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Vertical Gallium Nitride (GaN) Technology: Unlocking High-Voltage Potential for Net Zero Applications

Catapult Compound Semiconductor Applications

UKRI Innovate UK

Executive summary

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This report examines the emerging field of vertical gallium nitride (GaN) technology and its potential to transform high-voltage power electronics. As the global push towards Net Zero intensifies, there is a growing demand for compact, efficient and reliable semiconductor solutions that can support next-generation energy systems and transport infrastructure. Vertical GaN, building on the inherent advantages of wide-bandgap materials, offers a compelling solution to meet these demands.

While GaN offers several inherent benefits over silicon (Si) and silicon carbide (SiC), current commercially available GaN devices are limited by their breakdown voltage. Vertical GaN architectures, fabricated on native GaN substrates, present a promising solution, offering substantial advantages:

- significant size reductions and higher efficiencies
- fast switching capabilities with reduced power losses and improved energy density
- superior thermal and mechanical stability due to lattice-matched GaN-on-GaN growth

Vertical GaN technology has the potential to influence many different industries. These include:

- consumer electronics, with smaller, more efficient power supplies
- automotive electrification, especially in high-voltage electric vehicle inverters and fast-charging infrastructure
- industrial and data centre power systems, offering improved energy savings and sustainability
- renewable energy and rail transport, where compact, high-voltage solutions are critical

Looking further ahead, research is pointing towards co-integrated vertical GaN ICs, where high-voltage vertical devices are combined with lateral GaN HEMTs and integrated gate drivers to create compact, “all-GaN” smart power ICs. These devices could deliver unprecedented switching frequencies, system-level intelligence, and higher reliability, marking a natural evolution in the GaN technology roadmap.

The market outlook is promising. Although commercial deployment is limited, interest is growing across industry and academia. The market for high-power GaN devices is projected to reach $1.5 billion in the next five years, with vertical GaN expected to capture a noteworthy share as the technology matures, potentially reaching up to $225 million within the same timeframe.

Executive summary

Despite its promise, several challenges remain. These include high wafer costs, limited long-term reliability data, and the need for advanced thermal packaging solutions. Addressing these issues will be key to unlocking the full commercial potential of vertical GaN technology.

As a UK centre of excellence, the Compound Semiconductor Applications (CSA) Catapult is uniquely positioned to support the growth of vertical GaN, which remains at an early stage of commercialisation. With specialised labs and expertise in independent testing, device benchmarking and advanced packaging, CSA Catapult helps de-risk key barriers while fostering collaborative R&D between academia and industry. By aligning development with Net Zero objectives and strengthening the UK supply chain, it provides a platform to accelerate the transition of vertical GaN from promising prototypes to commercially viable solutions with global impact.

Introduction

Introduction

Gallium nitride (GaN) is a compound semiconductor composed of elements from groups III (gallium) and V (nitrogen) of the periodic table. In recent years, GaN has emerged as a transformative material in electronics, offering high performance across a wide range of applications, including power electronics, radio frequency (RF) components, lasers and photonic devices. Its material properties enable faster, smaller and more efficient systems, capabilities that are increasingly critical in today's performance-driven technology landscape.

Advantages of GaN over silicon and silicon carbide

GaN offers key advantages over silicon (Si) and silicon carbide (SiC) in high-frequency, high-efficiency applications. With a bandgap of ~3.4 eV, wider than Si and slightly greater than SiC, GaN supports a higher critical electric field, giving it potential for higher breakdown voltages when paired with suitable device design. Its higher electron mobility lowers conduction losses, while its superior saturation velocity enables much faster switching. Together these properties reduce overall power loss and raise system efficiency, making GaN well-suited for compact, high-performance systems such as electric vehicle (EV) power electronics and energy-efficient data centre power supplies.

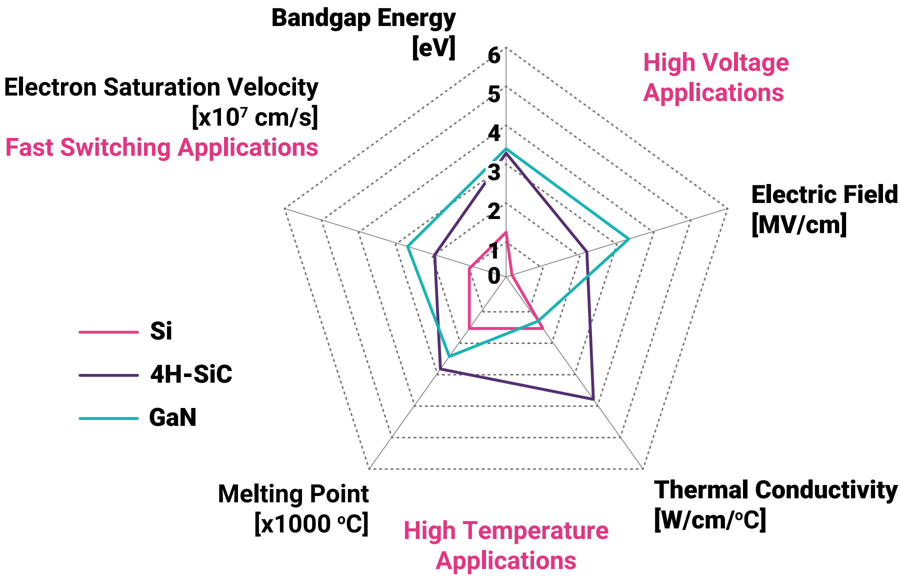

Figure 1: Comparative material properties of Si, 4H-SiC and GaN. The figure illustrates GaN's combination of wide bandgap and high electric field strength for voltage handling, alongside high electron saturation velocity for fast switching. It also highlights GaN's limitations in thermal conductivity compared with SiC, underscoring the importance of packaging and heat management in high-power designs.[1]

Introduction

Structure and substrate considerations

Typical GaN power devices include discrete high-electron-mobility transistors (HEMTs) and packaged integrated circuits (ICs). Traditionally, GaN crystals are grown on foreign substrates, such as sapphire, SiC and Si, which are known as planar or lateral structures. Figure 2 illustrates a lateral GaN-on-Si design.

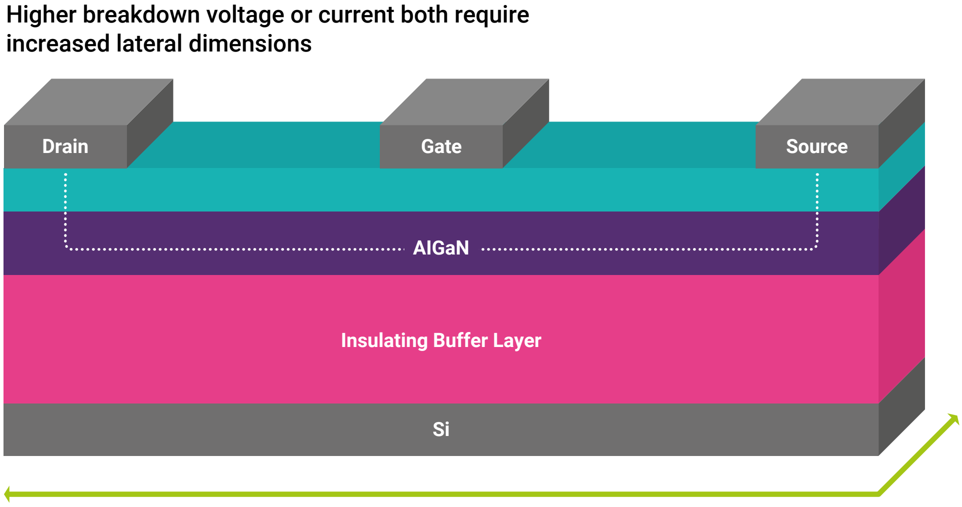

Figure 2: A lateral GaN-on-Si device illustration.

Si is a popular substrate due to its low cost and compatibility with existing manufacturing infrastructure. However, growing GaN on Si introduces significant challenges. One of the primary issues is the lattice mismatch between the two materials, which promotes dislocations and other structural defects in the GaN epitaxial layer. Furthermore, a large difference in thermal expansion coefficients leads to mechanical stress during cooling, often resulting in cracks or delamination, issues widely reported in the literature, including by Langpoklakpam *et al.*[2]

Introduction

Limitations of lateral GaN devices

One of the key limitations of currently available commercial lateral GaN HEMTs is their breakdown voltage (V_{BD}). As shown in Table 1, most commercial GaN HEMTs offer V_{BD} values in the range of 650–900 V, with only a few devices, such as those from Power Integrations, reaching 1250 V or 1700 V.

Table 1: List of commercially available power GaN devices.[3]

Manufacturer	Breakdown voltage
Power Integrations	1700/1250/900 V
Innoscience	900 V
Infineon	700 V
STMicroelectronics	700 V
Navitas	700 V
ROHM	650 V
GaN Systems (now Infineon)	650 V
EPC	350 V

To achieve higher breakdown voltages, designers must increase the distance between the gate and drain. While this method improves voltage handling, it introduces trade-offs such as higher channel resistance, which reduces current-carrying capability. Additionally, the increased lateral footprint consumes more silicon area, escalating production costs and limiting scalability.[4,5,6]

The need for vertical GaN or GaN-on-GaN

To address the voltage and scaling limitations of currently available lateral GaN devices, research and development efforts are increasingly turning to vertical GaN device structures grown on native GaN substrates (often described as GaN-on-GaN technology). As discussed in the following sections, these vertical GaN solutions offer the potential for improved voltage performance and efficiency, without the spatial and electrical trade-offs observed in today’s commercial lateral implementations.

In this report, the term “vertical GaN” will be used specifically to refer to GaN-on-GaN device structures, unless otherwise noted.

Vertical GaN technology

Vertical GaN technology

Vertical GaN technology is based on the growth of a GaN layer directly on a native bulk GaN substrate, rather than on foreign materials like Si or SiC. This homoepitaxial approach eliminates the mismatches typically found in heteroepitaxial designs, resulting in a more uniform crystal lattice. The outcome is a more stable and reliable device structure, especially suitable for high-voltage and high-power applications.

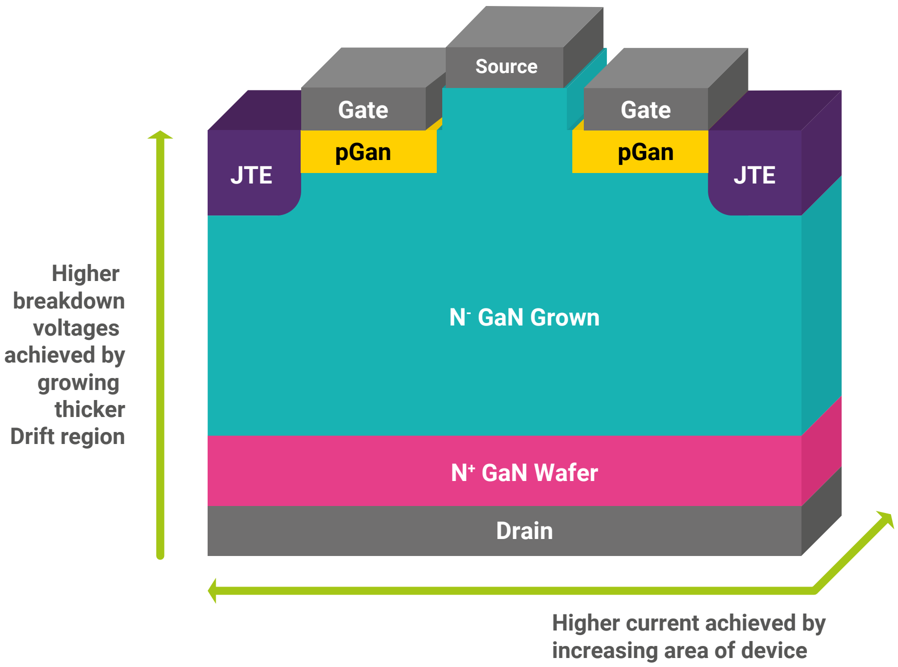

Figure 3: A vertical GaN device illustration. (image credit: NexGen Power Systems)

Reduction in defect densities and improved thermal stability

By growing GaN on its native substrate, vertical devices demonstrate far fewer crystal defects than lateral devices. This low defect density enhances conductivity, reduces resistance, and increases energy efficiency in power applications.

Another significant advantage is the elimination of thermal expansion mismatch. In lateral designs, different expansion rates between materials can introduce mechanical stress as devices heat and cool. Vertical GaN avoids this issue altogether by using the same material throughout, ensuring thermal stability and enhanced long-term reliability.[i]

[i] Industry data from NexGen show that lateral GaN-on-Si suffers from large lattice (~17%) and thermal expansion (~54%) mismatches, leading to defect densities of 10^8–10^{10} cm^{-2}. GaN-on-SiC offers some improvement (lattice ~3.5%, CTE ~25%) but still records defect densities around 5×10^8 cm^{-2}. By contrast, vertical GaN-on-GaN eliminates mismatch altogether, lowers defect densities to 10^3–10^5 cm^{-2}, and supports thick epitaxial layers (>40 μm), enabling higher voltage capability and far greater reliability.

Vertical GaN technology

Compact size and higher power density

Vertical GaN devices are reported to be remarkably compact, i.e. up to 95% smaller than their silicon-based equivalents[8] and significantly smaller than other wide-bandgap devices. This reduced size enables much higher power densities, supporting miniaturised system designs without compromising performance.

Faster switching speed and higher efficiency

Vertical GaN devices have been reported to deliver outstanding switching performance, capable of operating at frequencies of up to 10 MHz,[8] about 100 times faster than traditional silicon devices, and offering up to 50% improved switching efficiency.[7] This performance significantly surpasses that of both lateral GaN and SiC metal oxide semiconductor field effect transistors (MOSFETs).

Properties	Si IGBT	SiC MOSFET	GaN-on-Si HEMT	Vertical GaN eJFET
Breakdown voltage	>1200 V	>1200 V	650 V	>1200 V
Max speed	100 kHz	250 kHz	2000 kHz	10000 kHz
Max operating temperature	150 C	200 C	150 C	200 C
On-resistance	2.3 Ω	1.6 Ω	2.25 Ω	1.6 Ω

Table 2: Example device comparison reported by NexGen. NexGen's vertical GaN eJFET is shown to achieve a breakdown voltage of over 1,200 V, a switching speed of 10 MHz, low on-resistance, and operation at 200 °C, illustrating the potential advantages of vertical GaN over Si IGBTs, SiC MOSFETs, atnd GaN-on-Si HEMTs.[8]

Another advantage is the absence of reverse recovery charge. In traditional Si power devices, the built-in diode introduces a delay when switching directions, leading to energy losses. Vertical GaN eliminates this issue entirely, allowing for cleaner, faster transitions and improved overall power conversion efficiency.[9]

Technical and commercial barriers

Despite its significant potential, vertical GaN technology faces several critical technical and commercial challenges that must be overcome before it can achieve widespread market adoption.

Reliability and failure mechanisms

Vertical GaN devices currently lack well-established long-term reliability, largely due to their relatively recent development and limited deployment in field applications compared to mature technologies such as Si and SiC. Key concerns include defect-induced degradation, instability under high electric fields, and insufficient empirical data on failure modes under real-world operating conditions. These factors hinder the development of standardised reliability models and predictive lifetime assessments, making it difficult to ensure consistent performance over extended periods.

Economic viability

The high cost of GaN wafers poses a significant challenge to the economic viability of vertical GaN devices. While 2- and 4-inch GaN wafers are in mass production, and 6-inch ones are under development, current wafer costs (including epitaxy) are around \$40–60/cm², significantly higher than \$7/cm² for 4-inch SiC and \$1/cm² for 8-inch GaN-on-Si.[10] This cost barrier must be lowered to enable the widespread adoption of vertical GaN transistors.

Vertical GaN technology

Thermal management and packaging

Vertical GaN devices are fabricated on native GaN substrates, which have relatively low thermal conductivity (~1.3 W/cm·K) compared to SiC (~4.9 W/cm·K).[1] As a result, vertical GaN devices may not dissipate heat as effectively as lateral GaN devices on SiC, despite their structural advantages.

To manage the high-power densities and maintain device reliability, advanced thermal management strategies are essential. These include high-performance heat sinks, thermal interface materials, and carefully engineered packaging. Furthermore, packaging must meet the dual demands of electrical isolation and efficient heat removal, especially in high-voltage applications. Achieving this balance remains a key challenge in scaling vertical GaN technology for commercial high-power systems.

Gate driver considerations

Gate driver requirements for vertical GaN devices are strongly influenced by device architecture. For example, NexGen's vertical GaN enhancement-mode junction field effect transistors (JFETs) employ a current-based gate drive approach, in contrast to the voltage-driven method used for conventional MOSFETs. The recommended interface for NexGen devices includes a bias resistor to supply steady gate current, a fast capacitor for rapid switching and negative gate bias, and an external gate resistor to control switching speed and suppress false turn-on events.[11] This approach reflects the specific gate diode structure of NexGen's devices; other vertical GaN technologies may adopt different gate driver strategies depending on their internal design.

Case study: integrating lateral and vertical GaN - towards smart power ICs

There is a growing emphasis on the importance of integrating vertical and lateral GaN technologies into complete vertical GaN ICs. The motivation comes from the complementary strengths of the two approaches: lateral GaN HEMTs are highly suitable for monolithic integration, allowing compact incorporation of gate drivers, sensors and logic, while vertical GaN devices provide the high-voltage and high-power backbone needed for demanding applications. By combining the two within a single platform, the aim is to achieve power ICs that are both compact and capable of handling significantly higher voltages and currents than lateral devices alone.

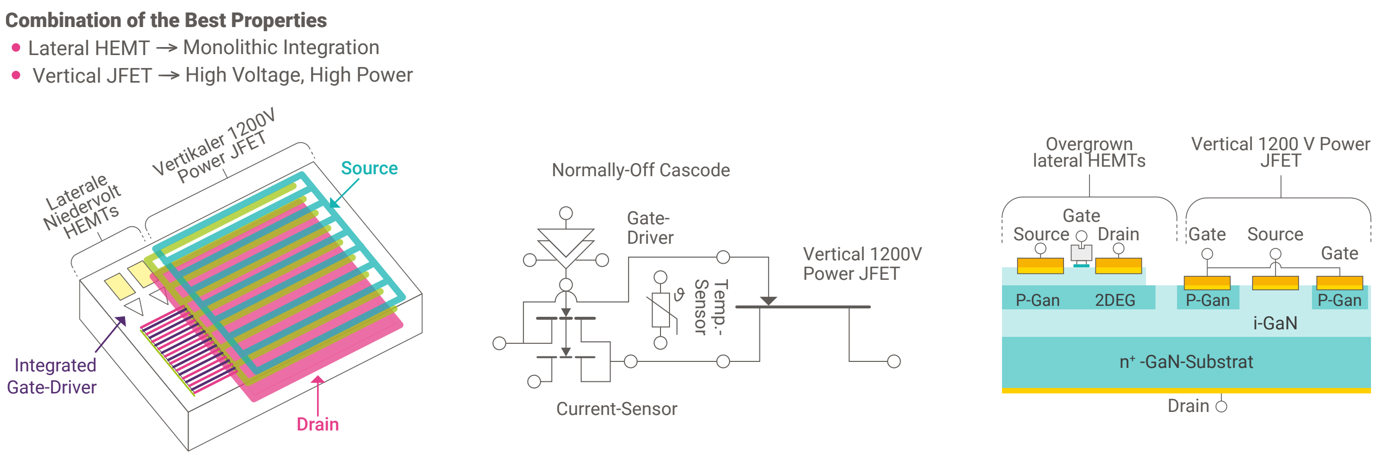

Figure 4: Vertical GaN power IC: a combination of lateral HEMT and vertical JFET.[12]

Vertical GaN technology

Fraunhofer IAF demonstrates this concept through co-integrated circuits where vertical devices such as current aperture vertical electron transistors (CAVETs) are combined with lateral HEMTs to form functional ICs. These prototypes integrate not only the power transistors but also gate drivers and, in some cases, additional sensing features, such as current and temperature monitoring. The result is a move towards “smart” power ICs, capable of efficient high-voltage switching while offering built-in protection and control. Similar co-integration approaches with vertical JFETs are being explored, extending the operating voltage towards the 1200 V class.[12]

This direction positions vertical GaN ICs as the natural progression of GaN technology, building on the path already established by lateral GaN. Just as lateral devices have advanced from discrete HEMTs to integrated ICs with embedded drivers and sensors, vertical GaN is expected to undergo a similar evolution. The outcome is a new generation of all-GaN ICs that combine high power density, high-voltage capability and system-level intelligence, with clear potential in electric vehicles, renewable energy conversion and advanced industrial power systems.

Emerging applications for vertical GaN

Emerging applications for vertical GaN

GaN-based semiconductors are established in low- to medium-voltage systems such as consumer electronics, automotive power electronics and industrial supplies. With the emergence of vertical GaN, the technology is set to address high-voltage applications including EV inverters and chargers, wind energy, photovoltaics and other large-scale power systems. The following sections outline key potential applications.

Consumer applications

In consumer electronics, GaN is most visible in the shift toward smaller, more efficient power adapters. Leading manufacturers have adopted GaN-based chargers across their product lines, with mainstream models delivering 30–65 W and higher-end designs reaching outputs of up to 150 W.

Vertical GaN is starting to appear in this space as well. NexGen Power Systems reports that its vertical GaN solutions have enabled power supplies that are 60% smaller, 45% lighter and 50% more efficient than conventional Si-based designs, making them particularly beneficial for high-performance laptops and mobile device chargers.[9]

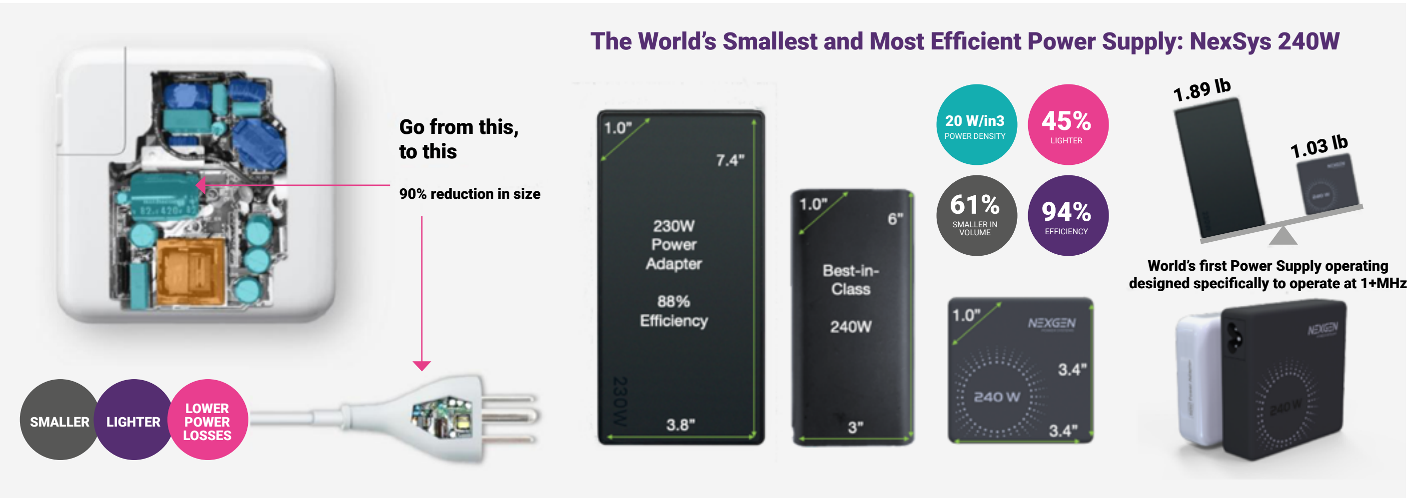

Figure 5: NexGen Power Systems' vertical GaN-based power adaptor. (image credit: NexGen Power Systems)

Automotive sector

The automotive industry is rapidly moving towards electrification, creating a strong opportunity for vertical GaN devices. In an EV, inverters convert DC from the battery into AC to power the motor, and onboard chargers perform the reverse. Both systems can benefit from vertical GaN's superior performance.

Vertical GaN can offer significant improvements over traditional Si in these systems, delivering higher efficiency and lower energy losses, and enabling more compact and lightweight designs. This is particularly important as manufacturers look to maximise driving range, minimise cooling requirements, and save space.

The broader EV market trends further strengthen the case for vertical GaN. Global EV sales are expected to grow from over 31 million units in 2024 to around 60 million by 2029, representing a compound annual growth rate (CAGR) of about 13%.[13] Leading automotive brands such as Volkswagen, BMW, Jaguar and Mercedes-Benz have set ambitious EV targets, with most aiming for around 50% of global sales to be electric by 2030, while Jaguar plans to offer an all-electric version of every model by the end of the decade.

Emerging applications for vertical GaN

EV shipment, global forecast

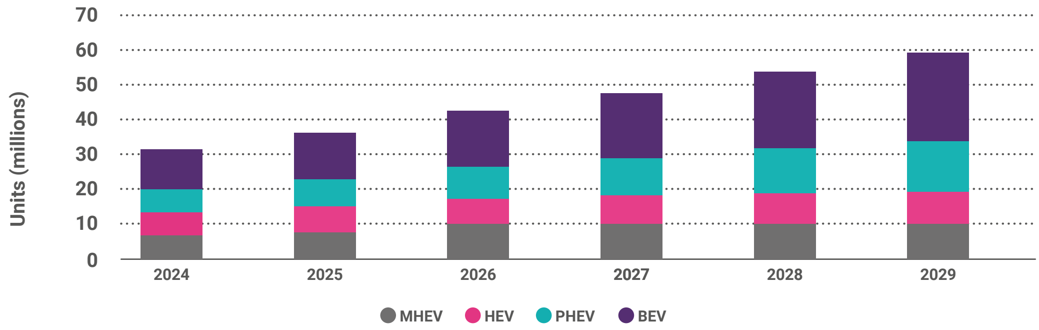

Figure 6: Global EV shipment forecast through to 2029.

At the same time, the rollout of EV charging infrastructure is accelerating. In 2023, there were around 4 million public charging points worldwide, a figure that could climb to nearly 25 million by 2035, with fast chargers accounting for about 40% of the total.[14]

EV charging points, global forecast

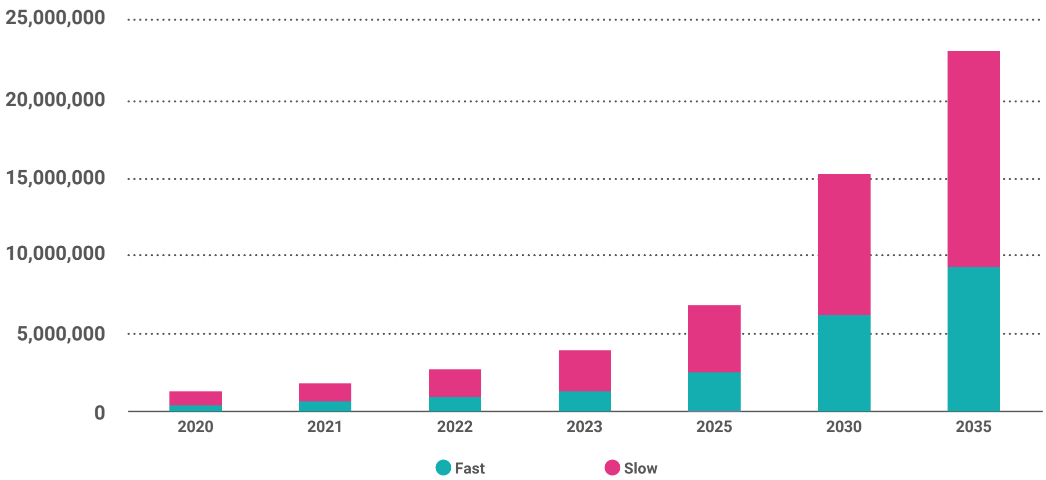

Figure 7: Global EV (light-duty vehicle) charger forecast through to 2035.

Fast charging infrastructure

Fast charging is a critical area where vertical GaN can excel. Chargers delivering 100 kW or more can recharge an EV battery to 80% in under 20 minutes. Achieving this requires power devices with high efficiency and compact form factors, both of which are strengths of vertical GaN.

Semiconductor leaders like STMicroelectronics and Infineon are already investing heavily in GaN technology for EV charging applications, highlighting growing industry momentum. Together, these factors present a compelling opportunity for vertical GaN to become a critical enabler in the next generation of automotive power electronics.

Emerging applications for vertical GaN

Application highlight: Sandia's progress in GaN power devices for EVs

Sandia National Laboratories has been developing vertical GaN power devices for electric vehicle drivetrains as part of the US Department of Energy's Vehicle Technologies Office (VTO) Electric Drivetrain Consortium. The consortium set ambitious goals, including a 100 kW traction drive with a power density of 33 kW/L, cost reduction to $6 per kilowatt, lifetimes of 300,000 miles, and significant improvements in power electronics and motor density. These targets aimed to halve system costs while doubling durability compared to available technology.

Early work at Sandia demonstrated the feasibility of vertical GaN devices. GaN diodes achieved blocking voltages up to 1500 V, while MOSFET prototypes showed promising switching behaviour and stable operating thresholds. However, challenges such as leakage at moderate voltages, field concentration at trench corners, and threshold shifts under stress highlighted the need for better dielectric layers, passivation, and surface processing.[15]

Building on this foundation, Sandia has now demonstrated the first 1200 V vertical GaN MOSFETs with a hafnium dioxide (HfO_2) high-κ gate dielectric. This breakthrough resolved long-standing integration challenges, achieving record-low leakage and a more than tenfold increase in current compared to leading GaN and SiC devices, while also demonstrating robust operation at 1200 V. The result confirms that advanced dielectric engineering can significantly enhance GaN performance in the sub-1200 V range, establishing GaN as a strong candidate to surpass SiC for next-generation EV drivetrains.[16,17]

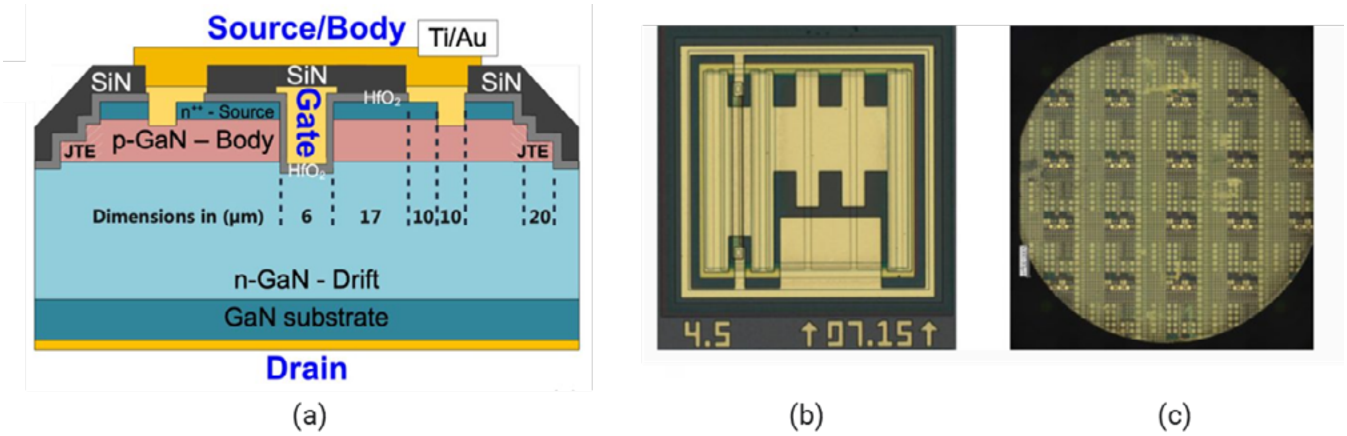

Figure 8: a) GaN trench MOSFET, b) Image of the MOSFET device during testing and c) Image of the 2" wafer as fabricated.[16]

Emerging applications for vertical GaN

Industrial power supplies

GaN has been reported to outperform SiC in the 3-3.5 kW power range, particularly in enterprise power supplies for data centres, telecom infrastructure and industrial power systems.

Globally, there are over 10,500 data centres in operation, including more than 1,000 hyperscale facilities.[18] This rapid expansion of data centres, driven by surging demand for cloud services, artificial intelligence, Industry 4.0 and cryptocurrency mining, is creating unprecedented opportunities and challenges in power efficiency and sustainability. Vertical GaN, with its superior efficiency, better thermal management and compact designs, can be a transformative technology that can improve power distribution networks in data centres.

Our analysis suggests that the power supply market in the four major data centre hubs – the US, China, the UK and Germany – has the potential to exceed $7.5 billion over the next seven years.18 This could be a massive opportunity for vertical GaN.

There is already evidence of the adoption of lateral GaN in power supply units. For instance, GaN Systems and xFusion Digital Technologies have developed a 3 kW power supply for data centres.[19] The UK-based Cambridge GaN Devices has partnered with Chicony Power Technology (Taiwan) and Cambridge University Technical Services (CUTS) to develop GaN-based 'Switched Mode Power Supply' systems.[20] Infineon offers GaN-based power supply solutions for 3.3 kW and above systems.[21]

Case study: Impact of GaN Adoption in Data Centres

Navitas estimates that upgrading data centre power systems from conventional silicon-based components to advanced GaN-based technology can achieve significant savings, including:

Cost savings: Applied in all data centres globally, this energy reduction translates to estimated annual savings of $1.9 billion in electricity costs.

Environmental impact: GaN adoption could reduce energy demand from data centres by over 15 TWh annually, leading to a reduction in CO_2 emissions of 10 million tons. This is equivalent to the annual emissions of over two million gasoline-powered passenger vehicles.

Energy savings: GaN technology can reduce electricity use by data centres by up to 10%.

(Source: Navitas, Sustainability Report 2021)

Emerging applications for vertical GaN

PSU demand forecast to 2031 in new data centres

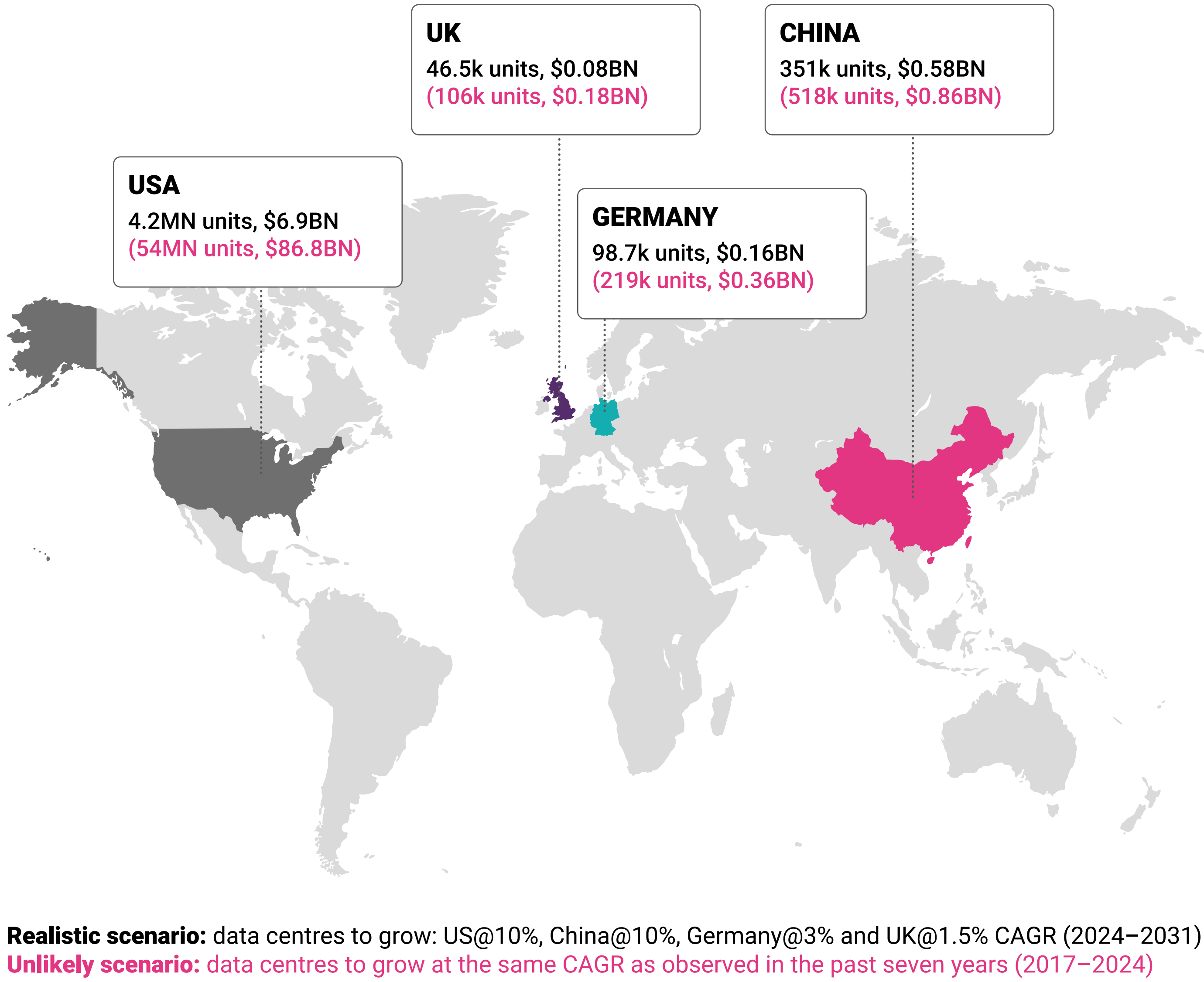

Figure 9: Estimated demand for power supply units from new data centres in the US, China, Germany and the UK.[18] It is imperative to emphasise that these figures are intended solely for indicative purposes. The accuracy and realisation of this projection rely on an array of assumptions, market dynamics, regulatory changes, etc.

Emerging applications for vertical GaN

Renewable energy

Wind power

The wind energy sector has already seen the adoption of SiC devices. While the most recent market data is limited, a 2022 report by Yole Développement estimated a CAGR of 163% for SiC in wind energy between 2021 and 2027. This trend highlights the growing importance of high-voltage compound semiconductors in the sector.

At present, SiC dominates the wind power market among compound semiconductor technologies. However, vertical GaN devices show strong potential for future adoption, particularly due to their high efficiency and reliability. Wind power systems are broadly divided into onshore and offshore installations, each with distinct technical requirements:

- onshore wind farms typically deploy turbines rated between 3–5 MW. These installations often face space constraints, which increases the demand for compact and efficient power electronics. Power devices such as 1200 V and 1700 V insulated-gate bipolar transistors (IGBTs) are currently used in these systems. Vertical GaN devices with comparable voltage ratings could emerge as a competitive option within the next five years
- offshore wind installations, by contrast, are rapidly scaling up, with turbine ratings reaching 12 MW and above. These systems require power semiconductors operating at much higher voltages, typically between 3.3 kV and 6.5 kV. While vertical GaN is not yet ready for these voltage levels, it could be a promising long-term solution. Continued development in vertical GaN technology could make it viable for offshore wind applications within five to ten years

Photovoltaics and energy storage

In the context of solar energy and grid-connected storage, vertical GaN, particularly in the 1200 V range, may offer a competitive alternative to current SiC-based solutions. Vertical GaN could also find future use in photovoltaic string inverters, which dominate residential and small commercial solar installations. Single-phase string inverters typically integrate a maximum power point tracker (MPPT) with a DC/AC conversion stage. While today’s implementations utilise lateral GaN FETs, the higher voltage capability of vertical GaN devices would enable these architectures to scale to the 1200 V class, paving the way for more compact and reliable string converters in the years to come.[22]

Rail transport

Railway systems are evolving towards lighter, more efficient and compact power solutions. Traction inverters and auxiliary power units used in trains and trams require high-voltage semiconductors ranging from 1.7 kV to 6.5 kV.

SiC has already made inroads in this field. Japan, for instance, has deployed SiC-based inverters in locomotives, and the European Roll2Rail initiative has explored similar technologies. Vertical GaN could eventually replace SiC by offering even better efficiency and enabling smaller, lighter systems. High-speed and intercity trains, which require power electronics with voltages ranging above 3.3 kV, may benefit from future advances in vertical GaN voltage ratings. With countries like China expanding their rail infrastructure, there is a growing opportunity for the adoption of vertical GaN in this sector.

Readiness for adoption and commercialisation

Vertical GaN is still at a pre-commercial stage, with promising demonstrations of devices showing high breakdown voltages (>1200 V), low defect densities, and thick active layers. These results confirm its potential for high-power and high-voltage use. However, adoption is currently constrained by several factors, notably the high cost of GaN substrates, challenges in packaging and thermal management, and the absence of long-term reliability data.

Current vertical GaN devices are generally between TRL 4 and 6. Prototypes are being validated in relevant environments, but the step to fully qualified products (TRL 8–9) has not yet been reached.[ii]

Adoption of vertical GaN is expected to progress in stages. In the short term (up to ~3 years), opportunities are likely to arise at lower voltages and power levels, where packaging and qualification requirements are less stringent. In the medium term (around 3–5 years), use in more demanding environments such as automotive and industrial systems becomes feasible, if reliability standards are met. In the longer term (beyond 5 years), adoption is anticipated in high-voltage infrastructure applications, where both technical and economic challenges remain the most significant.

While technical readiness defines what is possible, the pace of adoption will also depend on commercial factors. Recent activity by key companies provides an indication of how the vertical GaN market is beginning to take shape, as outlined in the following section.

[ii] These timeframes and TRL levels are indicative, based on current device demonstrations and published research.

Market outlook

Market outlook

Commercial readiness

The two key players in vertical GaN development in recent years have been Odyssey Semiconductor Technologies and NexGen Power Systems.

Odyssey, based in New York, focused on high-voltage vertical GaN devices as a potential alternative to SiC in applications such as EVs, industrial drives and renewable energy. The company released sample devices rated at 650 V and 1200 V before being acquired by Power Integrations in mid-2024 for $9.5 million.[23,24] The deal included Odyssey's fab, intellectual property and key staff, and is expected to accelerate Power Integrations' roadmap for higher-voltage GaN devices.[25]

NexGen Power Systems, once a leader in vertical GaN devices, announced the availability of engineering samples for its 700 V and 1200 V vertical GaN devices in early 2023.[26] These devices demonstrated switching frequencies exceeding 1 MHz at 1400 V rated voltage. Despite these advancements, NexGen ceased operations in December 2023. Subsequently, OnSemi acquired NexGen's GaN fabrication facility in DeWitt, New York, along with its patents and other assets, for $20 million.[27]

Other market developments and key global players

This section outlines notable developments in vertical GaN across industry and academia, highlighting the key players shaping its commercial trajectory.

Avogy (NexGen)

Avogy was a pioneer in vertical GaN development. The company secured $40 million in investments from Intel Capital and Khosla Ventures in 2014, indicating strong industry interest.[28] However, in 2017, Avogy sold its intellectual property (IP), including 60+ patents, to NexGen for $200,000.[29] The IP transfer highlights the potential for vertical GaN but also underscores the challenges in scaling this technology commercially.

Sumitomo Electric

Sumitomo holds over 30 patents on vertical GaN devices, but no significant commercial activity has been reported. Research demonstrates promising results, such as vertical GaN Schottky barrier diodes (SBDs) with a forward current of 5 A and a blocking voltage of 600 V. Stability tests with under 1,000 hours of operation at 150°C further confirm the material's reliability.[30]

Fuji Electric

Fuji Electric has focused on developing vertical GaN planar MOSFETs through ion implantation. Their devices demonstrate a blocking voltage of 1200 V and an on-resistance of 1.4 $m\Omega \cdot cm^2$.[31,32] Despite holding 20 patents in this area, Fuji has yet to commercialise vertical GaN products, possibly due to cost and scalability challenges.

HRL Laboratories

HRL Laboratories participated in an ARPA-E project (2014–2018) with a funding value of $3.5 million.[33] This collaboration aimed to develop high-performance, low-cost vertical GaN transistors capable of replacing silicon technologies. While HRL holds 15 patents, there is no evidence of commercialisation, indicating that the technology is still in the research phase.

Market outlook

BOSCH and YESvGaN project

BOSCH, alongside 23 partners, is participating in the European YESvGaN project to develop low-cost, high-performance vertical GaN transistors.[34] The project aims to surpass the performance of SiC MOSFETs while maintaining competitive costs with silicon IGBTs.[35] BOSCH has also contributed to thermal management solutions for vertical GaN devices, addressing a critical barrier to commercial adoption.

Arizona State University (ASU)

ASU has been active in publishing research on vertical GaN devices. Key studies focus on improving material properties, device structures and fabrication techniques, contributing valuable insights to the broader research community.[36,37,38]

Qorvo

Qorvo participated in two SWITCHES projects (2015), focusing on vertical GaN for RF applications. The company appears to prioritise RF applications rather than power electronics, limiting its involvement in broader vertical GaN development.

These cases suggest that while vertical GaN is technically viable and continues to attract interest, especially for high-power and high-frequency applications, its path to widespread commercial use may depend on its adoption and integration by larger semiconductor players with the resources to bring it to scale.

Patent landscape and innovation activity

The patent landscape for vertical GaN devices reflects strong and growing global interest in the technology. Over 300 patents have been identified, covering innovations in device architecture, manufacturing techniques and performance enhancement. While numerous semiconductor companies, such as Infineon, ROHM, Sumitomo Electric, Fuji Electric and Fujitsu, are actively developing vertical GaN technologies, NexGen and Odyssey are the only firms that have brought devices for industry testing so far.

NexGen holds a leading IP position, with ten patents valued collectively at over $12 million. Several of these were acquired from Avogy, an early innovator in vertical GaN technology. Odyssey holds a smaller IP portfolio, with three patents estimated at approximately $150,000 in value.

Geographically, the US leads in granted vertical GaN patents, followed by other major patent authorities and jurisdictions, including the EPO, Japan and China, with significant international filings via WIPO, highlighting the global race to secure strategic positions in this emerging power semiconductor domain.

Market outlook

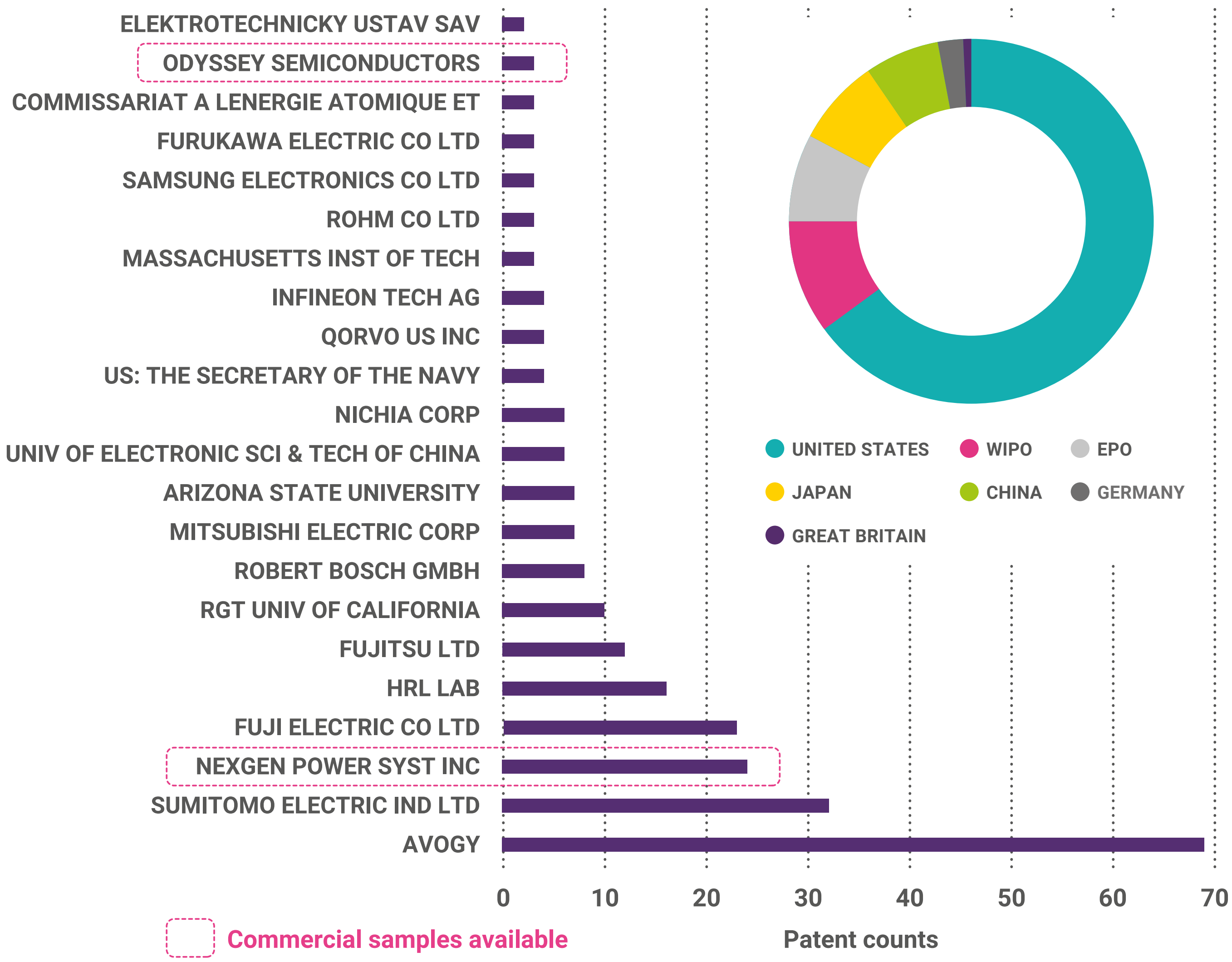

Figure 10: Vertical GaN patent landscape.[39] (non-exhaustive[iii])

[iii] The patent landscape presented here is limited by the scope of the search parameters and should be viewed as indicative of research interest rather than an exhaustive survey of all relevant patents.

Market outlook

Market size and growth potential

At present, SiC dominates the high-voltage power device market, particularly for voltages at and above 1200 V. SiC devices are widely manufactured and readily available from a range of established suppliers. While there are signs that lateral GaN devices may begin to penetrate the automotive sector, the role of vertical GaN in this space is still being defined.

The total available market (TAM) for high-voltage power devices is expected to reach around $7.5 billion by 2029. Within that, the addressable market for high-power GaN devices is projected at $1.5 billion.[13] Even a modest adoption scenario, where vertical GaN captures just 5% of this segment by 2030, would represent a $75 million market opportunity. If the technology gains broader traction and reaches a 15% market share, the potential could exceed $225 million.

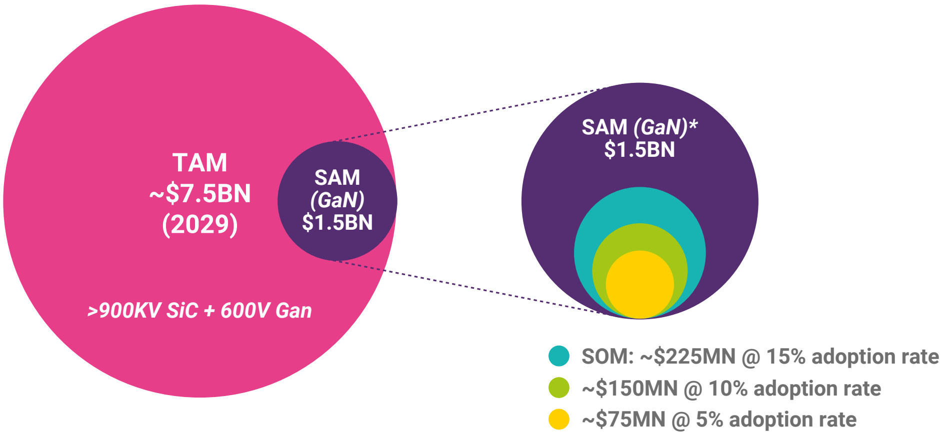

Figure 11: Market potential for vertical GaN. The Total Addressable Market (TAM) covers >900 V SiC and >600 V GaN devices. The Serviceable Addressable Market (SAM) refers to the portion of this market addressable by >600 V GaN, while the Serviceable Obtainable Market (SOM) represents the share realistically attainable by vertical GaN.

Despite early interest, widespread commercial availability is still limited. Industry evaluations are ongoing, and many performance claims await independent validation. NexGen holds a patent portfolio estimated at over $10 million,[39] although third-party confirmation of this valuation has not been disclosed.

UK ecosystem strengths

The UK has an emerging vertical GaN ecosystem spanning research, supply chain and end-user industries. The Cardiff-led GaNTT project (with Swansea, Coventry, CSA Catapult and Turbo Power Systems) developed expertise in thick GaN epitaxy, trench etching and gate stack integration, with simulations predicting ~540 V blocking capability and ~1.4 mΩ·cm² specific on-resistance for a 4 µm drift region.[40,41] Cardiff has since demonstrated the UK's first vertical GaN-on-SiC trench MOSFETs with measured 334 V breakdown, confirming progress from design to device fabrication.[42] These initiatives to date have focused on GaN-on-SiC substrates rather than GaN-on-GaN, highlighting the importance of future access to bulk GaN wafers as the technology matures.

Industrial strengths include IQE (epitaxy), Cambridge GaN Devices (design), KLA (etch tools) and packaging firms such as PPM and Dynex. Major UK OEMs in automotive and aerospace (BMW, Jaguar Land Rover, Rolls-Royce, Boeing UK) provide potential routes to application. National innovation assets, including CSA Catapult and the Offshore Renewable Energy Catapult, together with initiatives such as Innovate UK funding programmes and the UK Semiconductor Strategy, could underpin coordination through a UK GaN consortium.

CSA Catapult

CSA Catapult

Compound Semiconductor Applications (CSA) Catapult was established in 2018 by Innovate UK to help position the UK as a global leader in compound semiconductor technologies. With headquarters in Newport, South Wales, and regional offices in Bristol, Durham and Glasgow, CSA Catapult is a not-for-profit organisation dedicated to advancing the commercialisation of compound semiconductor applications.

As the UK's authority in this space, CSA Catapult brings together a world-class team of engineers, scientists and commercial specialists with deep expertise in power electronics, RF, photonics and advanced packaging. Its mission is to bridge the gap between research and industry, accelerating the development of high-performance technologies for Net Zero and Future Telecoms applications.

Supporting the development of vertical GaN

CSA Catapult is well-positioned to support the growth and adoption of vertical GaN technology through its technical capabilities, specialised facilities and collaborative innovation model.

With state-of-the-art labs and a dedicated engineering team, the Catapult offers a range of services to help industry and academia de-risk vertical GaN development. These include:

- device characterisation and reliability testing under realistic operating conditions
- performance benchmarking across switching, thermal, and efficiency metrics
- packaging and system integration for real-world application readiness

Beyond technical support, CSA Catapult plays a strategic role in strengthening the UK supply chain. It connects partners across industry and academia, facilitates collaborative R&D, and helps identify opportunities for investment, scale-up and commercialisation.

With a strong focus on Net Zero-aligned sectors, CSA Catapult provides an effective platform for advancing vertical GaN technologies from the lab to market.

Organisations developing or evaluating vertical GaN solutions are encouraged to engage with CSA Catapult to access technical expertise, explore partnerships, and accelerate innovation.

For more information, contact collaboration@csa.catapult.org.uk.

Conclusion

Conclusion

Vertical GaN technology is emerging as a credible pathway towards the next generation of high-voltage, high-efficiency power electronics. Considerable progress has been made in demonstrating device performance, particularly in switching speed, power density and thermal stability, confirming the material's potential to go beyond the limitations of commercially available lateral GaN. Early prototypes and industry-led projects show that vertical GaN can deliver meaningful improvements in critical applications ranging from fast EV charging to renewable energy and data centre power supplies.

At the same time, vertical GaN is still at the stage of proving its commercial readiness. Wafer costs, packaging requirements and long-term reliability remain open questions, and the industry will need robust roadmaps, validated reliability data and scalable supply chains before widespread adoption can take place.

Looking ahead, one of the most promising directions is the development of co-integrated GaN ICs, where lateral and vertical devices are combined with integrated drivers and control circuits. Such advances could accelerate the transition from individual prototypes to complete system solutions, enabling more intelligent, compact and efficient power architectures.

The UK has an opportunity to capture value in this transition. By leveraging organisations like the CSA Catapult, which connect academia, UK SMEs and global semiconductor leaders, the ecosystem provides a platform to de-risk innovation and build robust supply chains. If current momentum continues, vertical GaN could advance from a promising laboratory technology to a commercially critical enabler of Net Zero targets and future digital infrastructure within the next decade.

Recommended actions include:

- **Accelerating collaborative R&D** between device manufacturers, packaging experts and system integrators to address cost, thermal and reliability barriers.
- **Expanding independent testing and benchmarking** to build confidence in device performance and lifetime.
- **Exploring integration pathways** for vertical GaN ICs that combine lateral and vertical devices with embedded intelligence.
- **Aligning funding and policy support** with Net Zero priorities to encourage early adoption in EVs, renewables and data centre markets.

By taking these steps, the technology can be accelerated from promising prototypes into commercially viable, globally competitive solutions.

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