The UK Power Electronics Opportunity

- A strategic position paper for UK industry -

This paper – prepared by a cross section of the UK Power Electronics industry – presents a view of the current industry landscape. It highlights how the sector can support UK economic growth and deliver on key Government policy objectives. Throughout, we consider "Power Electronics" to include power semiconductor to converters and related software, sensing, and processing.

The Power Electronics Opportunity

Power Electronics (PE) is a fundamental building block in all critical technologies from artificial intelligence and data centres to renewable power generation and electric vehicles, and from industry 4.0 and robotics to biomedical implants. Indeed, the provision of electrical energy in a stable, reliable and highly efficient manner is fundamental to all information & communications technology applications.

The UK already has strengths in many key aspects of PE and can secure world leading positions in product offerings by focusing on these. This comes at a time where electrification has been recognised globally as foundational to the energy transition towards NetZero and this global shift provides a unique opportunity for the UK to tap into new global growth opportunities by building on our strengths.

The UK government published their Semiconductor Strategy [j] in May 2023, which set out a 20-year vision for the UK to develop a world leading position in future semiconductor technologies based on UK strengths in intellectual property and design, compound semiconductors and research and development.

PE was not specifically identified in the document, and yet the sector is well positioned to address the core missions identified in the strategy, namely to: **1. enable domestic sector growth**, **2. help to mitigate the risk of supply chain disruptions** in critical sectors, such as automotive, public & goods transportation, telecom's, electrical grid and industrial robotics and **3. protect our national security;** there are myriad applications of PE in Critical National Infrastructure (CNI) and defence from electrically powered ships to radar and missile systems.

Approach

This is a strategic position paper written by a cross section of the PE industry, associated with Power Electronics UK (PEUK)[1] and contains recommendations based on a wealth of information and discussion from stakeholders. Within this document, we focus on the two societal transitions which are driving the importance of PE: The **Digital Transition**[7] and the **Energy Transition**[8] and the impact of these on three significant sectors: **Energy**, **Transport** and **Industry**.

Executive summary

What is Power Electronics?

Power Electronics (PE) is the branch of engineering concerned with the processing and control of electricity to move and condition energy from a source (battery, solar panel, or electrical generator) to a device which needs electrical power to operate. From household electronics to space satellites, all electrical devices need stable and reliable electric power.

PE plays a crucial role in society by delivering energy to numerous important applications, supporting all aspects of modern information & communications technology in a highly efficient and reliable way. It is a critical component in small applications like pacemakers and mobile phones to large applications like turbines, solar PV and electrical grids powering entire cities.

A PE system comprises power semiconductor[2] devices, electronic control circuits, switchgear, software, cooling systems and mechanical packaging, in many cases using a range of advanced and emerging materials. The PE system is completed by the application of the electrical energy to an electrical machine, drive, actuator or other energy consumer.

Why is Power Electronics important?

As a cross-sector technology and multidisciplinary activity, the PE industry brings multiple players together, striving to achieve precise control and higher levels of power efficiency. Within the UK, there exist a number of companies working across the Power Electronics sector with unique capabilities and strengths in many important areas, together with a strong history in end-to-end systems know-how and some world leading product offerings.

Energy efficiency and conservation is a major global priority as the world aims to transition from reliance on fossil fuel towards sustainable and renewable energy supplies, whilst our appetite for energy and the cost of it continues to rise. There is a significant opportunity to build more efficient, smaller and lower cost PE solutions as the world simultaneously follows the digital and energy transitions towards Digital Transformation and NetZero. The UK possesses strengths in innovative design, advanced materials manufacture and systems know-how which means we are well positioned to address the resulting global market opportunities.

Power Electronics in the UK

Power Electronics is often a hidden industry, yet critically important in achieving net zero, sustainability and to enable the incredible growth forecasted in modern information processing systems (data centres and cloud AI processing).

This paper sets out to show why Industry leadership in Power Electronics is imperative to the UK's national economic security and that a focused activity, in partnership with public sector support, can help drive continued high growth, directly, and as an enabler of other key UK sectors including automotive, public and goods transportation, aerospace, renewable energy, telecommunications, agriculture, heath services, manufacturing and consumer electronics.

PEUK provides a focal point for the Power Electronics industry in the UK, convening industry and academia with government and providing a unified voice to assist in navigating this complex sector and ensuring maximum impact from any investments.

Our Recommendations

In this position paper we present the key findings of an industry-wide SWOT analysis, leading to recommendations that we propose should become the basis of a UK Industrial Strategy for Power Electronics to guide investment and deliver the best economic value to society.

<u>This paper makes five important recommendations, which may be summarised as follows:</u>

- ❖ Coordinate, promote and grow the UK Power Electronics sector
- ❖ Strengthen the UK Power Electronics Supply Chain
- ❖ Advance digitalisation[6] in UK Power Electronics
- ❖ Stimulate Power Electronics technologies and products through growth and investment
- ❖ Enhance UK Power Electronics talent and skills development

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These recommendations and the vision presented here are directly aligned with the government missions identified in the Labour party manifesto:

1. Make Britain a clean energy superpower

The UK has opportunities to harness new technology in **upgrading infrastructure** not just in the domestic market but to export worldwide. A change in the way energy is generated, distributed and used will need PE innovation to succeed and this provides a perfect opportunity for UK business growth. Modernising the national electricity grid will enable opportunities in renewables, micro-generation and scale up of electric vehicles.

2. Kickstart economic growth

PE provides numerous opportunities to grow jobs and productivity across multiple sectors, **supporting businesses to start and grow.** The UK is known for innovation and in domains such as electrified transport and industry 4.0 power electronics is key. Furthermore, sustainability and reduction in non-UK critical materials, such as rare earth magnets (used in renewable power generators and motors) and copper (used in the National Power Grid lines, cables and Transformers, and most electronic equipment) can be unlocked through PE innovation.

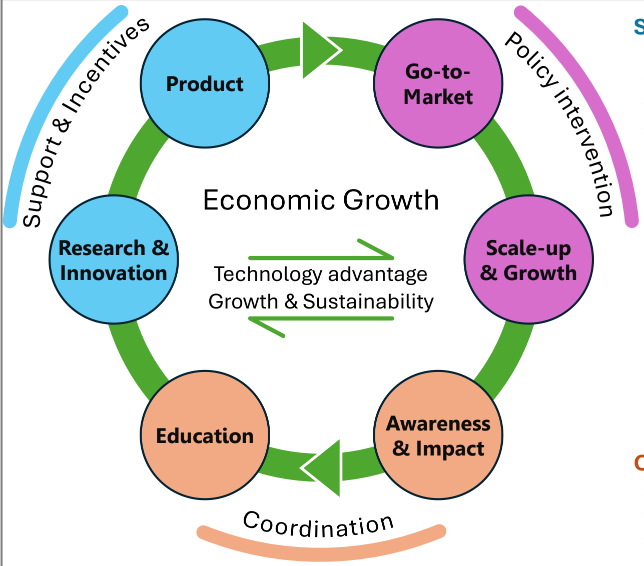
3. Break down barriers to opportunity

Within the PE sector, there is a strong history of collaboration between academia, industry and entrepreneurs, with many examples of successful commercialisation of innovative research. Providing access to industry via **developing skills** and harnessing talent and ambition enables PE to create a significant **return on investment in science, research and innovation** for the UK**.**

4. Identifying critical technologies

The Science and Technology Framework articulates the need to choose which critical technologies the UK should focus on to build strategic advantage. **PE is an underpinning technology**, which by its nature, is **critical to many future and emerging technologies**.

How do these proposals impact economic growth?



Stimulate domestic innovation, supply and demand

- Incentivise collaboration towards commercial exploitation
- Scale-up core infrastructure and services
- Level the playing field compared to overseas incentives
- New funding to support long-term collaboration

Strengthen the UK PE Supply Chain

- Build on UK strengths, supporting scale-up and reducing dependence on imports
- Create domestic demand through focus on NetZero and public procurement

Coordinate and promote the PE sector

- Facilitate domestic growth and export opportunities
- Advance digitalisation to stimulate wider opportunities
- Enhance PE talent and skills development

Introduction

To **make the UK a clean energy superpower** and achieve **Net Zero**, we are undergoing a transition to an All-Electric Society. This *Energy Transition*[8] brings with it significant and wide-reaching implications across society and multiple industries. At the same time, we are also transitioning to a digital society (The so-called *Digital Transition*[7]) to address the challenges of productivity and societal inclusion, this increase in the use of computing, AI and connectivity is also driving demand for electricity. These transitions impact significantly on three important industries, which are considered within this paper:

- **Energy – The move to green renewable energy supply**,
  requiring an enhanced electricity distribution system (grid) and energy storage,
- **Transport – Future mobility, new modalities and electrification**,
  using new motor drives, increasing autonomy, and require charging infrastructure, and
- **Industry – Efficient and intelligent industry,**
  driven using electric power in various forms.

Delivering on these transitions will rely on the efficient conversion and control of electrical energy, and in turn, on Power Electronics (PE)[3]. The objectives driving change in each of the three industries above are as follows:

- **Greater efficiency** (less wasted energy, less weight and longer range in EVs),
  This is being enabled by modern power semiconductor devices.
- **Lower use of resources** (sustainability and reduction in negative impact materials)
  Leading to significant non-UK resourced materials savings and better resource utilisation.
- **Better value** (lower cost and increased performance)
  Leading to more competitive products and increased exports.
- **Digital Transformation[7] and machine learning**,
  For example, artificial intelligence providing extended functionality to the user, system monitoring and control, greater resilience and optimal energy savings.
- **Increased reliability**,
  A cross-sectional and multi-disciplinary topic including material science and covering product qualification and testing, condition and health monitoring.

The future smart grid

A good example of these drivers and the resulting needs and opportunities can be seen if we consider the electrical power grid, which brings all three industries together: energy, transport and industry. Grid flexibility, resilience and efficiency are key to meeting our net zero targets.

National electric power grids around the world are changing significantly. Simultaneously impacted by both the Digital Transition and the Energy Transition, they must become fully bi-directional, dynamic in operation and real-time intelligent. This historic transformation requires new advances in Power Electronics as an enabling thread that underpins generation, distribution, storage and supply, alongside new use-cases, such as EV charging, Smart Homes, City Microgrids, Data Centres and Electrical Mass-Transport.

Fixed function wound transformers and electro-mechanical switchgear will be replaced by solid state, flexible and more efficient components such as Solid State Transformers, Soft Open Points, Soft Power Bridges and DC and AC micro grids. These elements of the UK's critical national infrastructure will rely on new semiconductor materials such as silicon-carbide.

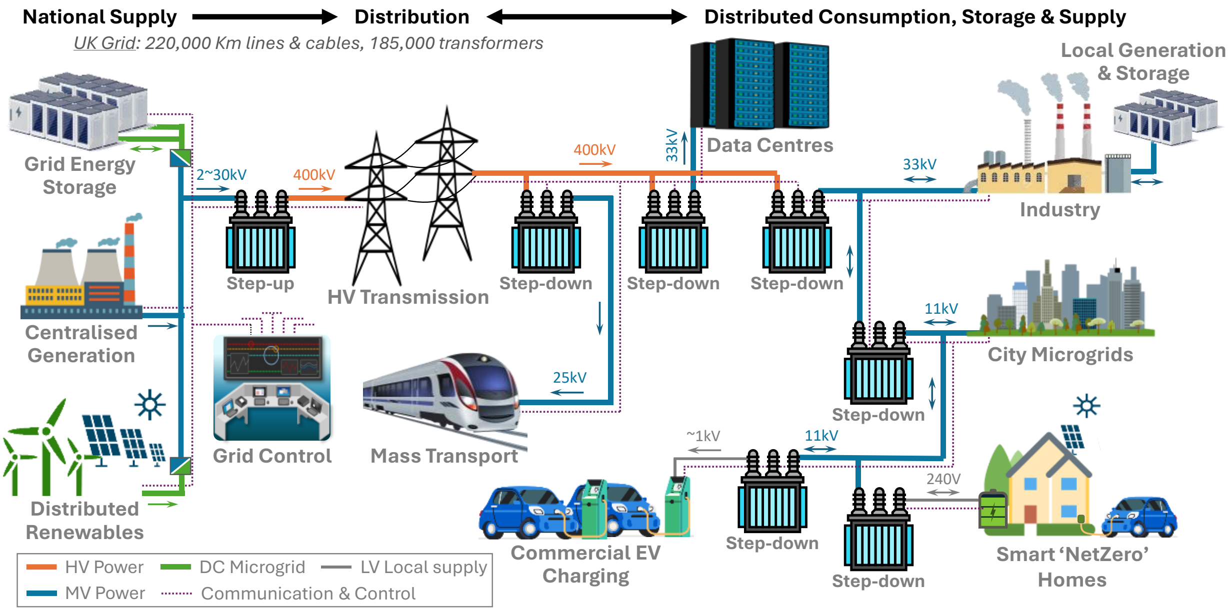


Figure 1 - Evolution of the national electrical grid

The Power Electronics sector

This technology sector has a **huge global market value**. Starting with the value of the power semiconductor content alone, which is estimated by "Yole Development" to reach $33B in 2028 with an 8.1% combined annual growth rate. It has been estimated that the market value of power electronics converter systems (built around the aforementioned power semiconductors) is typically between 4- and 8-times the power semiconductor content, **$133B to $266B** [b].

The UK has a small yet agile, capable and leading technical base for power electronics. Industry and academia work well together driving the research, design and realisation of systems and their supply chains. The products cover a range of sectors including automotive, aerospace, railway, industrial automation, domestic and industrial power, heating and ventilation, wind power, solar power, green hydrogen, electric grid, agriculture, and health care.

Over the past ten years, there have been **successful government initiatives** to support research and innovation in Power Electronics, including the EPSRC Centre for Power Electronics "CPE", [f], Innovate UK's Driving the Electric Revolution "DER" [g], the Compound Semiconductor Applications Centre "CSAC" [h] and the APC funded ESCAPE project (developing a UK based Silicon Carbide EV supply chain) [i].

Most recently the **National Semiconductor Strategy** [j] has established a greater awareness of the national importance of semiconductor chip and advanced packaging technology that will lead to government led initiatives and stimulate investment in the sector. DER has recently issued a document [l] that highlights the importance of the power semiconductor and lays out some clear recommendations which PEUK fully supports.

It is vital to continue to support Power Electronics in the UK as the electrification challenge and the resulting economic opportunity continues to drive the need for technology and manufacturing growth. The DER initiative laid solid foundations for a sovereign PE supply chain to capitalise on such opportunity to boost the UK economy and jobs, but without the next stage of growth capital and domestic demand the opportunity will be lost.

UK PE SWOT assessment

Based on this need, PEUK initiated a study to collect the views of UK Power Electronics stakeholders in the form of a SWOT review analysis over a period of 9 months. This review has been conducted based on evidence collected from industry, academic and other stakeholders at workshops, by interview, through questionnaires, as well as by review of recent published information. The full SWOT analysis is summarised in Appendix A.

Strengths and Opportunities

In summary, our analysis shows that the UK enjoys a strong research and innovation base, led by world-class academic institutions and low volume specialised product design and manufacturing companies. This enables us to commercialise innovation at prototype and pilot level. We have thereby earned a strong reputation internationally for innovation, quality and reliability. Our wide bandgap capabilities are well recognised, especially in GaN[9] and SiC[10]. We have a strong skills base in the sector due to university activity and industrial collaboration and can attract overseas talent due to our strong reputation. In addition, the UK enjoys highly relevant market sectors such as motor sports and aerospace.

The impending Digital Transition and Energy Transition represent significant global opportunities for the PE sector and long-term benefits to the UK, such as the future UK national electrical grid. Because PE is cross sector and cross discipline, existing talent can be re-trained from other disciplines to help fuel growth. Establishing supply chain sovereignty and localisation within the UK will give longer term resilience and sustainability together with export market opportunities. With a strong position in wide bandgap chip and module technology and power converter systems expertise, the UK is well positioned to take a lead globally. The addition of control and digital systems to PE also brings a new opportunity for industry and talent development.

Weakness and Threats

The business case and RoI for modernisation of the electrical power network is not well articulated and yet is critical to achieving both the UK's Energy Transition goals and growing our PE sector. Furthermore, there are few large-scale manufacturing businesses in the UK able to supply at attractive price-points, leading to procurement resistance and key supply chain gaps.

Much of our industry consists of early-stage business and SMEs with insufficient access to scale up investment to enable crossing the valley of death. This lack of scale and lack of government support for manufacturing means that we continue to procure key components of our Critical National Infrastructure (CNI) from low-cost suppliers' overseas (some of whom may be in politically unstable countries) rather than UK sovereign suppliers. In addition to economic security, this represents a national security threat due to cyber security and reliability and resilience concerns in critical applications such as energy, transport and industry. In other countries, state funding supports technology innovation and commercial scale-up to meet domestic needs and provide the basis for successful export business. This puts UK suppliers at a disadvantage and un-levels the global playing field.

From a skills perspective, in common with other technology sectors, the talent pipeline is weak due to a lack of engineering graduates, technicians and weak diversity in the talent pool. But PE also suffers from insufficient practical lab work at university and schools leading to a lack of hardware skills. Furthermore, it has become difficult and expensive to attract and retain students and experienced staff to the UK from overseas due to tougher border controls.

Recommendations

1. Coordinate and promote UK Power Electronics

Power electronics is too often a hidden industry, yet critically important in achieving net zero and sustainability goals. It is a rapidly growing market in the UK and abroad, and, as an enabling technology, this accelerates growth in other technology areas. The DER UK Power Semiconductors Landscape Report (2024) [l] included a recommendation to unlock the UK power electronics and semiconductors ecosystem which will require coordination to enable an enhanced electricity distribution system, accelerate electrification of the manufacturing industry, and the achievement of net zero emissions.

We recommend **creating an independent group** to:

- **Coordinate and promote** the UK Power Electronics brand to stakeholders and investment communities,
- **Collate advice** on industrial impact of research and skills,
- **Develop a technology roadmap** for future materials, devices and solutions
- **Provide reviewers** of standards, regulations and policy,
- **Facilitate export opportunities** identification initiatives, and
- **Support business development** and investment through collative expertise.

Around the world, sustainability has created an urgent need to move towards widespread electrification, renewable energy and efficient transmission & distribution. The UK must prioritise PE innovation to enable domestic electrification growth. However, such UK innovation can, in turn, realise significant export business and UK economic growth if it is supported.

2. Strengthen the UK Power Electronics Supply Chain

Reduce UK dependence on imported items and build on UK strengths in materials science and engineering so we close the gaps in supply and, in line with our National Semiconductor Strategy, realise the full potential of wide band gap semiconductors and advanced packaging.

The global supply chain is constrained in many areas and may struggle to meet governmental and commercial targets. The move to a low carbon economy offers many opportunities for power electronics but will ensure that supply chains are constrained for at least the midterm.

We recommend:

- A **focus on zero carbon, efficiency, productivity and sustainability** in the UK manufacturing industry to create the demand for power electronics and accelerate innovation in technically challenging areas creating future UK opportunities.
- Encouraging **local and regional power electronics supply policies** to stimulate use of sovereign sources to create local job opportunities for trained staff and support the UK domestic and industrial electrification agenda. Achieved by strategic investments to ensure legacy large scale manufacturing footprints remain competitive and innovative.
- **Building on UK strengths in design, research and innovation** in power electronics to realise a more effective power electronics industry, particularly around top-level suppliers and their supply chain. This is to compete with imports by building the UK brand as a world leader in quality design, R&D and reliability.

- **Enable scale-up of PE manufacturing and supply** by supporting UK manufacturers and strengthening links between industry, academia/research and investors to encourage uptake and scale up following established models. Further develop innovative packaging and assembly solutions supported by open access facilities such as catapults and DER-ICs for next generation high-power products. See DER recommendations 1, 2 & 4 [l].
- **Incentivising regional clusters** of power electronics manufacturing across the key UK sectors to deliver UK economic benefit and security. Sectors include Electric Vehicles, Power Generation and Distribution, Renewable Energy, Aerospace, and Agriculture. This would enable the drive to net zero and use of renewable electric energy.
- **International collaboration** in R&D and inward investment to complement the UK strengths, and leading to UK content in the end-to-end global supply chains for PE

3. Advance digitalisation in UK Power Electronics

As we move to an intelligent automated world, where machines and plants can 'think for themselves', the power electronic control systems will become highly complex, with sophisticated algorithmic software running on distributed computing, both in-device and in the cloud. Adoption of AI will take this further and globally there is a strong trend towards integrated power electronic systems connected through the Internet of Things[5], with AI and machine learning enabling truly smart manufacturing and industrial automation. This is of relevance for the future national electrical grid, where sources of power generation and consumption can be any of residential, industrial, centralised or distributed, requiring real-time intelligent load balancing and routing to manage the complexity. Note, this in turn, makes appropriate and robust cyber security measures highly critical.

We recommend:

- **Raising awareness of the opportunities and supporting the adoption of digitalisation**[6] in power electronics and the integration of information, computing, and sensing to enable control and resilience across complete systems.
- **Enabling opportunity, innovation and creativity** in the power electronics industry including a total electrical distribution system view of digitalisation including grid connectivity, local energy storage and onsite renewable power generation.
- **Stimulate more industry activity and collaboration** in the lower and mid supply chain levels through expanded activities.
- Fostering **collaboration between power electronics and adjacent digital technologies** to enable 'smarter' power solutions with greater integration of power converter and inverter electronics. This can be achieved through targeted R&D collaboration. (See DER recommendations 4 in [l].

4. Stimulate new Power Electronics technologies and products

Stimulate new technologies capable of operating at high frequencies, power levels, temperatures and voltages. This includes magnetics, capacitors, dielectrics and thermal management.

We recommend:

- **Financial support for targeted R&D collaboration** with power electronic converter and inverter development businesses focused on commercial exploitation of new technology.

- **Providing 'core services'** that can be drawn on by industry partners at an economic cost. For example, tests such as failure analysis, reliability, and electromagnetic compatibility. See DER recommendations 2 & 4 [l]. This will also **support supply chain scaleup**.
- **Commercialise the UKs agile and innovative culture** where smaller teams and companies can rapidly adapt to technology, customer, and societal needs. This is a strong enabler within emerging markets.
- **Provide a level playing field** when comparing the UK to overseas government financial support and incentives, such as for industrial CAPEX, in areas that align with UK goals. Develop a specific funding program for critical technology development in the UK, similar to the approach of DoE and DoD in the US.
- **Increase the number of industry-academic partnerships** such as KTPs or prosperity partnerships that address power electronics and increase the length of those activities to make true market impact for all involved partners.
- Develop new funding mechanisms and opportunities that **support very long-term collaborations** between industry/academia and stakeholders for identified key power electronics components/systems. Financial support should span TRL 1 to TRL 9**.**

5. Enhance UK Power Electronics talent and skills development

Skills are vitally important to the power electronics industry. We recommend **enhancing power electronics talent development** via:

- **Raising awareness** and interest in PE from an early stage, with a focused approach aimed at 11–16-year-olds and targeting equality, diversity and inclusion (EDI). Partnering with the UK Electronics Skills Foundation (UKESF) [n], to provide social media tutorials, visits to industry, and exhibitions. Enhancing the DER Electric Revolution Skills Hub (ERS), to give greater visibility in schools and universities and wider society.
- Promotion of the **benefits of home-grown talent** from college.
- **Encourage more bursaries** and re-training / re-skilling / transfer of skills support.
- **Create collaborative channels** between academia/industry/education/experts. Encourage cross university collaboration for more focussed subject area teachings in practical power electronics topics
- **Extend proven schemes** such as engineering apprenticeships, Centres for Doctoral Training, Knowledge Transfer Partnerships, and outreach via Universities, Catapults and other organisations.
- **Promote cross disciplinary training** to encourage solving of system cross-interdisciplinary challenges.
- **Stimulate international cooperation** in research and education and establish outreach projects to attract talent from offshore.

Appendix A. Industry SWOT analysis

PEUK initiated a SWOT analysis in spring 2024, consisting of a survey, online meetings, individual interviews and a face-to-face workshop. The work focused on three major application sectors:

1. **E-mobility**: all forms of freight and people transportation road, rail, air and marine, also aerospace and off-road construction, agriculture
2. **Industrial**: industrial automation, heating and forming, air conditioning and ventilation, data farms, etc
3. **Energy**: electric power generation, energy storage, power transmission and distribution.

In each sector we considered technology, manufacturing, and skills. Recommendations were derived from the SWOT analysis, the collected data, and discussions with experts. The results were then combined into one "cross-sector" SWOT summary as shown below and summarised through three different perspectives: Industry, Technology and Skills.

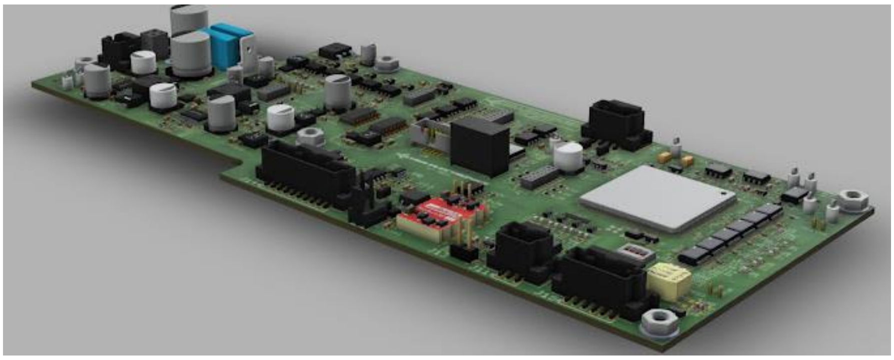
Industry	Technology	Skills
	Strengths:	
Excellent low volume specialised product design and manufacture,	Good at innovation to prototype and low volume level	Power Electronics skills are transferable across a wide range of sectors
UK academic research groups are internationally leading in PE	Wide bandgap Innovation specifically GaN	Respected education in UK by world renowned experts in many Universities
International brand recognition for quality and reliability	Academic institutions are internationally recognised for PE and semiconductor chip research	Attract overseas talent to UK due to strong reputation in research, Innovation and sectors such as motor sports and aerospace
	Weaknesses:	
Poorly understood business cases in the critical opportunity area of smart electricity network distribution	Lack of passive component skills and manufacture (magnetics and dielectric)	Not sufficient opportunity for practical lab work leading to a lack of hardware skills, more lab teaching facilities needed
Too few large-scale manufacturing businesses leading to gaps in the UK supply chain	Lack of government knowledge of PE manufacturing technology	Poor recruitment and retention of engineering graduates for UK industry, and very weak diversity in the talent pool
High manufacturing costs and therefore resistance to procure from the UK to ensure sovereign supply is available when needed	Access to scale up investment for SMEs to cross the valley of death	Electronics is not taught in many Schools; thus, the talent pipeline is inadequate
	Opportunities:	
Drive to net zero, renewable energy and sustainability can drive techno-commercial propositions with informed long term cost benefits to UK	A harmonised challenge to realise smart electricity network opportunities in Power Electronics	Power Electronics is cross sector and cross discipline so existing talent can be re-purposed from other disciplines and sectors
Financial incentives to overcome the higher cost of low carbon technology in some industrial processes	Greater international collaborative R&D to complement UK PE capability	Degree apprenticeships connected with local industry can be encouraged
Establish supply chain sovereignty and localisation to give longer term resilience and sustainability	Extend wide bandgap chip and module technology to power converter level	Control and digital systems bring a new opportunity for talent to move into the power electronics industry
	Threats:	
Low cost of imported goods and services	Imported converter level technology / lack of Tier 1 manufacturing	Difficult and expensive to attract and retain students and experienced staff to UK due to tougher border controls
Lack of investment for scale up in UK vs many countries' state-aid and subsidies	Cyber security of critical infrastructure	Lack of STEM teachers at all levels.
Lack of appropriate skills, education and training	Reliability and resilience concerns related to geopolitical concerns	Poor societal view of "Engineering"

Appendix B. Case Studies

1. Lyra Electronics

Lyra Electronics Ltd is a Power Electronics design consultancy based near Warwick in the UK. It was founded in 2011 to address the need for power electronics for the electrification of transport. Lyra has grown organically, developing IP by leveraging R&D grant scheme from Innovate UK and then exploiting this IP with commercial development projects. As Lyra grew, the project size and maturity of the technology grew. Lyra was able to join collaborative projects through Innovate UK and the Advanced Propulsion Centre and this gave Lyra the opportunity to work with OEMs and Tier 1's developing DC-DC converter and On Board Chargers for the automotive industry. Lyra was also able to access resources at the Compound Semiconductor Applications Catapult , and key member of the ESCAPE project that demonstrated the potential of UK based end to end supply chain for SiC power electronics in the UK, and their Founder Pete James has been a key member of the PEUK Leadership Team. Such UK support enabled Lyra to provide a bigger technical capability and work on more advanced projects to higher Technology Readiness Levels.

Lyra is very fortunate to be in the UK and have access to these government backed interventions. They enabled the development of IP which otherwise would have taken much longer and might never have happened given the risk involved, and training through Driving the Electric Revolution to upskill our workforce. These have also given Lyra, a small SME, the chance to work with much bigger companies who wouldn't normally work with a company such as Lyra, and this in turn has provided Lyra with valuable experience of bigger company processes, product development for volume manufacture and design validation.



2. Custom Interconnect Ltd – *'Bringing semiconductor manufacturing back to the UK'*

With over 36 years of electronics assembly and semiconductor packaging experience, and as a result of multiple UK government co-funded projects, Custom Interconnect Ltd "CIL" is currently experiencing 40% annual growth.

Starting in 2019, CIL successfully got involved in eight Innovate UK/ DER/ APC/ DSIT projects of which seven involved PE R&D utilising GaN and SiC based devices. These projects were:

GaNSiC:	SiC & GaN packaging – Ink Jet of Silver sinter paste
APC15@FutureBEV:	SiC module development and manufacture & Power PCBA Manufacture
APC20 EleVAIT:	SiC module development and manufacture & Power PCBA Manufacture
ELIPS:	GaN Power PCBA liquid immersed development and manufacture
PE2M:	SiC Power discrete device development and manufacture

ORanGaN:	RF MMIC Device packaging in QFN package development and mfg.
CervSELF:	Power substrates for SiC modules
ELEGaNT:	GaN Power PCBA air cooled development and manufacture

In 2024, all but one of these projects have now been completed and the net result of these projects, coupled with the lessons learned and applied to other assembly technologies and existing customer growth directly resulted in CIL opening its BP2 Semiconductor packaging facility in June 2023. It houses the largest semiconductor packaging facility in the UK and this highly automated factory includes both a volume PCBA production area and a 15,000 sq ft semiconductor packaging ISO 7 clean room. All of this is in addition to CIL's long-established production area in CIL House, which houses a further 6 SMT lines and associated equipment.

At the start of the projects which coincided with the COVID pandemic, CIL's turnover was £15.3M, CIL has just closed its current financial year at £31.5M and is forecasting £42M for its current year with a 3 year plan to grow to £80M. Headcount over the same period has grown from 135 persons, to 215 today and a 3 year plan to grow to over 350 persons.

3. Turbo Power Systems

"Building on established pedigree with UK funding to meet the need for British EV chargers"

Based in Gateshead, Turbo Power Systems "TPS" are a UK based developer and manufacturer of power electronics and high-speed motors. with a history spanning more than 45 years. Having supplied over 25,000 power supplies, drives and motors world-wide to rail, aerospace and industrial markets, electrification brings to the company a whole new world of opportunity.

Working with UKs Network Distribution Operators, TPS have developed unique high-power converters to increase the capacity of the existing low and medium voltage electricity distribution networks to contribute toward deferring a forecast re-enforcement cost of £50bn by 2035, required to meet the increased demands put on the network by electrified transport and heat. Ofgem's National Innovation Competition (NIC) and Innovation Allowance (NIA), now the Strategic Investment fund (SIF), has contributed towards the development. Whilst effective mechanisms for developing and demonstrating network innovation is important, there is still much to do to ensure UK suppliers and DNOs can capitalise on the technology. Easier access to necessary growth capital for facilitating larger network pilots and, ultimately, commercialisation, is required.

Funding from the previous Department for Business Energy and Industrial Strategy "BEIS", the Advanced Propulsion Centre and Driving the Electric Revolution, has enabled TPS to extend these developments to Ultra Rapid Electric Vehicle charging. As a result, DC microgrid charging systems with Vehicle to Grid/Everything (V2X) capability will enable rapid charging of large fleet vehicles, even in areas where the necessary grid capacity may not be available. One such system, installed in Central London (pictured), enables refuse trucks to operate as generators, thus reducing Veolia's on-site electricity costs using, uniquely, the V2X charger capability provided by TPS' 'Velox' chargers.

Furthermore, Velox chargers are Megawatt Charging Scheme (MCS) ready in anticipation of release of the forthcoming charging standard for heavy duty vehicles demanding charge rates of many times that possible today with Combined Charging System (CCS) charging.

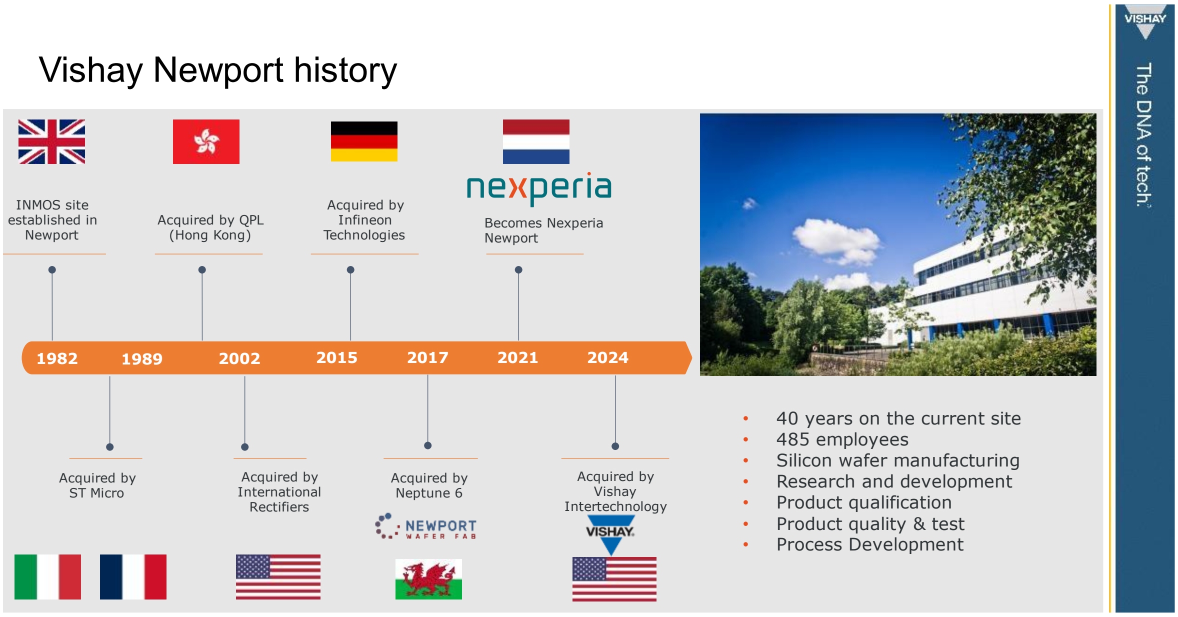
'Velox' V2X EV Chargers (Left) and their internal DC to DC power electronics with Silicon Carbide devices (Right)

'Potenza' Inverters for Micro Grid EV Charger systems (Left) and Soft Open Point Grid capacity expansion (Right)

4. Vishay Newport and the ESCAPE Project

In 2019 a consortium headed by McClaren Applied made a successful bid for the £20M ESCAPE project. The project aimed to establish a globally unique and cohesive end-to-end supply chain capability for innovative SiC power electronics. This was partially funded by the Collaborative Research and Development (CR&D) programme delivered by the Advanced Propulsion Centre (APC). The successful proof-of-concept supply chain developed by this project showed that the companies involved could work collaboratively to service both UK and global end user demand. It was successful during its lifetime in attracting a major global company to invest in the UK.

In March 2024 UK government approved the acquisition of Newport Wafer Fab by US based company Vishay for $177, securing the jobs of 450 staff. Newport Wafer Fab was built in 1980 and has been owned by several companies over the years. In 2022 the fab was owned by Nexperia, a Chinese company, and in November of that year the Department for Business, Energy and Industrial Strategy ordered the company to divest 86% of its ownership for national security reasons, meaning that a buyer needed to be found.



Vishay (based in the USA) wanted to set up a silicon carbide wafer fab and they were searching for suitable sites around the world. They had recently acquired Maxpower, a subsidiary of which, Maxpower UK, was part of the ESCAPE project. Due to their intimate knowledge of the supply chain, the former Maxpower directors were able to persuade Vishay to look at Newport Wafer fab as a potential site. The successful outcome of the ESCAPE project showed Vishay that there is a clear supply chain in place and ready to go in the UK and this led to the successful acquisition of the site by Vishay in 2024. Vishay are now engaged in transforming the Newport site for Silicon carbide production and are also setting up a research site at Warwick University.

Professor Phil Mawby at Warwick University who played a key part in the ESCAPE project and the relationship with Vishay and Maxpower commented that "this investment retains the UKs ability to profit from some of the exponential commercial growth in this sector both now and in the years to come, and shows clearly how effective collaboration between research and industrial partners, supported by appropriate grant funding, can lead to highly successful outcomes for the UK industrial economy"

5. GE Vernova

GE Vernova Grid Solutions is one of the world's leading providers of equipment and systems for electrical power grids. Its site in Stafford, UK, includes the worldwide Centre of Excellence for High Voltage Direct Current (HVDC) power transmission systems. HVDC is a vital technology for the Energy Transition in UK and many other countries. The UK is already a world leader in offshore wind, but the wind farms now being developed are so far from the shore that conventional AC transmission cannot be used and the only viable means of importing the generated power to the mainland is via HVDC. For the same reason, HVDC is the only technology suitable for the growing number of interconnectors between Great Britain and our neighbours, to allow renewable energy to be pooled over a wider geographical area. HVDC is also used to strengthen the electrical grid within Great Britain, with several links already running or being built between Scotland and England.

The Stafford Centre of Excellence for HVDC includes the design, testing and manufacturing of the converter "valve" modules, with a global class-leading test facility (pictured) for performing operational type tests on the valve modules, as well as the design and testing of the control and protection system and overall HVDC system design. Also present at the Stafford facility are engineering teams specialized in the design of AC substations and power system protection relays, and the only remaining factory for large power transformers in the UK.

The Stafford Centre for Excellence for HVDC test facility.

GE Vernova's Power Conversion business in Rugby, the UK has long-standing experience in Power Electronics, part of its extensive PEMD portfolio. Their power-to-x systems support customers' electrification and decarbonisation transformation across industrial, energy, rail and maritime sectors. With deep domain expertise in power electronics, protection, control and systems engineering, Power Conversion in the UK is recognized for its integrated system design capability for low and medium voltage applications. Using its specialist test and innovation facilities, Power Conversion is at work on the next generation of power-dense systems and microgrids. Dedicated teams of field service engineers support customers in the UK and around the world.

Appendix C. Glossary of terms

1. **PEUK** – an industry body which draws together relevant UK organisations and experts in the Power Electronics sector. PEUK aims to provide a voice for the PE industry in the UK and to promote cross-industry collaboration, skills development, industry and academic R&D and business and investment opportunities. PEUK is supported by TechWorks, the UK deep tech and semiconductor trade body.
2. **Semiconductors** – a class of electronic materials with unique properties that sit at the heart of the devices and technology we use every day.
3. **Power Electronics** – the branch of engineering concerned with the processing and control of electricity to move energy from a source (battery, solar panel, or electrical generator) to a device which needs electrical power to operate. A typical system comprises power semiconductor devices, sensors, capacitors and inductors, electronic control circuits, software, cooling systems and mechanical packaging.
4. **SWOT** - Strengths, Weaknesses, Opportunities and Threats. A review of these attributes relative to each other to ascertain where to focus efforts in building a strategy.
5. **Internet of Things (IoT)** – network of connected devices and sensors, able to exchange data and communicate with the cloud to enable intelligent monitoring and control.
6. **Digitalisation** – The use of digital technology within a system to improve its operation through data accessibility, intelligence and automation gaining process improvements and efficiencies. This typically refers to a system or device-level activity, as opposed to digital transformation (below) which involves a comprehensive change in an enterprise or society.
7. **Digital Transition** – Also known as Digital Transformation. The integration of digital technology into all areas of an enterprise, fundamentally changing the operation, providing real-time insight, intelligence and automated action. The goal is to increase productivity and efficiency, providing more capability and value at scale. Key technologies are AI, Sensing, Communications, Cloud compute and Data Centres. what is digital transformation
8. **Energy Transition** – The the journey towards an All-Electric Society, where clean energy generation from renewables powers multiple industries and allows us to achieve Net Zero in carbon emissions. This requires the participation of all sectors and all nations to achieve and dates to the Intergovernmental Panel on Climate Change (IPCC) 2018 report, which set the target of reaching net zero GHG emissions by 2050. Energy transitions.org
9. **GaN** – Compound of Gallium and Nitride. A wide bandgap material used to create efficient, high-power devices. Provides higher voltage operation and thermal conductivity at faster switching speeds and lower on-resistance than silicon. Performance benefits in high efficiency applications for consumer and medium power industrial, typically around 650V.
10. **SiC** – Compound of Silicon and Carbon. A wide bandgap material used to create efficient, high-power devices. Provides superior thermal performance to GaN and higher voltage operation than GaN and Si. Retains some silicon process compatibility but is more expensive to produce than Si or GaN. Performance benefits in high voltage and power applications such as automotive, railway, high power solar inverters and HV grid.

Appendix D. References

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Appendix E. List of Contributors

1. Amantys
2. Aston Martin
3. BMW
4. BDJ Group Ltd.
5. Clas-SiC Wafer Fab
6. Collins
7. Communications and Power Industries
8. Compound Semiconductor Applications Catapult
9. Create Innovation Solutions Ltd
10. Custom Interconnect Ltd
11. Danfoss
12. Driving the Electric Revolution Industrialisation Centres
13. Dynex Semiconductor Ltd
14. GE Vernova
15. GKN Automotive
16. Hitachi
17. IMAPS-UK
18. Imperial College London
19. Inductotherm
20. Industry Wales
21. InnCat Ltd
22. Inspirit Ventures
23. Jacobs
24. Jaguar Land Rover
25. Littlefuse
26. Lyra Electronics
27. Maclaren Applied
28. Network Rail
29. Nidec
30. Northern Power Grid
31. Nyobolt
32. Power Electronics UK
33. PPM
34. Protean Electric
35. RAM Innovations
36. Renesas
37. RXHK
38. Schaltbau
39. Scottish Power Energy Networks
40. Siemens
41. Scottish and Southern Energy
42. Syselek
43. TechWorks
44. Turbo Power Systems
45. UK Electronic Skills Foundation
46. UK Power Networks
47. University of Birmingham
48. University of Bristol
49. University of Cardiff
50. Newcastle University
51. University of Nottingham
52. University of Swansea
53. University of Strathclyde
54. University of Warwick