2025 predictions – GaN power semiconductors

Vital to solve the contradiction between rising energy demand and a net-zero economy

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GaN power semiconductors are on a tremendous growth trajectory. GaN is on its way to reaching more tipping points in its adoption in more industries. Consumer chargers and adapters have been the forerunner, more applications are expected to tip this year, with many others to follow in time. Still, there are some headwinds for GaN to reach this adoption level. Why is that and how can we overcome these to create value and scale all the opportunities that GaN has to offer?

With our 2025 predictions eBook, we provide predictions and outlooks for the most mature and relevant applications of GaN power semiconductors. Additionally, I would like to share some insightful observations pertinent to the GaN journey:

1. The relevance of comprehensive power systems will increase. GaN will manifest its role due to its product benefits in efficiency, density, and size.
   > Winning the 'system's game' is winning with GaN.
2. Besides 'sheer' component optimization, the entire industry is required to drive innovation in joint approaches to ensure a robust ecosystem is in place. This includes packaging, multi-sourcing as well as manufacturing innovation. The expansion of the innovation funnel will be key.
   > Innovation relies on collaboration.
3. The reach of cost-parity with silicon is in sight. Besides that, there are also hybrid approaches with other materials which create benefits for the customers.
   > GaN is a game-changer and a 'team player' for customer benefit.

As a leader in power systems, we at Infineon have the ambition to scale, advance, and enable the GaN market. With the broadest product and IP portfolio, the highest quality standards, leading-edge innovations such as 300 mm GaN wafer manufacturing, integrated GaN solutions, our bidirectional switch (BDS) technology, and lastly our systems IC capabilities, we prove this daily.

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Introduction

Technological advancements hold significant potential to address environmental challenges [1]. However, many innovations aimed at fostering sustainability – such as electric vehicles and solar farms – depend on electrical systems that can inadvertently introduce environmental trade-offs. Resolving these complexities is critical in driving meaningful progress toward sustainable development. Progress must coexist with innovation aimed at reducing CO_2 emissions through greater efficiency. This is where GaN is providing part of the solution.

Present and future technologies highly depend on electrical energy, powering innovation and at the same time causing significant environmental concerns.

The Information and Communications Technology (ICT) sector, for example, is estimated to account for between 4 and 10 percent of global CO_2 emissions [2] – even higher than the aviation industry. This underscores the urgency of addressing solutions to reduce energy consumption across all sectors. This is additionally driven by the initiatives of the majority of global companies now citing sustainability as a core factor in their business decisions. When questioned, eight out of 10 executives stated that their organization is prioritizing investments in sustainability initiatives 'for the purposes of growing profits and the business.'

Gallium Nitride (GaN) is proving to be one of the solutions to improve efficiency in a wide variety of applications [3]. GaN semiconductors have been described as a game-changer [4] in electronics due to their high-speed performance and reduced carbon footprints, allowing manufacturers to create smaller and more efficient devices.

Utilizing GaN effectively will continue to be key in 2025 and beyond, not only for enabling the continued advancement of multiple technology sectors but also for the sustainability goals of business and wider society.

However, the adoption of GaN is deeply tied to its affordability [5]. While GaN has reached a tipping point in consumer applications, such as chargers and adapters, the broader adoption across industrial and automotive sectors is expected in the next few years, as the price of GaN approaches that of Silicon.

In 2025, we will see GaN increasingly being used across a range of industries, both in the consumer and industrial fields. The markets have seen a growth from just $45.8 million in 2020 to $407.2 million in 2025, an 889 percent increase in only five years [6]. The following prediction chapters will shed light on this growth and back it up with market insights.

Consumer

Robotics

Prediction: Robotics will see widespread adoption, supported by GaN's ability to enhance efficiency and compactness, driving growth in humanoid robots, care robots, and delivery drones.

The overall robotics market is poised for significant growth and is expected to reach between $99.8 billion [7] and $110 billion [8] this year, with the market value set to rise between 98,2 percent [9] and 132,7 percent [10] by 2030. Embedded within the broader robotics market are several distinct segments – among them collaborative robots, humanoids or commercial drones – each experiencing unique and notable growth patterns [11, 12, 13].

The convergence of increasing demand and technological advancements is driving the growth of the robotics sector. One major factor contributing to this growth is the rising population age, which is contributing to labor shortages. Additionally, the rapid progress in AI and sensor integration is making the use of robotics even more attractive and viable throughout a broad variety of industries.

As robotics technology integrates AI advancements like natural language processing [14] and computer vision, GaN will provide the efficiency required for compact, high-performance designs.

GaN-based motor drives provide superior efficiency and performance, increased power density and less motor losses and high-speed switching. These advances provide a range of benefits, such as eliminating bulky electrolytic capacitors, reducing size, and highest reliability. Integrating inverters within the motor chassis eliminates the inverter heatsink while reducing cabling to each joint/axis and simplifying EMC design. Higher control frequency improves dynamic response.

GaN-based motor control designs with high switching frequencies also allow for higher power in compact sealed housings. GaN offers superior performance at high frequencies, further improves system efficiency (inverter and motor losses), and provides lower operating temperatures.

Looking at the sector’s future development, robots and their associated applications are most likely to become an increasingly important part of industrial processes and everyday life.

USB-C adapters & chargers

Prediction: GaN-powered USB-C adapters and chargers will dominate the market, offering compact, high-output solutions while setting new benchmarks in energy efficiency and environmental sustainability.

GaN has enabled a significant reduction in the size of USB-C chargers while simultaneously increasing their output power. Leading brands like Apple [15], Samsung, Dell, HP, Razer, Asus, Anker, and many more are now actively embracing GaN technology, offering compact chargers capable of delivering up to 300 W of power. GaN has furthermore become a key part of product branding, as seen with 'GaN-powered' chargers from top consumer brands.

GaN chargers, with their superior efficiency and thermal management, are setting new benchmarks in fast charging. By 2030, consumer applications, including fast chargers, are expected to drive over 52 percent of the total Power GaN device market [16]. This widespread adoption underscores the growing recognition of GaN’s role in advancing decarbonization and digitalization.GaN chargers are not only more efficient but also support the environment. Their smaller size reduces the resources needed for production, packaging, and recycling, contributing to a lower environmental footprint.

Home appliances

Prediction: GaN is expected to gain significant traction in the home appliance market, driven by the need for higher energy efficiency ratings, reduced energy consumption, and reduced system costs.

GaN in home appliances gains strong momentum, followed by a rapid increase over the next four years with a projected compound annual growth rate of 121 percent from 2023 to 2029 [17] . One of the driving forces behind the adoption of GaN in applications such as laundry washing machines, refrigerators, and other home appliances is the need to comply with energy regulations and differentiation via energy labels in major markets. The energy label rates appliances based on their energy consumption and is a crucial factor in consumers' purchasing decisions. To achieve the highest ratings, manufacturers must decrease energy consumption while maintaining high performance levels. One potential solution is to increase the efficiency of the power conversion inside home appliances. GaN technology is well-positioned to play a key role in this effort. The efficiency gains offered by GaN are significant [18]. In 800 W applications, for example, GaN can enable a 2 percent efficiency gain [19], which can help manufacturers achieve the coveted A ratings. This is possible through GaN's ability to switch faster and, therefore, more efficiently, and as such, it matches the performance needs of high-efficiency motors required to decrease losses.

As the home appliance market continues to evolve, adopting GaN technology will likely play a key role in driving innovation and reducing energy consumption - a positive contribution to decarbonization. A GaN-optimized inverter design can also benefit from reduced electromagnetic interference (EMI). Unlike traditional power devices, GaN has no body diode, which reduces parasitic effects like reverse recovery charge. In addition, GaN-based inverters switch faster, allowing small high-inductance motors to operate at higher speeds. This reduces the need for complex transmission systems in certain home appliances, thus saving costs. In addition, it allows for more compact motor drives and helps lower the audible motor noise.

Finally, the efficiency benefits of a GaN-based inverter are that it has less heat to dissipate, allowing engineers to eliminate the need for heat sinks. Heat sinks, typically made of aluminum, are bulky and require manual mounting during manufacturing. When operating in high-humidity environments, heat sinks become a point of failure due to condensation, decreasing reliability. By eliminating heat sinks, manufacturers can save an estimated 3 USD per system. These cost savings, combined with the improved performance, efficiency and reliability of GaN-based inverters at higher power density, make GaN-based solutions an attractive alternative for modern home appliances' designs.

Residential solar & energy storage systems (ESS)

Prediction: GaN will further enable efficiency and performance across the residential solar and ESS markets while helping to underpin the reduction of BoM costs.

One of the biggest success stories in clean energy transitions to date has been the rapid rise of solar PV power. Between 2010 and 2023, global solar photovoltaic capacity increased 40 times. Despite these gains, growth in clean power generation has not kept pace with global electricity demand and needs to rapidly scale up to get on track for net zero emissions. [20]

Today, solar PV generates just over 5 percent of total electricity generation, but it is set to increase its share to 17 percent in 2030 [21]. These growth projections are driven by increasing consumer awareness of the need for sustainable power generation as well as greater tax and grant incentives [22]. This type of supportive policy environment, among other factors, is expected to propel solar PV to become the main source of electricity by 2035, providing 25 percent of total generation in the STEPS and 35 percent in the NZE Scenario [23].

As the world continues to shift towards renewable energy sources, the importance of efficient power conversion and transmission cannot be overstated. This is where the highly efficient GaN technology comes into the game, playing an increasingly important role in the residential ecosystem, ranging from micro and string/hybrid inverters to optimizers, portable power stations, and vehicle-to-grid (V2G) EV charging.

The utilization of GaN devices in solar micro inverters offers several benefits. One significant advantage is its ability to handle higher power levels while maintaining a small inverter form factor, resulting in compact and efficient designs. Additionally, GaN devices exhibit faster switching times, which also helps increase efficiency and reduces heat generation. Both uni-, as well as innovative bidirectional GaN, play a significant role in solar micro inverters.

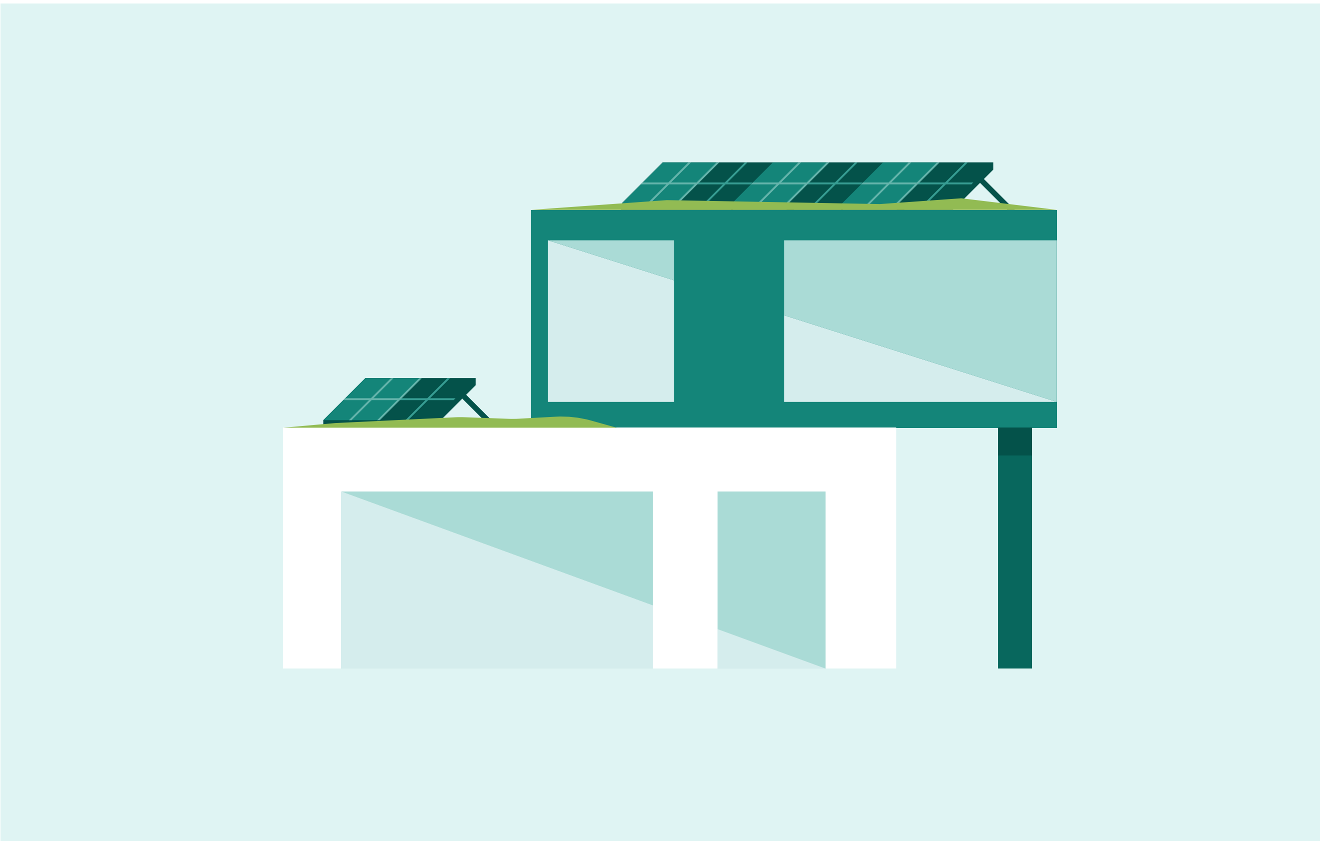
Another trend in solar is the need to charge and discharge batteries located in the residence or electric vehicle, referred to as V2X systems. GaN bidirectional switches (BDS) are an innovative game-changer in V2X systems, able to block voltage in both directions. The

BDS devices enable efficient control of energy flow and ensure safe and reliable operation under varying conditions. In addition, they eliminate the need for intermediate DC links and thereby increase power density while reducing the form factor and costs. In other words, compared to the installation of traditional back-to-back switches, using one bidirectional GaN switch is not only more cost-effective but also requires less PCB area.

Also, in hybrid/string inverters, uni- or bidirectional GaN devices enable significant system cost reductions, improved power density, and increased efficiency. Furthermore, GaN-based hybrid/string inverters can achieve high efficiencies due to low switching losses and ideal thermal performance. This is particularly important in energy storage systems, where hybrid inverters can efficiently manage the flow of energy between the grid, the energy storage system, and the load, enabling a more reliable and efficient energy supply.

In power optimizer systems, which regulate the photovoltaic (PV) panel, optimal current and voltage, GaN again brings the aforementioned power density and efficiency benefits to the table. Another aspect that is crucial for optimizer systems is thermal performance. GaN devices have a higher thermal conductivity compared to traditional silicon-based devices, which allows for more efficient heat dissipation. This results in a lower operating temperature, reducing the risk of overheating and increasing the overall reliability of the system.

In conclusion, GaN power semiconductors are poised to drive efficiency and performance gains in residential solar and energy storage systems, enabling more compact and efficient designs that are critical to achieving a net-zero emissions future.



Mobility

On-board chargers and HV/LV DC-DC

Prediction: GaN-based on-board chargers and DC-DC converters are expected to significantly contribute to higher electric vehicle (EV) charging efficiency, power density, and material sustainability, with a market shift towards 20 kW systems and higher

Despite a slight slowdown in worldwide EV adoption, we anticipate further shifts towards electrified mobility over the next years, driven by new solutions enabling affordable [24] and future-oriented platforms.

Government policies, such as CO_2 emission standards in the EU and Environmental Protection Agency (EPA) regulations in the United States, will further drive this demand. Higher efficiencies, compact size, and weight reduction are the key optimization parameters on the EV technology roadmap, all enabled by wide-bandgap solutions such as GaN.

GaN is expected to gain higher penetration in automotive applications like on-board chargers (OBCs) and DC-DC converters, thanks to its unique electrical parameters, higher integration options, and improved market maturity.

GaN offers several critical advantages over traditional silicon-based solutions in this field, perfectly aligning with market demands for sustainable, efficient, and cost-effective solutions. GaN improves efficiency, enabling energy savings and reducing heat dissipation. Its high-power density minimizes material usage, leading to more compact and lightweight designs. GaN-based solutions enable smaller, more cost-efficient capacitors and transformers, reducing overall system volume and cost while maintaining high performance. GaN technology integration enables innovative features like bidirectional switches and integrated logic, leading to even more compact systems, simplified diagnostics, and future-proof mobility applications.

For on-board chargers, GaN facilitates reduced electromagnetic interference (EMI) through its zero reverse recovery charge. It also provides lower switching losses, enabling smaller magnetics and easier implementation of advanced topologies like zero voltage switching (ZVS).

In DC-DC converters, the utilization of higher switching performance becomes even more important, where GaN supports high system size optimization and enables air-cooled systems for future system architectures.
GaN adoption in mobility applications will continue to gain momentum, with the first production-ready designs expected by late 2025 or early 2026. Automotive OEMs and suppliers are actively validating the quality, robustness, and cost-effectiveness of GaN solutions, preparing for widespread deployment.

While GaN presents immense potential, the industry must address challenges like quality validation, manufacturing scalability, and regulatory compliance. However, the opportunities are equally compelling, including expanding applications in electric vehicles and renewable energy systems, driving innovation in power electronics topologies, and supporting global decarbonization efforts through superior energy efficiency.

Traction inverters

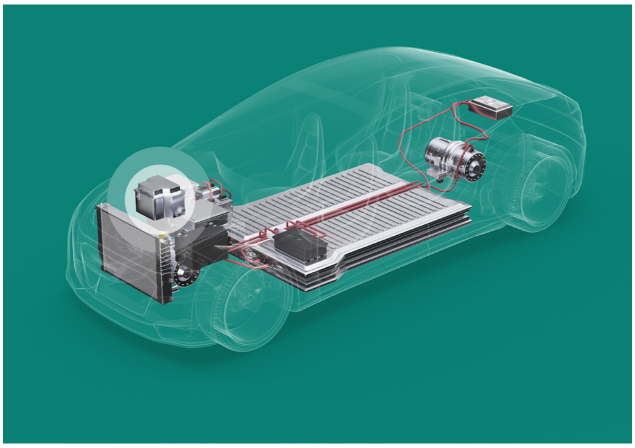
Prediction: The adoption of GaN in automotive traction inverters will enable more efficient electromobility for both 400 V and 800 V EV systems.

The market of electrified vehicles (xEV) – including battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and range-extended electric vehicles (REEV) – is expected to continue growing from 18.4 million vehicles in 2024 to 46.1 million vehicles in 2030, which translates into a strong growth rate of 16.5 percent per year. This growth is expected to continue, with projections that xEVs will account for about 62 percent of all light-vehicle sales by 2035 [25].

The traction inverter is the heart of an electric vehicle's high-power drivetrain. It converts the DC current from the battery into the AC current that drives the electric motor and controls the vehicle's speed and torque. Key requirements for semiconductor selection in today's state-of-the-art designs include the demand for high efficiency to maximize driving range from a given battery size, while still being cost-effective for the overall EV system. The industry uses both 400 V (low-cost, lower-power) and 800 V (higher-performance) inverters today, and is set to continue to do so in the future.

In future 400 V drivetrain systems, GaN's superior switching performance can further reduce inverter losses, especially in light-load conditions. This gives relevant efficiency improvements in real-life driving, where the drivetrain spends most of its time at light load. Thanks to these efficiency gains, GaN can extend the driving range or enable vehicles with smaller and less expensive batteries. Also, because GaN can be manufactured on 300 mm wafers, it is likely to become a cost-competitive WBG solution in 400 V traction inverter systems.

GaN also supports future application trends in 800 V systems. Today's 800 V traction inverters are already highly efficient, requiring innovation at the system level to enable the next leap in overall system efficiency. With 3-level topologies in traction inverters, losses in the electric motor can be significantly reduced as the inverter creates more sinusoidal waveforms. Compared to today's state-of-the-art 2-level inverters, 3-level



‘T-type’ inverters can further increase efficiency by an additional 3-4 percentage points.

Bidirectional GaN switches are a game-changer for the 800 V T-type 3-level inverter. In this topology, a bidirectional GaN switch can be used to replace two back-to-back switches in each phase leg. Due to the unique characteristics of the bidirectional GaN switch, efficiency is improved while simultaneously reducing semiconductor size and cost. Therefore, combining 650 V bidirectional GaN with 1200 V unidirectional silicon or silicon carbide devices is a good example of system-level innovation in next-generation traction inverters, combining the unique benefits of different semiconductor technologies.

In summary, GaN technology will help increase acceptance of e-mobility by enabling increased driving range and boost efficiency in 400 V and 800 V systems.

48 V

Prediction: The adoption of 48 V power architectures will continue to grow in the automotive sector with increasing usage of GaN technology.

As performance demands grow, today’s cars are experiencing a large increase in power/current requirements. This poses a challenge to conventional 12 V power architectures, which would require increasingly result in large, heavy, and difficult-to-process wire harnesses to accommodate the power increases. However, 48 V power architectures are better suited to handle these increased demands, as the higher voltage reduces the current for the same power by four and, therefore, the wire thickness by up to 16 times. It also reduces the need for high-current screw terminals and high-current connectors. It is for this reason that the 48 V system market is expected to grow by 26.7 percent by 2028 [26].

A transition to a higher-voltage power architecture necessitates power components and systems that can withstand greater voltages. GaN is particularly advantageous for 48 V automotive architectures due to its superior electrical properties. Their high electron mobility and wide bandgap enable low on-resistance and minimal switching losses that enhance overall system efficiency. Additionally, GaN devices can operate at higher switching frequencies, allowing for the use of smaller passive components, which reduces the size and weight of power conversion systems.

Further, GaN transistors exhibit negligible reverse recovery charge, resulting in minimal energy loss during switching transitions and improved thermal performance. GaN is a clear choice in DC-DC converters in 48 V systems.

Telecom & infrastructure

Telecom / 5G

Prediction: GaN will power the evolution of 5G base stations, improving energy efficiency and scalability while supporting the growing demands of AI-driven telecommunications networks.

The global migration to 5G infrastructure is progressing at a moderate pace, largely prevented by limited return on investment (ROI) [27]. Many companies remain reluctant to invest heavily in upgrading their networks, satisfied with current solutions that meet their operational needs.

The evolution of underlying technologies will be a game-changer to pave the way for significant advancements in this sector. Among these, GaN stands out as a critical enabler of 5G's future potential.

The deployment of 5G networks introduces significant power challenges, particularly for base stations. With the need to handle exponentially larger data capacities and provide seamless connectivity, these stations require advanced power solutions capable of managing high loads efficiently.

GaN is uniquely equipped to address these demands. Its high efficiency, superior heat dissipation, and ability to operate at higher power densities make it a perfect fit for modern 5G base stations. As networks expand and data capacities grow, GaN's role in powering these systems becomes increasingly vital.

While base stations remain a cornerstone of 5G infrastructure, GaN's value extends well beyond this application. Insights from Yole Group's Power GaN 2024 report [28] highlight that GaN's power efficiency makes it highly attractive in other sectors, such as data centers and AI-driven systems. These markets, which often outpace 5G infrastructure in scale, are poised to benefit significantly from GaN's capabilities.

The intersection of AI and telecommunications presents another growth area for GaN adoption. Alliances among leading companies in these fields are driving innovations in power management and AI-enabled optimization. These collaborations aim to unlock new efficiencies and applications, leveraging GaN's unique properties to meet the evolving demands of both industries.

GaN is emerging as a game-changing technology, particularly for 5G base stations with surging power demands. The growing integration of AI and telecommunications highlights additional opportunities for GaN, especially in high-demand areas like big metropoles and city centers. As these technical trends gain momentum, GaN is set to play a pivotal role in shaping the next generation of connected and intelligent systems.

AI data centers

Prediction: GaN adoption to power AI data centers will reduce energy consumption and cooling requirements, meeting the rising demands of AI and high-performance computing by enabling compact, high-efficiency designs.

Data centers - the backbone of AI and digital services - are experiencing exponential growth. Global electricity consumption by AI data centers is expected to rise significantly by 2030 [29], with AI-specific applications adding to energy demands [30].

Data centers are also consuming an ever-growing share of global electricity, currently estimated at around 2 percent and projected to reach up to 7 percent [31] as AI and high-performance computing are growing. This increase in demand drives the need for advanced power solutions capable of handling the substantial loads associated with AI servers. Power supplies that once managed 3.3 kW are now evolving towards 5.5 kW, with projections moving towards even 12 kW or more per unit. Such scaling requires power components that are efficient, compact, and capable of operating at high power densities, making GaN an attractive option.

GaN has emerged as a critical technology in addressing these needs, especially in AI data center power supplies.

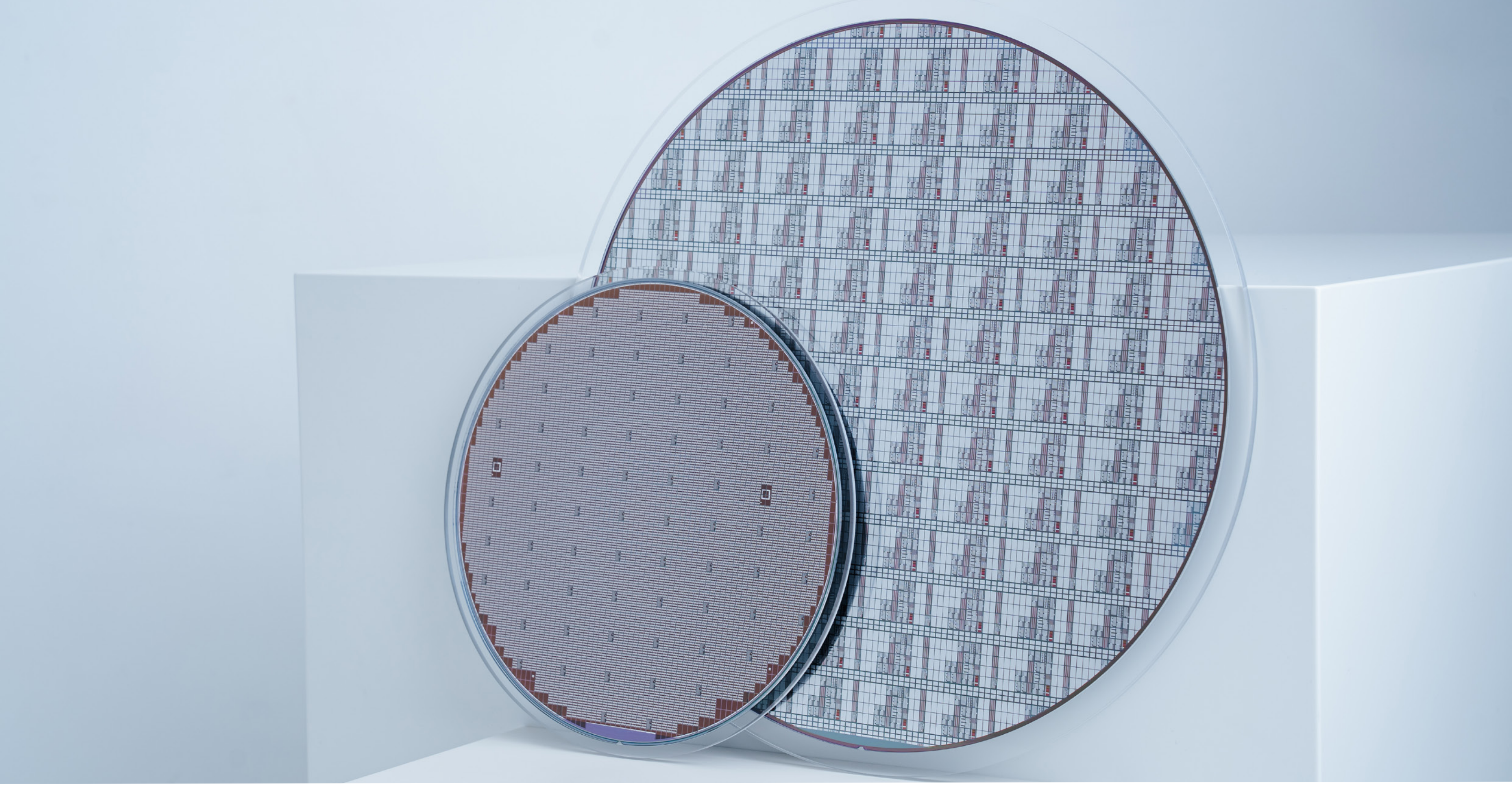
Powering AI will be highly depending on GaN. It is uniquely suited to the needs of latest AI data center architectures due to its efficiency and compact form factor. By leveraging GaN in power conversion applications, data centers can improve power density, directly influencing the amount of computational power delivered within a given rack space. Traditional power supplies with silicon components face limitations when it comes to minimizing energy losses and heat generation, especially at higher power levels. GaN, however, enables significant gains in efficiency, reducing both power losses and the cooling requirements within data centers.

While GaN presents clear advantages, hybrid architectures that combine GaN with silicon and silicon carbide (SiC) offer a balanced approach to meeting various needs in AI data centers. For instance, a hybrid power supply may utilize silicon for power factor correction (PFC), silicon carbide in specific high-stress circuits, and GaN in LLC topologies to maximize power density and optimize efficiency across different segments of the power architecture. This modular approach allows each technology to be utilized where it excels, creating a synergistic system that maximizes efficiency and power density. As a leader in providing adaptable and efficient power supply options for AI data centers, Infineon is at the forefront of developing these hybrid solutions.

Improving efficiency is not just about reducing operational costs; it is essential for thermal management. Inefficient power supplies dissipate more energy as heat, which requires substantial cooling infrastructure in the data center. As data centers scale, cooling demands can become a bottleneck, necessitating advanced cooling methods like liquid cooling. By integrating GaN, AI data centers can reduce power losses and associated heat generation, thereby reducing the overhead needed for cooling systems and improving overall energy utilization.

Furthermore, the adoption of wide-bandgap semiconductors, including GaN, is accelerating in data center applications. While GaN has already reached a tipping point in other sectors like chargers and adapters, its use in AI data centers is gaining traction as power levels continue to rise. GaN’s deployment in next-generation power supply designs is already underway, supported by the increasing demands of AI workloads. In the coming years, GaN is expected to become a staple in high-density power supplies, driven by the need for compact, efficient, and high-performance power solutions.

GaN technology represents a significant advancement in meeting the power demands of AI data centers. Through hybrid architectures, efficiency improvements, and enhanced thermal management, GaN is set to play a pivotal role in powering the future of AI and high-performance computing. As data centers continue to grow in both scale and complexity, GaN will be crucial in enabling the next generation of energy-efficient and high-density power solutions.



Outlook

All industries share one challenge: the increasing dependency on energy and the requirement to improve the energy balance to positively impact the sustainability of our planet. Turning this challenge into an opportunity will be key to reaching this goal, with technology being a key lever of the solution.

In this year's predictions eBook, we have outlined the effects and efficiency of GaN for a broad variety of use cases. We have shown that GaN power semiconductors play or will play a significant role in many applications, such as robotics, EVs, chargers and AI data centers. The interdependency of technology and sustainability is a cornerstone in all GaN-based solutions, offering wide benefits and advancements while at the same time supporting the most efficient use of electrical energy in each device or application.

The growth of renewable energy as well as the rapid progress in technologies from EVs to AI data centers and robotics, is dependent on devices that are more efficient and can be more cost-effective. These factors continue to be the principal drivers of market growth, with GaN as one of the technology advances that can have a positive impact on both. This means that despite the unmatched efficiency of GaN, its broader adoption requires reducing production costs and increasing scalability. Innovation is needed here. Transitioning to the latest GaN wafer technologies, such as 300 mm, could significantly lower costs and even unlock opportunities in new applications.

Once this has happened, we will see that more and more industries will deploy GaN-based solutions for power conversion in the voltage range of up to 700 V and beyond. Bidirectional switches will additionally push growth and become a game-changer in several applications. In addition, certain regulations, such as the EU's mandate for USB-C chargers and incentives for renewable energy technologies, are supporting the way towards GaN adoption. In the EV market, subsidies and CO_2 regulations are driving demand for high-efficiency on-board chargers and DC-DC converters, which have a high impact on GaN roadmaps and developments.

The future of GaN lies in its ability to enable a sustainable, interconnected world. GaN technology is paving the way for lighter, faster, and more efficient solutions. As we move into 2025 and beyond, GaN's role will expand, transforming technology and contributing to sustainability.

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Where to Buy

Infineon distribution partners and sales offices:
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Infineon offers its toll-free **0800/4001** service hotline as one central number, available 24/7 in English, Mandarin and German.

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