Ripple Report Series

September 2021

Silicon carbide in the UK: electric vehicles and beyond

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Compound Semiconductor Applications

Silicon carbide in the UK: electric vehicles and beyond

Executive summary

Introduction

Silicon Carbide in the UK: Electric Vehicles and Beyond is the first in a series of reports under the Catapult's *Ripple* banner. Produced in cooperation with leading industry experts, *Ripple* reports aim to stimulate thought leadership through market insight and informed opinion while providing a comprehensive snapshot of advanced electronics technologies, that the Compound Semiconductor Applications (CSA) Catapult is involved in, helping British companies identify and capitalise on emerging trends that may have future impact on the industry.

In this report, which examines the silicon carbide (SiC) opportunity, we have collaborated with leading UK industry strategic consulting company Exawatt, which specialises in understanding solar photovoltaic (PV), power electronics, energy storage and the electric vehicle (EV) market.

The UK data used in this *Ripple* is a sample set derived from Exawatt's recently updated report: Silicon Carbide in Electric Vehicles: Market Outlook. The comprehensive second edition of the report, published in July 2021, provides further detail on the global supply chain as well as analysis on such items as SiC module cost, total addressable market (TAM) and forecast data for EV sales to 2030.

TechWorksHub, an industry association that has established communities in semiconductor manufacturing and electronics design, including the associated supply chain (NMI), automotive (AESIN), and Internet of Things security foundation (IoTSF), also contributed insight and expert opinion to this *Ripple* report.

Overview

Power electronics systems based on silicon carbide (SiC) semiconductors are beginning to revolutionise the EV industry, providing significant performance gains and delivering system- level cost savings relative to incumbent power converter designs based on silicon technology.

SiC has long been touted as a game-changer for the EV industry. Still, until 2018, Tesla was the only manufacturer to have committed to, and to have produced, vehicles using SiC MOSFETs (metal-oxide-semiconductor field-effect transistors) in significant quantities in the vehicle powertrain.

While SiC still faces challenges in material production cost, production capacity, and system integration, we have seen the tide turn for SiC adoption in the automotive industry in the past couple of years. This trend is converging with the rapidly accelerating push for vehicle electrification, creating huge potential for SiC in EVs.

SiC's greatest challenge today is the high manufacturing cost of the crystalline material, which is time-consuming and complex to grow. But as the cost of SiC crystal growth falls significantly in the next few years and as further improvements are made to device performance and yield, SiC-based inverters will fall to prices that are competitive with their silicon counterparts. By this point, SiC will have become widely deployed in substantially all battery electric vehicle (BEV) inverters.

As of September 2021, almost all major global vehicle manufacturers have announced some form of development or strategic partnerships involving SiC.

Despite the major disruption of a global pandemic, the automotive industry has significantly accelerated its shift to EVs. Global regulation, investments, and technological development are increasingly focussing on the transition to electrification. However, challenges still remain, not least of which is that BEVs continue to be significantly more expensive than their ICE (internal combustion engine) counterparts. This is primarily due to the high, but falling, cost of lithium-ion batteries.

Perhaps the greatest single opportunity for SiC in the near term relates to SiC's ability to increase BEV range, typically by between 5% and 10%. This range increase can be traded for a reduction in battery size – and consequently battery and vehicle cost – for a given range. At the whole-vehicle level, it can already be shown that SiC-enabled BEVs can be made more cheaply than their silicon-based equivalents.

Further, the emergence of 800V BEV systems, which promise higher powertrain efficiency, lower weight and smaller converters than the 400V systems that currently dominate the BEV space, will also be a key enabler for SiC devices. SiC's electronic properties make it particularly suitable for higher- voltage applications, where it can deliver superior performance at a more competitive cost.

Finally, from 2022/2023, high-volume SiC device manufacturers will begin to migrate from the current 150mm wafer standard to 200mm, further increasing device yield and, ultimately, cost reductions, making SiC increasingly competitive with silicon. However, the UK is not yet at this stage, and if the country aspires to become a large-scale producer, investment in SiC development, culture, and capability will be required, backed by UK demand.

The opportunity for SiC in EVs

Our confidence in the prospects for SiC is based on the following key expectations:

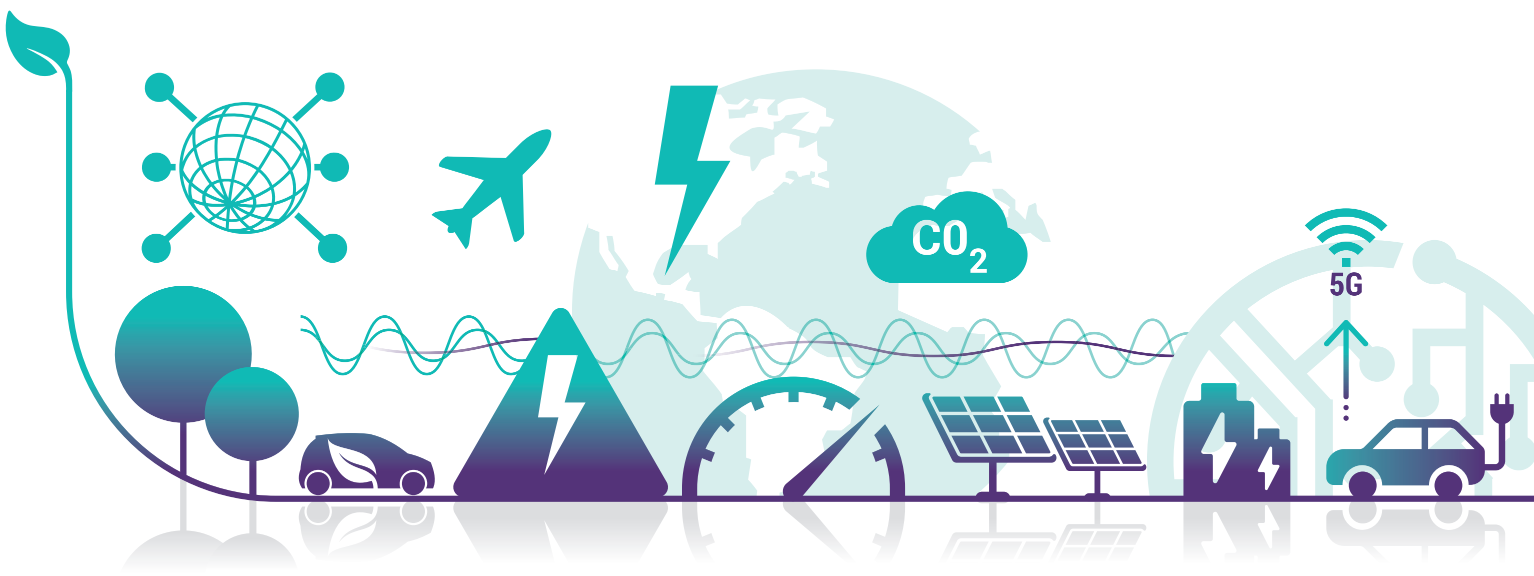
- A fall in the manufacturing cost of SiC substrates to below half of their current price point within the next five years.
- Semiconductor device manufacturing cost reductions, accelerated by migration from 150mm to 200mm manufacturing (beginning with larger global manufacturers from 2022/23).
- Device yield and performance improvements, driven by improving material quality and increasing device current density (i.e. shrinking die size for a given device current).
- Increasingly competitive pricing vs silicon-based devices and power converters.

Although we do not believe those SiC costs will reach parity with that of silicon, our view is that, over time, the cost gap between SiC and silicon at the device level will become close enough that any differences will be more than offset by savings on balance-of-system costs (chiefly cooling systems and passive components) at the converter level. We believe that SiC already offers cost savings at the system level when considered alongside potential battery cost savings.

In the mid-2020s, driven by falling costs, BEVs will begin to become established as the platform of choice for passenger vehicle buyers.

Once the decision to buy a BEV has been made, consumer behaviour will focus increasingly on the relative benefits of competing BEV technologies. The “range wars” will start – positioning SiC to benefit as an enabler of longer-range vehicles with smaller battery packs than equivalent vehicles with silicon-based inverters. At this point we believe that EVs, especially BEVs, will become the vehicle of choice, and that SiC will become the dominant power semiconductor technology in these applications.

This presents a significant opportunity for the UK power electronics supply chain, but the challenge is that current UK manufacturing capacity is too low to meet expected UK SiC demand for BEVs, and this will require significant investment in the near future in order to address this issue.



Power electronics in the EV powertrain

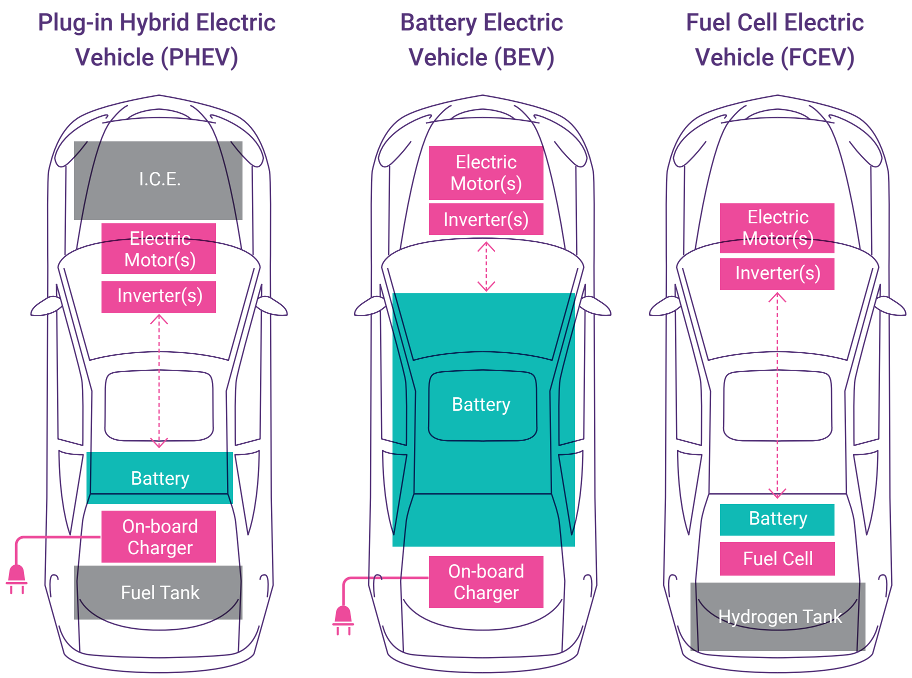
The powertrain of an EV typically consists of three core elements:

- Energy storage/generation: battery pack (BEV) or hydrogen fuel cell and tanks (FCEV)
- Inverter: converts DC power to 3-phase AC for the motor
- Motor: normally powered by 3-phase AC, typically at 350-400V (although, as with battery systems, we expect 800V motor sales will grow significantly over the coming decade)

The graphic below shows the main components of BEV and FCEV powertrain alongside a plug-in hybrid electric vehicle (PHEV). The PHEV includes an ICE (including gearbox) and fuel tank, while the FCEV replaces the larger battery with a hydrogen tank, a fuel cell and a smaller battery for short-burst power and to capture energy during regenerative braking.

The amount of power electronics content in a vehicle powertrain is governed by the peak current requirement for each converter and by the number of converters used (most vehicles have one motor and inverter. But some have one motor/inverter per axle, and future vehicles may also have in-wheel motors).

Our view is that SiC is somewhat "powertrain-agnostic", so long as the powertrain is electrified, but that SiC is more likely to be adopted where it can deliver significant savings at the energy storage level that offset the increased costs of SiC inverters relative to the silicon-based alternatives. An FCEV is still an electric vehicle and will require an inverter of similar power to a corresponding BEV. Given that hydrogen fuel is relatively expensive, we therefore see significant value for SiC in reducing the running cost of FCEVs.



Source: US Department of Energy; Electrical and Electronics Technical Team Roadmap, October 2017
Source: Exawatt

Why SiC is beneficial in EV powertrains

In brief, SiC can provide the following benefits to power electronics in EVs:

- Reduced on-resistance, leading to greater power-conversion efficiency relative to silicon-based power electronics
- More-efficient power conversion leads to reduced cooling requirement, enabling reductions in cost, size and weight, which have a compounding effect on vehicle "fuel efficiency" (e.g. in kWh/mile)
- Reduced switching losses in SiC devices enable operation at higher switching frequencies, which allows for reduction in the size of passive components and the motor. Alternatively, SiC can be used to reduce switching losses (vs silicon) at the same switching frequency
- Higher device current density (via reduced on-resistance), leading to smaller devices and modules
- Superior performance at higher temperatures
- Higher device breakdown voltages vs silicon. This allows high-voltage conversion systems (e.g. 800V inverters) to be designed using simple and efficient circuit topologies.

Impact of SiC on BEV designs

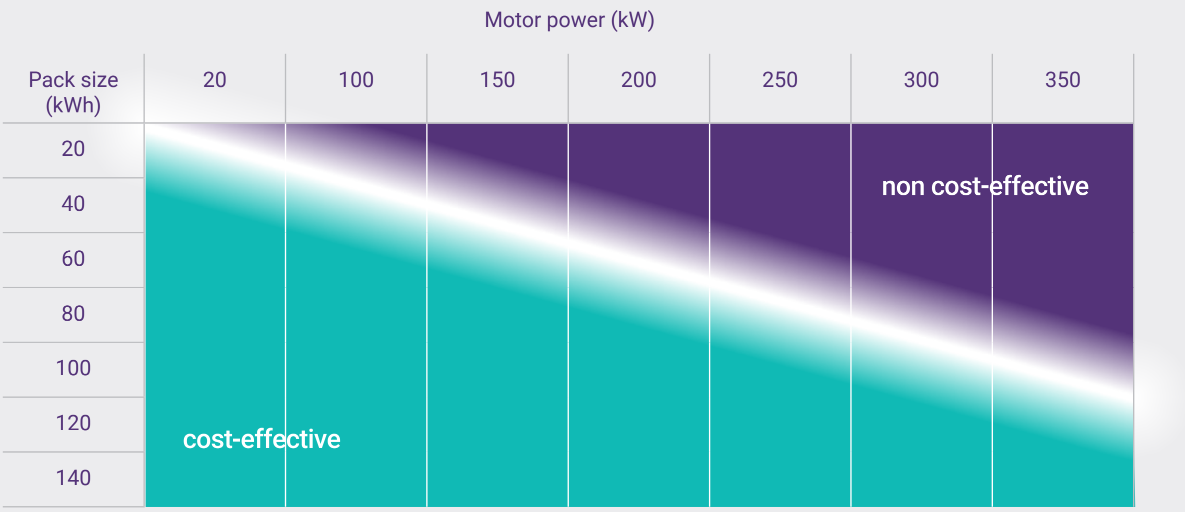
The benefits of SiC power electronics listed result in the following vehicle-level benefits for EVs:

- Increase battery range between 5% and 10%
- Significant weight saving
- I2R losses reduced, allowing for smaller, lighter power cabling
- Reduced charging time

The table below shows a basic estimation of the relative cost impacts of using SiC in the inverter for a range of motor powers and battery pack sizes.

Our calculations consider the estimated costs of replacing a silicon IGBT-based inverter with a SiC MOSFET-based inverter. These are set against the cost decreases that can theoretically be achieved by maintaining vehicle range at a constant level and reducing battery pack size, based on an assumed 5% range increase from switching to SiC. We note that this is only a rough estimation of the potential savings that could be achieved, as several other factors should be considered when switching to a SiC-based converter, such as switching frequency, voltage, gate drivers/control systems, reduced passive size, reduced cooling system size, and impacts across the whole drive cycle.

Savings (blue) and costs (purple) attributable to using SiC-based inverter vs Si-based inverter, 2020



Source: Exawatt

Key SiC challenges

Despite the clear technical and system-level economic benefits of SiC in EV power electronics, the technology faces challenges to widespread adoption beyond the relatively high cost of SiC devices. Chief among these is the need to use SiC devices optimally to achieve the full benefits of the technology. For example, SiC devices are capable of withstanding high junction temperatures and operating at high switching frequencies, but in order to extract the full potential from these features, innovative packaging will be required, presenting an opportunity for UK industry.

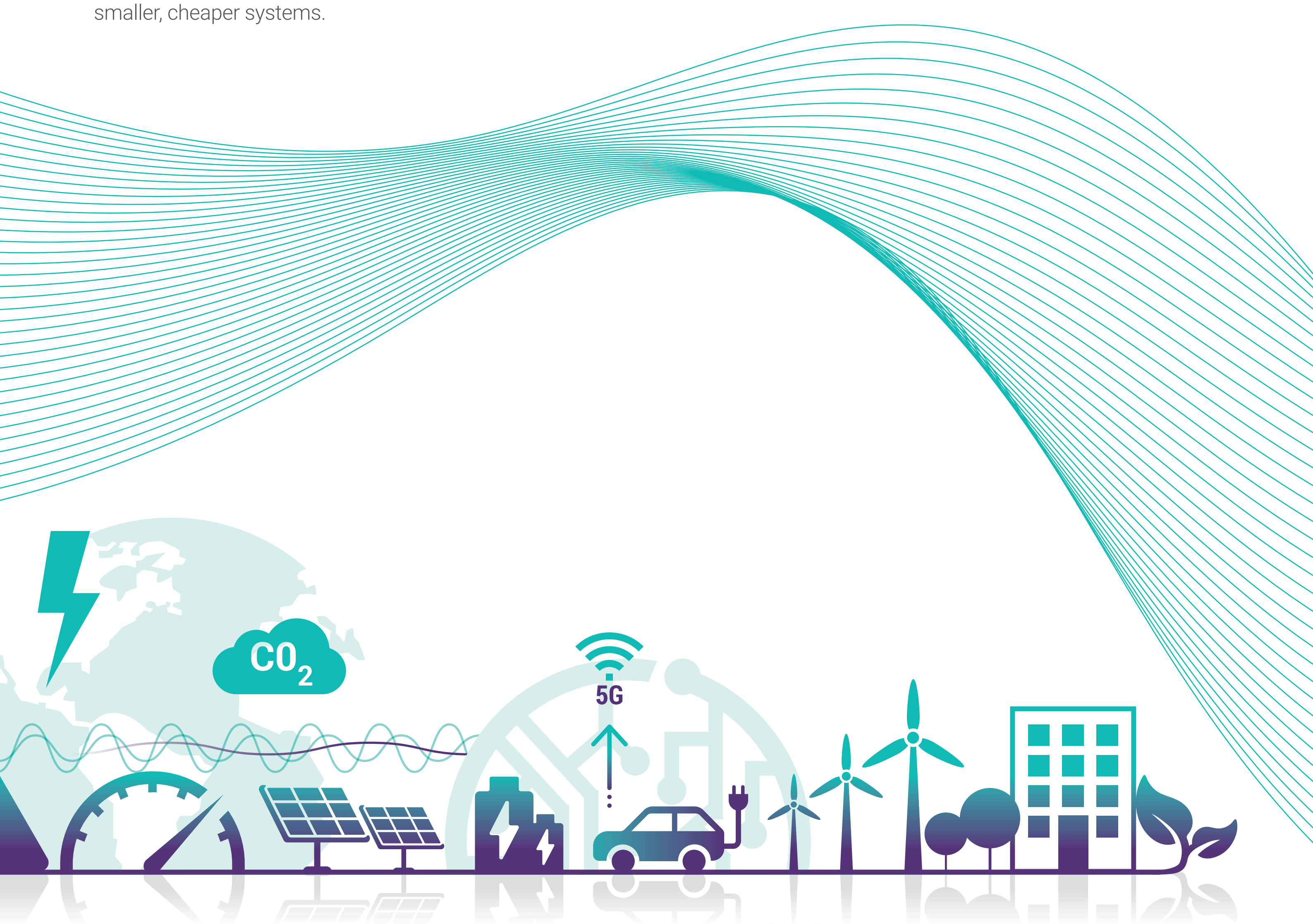
Also, many of the attributes that make SiC attractive as a wide-bandgap semiconductor material also apply to gallium nitride (GaN). In general, GaN devices are better-suited to lower voltages than SiC devices.

For now, industry support appears to be strengthening for SiC, at least in the inverter market. In other EV-based converters, such as on-board chargers, GaN may enjoy greater success in the medium to long-term, as it enables smaller, cheaper systems.

SiC use in discrete devices and modules

Most EV manufacturers and Tier 1 suppliers will use module- based systems for the inverter in the medium to long term – mounting individual dies in a larger, combined package within the system. By using a module-based system, OEMs (original equipment manufacturers) and Tier 1 suppliers can potentially save on design costs for integration/mounting of the die, and benefit from greater power density, reduced parasitic inductance, and improved cooling.

However, modules cost more than discretes on a like-for-like basis at the semiconductor product level. This is due to a range of factors including the requirement for additional materials, value added in the product design, more complex testing and handling, a lack of standardisation, and greater manufacturing capital cost. We believe a significant opportunity exists for UK industry to develop novel module technologies to extract the maximum performance from SiC.



Trends in SiC adoption

Signs are already emerging of an increasingly diverse global SiC market within passenger BEVs. Joining Tesla, Chinese vehicle manufacturer BYD, in its Han BEV, and Toyota, in the latest version of its Mirai FCEV, have begun to use SiC MOSFETs in the traction inverter.

Hyundai and Kia have also begun to ship vehicles with SiC- based systems using Hyundai's E-GMP BEV platform. Almost all other major manufacturers have announced that they are developing SiC-based systems in some capacity.

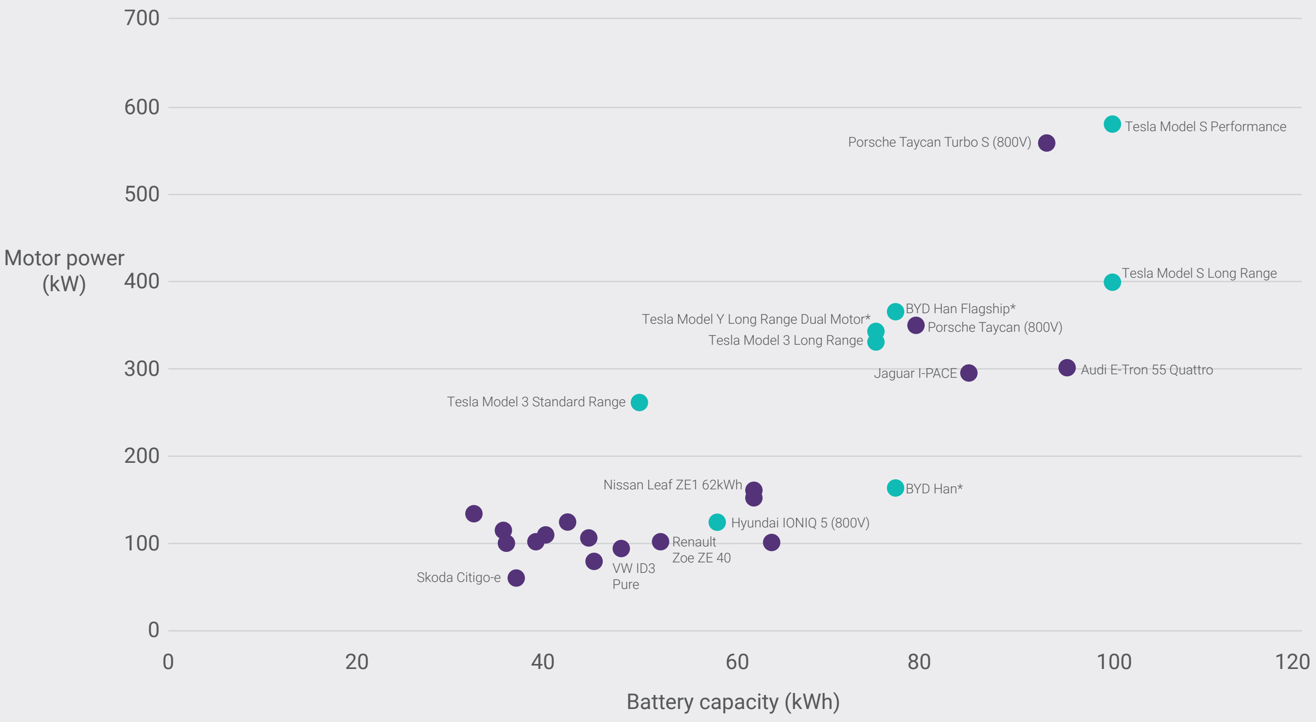
Meanwhile, various Tier 1 suppliers are working on SiC-based inverters, including: BorgWarner, Denso, Hitachi, ZF and Vitesco Technologies.

In the near term, SiC will most commonly be used in premium, high-performance vehicles, of which the UK is the second- largest manufacturer in Europe, before becoming widespread in cheaper, lower-powered mass-market BEVs. As a result, the average power of a SiC-based vehicle will decrease only gradually over the coming years.

As already discussed, the value case for SiC is highest in vehicles with large battery packs. The chart below shows motor power vs battery capacity for a range of BEVs, with vehicles that use SiC MOSFETs in the main inverter highlighted in red. This also shows that vehicles with larger batteries, unsurprisingly, tend to have greater motor power.

We note that battery pack size is also strongly correlated with vehicle price, and so the high-power, high-battery-capacity vehicles that are likely to adopt SiC first are in the high-end/luxury vehicle segment. We also expect a greater value case for SiC usage in larger vehicle segments, such as SUVs, which require higher motor powers and larger battery packs.

EV battery capacity vs motor power



Vehicles in red use SiC MOSFETs in the inverter. Vehicles in blue use silicon IGBTs

** Vehicle not yet available in the UK/European market; prices and specifications may be estimates or subject to change*

Source: Exawatt EV Market Tracker

Opportunities beyond EVs

SiC-based power electronics also have the potential to offer efficiency, cost and operating benefits in a number of other applications in adjacent markets. These applications offer alternative opportunities for the UK supply chain, and include lower-volume, high-performance applications that the smaller- scale, high-value manufacturers in the UK can address.

- **Off-highway vehicles:** Vehicles and machinery for use in construction, mining or other non-road-based applications also face electrification-related challenges, giving SiC an opportunity to provide the required level of power-conversion efficiency
- **Aerospace:** Aircraft electrification, for both propulsion and auxiliary power and for aircraft ranging from small personal aircraft to large commercial planes, offers opportunities for high-value, high-margin manufacturing for UK industry
- **Rail:** While the concept of electrified rail is not new, the high- power and high-voltage conversion of power required for rail propulsion and auxiliary systems can benefit hugely from the advantages afforded by SiC
- **Shipping**: Ferries, as well as international shipping of goods and resources, will become increasingly electrified, and SiC can provide significant energy savings here
- **Industrial drives**: High duty cycles of industrial drives offers the opportunity for efficiency gains and cost savings from a switch to SiC, and represents a significant market opportunity in the UK, where this is a core sector competence
- **Renewable energy:** The government's commitment to NET ZERO 2050 means increased investment and installation of renewable energy sources, notably PV and wind power. These require significant power conversion infrastructure at both the generation and grid distribution steps, where SiC-based solid-state power conversion offers significant benefits for grid balancing and efficiency

UK SiC demand in EVs

The UK EV market alone offers significant potential demand for SiC power electronics systems, modules, devices and wafers, providing a significant opportunity for the UK power electronics and automotive supply chain.

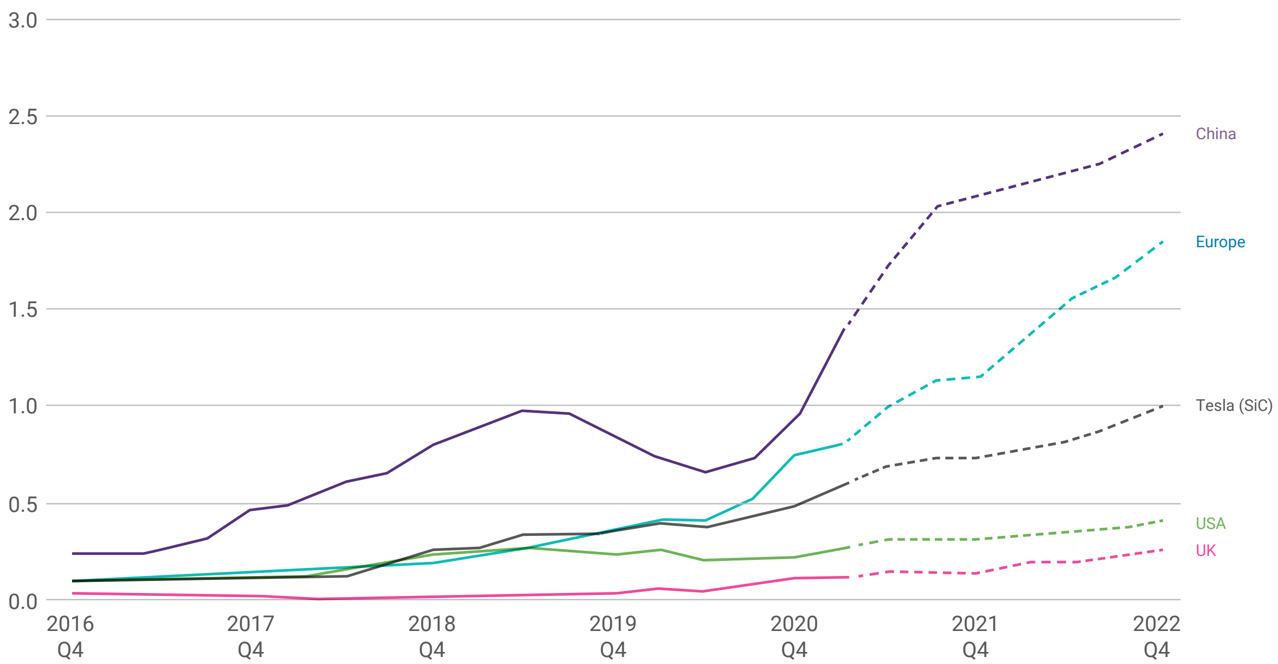
UK EV market

Exawatt's primary focus for the EV market is on forecasting the demand for passenger BEVs, as the consultancy believes this will be the most significant driver of SiC demand in the EV market as a whole. Passenger vehicles account for approximately 80% of UK vehicle sales (of all propulsion types) today. We expect this share will be maintained in the BEV market over the long term. However, we also include commercial vehicles in our SiC demand forecasting.

In 2020 and 2021, Tesla remained the only mainstream automotive manufacturer that used SiC in significant quantities.

In the graph below, Tesla is also represented alongside regional BEV sales to demonstrate the magnitude of the company's sales; in BEV terms, Tesla is significantly larger than the entire UK market.

Passenger BEV demand (TTM) (million units)



Dotted lines represent Exawatt forecasts

Source: Exawatt EV Market Tracker

Exawatt argues that the PHEV – and the hybrid vehicle more generally – will be a relatively short-term transitional technology, as manufacturers undergo a gradual shift to fully electric manufacturing – mostly BEV, with some fuel-cell EVs (FCEVs). The reasons for this are as follows:

- BEVs, in general, provide a superior driving experience relative to their hybrid cousins; they are quieter in operation, simpler and more enjoyable to drive, and in many cases offer higher performance (as exemplified by the Tesla Model 3)
- BEV operating costs are lower than those of hybrid vehicles, in terms of both fuel/electricity costs and maintenance costs
- In the longer term, BEV manufacturing costs and selling prices will achieve parity with internal combustion engine (ICE)/hybrid vehicle costs, as battery manufacturing costs fall and powertrain efficiencies improve, bolstered by SiC-based power electronic systems. Relative to hybrid vehicles in particular, BEVs have the advantage of not requiring both an electric drivetrain and an ICE (and associated systems)
- BEVs offer a better route for vehicle manufacturers to meet increasingly strict fleet emissions standards (where applicable, e.g. in Europe)

In the near term, although PHEV sales will continue to be significant, Exawatt does not believe they will significantly influence the SiC market, as the value proposition for SiC in PHEV inverters is less compelling, due to the smaller battery pack size in PHEVs. Accordingly, these vehicle forecasts are not presented in this report.

Exawatt has also included FCEVs in its SiC forecasts, as FCEV powertrains require traction inverters. However, FCEVs represent a tiny minority of total EV sales compared to BEVs, with fewer than 100 vehicles sold in the UK in 2019 and 2020. This trend will continue in passenger vehicles, although we acknowledge there may be an increasing role for FCEV commercial vehicles in applications with high duty cycles and long vehicle range requirements, where refuelling time and frequent refuelling stops are costly.

The UK is planning to ban new ICE passenger vehicle and LCV sales in 2030, but with some PHEV sales allowed to continue to 2035. The UK Government also currently offers a grant of up to £2,500 off the purchase price of BEVs with a sale price below £35,000 and offers tax breaks for BEVs bought as company vehicles.

UK EV SiC device and module demand

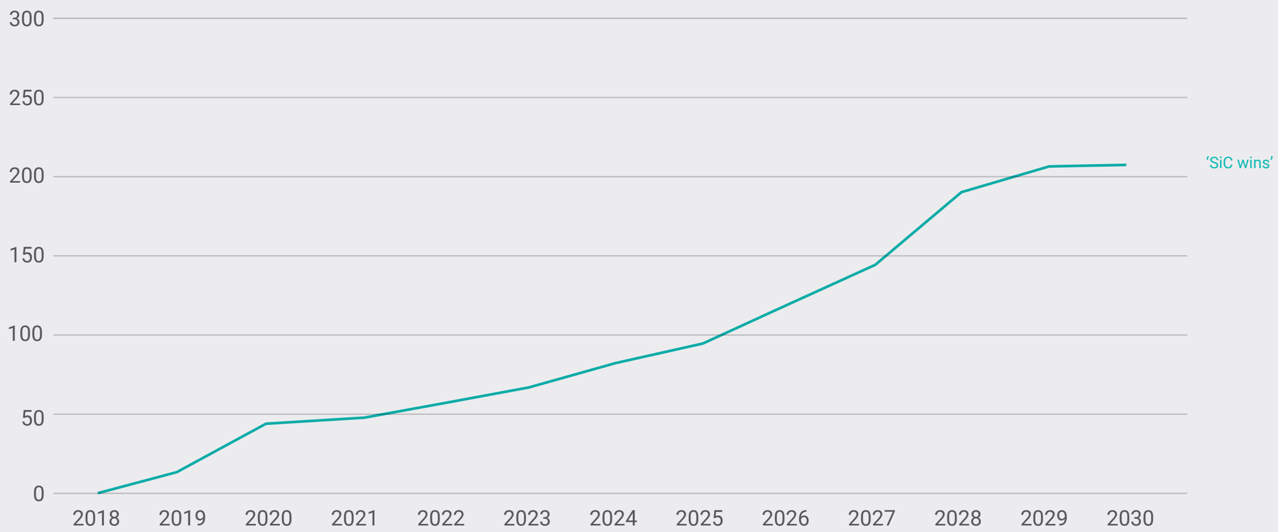
Exawatt forecasts a combined SiC device and module TAM for the UK EV market of approximately $204m in its "SiC wins" scenario. This assumes a realistic best-case scenario for all factors that lead to maximum adoption of SiC.

UK vehicle manufacturing and export demand

The majority of vehicles sold in the UK are imported, with UK manufacturing accounting for approx. 56% of passenger vehicles and 19% of commercial vehicle sales in volume. However, the majority of UK-made vehicles are exported, with UK sales predominantly from imported vehicles. About 80% of UK-produced passenger vehicles are exported, while 55-60% or commercial vehicle production is exported. About 1.3m vehicles were manufactured in the UK in 2019, falling to 920,000 in 2020, corresponding to 56% of total UK car sales in both years.

However, the UK produces a far higher proportion of engines (2.5m units in 2019, falling to 1.8m units in 2020). If this engine manufacturing capacity were to be replaced by EV drivetrain manufacturing this would provide a significant boost to the UK SiC manufacturing opportunity. It's notable that 63% and 61% of UK-produced engines were exported in 2019 and 2020, respectively.

UK SiC device and module TAM for EVs ($ millions)



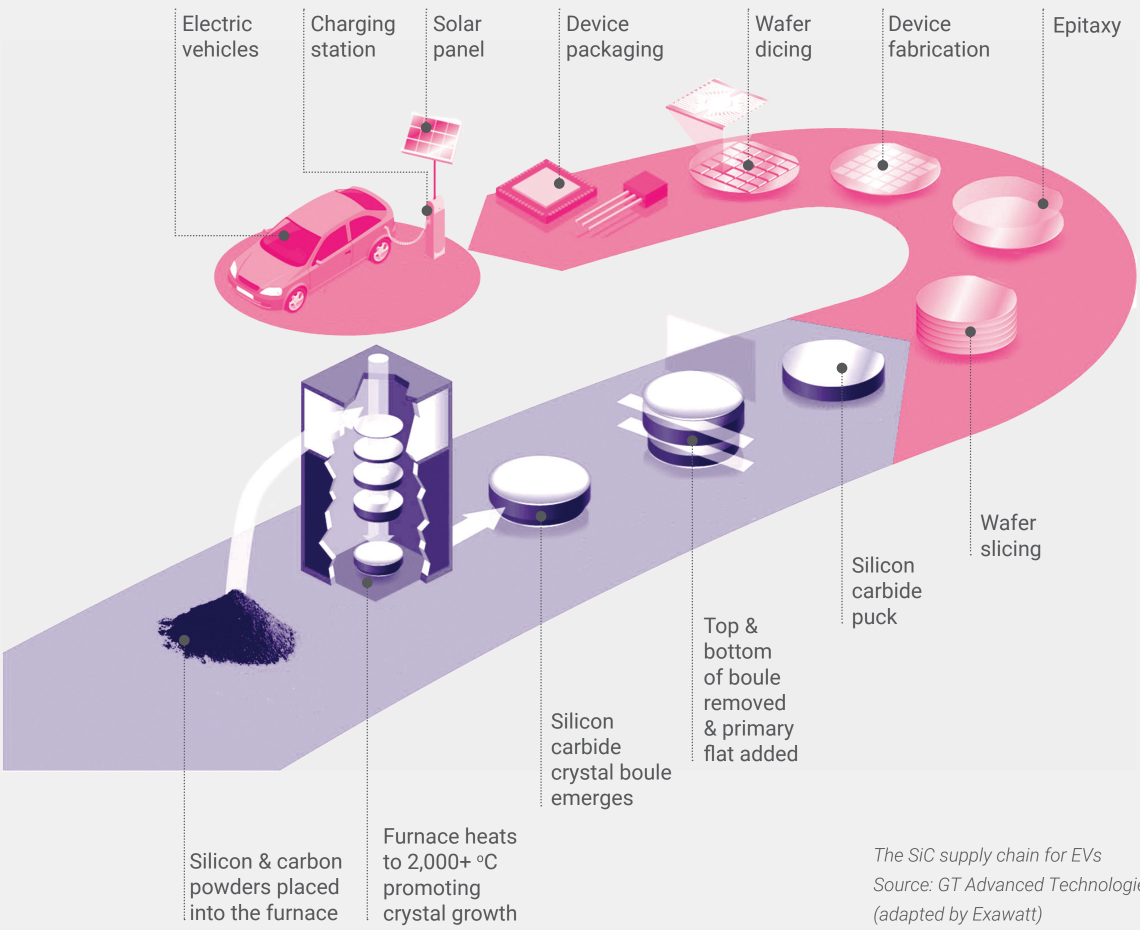
Source: Exawatt SiC Market Model

UK SiC power device supply chain

As the UK prepares to make the transition to pure-electric vehicle production over the next 10 to 15 years, with some manufacturers and brands committed to going 100% electric as early as 2025, demand for critical power electronic devices and systems is set to increase.

A typical SiC supply chain has the following components:

1. Crystal growth
2. Wafer slicing
3. Epitaxial deposition of drift layer (leveraging existing UK expertise)
4. Device design (leveraging existing UK expertise)
5. Device fabrication
6. Discrete and module packaging house
7. System design, e.g. inverter, DC-DC converter, on-board charger or charging station (including significant UK expertise)
8. System manufacturing/assembly
9. Tier 1 and automotive OEMs that develop and integrate SiC- based systems



The SiC supply chain for EVs
Source: GT Advanced Technologies (adapted by Exawatt)

The UK already has expertise and some capacity in several of these supply-chain steps, such as device manufacturing and packaging although scale-up will be required. The supply chains are also fed by a range of equipment, materials and consumables suppliers, several of which have operations in the UK.

Academia also plays a role, in terms of creating and inventing new processes that can be industrialised, and by developing expertise that can be leveraged by industry.

To take full advantage of the opportunity presented by SiC, the UK must continue to develop a domestic supply chain in the coming years to service the automotive industry, by manufacturing as much as possible in-country rather than relying on imported components and systems.

Initiatives such as the £20m ESCAPE (End-to-end Supply Chain development for Automotive Power Electronics) programme, supported by Innovate UK and the Advanced Propulsion Centre, aim to address this with a focus on supporting a home-grown SiC supply chain, from epitaxial deposition to power converter manufacturing.

UK power semiconductor manufacturers

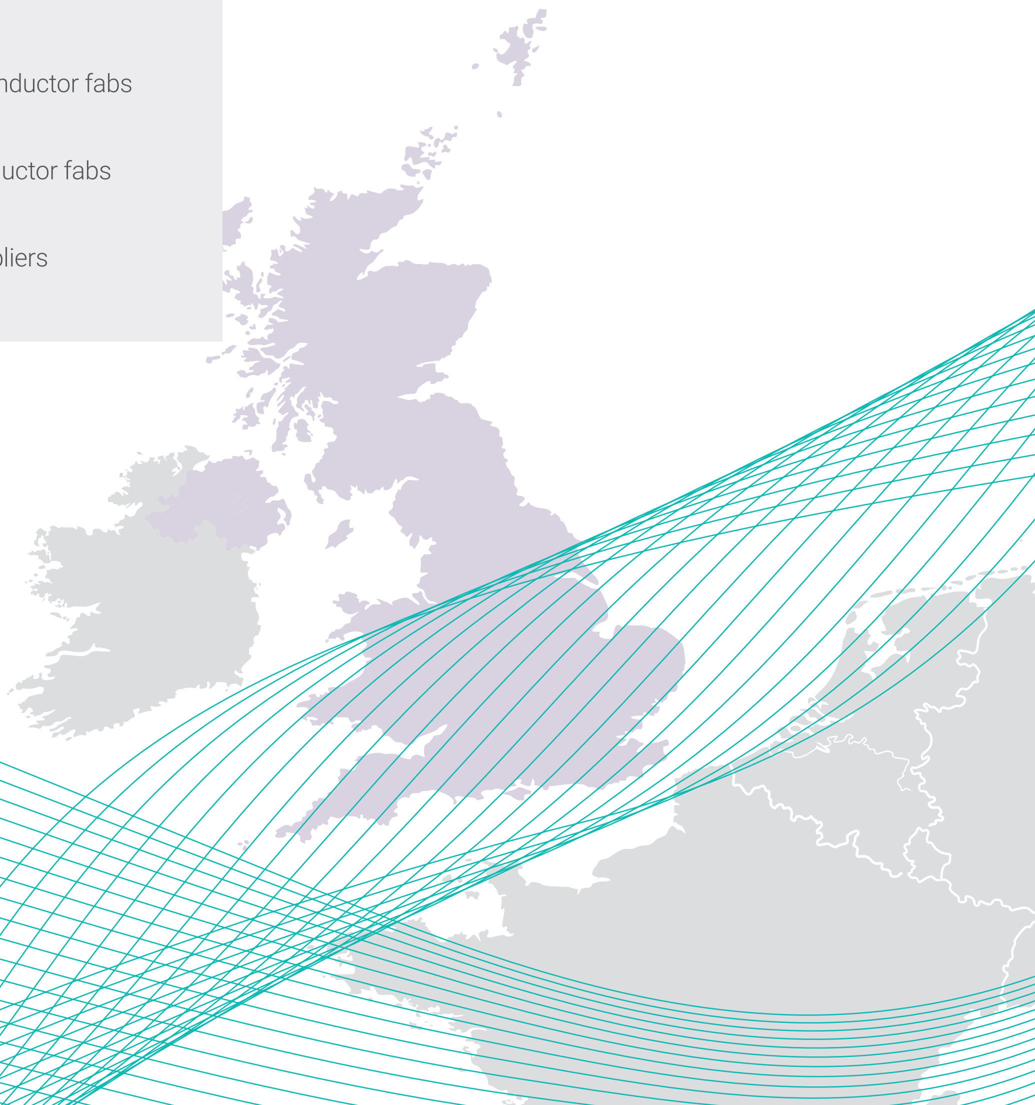
Semiconductor manufacturing capability has a broad reach across the United Kingdom, with strengths in conventional silicon as well as compound semiconductor technologies, including GaN and SiC for power electronics, and in power management systems at the fab and substrate level.

Existing silicon manufacturing sites can be converted to SiC, with investment, and there is evidence of some domestic appetite for this. The UK also has design, tool manufacturing and packaging capability for SiC and compound semiconductors.

However, the landscape is ever changing. The map overleaf is illustrative of all the companies that currently work within power electronics across the supply chain, including academia. Through the ongoing ATLAS project that CSA Catapult is championing, we aim to capture every company that works within this space to help build collaboration between organisations via an interactive map linked to a comprehensive database of capabilities.

Currently the UK has:

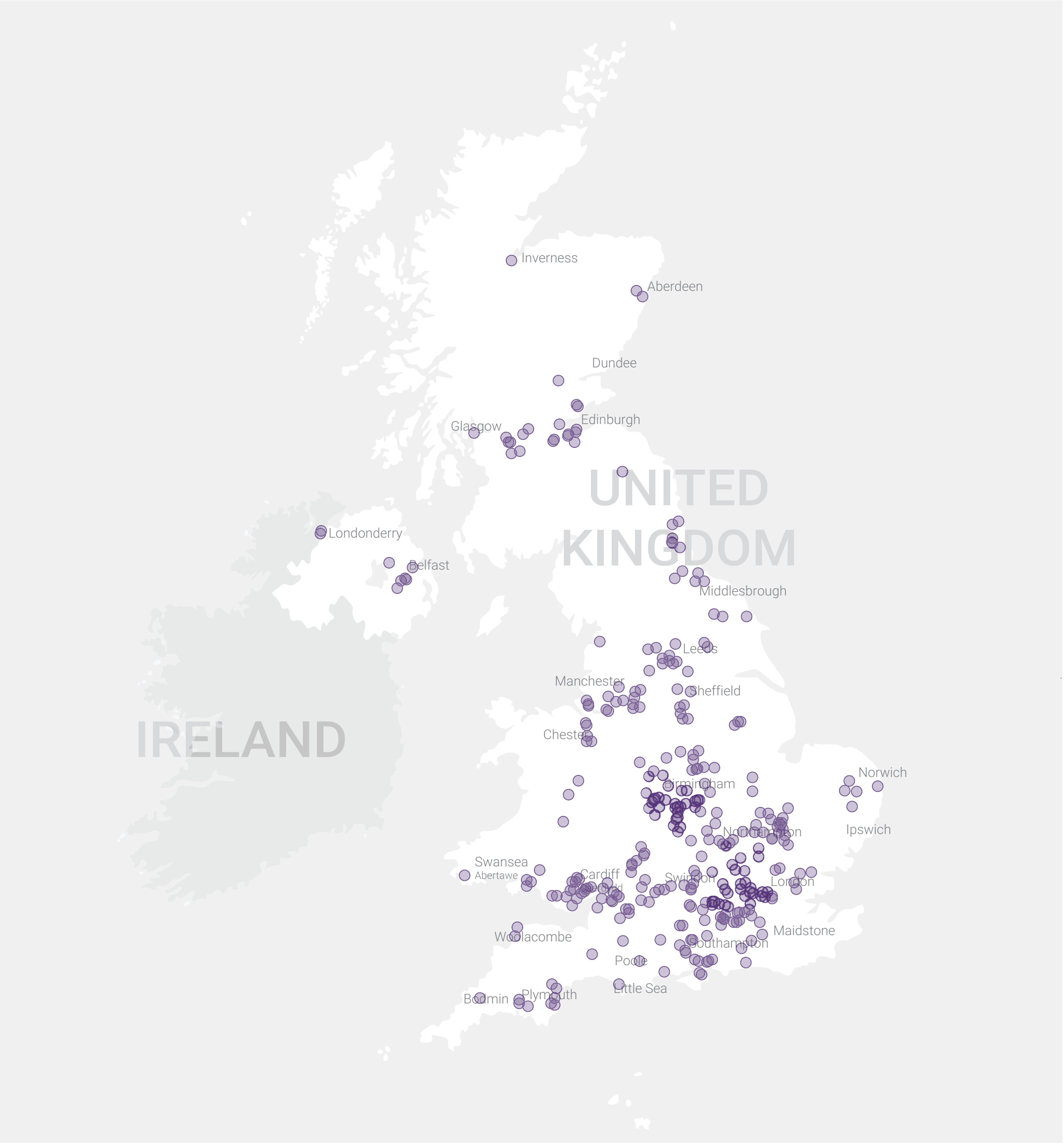
- 9 silicon power semiconductor fabs
- 2 GaN power semiconductor fabs
- 2 silicon substrate suppliers



UK projects and research

As has been discussed constantly throughout this Ripple report, in order for the UK to seize this valuable opportunity presented by SiC and the switchover from ICE to BEV transport in the next decade, the country needs to accelerate its research and development in this technology and build up its domestic supply chain.

As ATLAS shows there are companies all over the country that feed into the power electronics industry. The CSA Catapult strategically sits at the heart of the compound semiconductor cluster in South Wales and is actively involved in a number of research initiatives that have been funded by the Government to accelerate SiC development in the UK.



CSconnected, as the cluster in South Wales is known, represents a globally significant investment, generating annual sales of £500m and employing 1,600 highly skilled engineers. Uniquely, the cluster includes world-leading university research working alongside large volume fabrication facilities. Capable of supplying global demand for compound semiconductors, the "fabs" operate an open foundry model, developing new compound semiconductor devices according to customer demands.

Recently, the compound semiconductor cluster attracted a £25m investment from UK Research and Innovation's flagship Strength in Places Fund to further its aims. The combined capabilities put the cluster in pole position to address a global market forecast to be worth $124bn by 2024.

From a standing start in 2018, the CSA Catapult has built a team of nearly 100 talented employees, developed a state-of-the-art innovation centre and initiated over £100m of projects. It has recruited a diverse team with over 30 PhDs and over 700 years of relevant experience. The Catapult team has the business acumen and credibility to help our customers negotiate the most complex contracts, ensuring maximum return from projects. Since 2018, it has started work on over 25 projects, involving more than 100 partners, which are currently valued at £145m. These projects are transforming the UK's electronics industry, from advanced electric vehicles to remote monitoring of rail infrastructure.

Catapult's collaborative projects and other activities are currently forecast to create or safeguard at least 4,700 jobs. Over ten years, the activities of the Catapult are forecast to generate over £500m gross value add to the UK economy, as the companies it works with grow their businesses.

The CSA Catapult has been invested in the adoption of SiC technologies in the UK since its inception, initially through the £20m ESCAPE programme, along with 12 consortium partners which includes Exawatt and TechWorksHub's AESIN. ESCAPE is dedicated to creating an end-to-end supply chain for SiC based components and system-level solutions for use in the automotive, off-highway and potentially rail and aerospace.

In addition, the CSA Catapult was chosen to work with BMW on a £30m industrial scale-up project called FutureBEV. This project exploits the higher operating voltage and current characteristics of SiC to significantly reduce charging times and improve BEV efficiency.

UK companies are benefiting from BMW's innovation in power electronics and the potential for new business opportunities with a major automotive manufacturer. The demonstrators being developed within the project could be incorporated into new BEVs as soon as 2024, helping to transform the UK's automotive industry to use clean energy.

The FutureBEV project lays the foundation for 100kW/l inverters, significantly exceeding the APC 2035 and other industry targets, and creates a new supply-chain solution for sub-components used in electric vehicles.

Finally, the CSA Catapult is also home to the Driving the Electric Revolution (DER) Industrialisation Centre for the South West and Wales, an £80m UK-wide project developing the UK's clean and resilient supply chains in power electronics, machines and drives (PEMD).

DER aims to identify gaps in the supply chain and help industry fill them and accelerate production scale-up, supporting the development and growth of UK SMEs, encouraging inward investment from global companies and increasing exports of technologies manufactured in the United Kingdom. And last but not least, supporting skills development to ensure there will be enough engineers today to help create the technologies of tomorrow.

Glossary

Commonly used acronyms and abbreviations used within this report

AC	Alternating Current
AESIN	Automotive Electronics Systems Innovation Network
BEV	Battery Electric Vehicle
BMW	Bayerische Motoren Werke
BYD	Build Your Dreams
CSA	Compound Semiconductor Applications
DC	Direct Current
DER	Driving the Electric Revolution
E-GMP	Electric Global Modular Platform
ESCAPE	End-to-end Supply Chain Development for Automotive Power Electronics EV Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GaN	Gallium Arsenide
ICE	Internal Combustion Engine
IGBT	Insulated Gate Bipolar Transistor
IoTSF	Internet of Things Security Foundation
MOSFET	MetalOxideSemiconductorFieldEffectTransistor
OEM	Original Equipment Manufacturer
PEMD	Power Electronics, Machines and Drives
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaics
RF	Radio Frequency
SiC	Silicon Carbide
TAM	Total Accessible Market
UK	United Kingdom
UKRI	UK Research and Innovation
ZF	Zahnradfabrik Friedrichshafen

About the authors

CSA Catapult

Compound Semiconductor Applications (CSA) Catapult is focused on bringing compound semiconductor applications to life in three key areas: the road to Net Zero, future telecoms and intelligent sensing.

CSA Catapult is a Not for Profit organisation headquartered in South Wales. It is focused on three technology areas: Power Electronics, RF & Microwave and Photonics. As well as the three technology areas, CSA Catapult is also working in Advanced Packaging for these high-power innovations.

The next wave of emerging applications will have an enormous impact on people's lives. Compound semiconductors will enable a host of new and exciting applications in the electrification of transport, clean energy, defence and security and digital communications markets. CSA Catapult exists to help the UK compound semiconductor industry grow and collaborates across the UK and internationally.

The Catapult network provides world-leading facilities designed to transform the UK's capability for innovation in specific areas and help drive future economic growth. Established by Innovate UK, which provides funding and support for business innovation as part of UK Research and Innovation (UKRI), Catapults provide access to expert technical capabilities, equipment, and other resources required to take innovative ideas from concept to reality. Catapults are a national asset – no matter where the physical HQ is located they are here to work with businesses and academic institutions around the UK.

csa.catapult.org.uk

CATAPULT
Compound Semiconductor Applications

Exawatt

Based in Sheffield and founded in 2015, Exawatt provides strategic consulting and research in industries that enable decarbonisation through electrification. These include solar photovoltaic (PV), electric vehicles, power electronics and energy storage.

Exawatt's proprietary forecast models combine detailed market analysis with technical understanding in all facets of the value chain, from materials supply and manufacturing cost to downstream project development. This approach allows Exwatt's customers and partners to make accurate forecasts about where, when and how new and evolving technologies will influence the development of their businesses.

In 2017, Exawatt began research on the emerging market for SiC power electronics, at the request of a customer in upstream SiC material manufacturing. The company's SiC customers and partners now span the entire supply chain, from crystal growth and device manufacturing to system manufacturing and downstream integration, plus investment funds and other critical industry stakeholders.

www.exa-watt.com

exawatt

TechWorksHub

TechWorks is operated out of Glasgow, Scotland and is the industry body for Deep Tech technologies representing almost 300 member companies across multiple sectors including Electronic Systems Design and Semiconductor Manufacture (NMI) and Automotive Electronics/Electrification (AESIN). Providing dynamic, connected technical and business focus communities to empower innovation and collaboration, supporting business growth and investment.

Our mission is to strengthen the UK's deep tech capabilities as a global leader of future technologies, forming adjacent connected communities that are influential in defining and shaping the advancements of industry. We aim to provide a platform to help our members strategically leverage products and services to drive profitable growth.

TechWorks Hub core activity identifies the critical common challenges and leads the responses to tackle them, building partnerships across industry, academia and government. Our NMI community champions the Electronics Manufacturing Industry supporting the established Semiconductor Manufacturing and supply chain communities with activities that encourage innovation, communication and collaboration.

Meanwhile the AESIN community is dedicated to accelerating embedded electronics and power systems innovation for both vehicle electrification and safer highly automated vehicles.

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