TechWorks
Semiconductor Leadership Group

# SEMI35 - A UK Strategy for Semiconductors

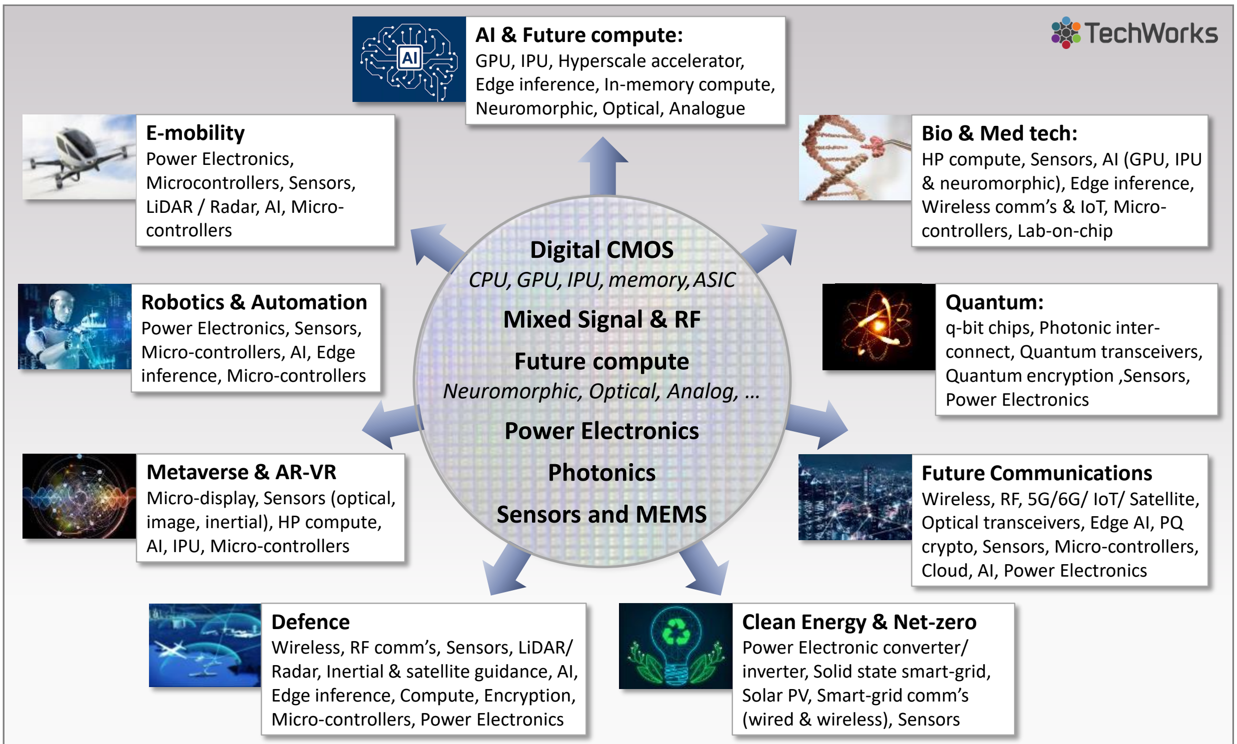
*This paper, prepared by TechWorks with input from TechWorks Semiconductor Leadership Group, presents an overview of the global semiconductor landscape, highlighting its critical importance to UK economic and geopolitical security, strength and credibility. The paper contains key policy recommendations to build a powerful contributor to the UK economy, returning billions in GDP and employing significantly more people in high value, high growth jobs over the next decade.*

## 1. Semiconductors are a Foundational Technology

The UK has experienced a long period of low productivity and economic growth. This is at a time when we also face major challenges such as climate change and access to health and social care, which also weigh heavily on our economy. How we address these issues is the defining question of our time. However, our increasing capabilities in science and technology are delivering breakthroughs. There is a coming tsunami of transformational technologies which will help to address these challenges and drive incredible growth here and across the globe: Digitalisation, AI, Automation, Med-tech, Future Communications and Clean Energy to name a few. The economic rewards are huge for those countries who build supply chains in these sectors, built from the underlying innovation which fuels each one.

**As an advanced economy, our future national wellbeing will depend on creating and growing highly competitive and successful companies that design, make and sell products and services in all these fields.**

Our ability to create and deliver these products and services is ultimately dependent on the myriad electronic circuits that are designed and built into them. That's because the electronics inside define the very function of the product or service and **are the innovation** which enables the business to exist. As digital technologies become more pervasive, there is increasing demand not just for digital chips[1] which fuel this, but also many other types of chips which provide real-world physical functions to bridge the digital with the analogue world. E.g. in sensing, power conversion, radio communications, optical processing and displays.



Semiconductor devices as drivers of emerging technologies

Semiconductors are the fuel which power new and emerging technologies – *TechWorks*

[1] A semiconductor *chip* is a fully Integrated Circuit (IC) cut from a wafer made from silicon or another material and which provides an electronic or photonic function within a piece of equipment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As we will see later, there are a range of materials from which we can build semiconductors and several distinct stages in the development and supply of these devices. There are also several business models we can choose from to extract value at each stage of development and supply. However, common to all of this, there are just a small number of specific classes of semiconductor chips as shown in the infographic above. The list of semiconductor device types in the middle are the fuel which power all the emerging technology markets displayed around the wafer.

Many chips are designed specifically to deliver unique features in the end-product by exploiting novel scientific properties. This valuable product differentiation is further enhanced by the chip vendor adding 'extra layers' of software and additional hardware components to create a total system solution. In many markets, the product vendor acts as a re-packager and marketing organisation, building on the underlying chip innovation.

In short, none of the transformational technology markets described above can exist without the semiconductor[2] components from which the products are built. Indeed, most markets already depend on such technology today, e.g. automotive, finance or entertainment.

**It is imperative to recognise that the global semiconductor industry is a critical foundational 'horizontal' technology, which cuts across all technologies and markets**, as illustrated in the infographic above.

## 2. Semiconductors are a Significant Growth Industry

Supporting all these markets, **the semiconductor sector itself has become a lucrative 'vertical' market,** that in 2024 will deliver more than a trillion chips, generating over $630 bn[3] in revenue ($804 bn including fab equipment revenues), and with a CAGR of 9~12%, reaching $1.3 - $1.9 trillion revenue in 2034[3]. It has already created massive wealth in the value of its most successful companies at a colossal $7.4 trillion[3], with so much more to come. **Because, on the shoulders of the semiconductor industry rests almost everything else.**

It is widely accepted that the sector creates significant numbers of high value, well paid jobs across skill levels, from technician to under-grad engineer to post-grad scientist, with a further 5.7 jobs in the wider economy for each semiconductor sector employee[4]. Globally, 1.7 million[4] skilled people work directly in the sector.

The diagram below shows global revenues split between fabless companies (31%), foundries (13%), IDMs (23%) and fab equipment suppliers (16%). Although the memory business is 14% of market share, it is highly specialised and yet a fiercely competitive commodity, serviced by only three companies. IP licensing, although only 0.5% of revenues, is strategically important where, in the case of arm, the IP is foundational to the success of the entire industry. Market cap per employee tends to be higher in IP companies reflecting their strategic value creation versus lower OPEX. The largest companies have grown on the back of the rise of computing, data centres, AI and 4G/5G communications over the last decade. Their common need for high performance but low-cost digital CMOS[5] manufacturing is how the fabless model emerged. TSMC (world's largest foundry) depends on Apple, Nvidia, Broadcom, Qualcomm, AMD and Mediatek for 60% of its business. The market is split roughly 50/50 between fabless companies and IDMs or foundries. Compound Semiconductors[6] form around 6%, or $50 bn in 2024[7] and are expected to grow to $80 bn by 2030[7].

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[2] Materials with unique electrical properties that sit at the heart of the devices and technology we use every day

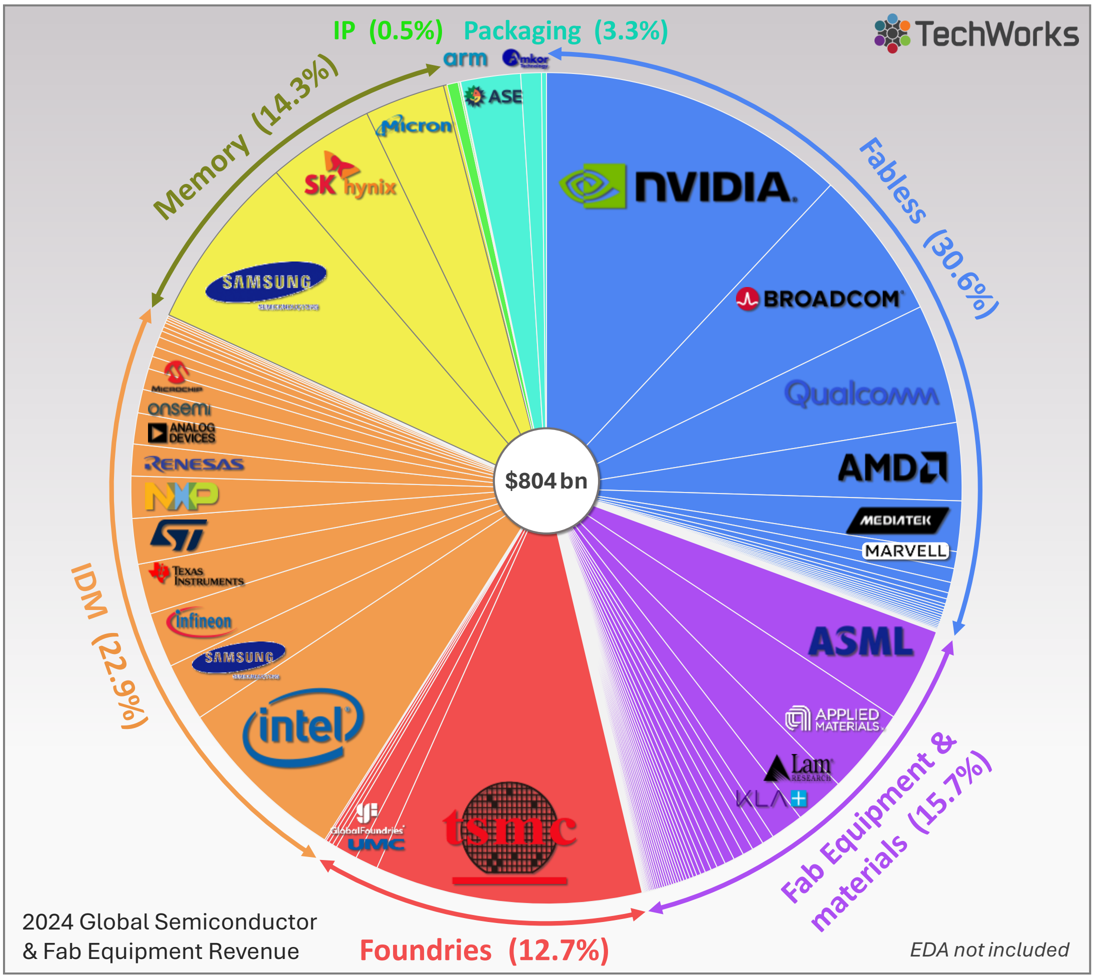
[3] TechWorks 2024, data and analyses from Gartner, Fortune Business Insights and TechWorks

[4] Semiconductor Industry Association (SIA) & World Semiconductor Trade Statistics (WSTS) 2024

[5] Complementary Metal Oxide Semiconductor is a process for creating low power yet high performance digital circuits on a silicon wafer. It is still the dominant process in use today.

[6] Chips made from two or more elements, as opposed to only silicon. This term describes a wide range of devices with quite different properties, applications and markets. E.g. silicon + carbon (SiC) or gallium + nitrogen (GaN)

[7] TechWorks 2024 (based on Markets and Markets, Future Market Insights and Precedence Research)




Global Semiconductor Market Share 2024 – TechWorks, public stock & performance analyses

## What are the political implications?

Leading in transformational technologies, and the semiconductors which power them, provides companies **and countries** with unique geopolitical power. As an example, the meteoric rise of AI has in large part been due to Nvidia's decision to refocus their GPU chips on AI and their creation of a full suite of AI software libraries and tools[8] for their chips. Today, the widespread use of Nvidia's chips and software gives them a unique monopoly position on the development of AI models and systems and has stimulated a significant AI ecosystem in the US.

Globally, there is a 'tech arms race' with many nations desperately rebuilding their once dominant position or investing to create their own industry. Unfortunately, the once strong UK semiconductor sector has declined in the last few decades due to underinvestment and general UK industrial decline.

During the late 20th century, leading western democracies formed the G7[9] to collaborate on economics, trade and security. In the 21st century, the new economic growth driver is semiconductor technology. As we leave oil and industrialisation behind for NetZero and Digital Transformation, those nations who don't possess a credible semiconductor sector may find themselves no longer part of the G7. A Wall Street Journal article from January 2023 entitled 'Chips are the new oil' highlights this.

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[8] See later section entitled *Inter-dependence of systems and semiconductors* on the significance of CUDA

[9] The Group of Seven was formed in 1973 as an informal bloc of industrialized democracies to collaborate on economic, security and societal issues. G7 members recognised their shared power due to post-war growth fuelled by industrialisation and carbon-based energy supply and use.

Semiconductors have become a critical 21st century economic and national security concern, providing:

- Significant national wealth, high-value jobs and Gross Value Add across the wider economy
- Global influence in emerging technology markets, control of supply chains and national resilience
- Full stack[10] Intellectual Property ownership, providing economic and political strength

In future, we should not just *rely* on the good-will of friendly nations, but rather, we must bring our own value to the table. Building a sustainable ecosystem in the UK with valuable elements of technology supply chains and globally successful companies will earn us our own seat at the international table, providing us a strong position to negotiate access to that which we do not have.

## 3. Structure of the Semiconductor Industry

The industry consists of a complex web of interdependent entities, each representing a uniquely valuable part of the overall supply chain and contributing to end market value. UK companies work in each part of this value chain, supporting jobs and valuable exports. The industry – and the competition – is global and the value built at each stage is dependent on the stage before. The overall ecosystem is, therefore, symbiotic, with innovation and business often growing from cross sector collaboration.

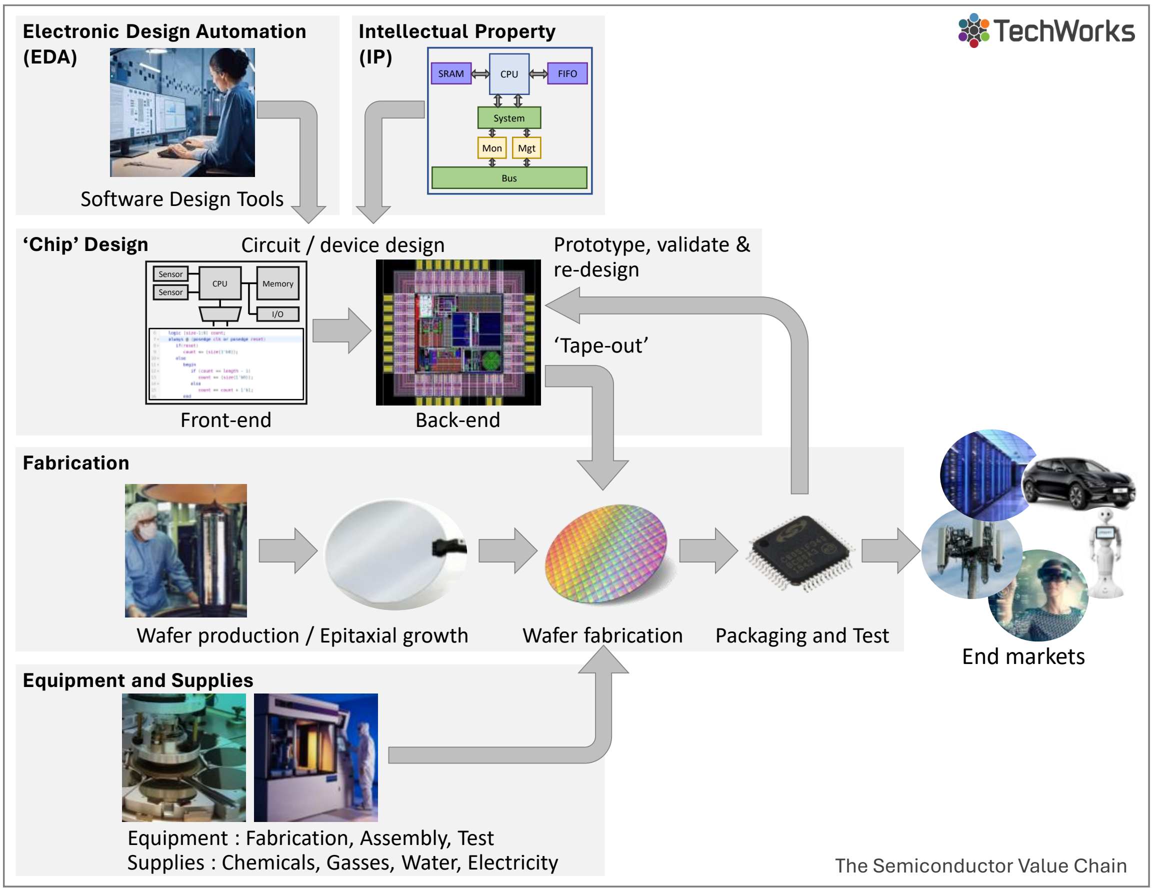
The technology and economic value created usually increases from the initial innovation (e.g. in university), through component development (the hardware chip) to a system level solution (chip + other essential hardware and software). Even without manufacturing the end product, the companies which sell chip-based system solutions to end-market product companies enjoy significant growth and value creation.

The diagram below highlights the distinct elements of the semiconductor value chain:

- *EDA Design Tools*: Software used to design, validate and prepare devices for manufacture.
- *Intellectual Property (IP)*: Licensable commonly used circuit building blocks for integrating into chips.
- *Fabrication*: The manufacturing of devices (diced from wafers) from a design. Two models exist:
  - *Integrated Design & Manufacture (IDM)*: Design and manufacturing occurs in one organisation.
  - *Foundry*: Outsourced manufacture of devices for multiple (fabless) chip companies.
- *Chip Design*: The design, validation, prototyping and testing of a device, ready for production.
  - *Fabless companies*: Design and sell semiconductors but outsource fabrication to a foundry.
- *Packaging*: Encapsulating the raw silicon chips into packages for end-product integration.
- *Fab Equipment Supplier*: Development and supply of the equipment used to manufacture devices.

Each of the sub-sectors listed above exhibit different market dynamics, regional strengths and numbers of players. However, they all interoperate to align on common technology roadmaps and shared business growth.

[10] End-to-end system solution including the chip, software and other essential system components




The Semiconductor Value Chain – *TechWorks*

## Semiconductor chip design

The design of complex systems-on-chip can take as long as 18~36 months with the cost of design tools, licensed IP, verification, fabrication and test running to tens or even hundreds of millions of USD. Such high-risk investment requires conviction and expertise as well as significant fund capacity from investors, all of which are in short supply in the UK, leading to under-investment in the national ecosystem.

## The rise of the fabless model

Semiconductors are built from many different materials. Since 1965, with the advent of Intel and 'Moore's Law'[11] silicon became the dominant material and digital logic the dominant application. Initially companies who designed chips had to also build the fabrication plants (fabs) to make the chips. However, a major evolution in the structure of the industry occurred progressively in the 1990s with the separation of chip design from silicon wafer fabrication. This 'fabless' digital CMOS model has enabled many creative ideas to be implemented by new design companies and has fuelled the creation of powerful new and successful companies, without the need for the enormous capital expenditure to pay for the increasingly expensive equipment needed to fabricate wafers. Today, global revenues of fabless companies have grown to around 31% of the total market, their foundry suppliers contributing 13%, dominated by TSMC, and IDMs accounting for 23%. The share of IDM in advanced digital is declining, in favour of the fabless/ foundry model because CMOS design rules are now generally standardised across industry, allowing multiple fabless design teams to supply designs which fill the foundry with multiple product lines, whilst the foundry focuses on process and yield optimisation. As CMOS has evolved, these state-of-the-art foundries have become so expensive to build that it only becomes financially viable by aggregating volumes across multiple design companies.

[11] Gordon Moore, co-founder of Intel, predicted that transistor density on-chip would double every 18 months. He has largely been proven right ever since.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## Why IDMs are still important

By contrast, IDMs develop and produce products for specific market applications using specialist silicon processes or compound semiconductors[12] for a long tail of various markets. IDMs gain value by owning their own fabs since the chip features depend specifically on the physical properties imbued by the proprietary fab processing they create. As mentioned above, bridging the digital with the analogue world is an important factor in the growth of non-digital CMOS in many emerging market areas.

## The important role of semiconductor equipment

Although third in revenue terms, the equipment used in semiconductor manufacturing, packaging and test is still a sizeable global industry, with high value companies built on strong science and engineering innovation and advanced manufacturing. There is a unique synergy between these companies and the fabs, with new process and equipment often developed in partnership, providing both with major first-to-market advantages. Dutch ASML's huge growth and near-monopoly are partly due to a symbiotic relationship with IMEC and TSMC.

## The rise of advanced packaging

Various methods exist to package chips for use in end-products, each depending on the application, from power electronics to high performance processors to photonic devices. However, there is a significant global effort underway to develop a new breed of packaging, *Advanced or Heterogenous Packaging,* to achieve increased performance, flexibility and decreased system cost. As a key component in realising the emerging technologies presented here, future systems-on-chip will likely comprise multiple chips from different companies, made in different processes (silicon & compound) and combined in a 3D structure in the advanced package. This market is expected to grow at a CAGR of 12% between 2024-2030[13].

# 4. United States Dominance

Fuelled by the 1960s space programs, deep venture capital investment and a strong university research base, the United States has grown to dominate the industry, with an estimated market share this year of 54%[14], employing 338,000 high-paid workers directly and another 2 million others indirectly[15]. Asia sits at 35% and Europe at 11% market share. US companies command an even higher share of the global wealth pie, its companies worth 75%[14] of the entire market value of the global semiconductor industry. Nvidia, worth just $10 bn ten years ago, is now the world's most valuable company with a $3.3 trillion market capitalization. Those jobs, and the enormous wealth created are key components of US economic success since the global financial crisis of 2008-9, strengthening its tax base and powering federal & state budgets.

## Inter-dependence of systems and semiconductors

Over time, US entrepreneurs, engineers and computer scientists have founded and grown most of the world's successful tech hardware and software titans: Apple, Google, Microsoft, Amazon, Meta and many more. The proximity of these systems companies to their semiconductor suppliers has been important to provide the essential steering of semiconductor product roadmaps and features to customers' needs. In meeting those needs, chip vendors aim to create a dependency that makes it more expensive for system companies to switch to alternative providers, often meaning that they provide as much of the software tooling, application software and hardware system design as possible. Silicon Valley calls this *building a defensive moat*. A perfect example of this is Nvidia's software platform called Compute Unified Device Architecture (CUDA). This makes it possible for software engineers to readily develop efficient code for Nvidia chips. Efficient access to the

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[12] Devices made from two or more elements, as opposed to silicon which is just one. This term describes a wide range of materials and devices with quite different properties, applications and markets.

[13] Semiconductor Packaging Market Size, Share & Trends Analysis 2024 - 2030, Grand View Research

[14] TechWorks 2024

[15] Semiconductor Industry Association (SIA) Handbook 2024

compute density of such chips has been instrumental in the explosive progress of AI and Nvidia has gone on to dominate the market for AI datacentre across the world.

Similarly, in cellular smartphones, much of the software executing the intense processing for high-speed air interfaces and their protocols, such as 4G, 5G and 6G is developed and provided by the semiconductor company Qualcomm. So intertwined are systems and semiconductors that the largest systems companies have themselves been acquiring and building their own elite semiconductor teams to maintain their control on innovation and product differentiation, Apple being the most prominent example.

## 5. The UK Semiconductor Sector

In the UK, today, there are approximately 160 design companies, 21 commercial fabs (IDMs and foundries), 10 packaging companies, 10 fab equipment manufacturers and 7 world leading university R&D fabs [14].

According to the recent economics report commissioned by DSIT[16], UK companies currently generate around £10bn in revenues, or 2% share of the global market, with more than 40% of this due to UK headquartered companies. 15,000 people are directly employed in the sector and a further 86,000 supported in the wider economy using an industry standard multiplier[15].

The study noted 10-year UK average growth of 8%. However, with a forecast global CAGR up to 12% to 2034 and noting the growth of Nvidia at 220%, or Broadcom at 76% in only the last three years, it is clear that the focused and ambitious policies described here can accelerate UK growth significantly in the next decade.

**Fabless design companies in the UK** – The UK has many promising fabless companies developing chips for emerging markets in AI, Future compute, Communications and Med-tech, etc. However, they need support and significant long-term investment to grow to become globally competitive. Furthermore, they depend on foundries, such as TSMC, and need support to gain traction and attention from these to make their chips.

**Semiconductor manufacturing in the UK** – The table below shows how UK production facilities span the entire range of current and emerging materials which drive applications across all emerging markets. However, as these markets scale globally, few will be able to meet that demand without additional CAPEX investment. The UK has a strong base of innovation and R&D across our academic and Research and Technology Organisations (RTO), and there are good prototyping capabilities. But, from pilot to moderate volume production, UK fabrication capabilities are constrained and, in some cases, non-existent.

In emerging markets, such as Power Electronics and Photonics and new materials such as Oxides and Thin films, the innovative process and manufacturing know-how gained from the beginning can deliver global market leadership with sufficient investment and ambition. In many of these areas, UK industry can demonstrate that it is not far behind the leaders, unlike in advanced digital CMOS.

**Fab equipment manufacturing in the UK** – The global growth of semiconductors and wide range of emerging materials and process techniques gives rise to significant opportunity for innovation in the manufacturing equipment used to fabricate the chips. Although the biggest players (Applied Materials (US), ASML (NL), Tokyo Electron (JP), Lam Research (US) and KLA (US)) are overseas. We do possess some innovative companies (e.g. Oxford Instruments, SPTS (KLA) and Thermco Systems) who innovate in partnership with UK chip manufactures and then export globally, including to Taiwan and the US.

[16] Semiconductor sector study, September 2024 - www.gov.uk/government/publications/semiconductor-sector-study

<table>
<tr><th colspan="2"></th><th rowspan="2">Fcst global market 2028</th><th rowspan="2">Applications</th><th colspan="4">UK Production Capability</th></tr>
<tr><th>R&D</th><th>Prototype</th><th>Pilot</th><th>Volume</th></tr>
<tr><td rowspan="4">Group III-V elements</td><td>GaAs</td><td>$4.9bn</td><td>Photonics, Lasers, Lighting, Displays, Quantum, Telecoms, RF, Health, Defence</td><td rowspan="3">Y</td><td rowspan="3">Y</td><td rowspan="3">Y</td><td rowspan="3">Y</td></tr>
<tr><td>GaSb</td><td></td><td>Infrared detectors & LEDs, Lasers, Solar (thermophotovoltaic), Quantum</td></tr>
<tr><td>InP</td><td>$5.9bn</td><td>LEDs, Lasers, Quantum, Telecoms, RF, Health, Defence</td></tr>
<tr><td>GaN</td><td>$5.38bn</td><td>Power Electronics, EV, Photonics, Lighting, Telecoms, RF, Defence</td><td>Y</td><td>Y</td><td>Y</td><td>Limited</td></tr>
<tr><td rowspan="4">Silicon compounds</td><td rowspan="3">Si</td><td rowspan="3"></td><td>Digital & Mixed signal</td><td>Limited</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Sensors, Si photonics</td><td>Y</td><td>Y</td><td>Y</td><td>-</td></tr>
<tr><td>Power, Analog</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>SiC</td><td>$9.7bn</td><td>Power Electronics, EV, HV grid</td><td>Y.</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td rowspan="3">Oxides, thin films and others</td><td>IGZO</td><td>$20bn</td><td>Flexible thin film chips for Photonics, Sensors, Health, Food labelling and AI</td><td rowspan="2">Y</td><td rowspan="2">Y</td><td rowspan="2">Y</td><td rowspan="2">Planned</td></tr>
<tr><td>$Ga_2O_3$</td><td></td><td>EVs, LV grid</td></tr>
<tr><td>Ca</td><td></td><td>Sensors, Fast switches</td><td>Y</td><td>Y</td><td>Y</td><td>-</td></tr>
</table>

UK fab capability, based on materials, applications and production capacity – TechWorks & IFM 2023

## Opportunities for the United Kingdom

It's incoherent for any national strategy to set missions and objectives for success in specific vertical technology sectors, such as quantum computing or AI and future compute, without also having a realistic and viable strategy to build full participation in the underlying semiconductor and software components that are needed to enable them. In short, **if we are serious about being an advanced technology economy, we must be just as serious about building the essential and enabling semiconductor companies too**.

HMG's green paper 'Invest 2035: UK's modern industrial strategy' identifies eight growth sectors to drive the core mission of next decade national growth. Four of the eight are directly driven by semiconductor technology (Advanced Manufacturing, Digital Technologies, Clean Energy and Defence), the others would not be at the scale and technological advancement they are without underlying semiconductor technology.

**In Advanced Manufacturing**, semiconductor technology drives precision machinery, automation, robotics, communications and intelligent microcontroller platforms. Of course, semiconductor manufacturing is an advanced manufacturing sector itself, employing a range of skills from technician to science and engineering graduates to post-graduate materials scientists. There are also many UK companies who manufacture the advanced equipment used in fabs globally to manufacture chips and these too are incredibly valuable in skilled employment, export and onward semiconductor innovation alongside their chip manufacturing partners.

**In Digital and Technologies**, the trend towards Digitalisation[17] is driven by semiconductor devices in AI, sensing, communications, cloud & edge compute and data centre processing and storage. The Internet of Things (IoT) and digital twins further build on this by linking these technologies together enabling a network of connected intelligent devices and sensors. Global economies will be redefined by these technologies as they drive geopolitical competition and disrupt existing sectors and markets. The companies and countries who originate these devices will enjoy economic and geo-political power in these markets. Furthermore, there exists a global race towards lower power exascale compute to mitigate the unsustainable exponential rise in energy consumption following our thirst for HP computing. Reduction of compute power consumption will have a dramatic effect on cost, scale and usability, enabling new industries to develop.

[17] Integration of digital technology into enterprise and society, fundamentally changing how we operate, providing real-time insight, intelligence and automated action increasing productivity and efficiency at scale.

**In Clean Energy Industries**, the transition to Net Zero and clean energy is only possible through the development and deployment of new semiconductor devices and power electronic systems. The UK is well placed to capture these opportunities[18] in energy efficient, smaller, intelligent and more flexible power conversion electronics. These will drive next generation wind turbines, solar PV, battery storage systems, electric transportation (e-scooters, cars, buses, trucks and airplanes), electrified industry 4.0 and re-imagined national electrical grids. The companies who deliver advanced power electronic semiconductors and control, inverter, converter systems based on these will enjoy significant economic rewards.

**In Defence**, HMG has announced a specific Industrial Strategy aligning our security and economic priorities. This is a unique opportunity to exploit homegrown innovation and capability to drive both domestic economic growth and livelihoods, prioritise national resilience through domestic supply chains and grow our share of exports in this highly valuable global sector. Reducing our reliance on imports of critical technology such as semiconductors into our defence sector and other Critical National Infrastructure (CNI) is important to both national and economic security. Relevant technologies here – which the UK has strengths in – are wireless & RF communications, sensors, LiDAR/ radar, inertial & satellite guidance, encryption, power electronics, quantum, AI and neuromorphic edge inference.

## UK fabless track record

UK universities have remained globally in the top tier for science and engineering and the UK has developed the largest venture capital industry outside of the United States, albeit still significantly smaller and culturally less risk-taking. As the fabless model emerged over the last twenty years, the UK became a European leader and a place where entrepreneurs and engineers have built several new fabless companies, particularly those in novel microprocessor systems design, a core UK strength. Nevertheless, the cost of chip design (even apart from the cost of building a fab), has escalated dramatically as designs have become larger and more complex and even the best-funded UK startups have exhausted the supply of home-grown venture capital. Entrepreneurs have been forced to lower expectations and, in markets that are increasingly winner-takes-all, lower expectations have generated a somewhat fatalistic outturn. The net result is that many emerging and promising startups have been acquired by US counterparts, notably the three largest fabless companies: Nvidia, Qualcomm and Broadcom[19], before they reached their growth phases in revenue, jobs and economic value. In short, the UK has been a feeder to the US, significantly under-achieving its true potential.

## UK compound semiconductor track record

The UK has also excelled in the development of new semiconductor materials and processes, leveraging its university materials science base and a cluster of small specialist wafer fabrication facilities that have been built over the years, scattered in the devolved regions of the country because of multiple waves of regional development and Foreign Direct Investment (FDI) policy. Compound semiconductors achieve high electron mobility and direct bandgaps, crucial for applications like optics, power electronics, sensors, lasers, power inverters and high-frequency devices. Although compound semiconductors are already a large and measurable part of the global semiconductor sector, worth around $50 bn in 2024[7], in the UK's case, to date little of our undoubted talent for innovation has been translated into meaningful high-volume products. A lack of pilot lines to develop repeatable and reliable processes for producing innovative new devices with accurate PDKs[20] and the lack of deep-pocketed investment to build high volume production lines means that UK startups often favour IP licensing models for their technology or early trade sales to large overseas chip companies able to take ideas from the laboratory to production fabs. In short, the UK has again been a feeder to US and Asian ecosystems. We do not currently have the right policy mix to achieve our full potential.

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[18] The UK Power Electronics sector is particularly strong. A recently published PEUK report discusses this

[19] Nvidia acquired Icera for $430M in 2011, Qualcomm acquired Cambridge Silicon Radio for $2.5 bn in 2014 and Broadcom acquired Element 14 for $640M in 2000 and Alphamosaic for $123M in 2004

[20] Process Development Kits provide designers with recipes and processing instructions to achieve reliable production

## Global trends and tailwinds

Four major trends spell change ahead for the semiconductor industry and, as a nation, we have a real opportunity to generate and apply insightful policy shifts that will, if executed well, change the weather, allowing us to build profoundly important semiconductor companies here in the United Kingdom as a result.

**The impacts of various CHIPS Acts** passed by federal and supranational governments will drive up spending in semiconductors in response to supply chain shortfalls (highly visible during the pandemic and its aftermath). Whilst some of these spending programs are targeted on funding greater R&D effort to solve 'grand science challenges' of the industry (which would be net competitive to UK), the majority of spending is centred on providing subsidies to on-shore advanced semiconductor foundries in countries that are friendly to the UK, notably in the US and EU. An advanced silicon digital CMOS fab can cost $20-30 bn to build and analysts fear this increased capacity may be mis-spent money giving rise to an extended period of advanced foundry capacity glut in the years ahead. Since the UK's core strength has been founding and building fabless companies, if we develop policies that solve the funding gaps for fabless companies, the effect of the CHIPS acts is likely to be net favourable to the UK delivering ready access to foundry capacity.

However, for compound semiconductors, the need for design and fabrication to work closely together means that physical proximity is a strong advantage. Some CHIPS act funding is also being spent on such fabs, which are far less expensive to build. Without this capability in the UK, we may find some compound semiconductor fabless design companies relocating overseas to be nearer to their fabs.

**The advent of artificial intelligence (AI)** demanding an enormous step-up in efficient computational semiconductors at all points in the value chain, from datacentres for AI model training, to efficient edge AI processing for embedded AI applications like robotics, automotive and consumer devices. The UK is a serious research contributor to AI science development globally and is home to many startup AI companies. Further, many US giants have either bought UK companies (such as Google DeepMind) or established greenfield sites in the UK to leverage our talent base. Nvidia's domination of the market for AI semiconductors is certain to be challenged by novel system architectures drawing on multiple different approaches, particularly **in new processor design, and the UK is incredibly well-placed to win-out** in the global competition to secure market position, provided we get policy right.

**Increasing demand for semiconductor novelty** at the edge of the science as applications in AI, bioscience, quantum, electric powertrains and more demand unprecedented system performance, data speeds and power efficiency only achievable in novel compound semiconductor materials. Compound semiconductor demand is widely expected to grow faster (10-12% CAGR) than the semiconductor sector as a whole in the next decade. As an acknowledged leader in these innovative materials, if we get policy right, the UK is perfectly positioned to grow a large and important place not just in the R&D lab, but in piloting devices all the way to volume production, either in the UK or in a fabless model as the compound semiconductor industry matures.

**State incentives** are widespread and have been around for many years. The CHIPS Acts noted above are more recent extreme examples of state aid. However, many countries provide incentives in recognition of the immense value of semiconductors as a foundational technology for other industries, such as automotive in the US and Germany, or computing and communications in Isreal. The UK should formulate an approach to at least level the playing field for UK companies who are unfairly impacted by these foreign incentives.

| | UK | US | Japan | S. Korea | Taiwan | Singapore | China | Germany | Israel |
|---|---|---|---|---|---|---|---|---|---|
| Capex reduction | | | | | | | | | |
| Land | 0% | 50% | 75% | 100% | 50% | 100% | 100% | 100% | 75% |
| Construction & facilities | 0% | 45% | 10% | 45% | 45% | 25% | 65% | 50% | 45% |
| Equipment | 0% | 45% | 46% | 45% | 20% | 30% | 35% | 50% | 30% |
| Opex reduction | | | | | | | | | |
| Labour & benefits | 1.5% | 5% | 5% | 5% | 5% | 15% | 33% | 7% | 5% |
| Tax reductions | | | | | | | | | |
| Corporation tax | 0% of 19% rate | 0% of 26% rate | 0% of 30% rate | 60% of 25% rate | 0% of 20% rate | 35% of 17% rate | 75% of 25% rate | 0% of 30% rate | 74% of 23% rate |
| State tax | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Property tax | 0% | 100% | 100% | 100% | 0% | 0% | 0% | 0% | 0% |
| Overall reduction on revenues | <0.01% | ~30% | ~28% | ~30% | 25-30% | 25-30% | 30-40% | ~30% | ~30% |

Regional State Incentives for Semiconductors 2024 – *Prof. D. J. Paul, University of Glasgow*

## 6. A Ten-year Strategy for UK Growth

Although this paper has been prepared in a short timeframe to meet the timescale for HMG's Industrial Strategy consultation, as the trade body for the UK semiconductor sector, TechWorks is keen to work with government to develop more detailed analyses and proposals consulting further across industry and beyond.

Based on our analysis of UK industry strengths, weaknesses, opportunities and threats (SWOT), we propose the following **five-point strategy for a successful long-term UK semiconductor industry**:

**1 Invest To Grow Globally Successful Chip Companies:**

- Foster a new generation of application-focused fabless chip companies. A ten-year target to build and retain $100 billion in value, followed by a 20-year goal of $1 trillion, is recommended. Access to leading global foundries, such as TSMC must be prioritised through international agreements.
- Foster a new generation of non-CMOS chip companies. New or existing IDMs or fabless with onshore foundries in silicon photonics, mems or compound semiconductors. The pilot line investment below will support productisation of compelling new chips. Our aim should be to establish at least one UK company among the global top 10 companies, valued at >$10bn, in 10 years, with others in progress.

**2 Provide Scale-up Support for UK Manufacturers:** Support SMEs with market leadership potential to enhance and expand production capability to stay globally competitive and grow. This is especially important in power electronics, photonics, quantum and emerging new materials, such as thin films.

**3 Incentivise Domestic Demand**: To grow UK supply chains, increase UK business cash flow, enable high TRL innovation and collaboration and increase national resilience.

**4 Create a UK Pilot Line and Innovation Facility**: To support prototyping and piloting where the UK has an emerging lead in process and design innovation, retaining UK skills and IP in emerging semiconductor technology. This is important to secure advantage in e.g. photonics, quantum, sensors and bio-chips.

**5 Establish a Design Competence Centre**: Ensure the UK maintains our lead in IP and chip design and provide support for UK chip design teams (startups, SMEs and OEMs) to become globally competitive.

**NOTE:** The UK should not copy the US and EU CHIPS Acts in seeking to subsidise the establishment of UK high volume advanced digital CMOS fabs. These are incredibly expensive and difficult to bring to efficient, profitable volume operation. Revisiting this as a viable goal should only occur after successfully implementing the above, which means at least a decade in the future.

# 7. What Policies Do We Need?

## ► Invest to Grow Globally Successful Chip Companies ◄

Building new chip companies requires significant investment, often reaching hundreds of millions or even billions of dollars over their lifecycle. Globally, especially in the US, venture capital has proven to be the most effective transmission method for funnelling funds into promising tech startups, bypassing weaker mechanisms like government grants.

### Substantially Increase Government Fund-of-Fund Investing

While the UK may host the most developed venture capital ecosystem outside the US, it still lacks the number of large-scale endowments, family offices and funds found in the US and therefore the scale of the US system. Despite the Mansion House reforms, UK pension funds remain largely inaccessible due to mis-structuring and regulatory constraints imposed over the past two decades. Consequently, UK venture funding rounds tend to be smaller, particularly in the critical later stages, reliably driving top companies to seek capital, or to be acquired in the US before they have reached the most significant growth phase in jobs and value.

Until pension funds have been restructured and have developed analytical expertise to make earlier stage technology investments, the substantial funding gap needs to be plugged. Fortunately, the mechanism for doing this already exists. Each year, British Business Bank (BBB), acting as a fund-of-funds makes approximately $800 million of new limited partner (LP) investments in UK-based VC firms and, with political will, this can be scaled up quickly.

We propose the size of this scale up should be substantial, with BBB (or the new National Wealth Fund) increasing its investment rate to $4 billion a year. As protection for the taxpayer, this increase must be contingent on a funding ratio that requires general partners (GPs) to *at least* match the new LP investment with an equivalent LP investment amount from reputable private investors. In doing so, an increase in the supply of venture capital of $7.2 billion a year, to $8 billion a year, would be achieved.

### Public investment to drive equity growth

While the scale of investment required to build successful chip companies is significant, unlike other sectors such as software or web services, the global scale of supply chains and end-markets, combined with the underlying complexity and significant protected IP wrapped up inside each chip means that successful companies deliver incredible returns over the longer term as described earlier in this paper.

Making public investments alongside professional LPs creates secure financial assets, they are not mere spending. US experience shows that quality fund-of-funds have never lost money, due to the diversity of funds and underlying equities in companies they turn into. In ten years, an additional $64bn of new equity capital would be made available to the industry and built up on HMG's balance sheet. If desired, these assets could be structured into securities and offered to UK pension funds, or even to the public.

In total, BBB/NWF investments would reach $80B in ten years, with guidance and targeting directing $20B to capital intensive sectors like UK semiconductors. If, as planned, using a bottoms-up startup sequence, the UK creates, builds and retains new semiconductor companies that do achieve the targeted $100B valuation, with the funds owning 80% of the equity, $40B, less fees ($30.8B) would return to BBB. This would result in a 13.9% Internal Rate of Return (IRR), significantly exceeding the current 4.8% yield of 10-year UK gilts and above the 6-12% IRR average seen across US fund-of-funds.

Significantly increasing the availability of venture capital will drive up pre-money valuations and the capital companies can secure per funding round. To achieve a venture return, expectations on founders will be ratcheted much higher, meaning they must rapidly scale their operations to meet market demands and to outpace competitors. An essential ingredient of the US playbook in markets that are often winner-takes-all.

### Help startups find product-market fit fast

Scaling a product to intersect a market at a suitable inflection point is critical to success. Being late or being on time with the wrong product can be disastrous. Strategic commercial insights, domestic support and staged funding for scale-up will help a start-up to plan their market entry in detail.

We need a program to help startups scale fast:

- **Achieving fast product-market fit** is the startup's superpower. It requires a bottom-up approach where entrepreneurs, product managers, engineers, scientists and business developers, fluent in the technology engage continuously with potential customers to understand candidate applications and find weakness in their competitors. The very best companies retain this superpower even as they scale; notably Nvidia, Qualcomm and Broadcom (all led by engineers).
- **Engaging Sector-Based Support** to bolster these efforts is crucial, requiring sector-specific programs to connect startups with mentors, advisors, and board members beyond traditional VC investors.
- **Targeted Acceleration Missions** for promising emergent spaces that show a promising fit to UK capabilities and to speed up development by providing non-dilutive acceleration capital that crowds in private VC money. ARIA is an example of this, pointing a national torch at important areas, for example in 'Scaling Compute'. Such programs can be widened and deepened.

## ► Support Manufacturing Scale-up ◄

UK fabs with innovative products in a growing market struggle to invest in production capability as the market grows since the investment required is typically much larger than net annual profit. This could even lead to company failure, as existing customers switch to offshore competitors rather than seek a second supplier. Finding equity investment is difficult due to the lack of understanding, short term and risk-averse nature of UK investors and returning the investment through increased turnover and profits could take 2 to 5 years. This is exacerbated by other regions offering various incentives to support production scale-up, often attracting matching private investment. However, where financing is difficult to obtain, alternative schemes supported by government would avoid otherwise promising companies failing due to their inability to scale.

Providing access to strategic capex funding would enable such companies to upgrade existing equipment or add additional capability to existing lines. This could be through reforms to innovation funding or more advantageous targeted tax schemes[21], allowing 50-100% capex recovery, or through investment or favourable loans supported by government backed banks. This would help UK businesses stay globally competitive as the market and their customers grow. This is especially important given the unfair competition from overseas players resulting from the many international government incentives and chips acts described above.

## ► Target Investment Towards Ambition and Potential ◄

The current UK policy framework leans heavily on passive investment that avoids trying to pick winners. But it also overlooks the importance of leadership, ambition, product-market fit and operational execution. An example is R&D tax credits, with SME R&D tax credits adding up to $6.5 billion per annum distributed as cash to 86,000 claimant companies. The rate of R&D tax credits is significantly higher than in the US and reforming these in the UK, in favour of targeted mission-based funding and increased venture capital flow would improve the mix of high-growth versus underperforming companies. The UK must welcome the combination of strong teams with higher risk / reward opportunities and pro-actively support these with patient investment.

**Programs that Permit Secondary Sales:** Building a large successful chip company can take a decade, during which founders and employees invest prime years, starting a family, needing a bigger house, etc. To mitigate financial pressure and encourage long-term commitment, company boards should establish programs where founders and senior employees are able to sell some equity (10-20%) in secondary sales as their companies

[21] The full expensing (of capital equipment) scheme is insufficient as it only applies to new equipment and is capped at 25% of capex as it's offset against corp. tax. Typical fab equipment costs can be many times annual profit of UK fabs

reach intermediate revenue goals. This process could be supported from BBB or the National Wealth Fund as a secondary buyer, provided the valuation aligns with market conditions for recently issued preferred stock.

## ► Find and Keep Talent ◄

Possessing a strong skills base is integral to future growth and will be an investment magnet. Although we must grow a domestic base, in the short term we need better support for skilled immigration to help companies tackle immediate/current skills gaps. In the longer term, sectoral benefits must be brought to the fore so that young people see such careers as a favourable option, with a wide range of jobs from vocational technicians to postgrad scientists, good salaries and long-term prospects. Generally, the UK suffers from a poor perception and devaluation of the engineering profession due to widespread adoption of the title in non-professional cases and we should make the title *Engineer* a protected title, as it is in much of the world.

Both the US and Europe face a significant shortfall in electronics engineers, estimated at 59,000-77,000[22] in the U.S. and up to 100,000 in Europe. According to a recent McKinsey report[22], the most critically needed skills in Europe are systems architecture (SoC, SiP, hardware), AI and machine learning and sector-specific applications knowledge. However, shortages are pervasive across all engineering disciplines from CTOs, product managers, engineering managers, team leads, and various specialized engineers such as SoC architects, to EDA tools engineers and verification engineers. Retaining and attracting top talent in the UK depends on the incentives offered by companies and on broader national factors.

- **Company-Specific Policies:** Companies should implement policies that boost engagement and retention, such as offering stock options to all employees, maintaining flat organizational structures, adopting agile working practices, providing summer internships with pathways to full-time employment, conducting rapid pay reviews for promising graduates, and allow flexible working hours.
- **National Policies:** The UK should facilitate the movement of skilled workers by reinstating freedom of movement between the UK and EU for workers and their families and by eliminating visa and NHS fees for qualifying technology workers. In the longer term, policies must be enacted to ensure we can grow our own talent (see below). Additionally, the UK must find ways to attract experienced entrepreneurs and managers, particularly with stateside success, to mentor UK startups. An innovative approach could involve agencies like BBB or NWF purchasing small equity stakes in startups to allocate to advisors and board members, thus incentivizing their involvement.

## ► Grow our Own Talent ◄

Our well-regarded university research base in the UK, that underpins our world-class innovation, is under threat of erosion if we do not attract more undergraduates to Electrical and Electronic Engineering courses. In 2023, according to UCAS, more than twice the number of UK secondary school students were accepted on Mech Eng courses (6,835) compared to EE Eng (3,200). However, as noted above, we need a wide cross-section of skills from technicians to engineers and scientists.

There are four principal needs:

1. More investment in school to raise awareness and stimulate interest in Electronics (primary schools) and semiconductors (secondary schools). Scale up current efforts into a national programme and provide financial support to encourage greater diversity among students.
2. At university, more opportunities for students to develop the specific know-how we need in semiconductors (e.g. Chip Design) and to gain work experience in the industry.
3. Closer links between industry and universities to ensure courses reflect the needs of industry, for instance mapping of competencies against curriculum.
4. Enhance and grow T levels, apprenticeships and degree apprenticeships to accelerate development of a competent workforce and enable vocational routes, especially as the cost-of-living increases.

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[22] How the semiconductor companies can fill the expanding talent gap, McKinsey, February 2024

## ► Grow Domestic Demand ◄

Specific and targeted missions which incentivise, or mandate domestic supply would enable UK chip companies to validate products, optimise and scale up their production, gain valuable orders, derisk venture investment and potentially attract corporate investment from large UK customers. This could be focused on major government priorities such as quantum computing, clean energy and net zero, or in areas of national security and resilience, such as defence, telecommunications, or the national power grid.

## ► A National Semiconductor Institute ◄

HMG have proposed the creation of a National Semiconductor Institute. However, the institute's mission and governance should be objective, clear and non-partisan. Specifically, it should:

- Oversee the creation and management of infrastructure. Specifically, the pilot line, innovation and advanced packaging facility and the design competence centre, as described below
- Manage and allocate sector growth funding (e.g. scale-up support for UK manufacturing)
- Develop alliances and collaboration opportunities with similar international bodies
- Develop sector-targeted missions based on RTO and industry roadmaps, to enable new technologies and supply chains which address future market opportunities. The institute would be supported by (public and private) investment and long-term strategic plans. Industry bodies like TechWorks, PEUK, PLG, UKESF and IET would be key partners in this.

**UK pilot line and innovation facility** - a good model would be that of IMEC, a Belgian non-profit spin-out from KU Leuven that attracts €750M pa of industry research and state contributions in semiconductor materials, fabrication and design. A UK equivalent working in novel non-CMOS silicon[23], one or two emerging compound semiconductor materials and advanced packaging would support UK companies with innovation in emerging fields such as photonics, sensing, quantum, future compute and communications. A joint public/ private model could be used with the right FDI partner, although a clear market focus and strategic plan would need to be created to avoid trying to be 'everything to everyone'.

**Design competence centre** - As other nations recognise the value of creating high-impact chip design teams[24], the UK is at risk of losing our lead in IP and chip design to competitors elsewhere. A design competence centre would provide support for UK chip design teams (startups, SMEs and OEMs) to:

- Access design capability combining commercial EDA, AI and open-source design flows
- Provide Chip Design flow support and design IP integration training
- Provide access to semiconductor foundries
- Catalyse UK design flow innovation and use of AI to accelerate design and enhance traditional EDA

The above proposal is in line with recommendations made in the 'UK Semiconductor Infrastructure Feasibility" study for DSIT submitted Dec. 2023. The institute should not aim to act as a voice of industry, or academia, as there are bodies which already do this, but should instead, work as a peer to such organisations.

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[23] We use the phrase *non-CMOS silicon* to highlight silicon applications outside mass-market CMOS. For example, power, analogue, RF, MEMS sensors, microfluidic biosensors, resonators & optical switches, photonics, novel computation, quantum & memory and advanced packaging interconnect. These are all expected to grow significantly.

[24] The EU Chips Act virtual Design Platform aims to accelerate design and reduce time-to-market with a cloud-based platform providing easy-access design facilities, from IP libraries to multi-vendor EDA tools. Several design centres across the EU will provide access to technical expertise and innovation, helping companies improve design capability and develop skills. However, due to BREXIT, the UK does not currently have access to these arrangements.

## 8. Summary

The UK's potential as a leading technology economy hinges on establishing a significant presence in the global semiconductor market. Successful development in this sector would not only enhance our exports but also create hundreds of thousands of high-paying jobs, substantially increase household net worth, and strengthen the UK's industrial and tax base.

To realize this potential, specific policy adjustments are necessary, which would neither be classified as public spending nor impair Public Sector Net Worth. On the contrary, these changes could reduce current wastage and capitalise on successful investments for the future.

**We urge the government to seize this opportunity with decisive action to transform the UK into a powerhouse in the global semiconductor industry.**


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