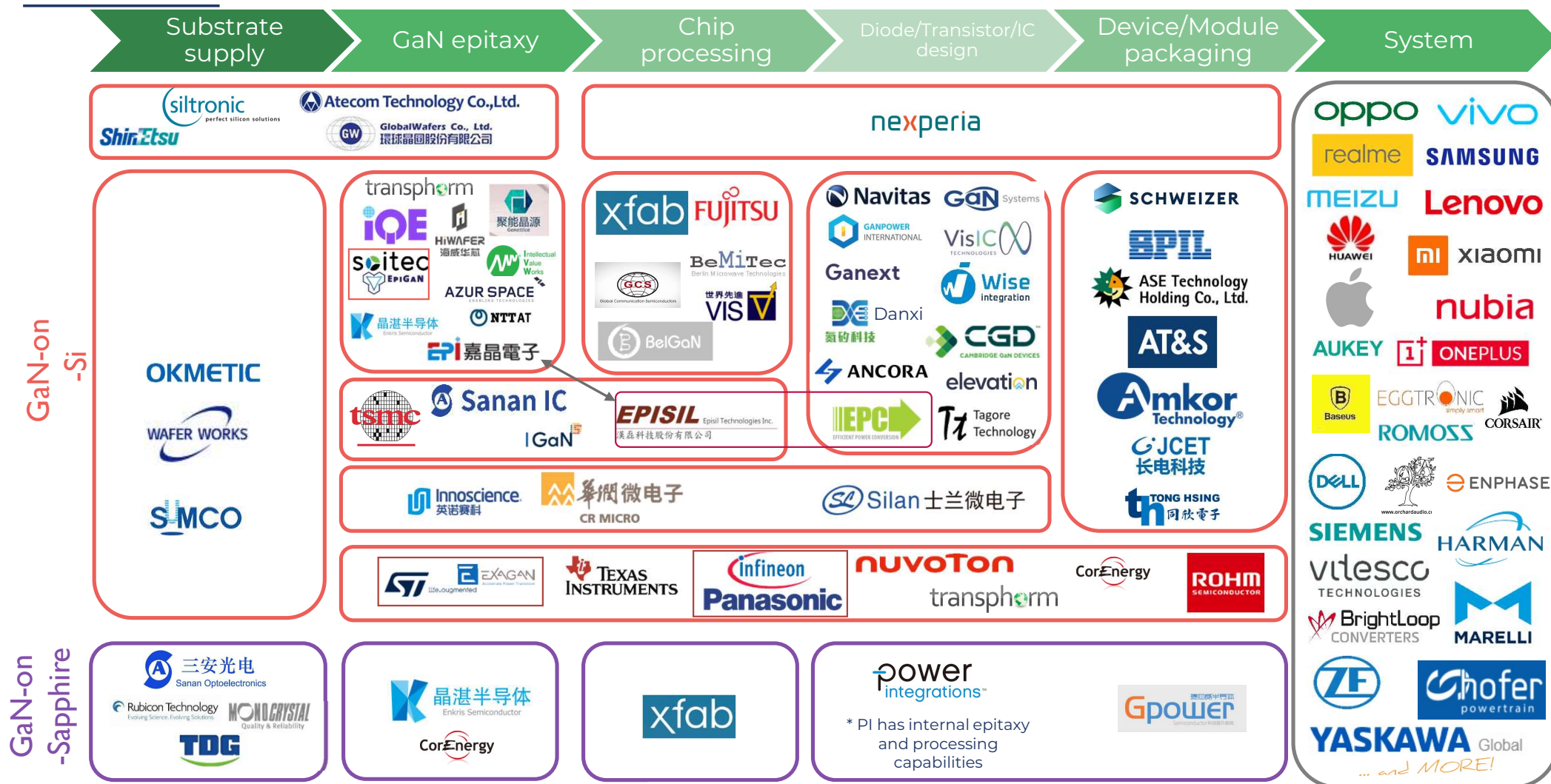
Following the expansion at substate level, the capacity at device level is accelerated due to the CAPEX announced by leading players.

Power GaN Market evolutions

POWER GaN DEVICE MARKET DYNAMICS



POWER GaN SUPPLY CHAIN AND BUSINESS MODELS AT A GLANCE



- YOLE Intelligence**
- Non-exhaustive list, including R&D
 - Most GaN epihouses could also have GaN-on-sapphire capability.
 - Infineon and Panasonic are partnering on an 8" platform

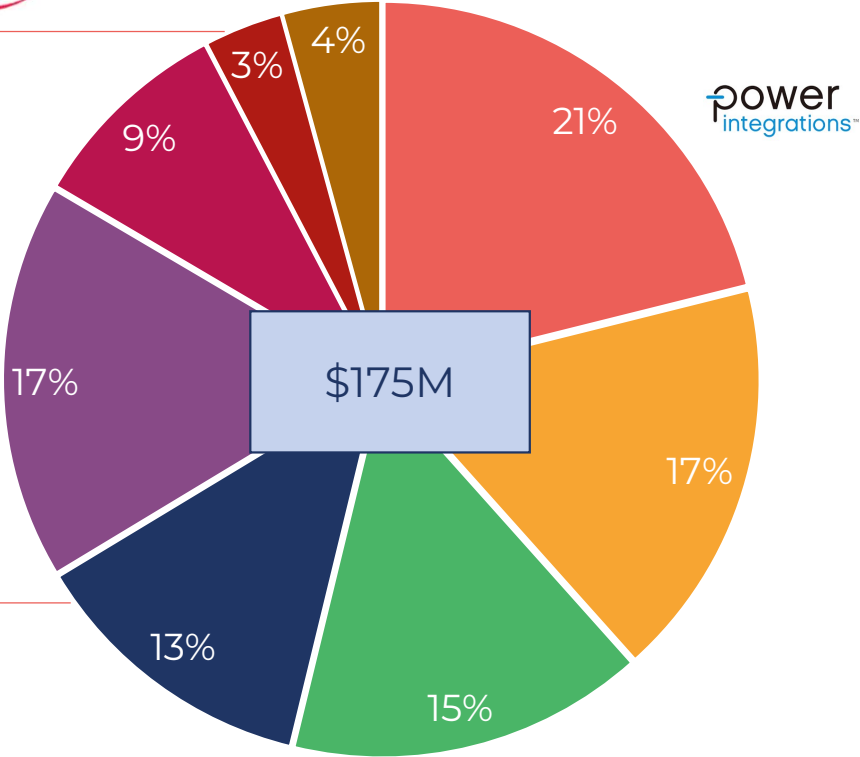
- STMicroelectronics acquired the majority share in Exagan in Q1-20.
- EPC has an asset-light vertically integrated model working exclusively with Epasil and internal epitaxy capabilities at Epi-Precision

POWER GAN DEVICE MARKET SHARE IN 2022 : INFINEON'S MOVE

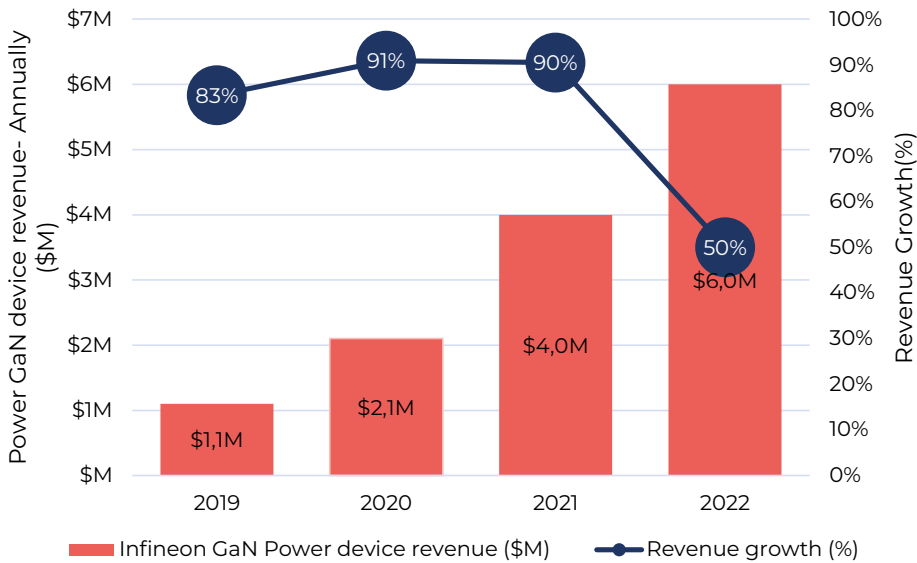
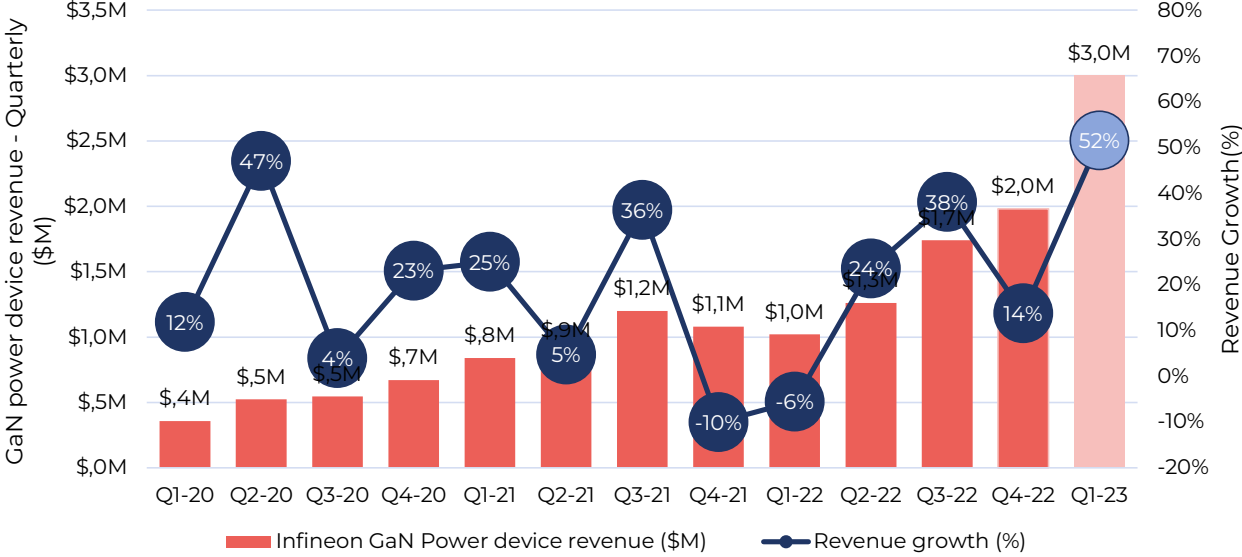


Larger portfolio
Team expertise
Patents
Clients/ongoing projects

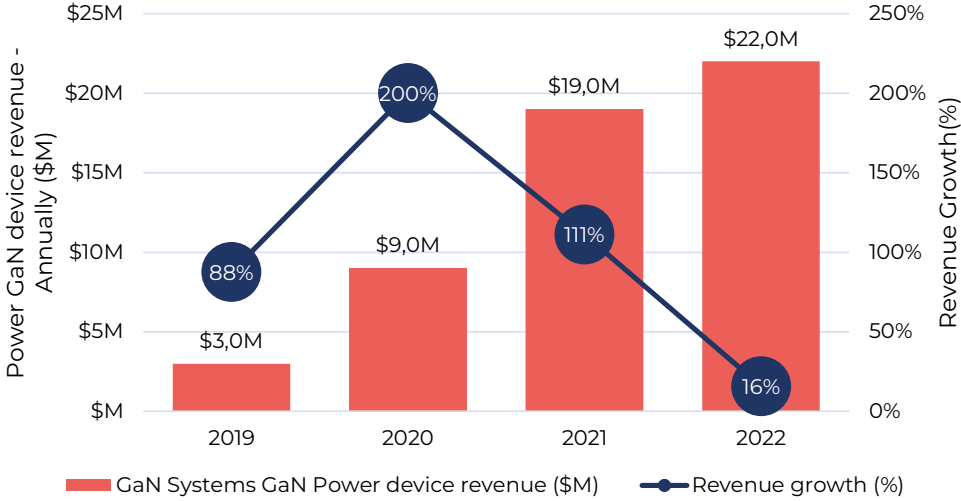
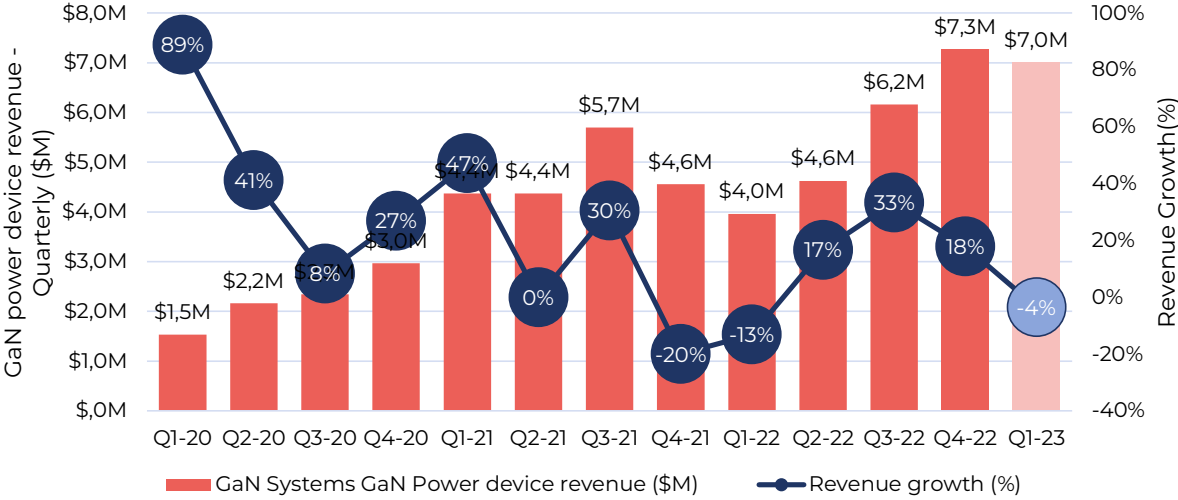
16%



INFINEON – POWER GaN DEVICE REVENUE



GaN SYSTEMS – POWER GaN DEVICE REVENUE

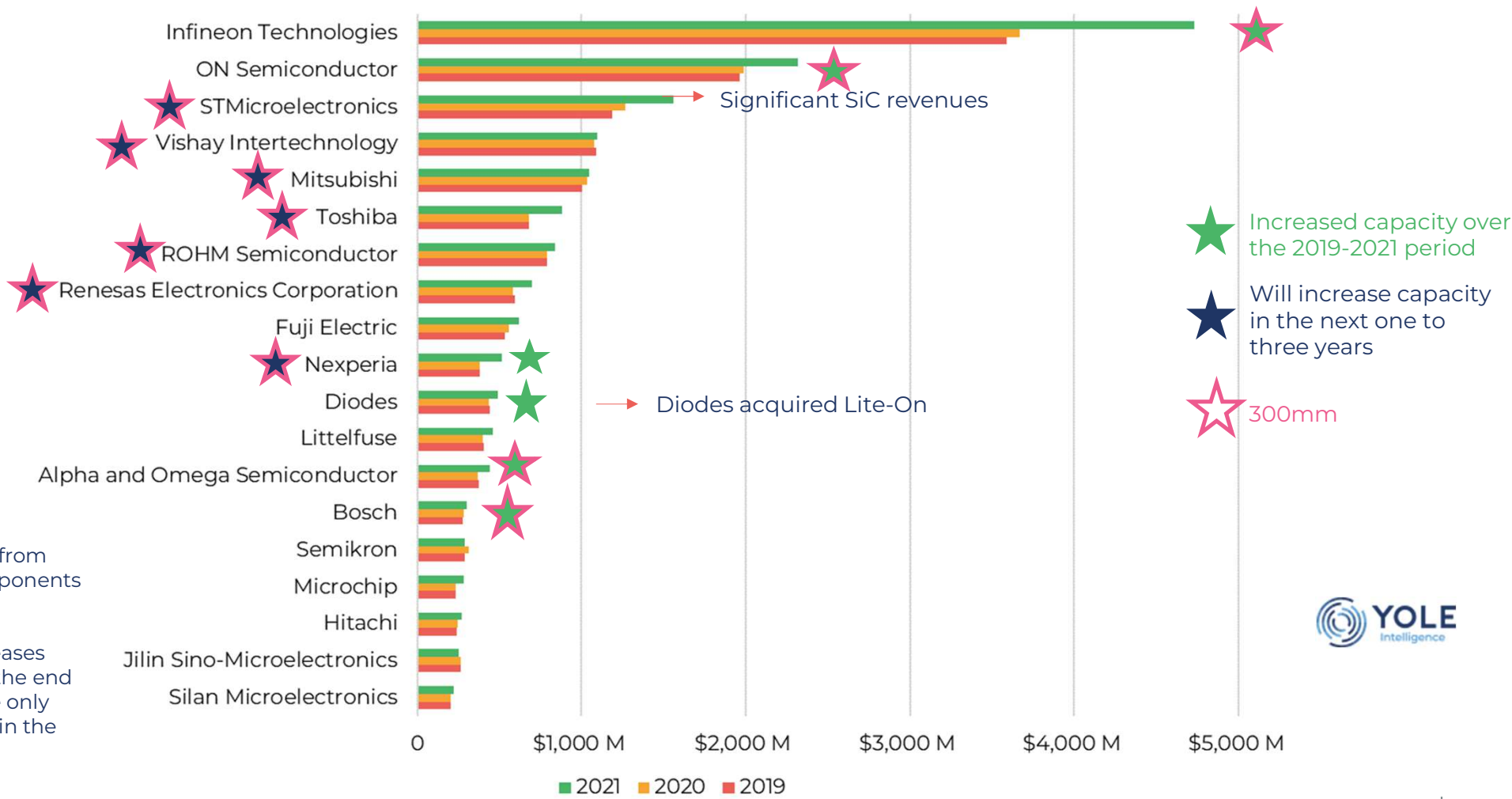


A conclusion

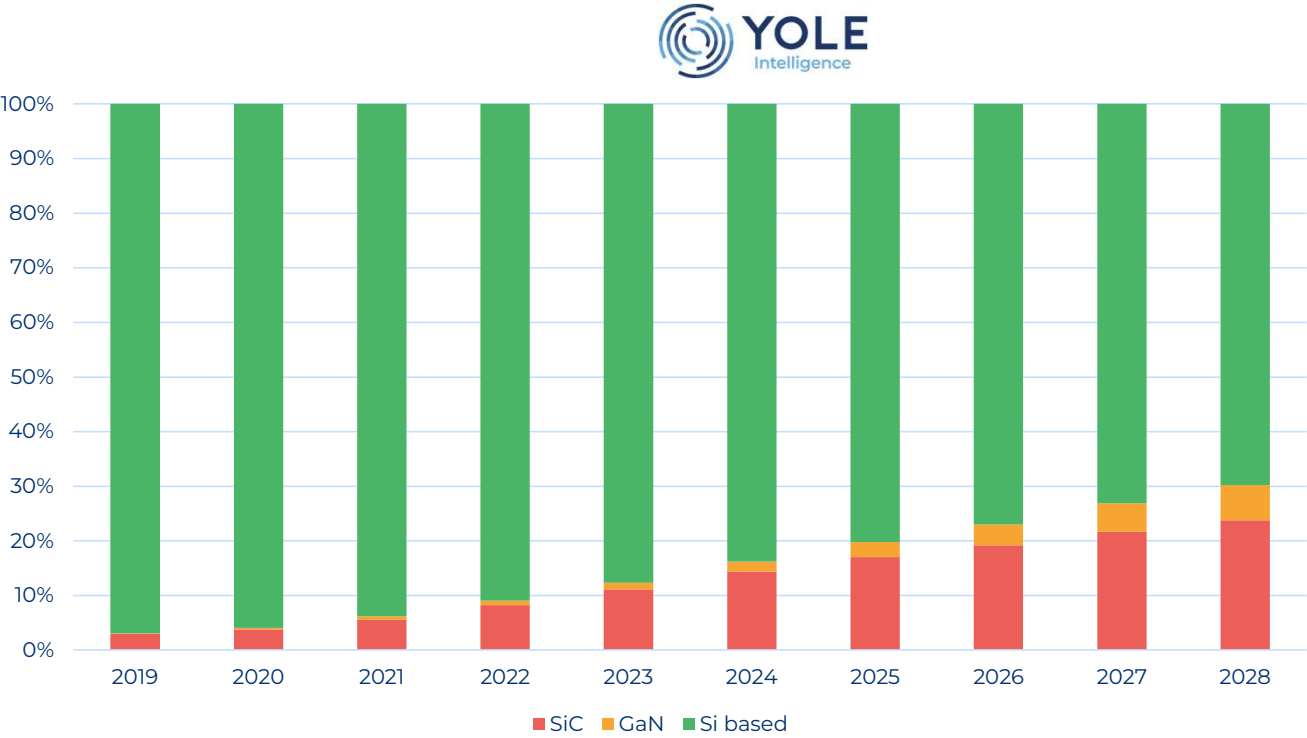
2019-2021 KEY PLAYERS AND THE POWER ELECTRONICS LANDSCAPE



Power device revenue evolution - 2019-2020-2021

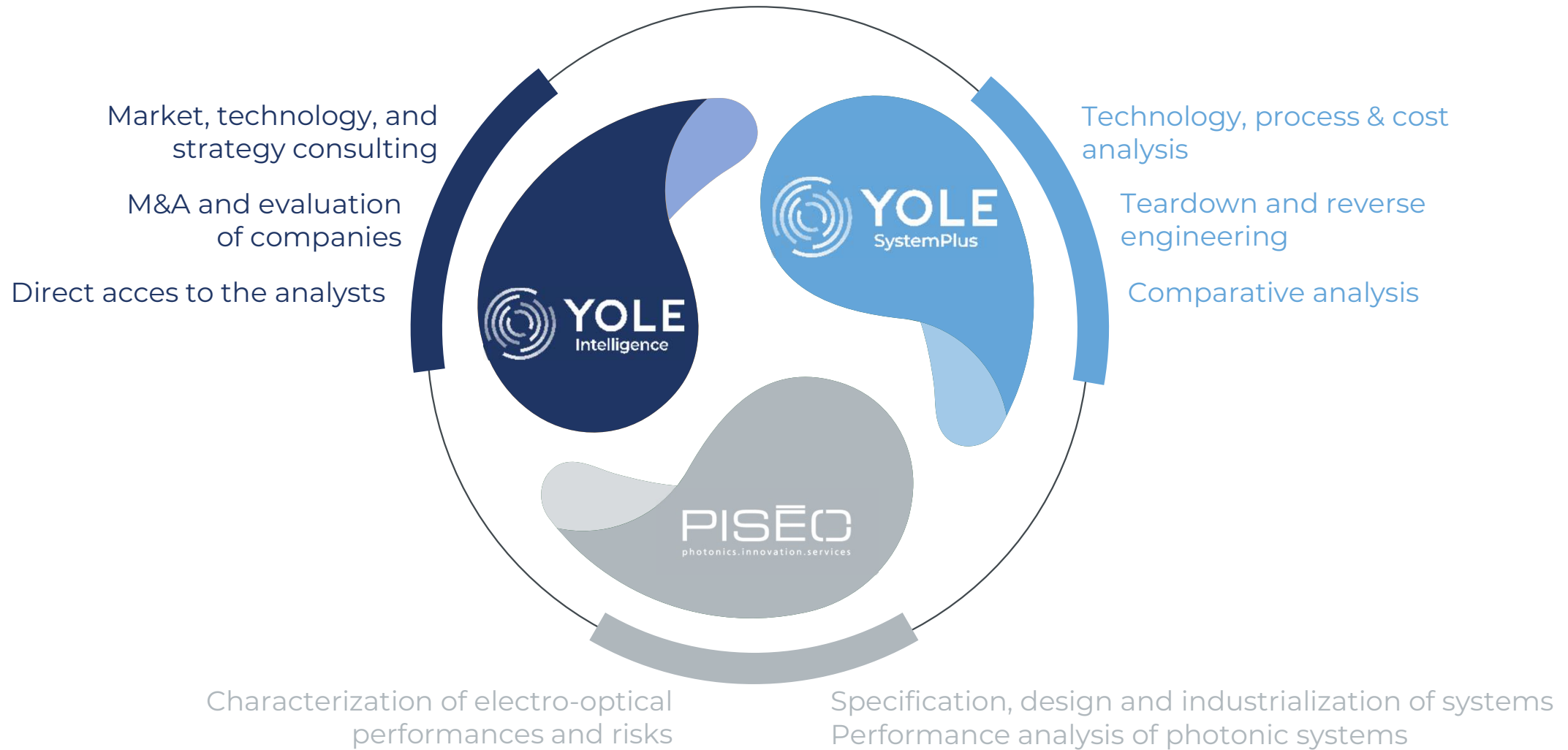


DEVICE REVENUE MARKET SHARES : SiC VS. GaN VS. Si



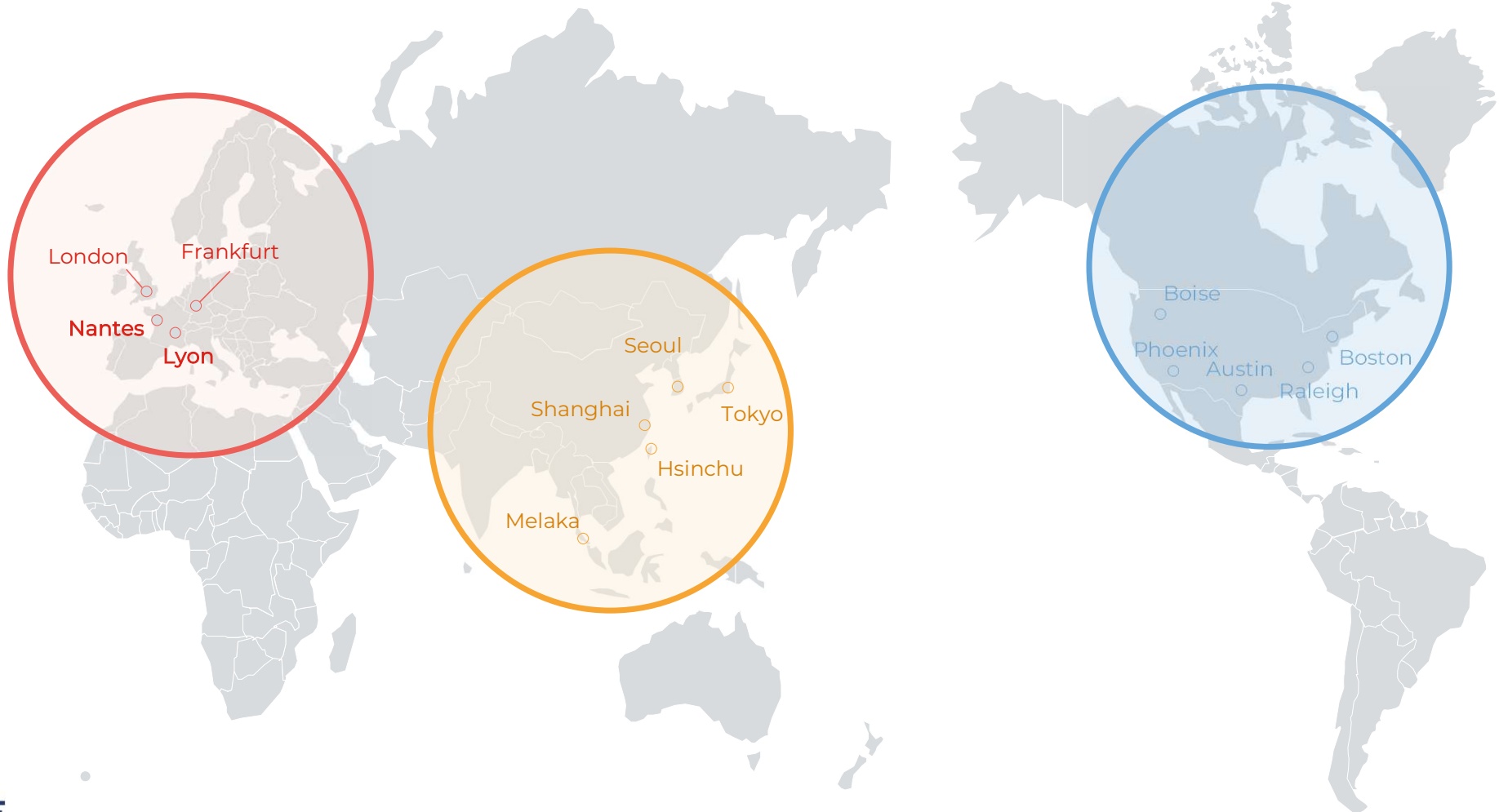
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- › Lighting & Displays
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- › CMOS Image Sensors
- › Micro-controller
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- › Computing & Memory

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