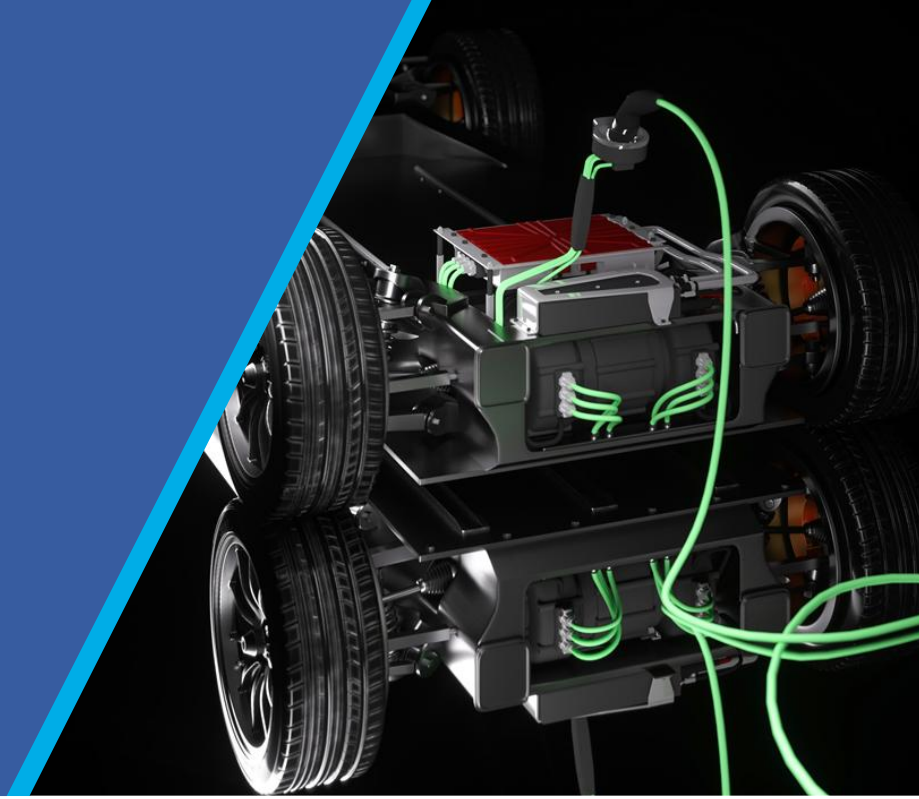
The Progress and Future of GaN Technology for the Automotive Power Electronics Market



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IDTechEx Provides Clarity on Technology Innovation…

Market forecasts

Technology assessment

Market sizing

Technology scouting

Strategic advice

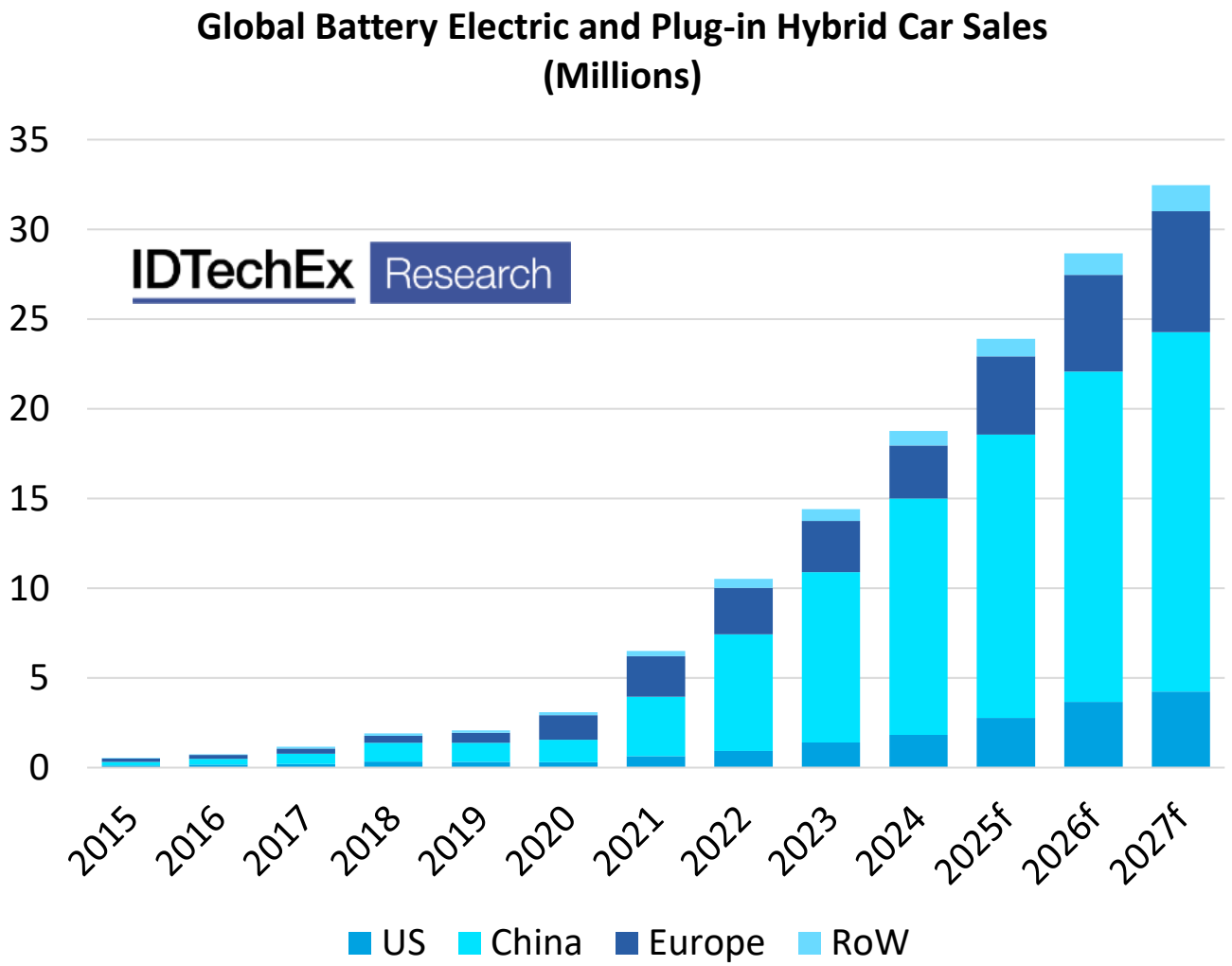
Company profiling

…And Covers a Wide Range of Topics

Wide Bandgap Semiconductors

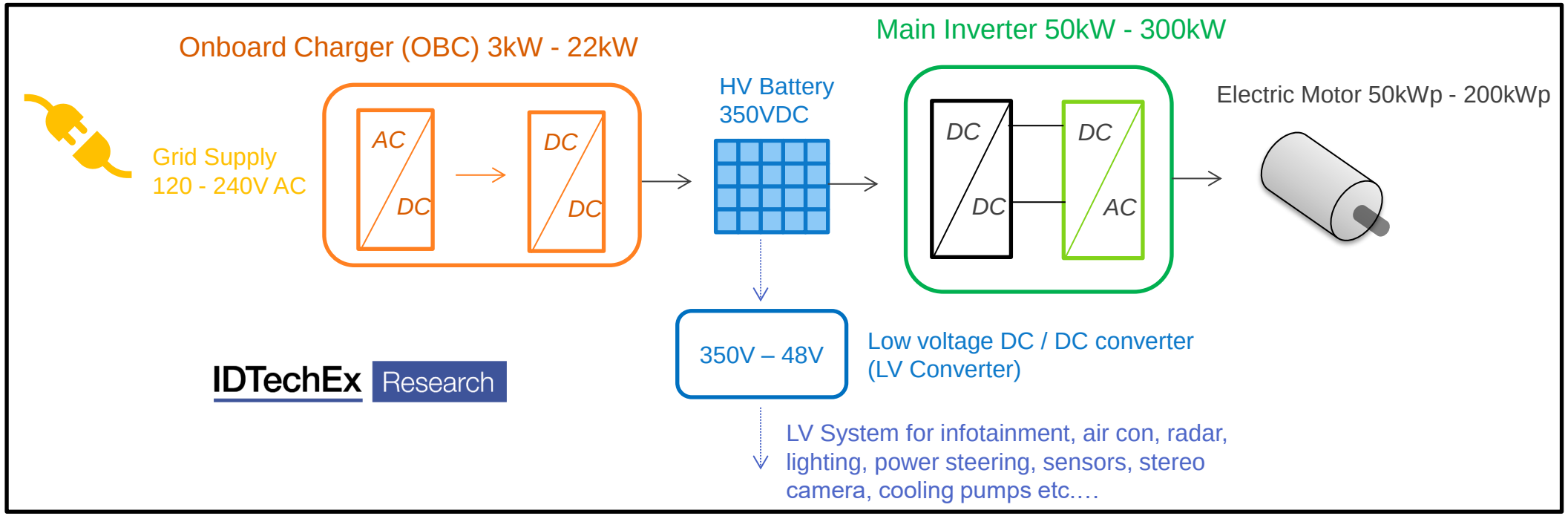
Global EV Sales

- Contrary to recent media reports, the EV market is still growing.
- Governments and OEMs still have announcements in place to drive electrification.
- IDTechEx has other reports that go into more detail on electrification, mobility, and other technologies.
- Key takeaway: demand for power electronics will grow due to the growing EV market



Power Electronics in an Electric Vehicle

- Inverter, typically 100-300kW, DC to three-phase AC.
- Onboard charger, typically 6-22kW, grid AC to DC for battery.
- DC-DC converter, typically ~10kW, high-voltage DC (400-900V) to low-voltage DC (12-48V) for auxiliaries.



Inverter, OBC, DC-DC converter

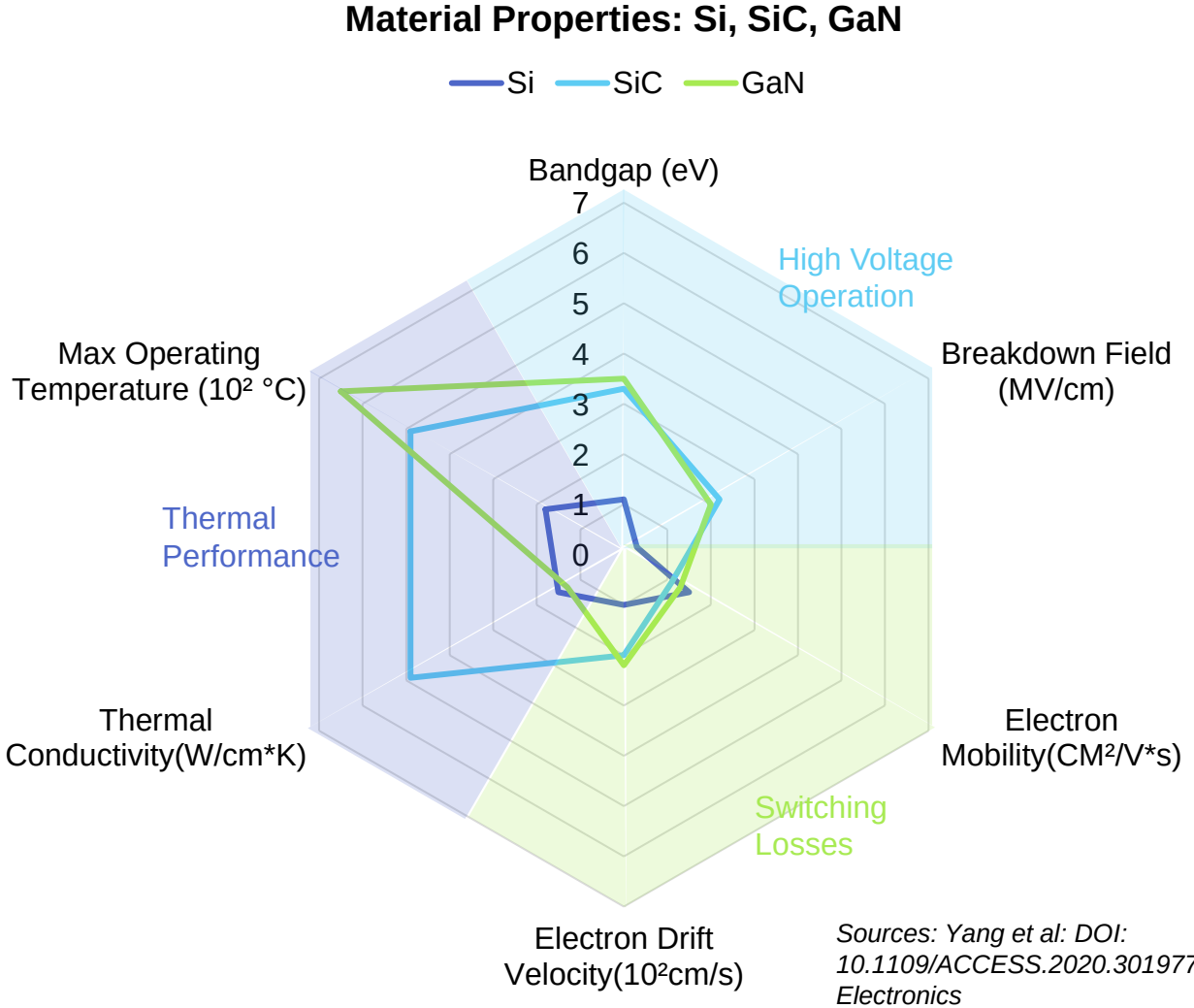
- The power electronics of an EV: inverter, onboard charger, and DC-DC converter, can be segmented by:
  - Function
  - Number of transistors
  - Transistor Technology
- Components need to all be able to handle high voltages (300-900V+), and very reliable (made possible through extensive testing).

Component	Typical Power (kW)	Typical number of transistors	Current Technologies	Future Technologies
Traction Inverter	100-300	24-48	Si IGBT, SiC MOSFET	GaN HEMTs?
Onboard charger	6-22	6-14	Si SJ MOSFET, Si IGBTs, SiC MOSFET	GaN HEMTs
DC-DC converter	~10	6-14	Si SJ MOSFET, SiC MOSFET	GaN HEMTs

What Is Wide Bandgap, and Why Is This Important?

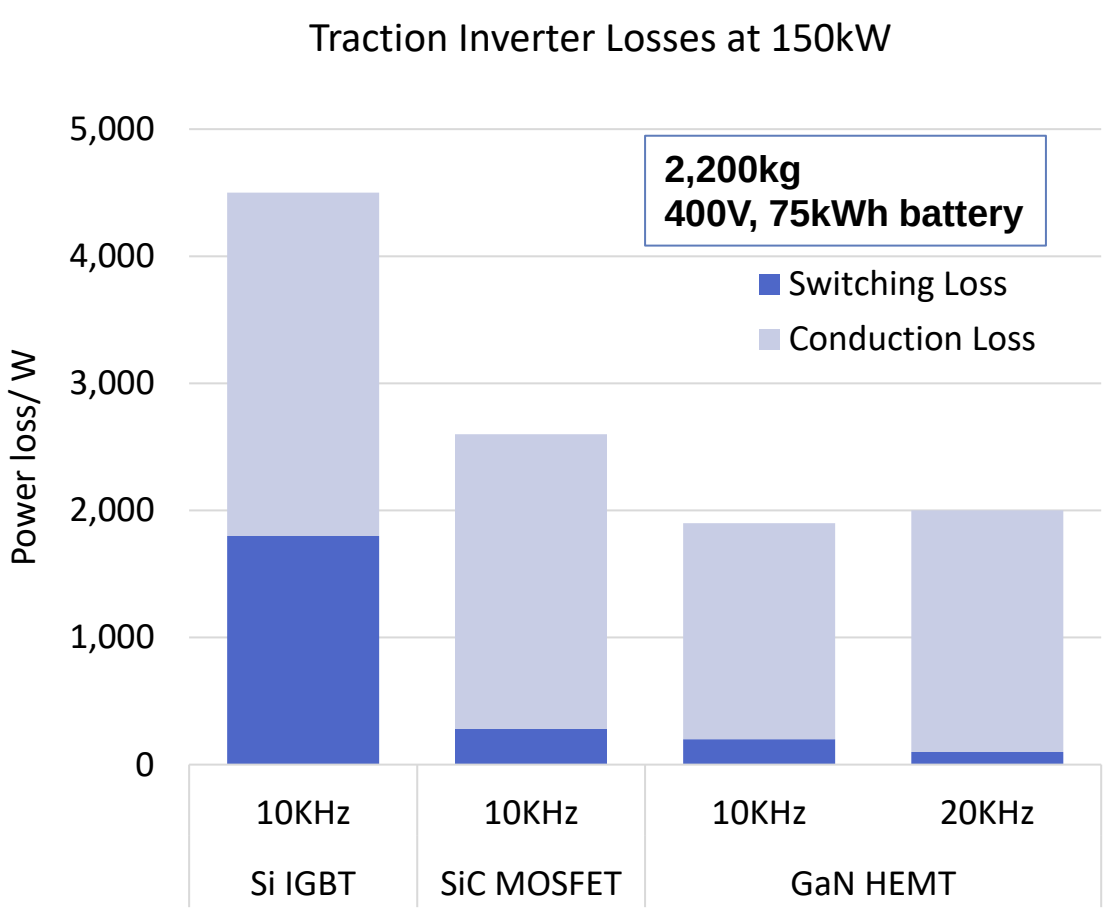
- For EVs, Si IGBTs and MOSFETs are the incumbent technologies.
- SiC and GaN are the two wide bandgap (WBG) options currently available.
- Generally, WBG allows for operation at :
    1. High temperatures
    2. High frequencies
    3. High voltages
- Currently, these potentials are only partially realized.

The chart denotes material properties which must be translated into device properties.

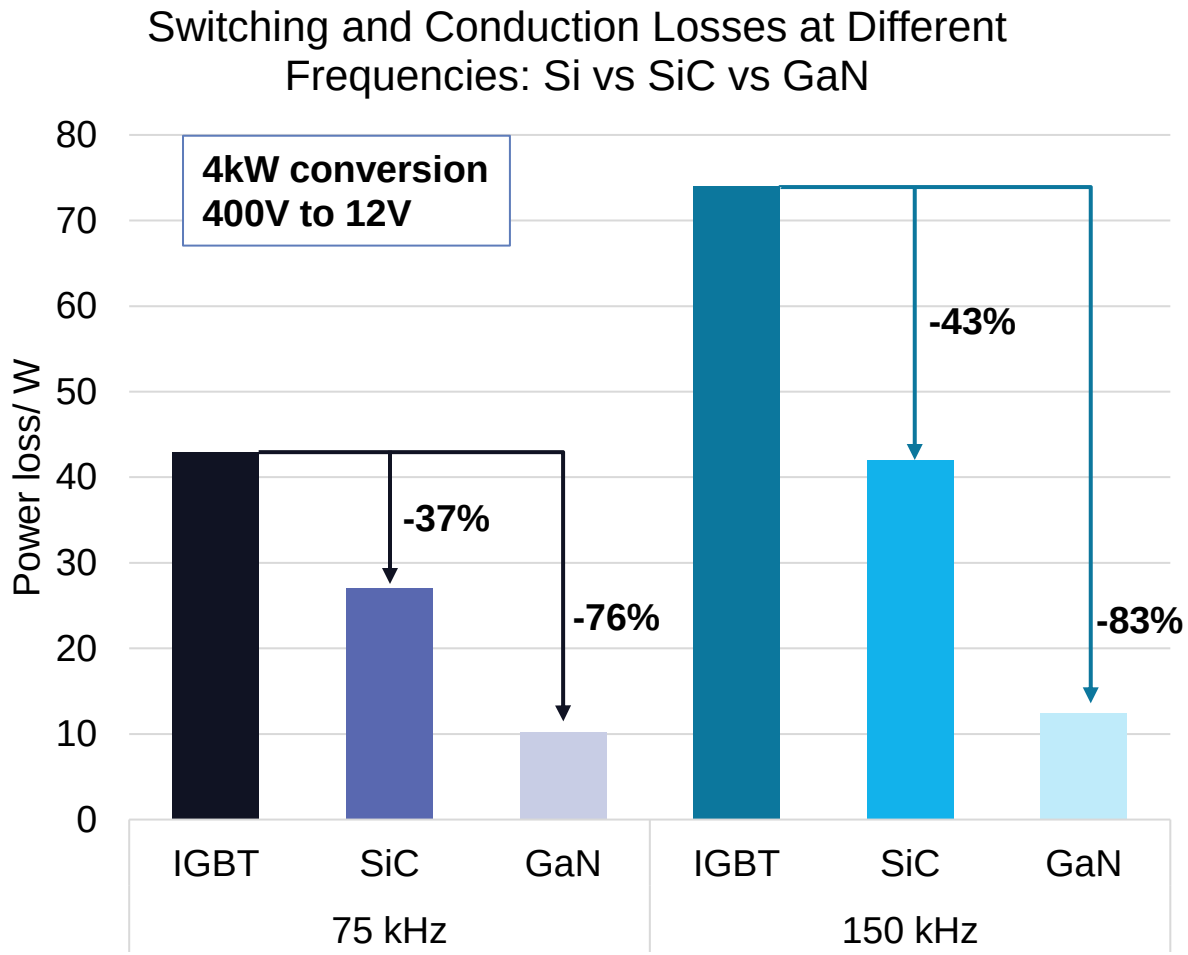


Sources: Yang et al: DOI: 10.1109/ACCESS.2020.3019775, Arrow Electronics

Switching Losses: Si vs SiC vs GaN



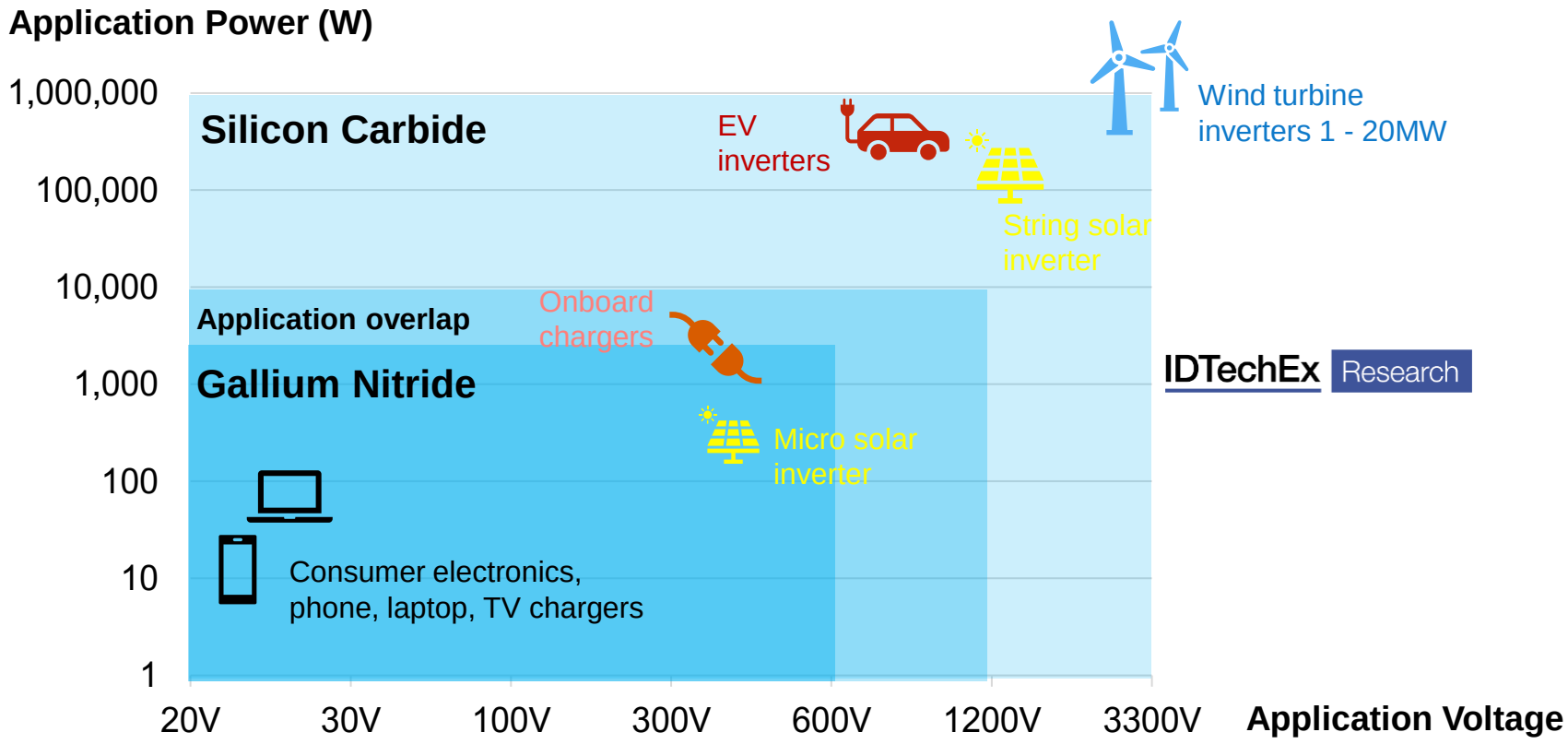
Adapted from Liu, J: GaN Semiconductors Driving More Efficient Automotive Traction Inverters



Data source: Rösel, G et al, Vitesco Technologies

Current SiC and GaN Landscape

- SiC and GaN will generally occupy different parts of the market, and in EVs the current overlap is with the OBC and high-voltage DC-DC converter.
- SiC has a head start in EVs, but GaN could potentially enter the market at high rates just like how did SiC to displace market share from Si



GaN Devices and Power Electronics

GaN vs Si: Die to Vehicle Level

- At the vehicle level, the smaller die area of GaN will yield smaller packages, and therefore less material use of aluminium for the casing, and thermal interface materials for thermal management.
- The greater efficiency means energy savings over a vehicle's running lifetime. There will also be a secondary effect on certain other components, e.g. the DC link capacitor can be downsized, yielding further savings in energy and cost.

IDTechEx Research	Si IGBT	GaN HEMT
Substrate	Si (200mm, **300mm**)	Si (150mm, **200mm**)
Masks	12	17
Front End Processing Steps	240	118
One processed wafer energy (kWh)	1,488	628
Energy per unit area (kWh/cm^2)	1.91-2.30, average 2.1	2.0
Average die area (mm^2)	~100	10-40, average 25
Energy per die (kWh)	**2.1**	**0.5**

These numbers are estimates and calculated to IDTechEx's best knowledge. Source: IDTechEx

Which Substrate will Prevail for GaN?

- Lattice mismatches between the Si wafer and epitaxial GaN result in a high defect density of 10^8/cm^2 to 10^{10}/cm^2, which also limits the reliability of GaN devices at high voltages, such that GaN HEMTs on the market are limited to 650V.

IDTechEx Research

150-300mm **US$3cm^{-2}**

GaN on Si

infineon

ROHM SEMICONDUCTOR

life.augmented

Up to 200mm **US$2.4cm^{-2}**

GaN on Sapphire

RENESAS

Acquired

transphorm

power integrations

Up to 100mm **US$30cm^{-2}**

GaN on GaN

power integrations

Acquired assets

ODYSSEY SEMI

JXT

Up to 200mm

GaN on engineered substrate

soitec

Acquired EPIGAN

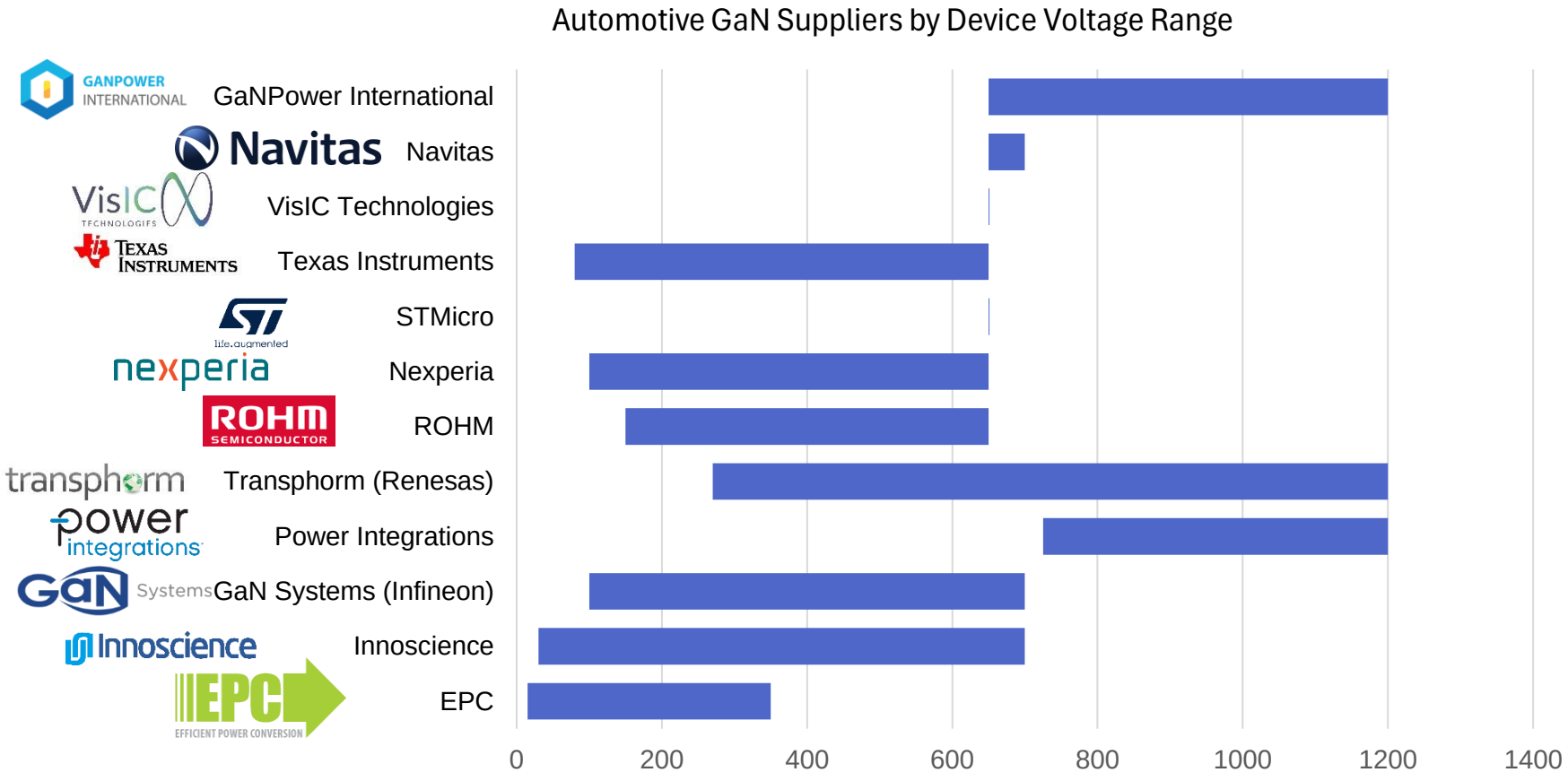
QROMIS 世界先進 VIS

Licensed production

ShinEtsu

GaN Suppliers by Voltage and on-Resistance

$R_{DS(on)}$(mΩ)	Mode
12-260	e
70-300	e
2.2-22	d
30-270	d
49-290	e
7-150	d/e
3.2-190	e
15-480	d
1-45	d
7-450	e
1.2-30	e
1.1-3300	e



This chart is to IDTechEx's best knowledge, and is not exhaustive. Devices include discretes, modules, and different ICs.

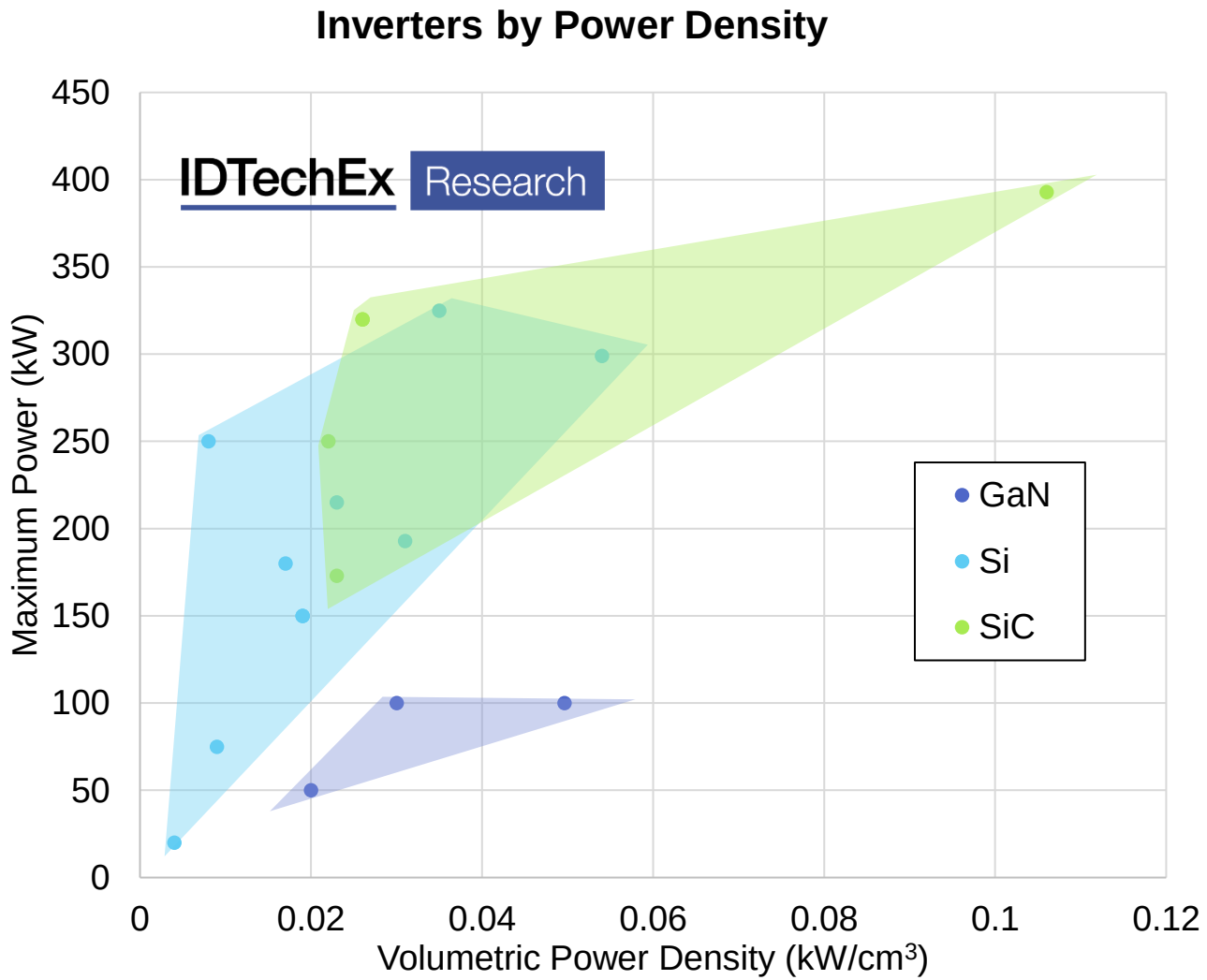
GaN in OBCs: Ahead of Forecasts

- As of November 2024, GaN has officially entered the commercial EV market, being implemented in the OBC of the Changan Qiyuan E07, selling 485 units as of January 2025.
- The increased efficiency can extend lifetime driving range by 10,000km,and that users of the car could enjoy a 15-20% decrease in charging costs (quoted as CN¥1,563, ~£167.20) during its lifetime compared to standard OBC solutions.
- IDTechEx forecasted GaN to be integrated into OBCs in 2026, meaning that Changan's integration of GaN has been ahead of forecasts.

Changan Qiyuan E07	Hella	Wolfspeed	Infineon	Valeo
GaN	GaN	SiC	SiC	Si/SiC
~7kW	22kW	6.6kW	11kW	Up to 22kW
96%	>96%	96.5% peak	97.2% peak	96%
6kW/L	4kW/L	3kW/L	4.1kW/L	2kW/L

IDTechEx Inverter Benchmarking

- There are currently no commercially produced GaN inverters.
- SiC inverters have been developed with power density far exceeding Si IGBT technologies.
- GaN has only been deployed in demonstration models and prototypes, typically at low power.
- In scaling to higher powers for larger segment vehicles, GaN will need to handle larger currents more reliably, while also paralleling more devices and maintaining small package size.



Progress of Different Applications of GaN

2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028

IDTechEx Research

VisIC TECHNOLOGIES + ZF

Collaborations to produce GaN inverters.

GaN Systems + BMW

Collaboration for GaN for all power electronics

Vitesco TECHNOLOGIES + Infineon

August 2024:

- Vitesco Gen 5+ DC-DC Converter will use Infineon CoolGaN 650V

IDTechEx Research

Original forecasts for market entry:

DC-DC Converter **OBC** **Inverter**

VisIC TECHNOLOGIES

Expecting volume production of its GaN inverters within 2 years

February 2025:

- Changan Qiyuan E07 announced to be using GaN in the OBC

power integrations

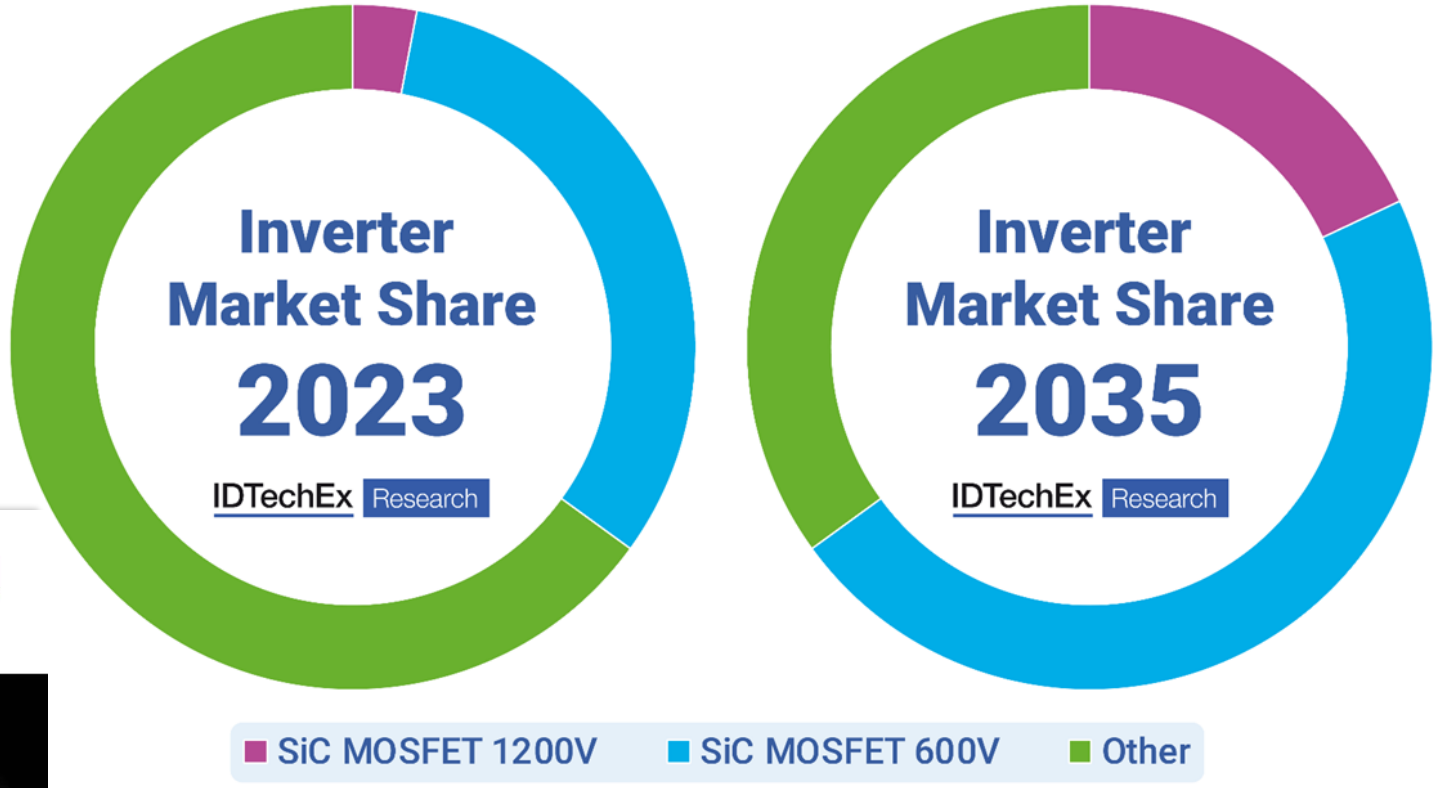
Predict that high current GaN will be available within 3 years, key for traction inverters

Other notable companies such as Ricardo, Nexperia, STMicroelectronics, and others have looked into GaN, and have produced numerous prototypes, studies, and proof-of-concepts.

Take Home Messages

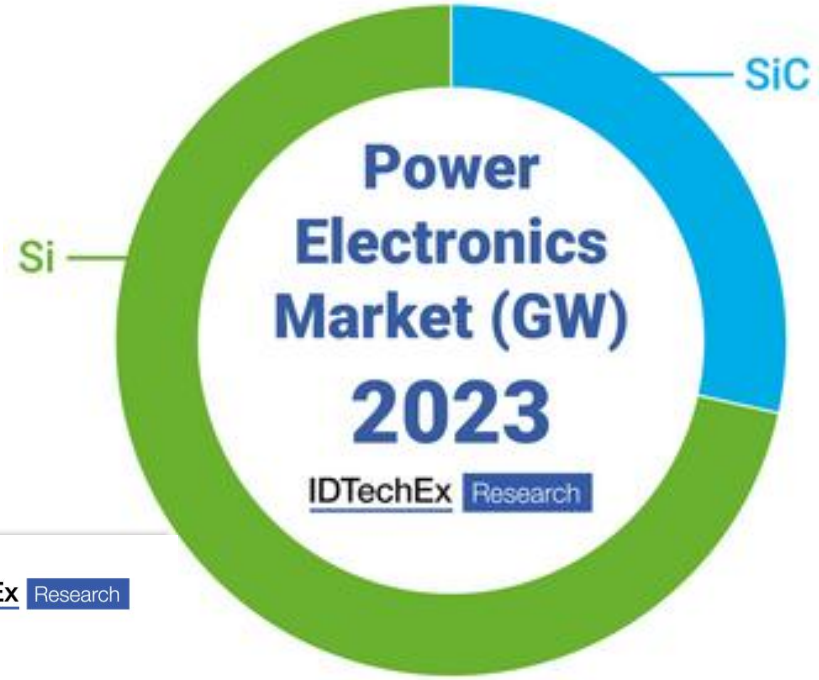
- SiC MOSFETs will become the go-to technology for traction inverters, claiming over 60% market share by 2035.
- Si IGBTs will remain a viable option for EVs, especially ones with smaller battery capacity, and PHEVs.
- GaN will enter the inverter market in 2027.

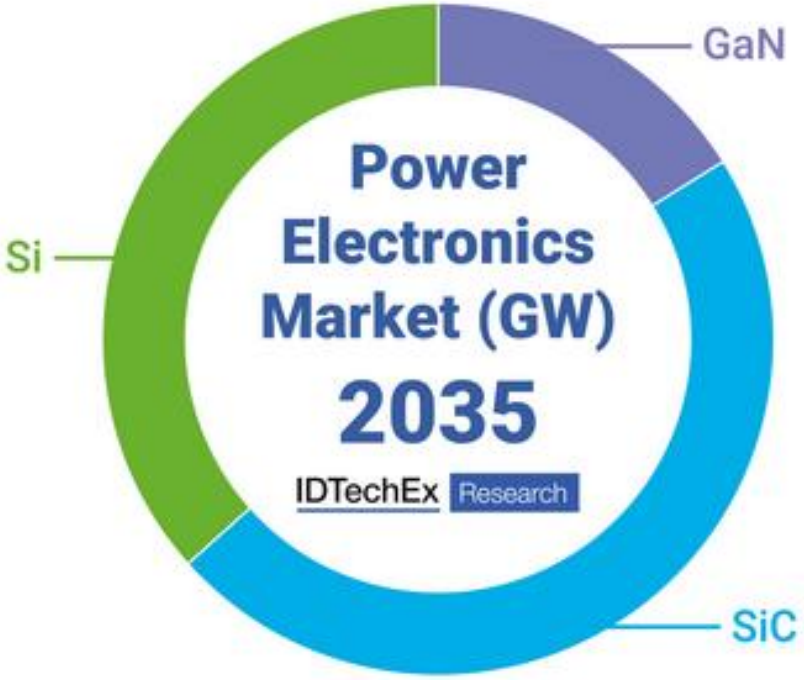
www.IDTechEx.com/PowerElec



Take Home Messages 2

- GaN will enter the market for OBCs and DC-DC converters earlier than in inverters, that operate at 10 times the power.
- GaN is a much more competitive technology at these lower powers,
- The power electronics market will grow faster than the EV market as a whole.





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