Written Evidence Submitted by the Institute of Photonics, University of Strathclyde (LEC0031)

Science, Innovation and Technology Committee
Inquiry on Low-Energy Computing

Submitted by the Institute of Photonics, University of Strathclyde

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Executive Summary

The University of Strathclyde's Institute of Photonics[1] welcomes the opportunity to contribute evidence to the Committee's inquiry into low-energy computing. The continued growth of artificial intelligence is driving a substantial increase in energy demand, largely associated with data movement, system complexity, and compute-intensive workloads. Neuromorphic computing and silicon photonics offer credible and complementary approaches to improving energy efficiency through event-driven processing, high-bandwidth optical interconnects, and integrated photonic–electronic architectures.

The United Kingdom is strongly positioned across the relevant research landscape, with established strengths in photonics, semiconductor technologies, neuromorphic systems, and heterogeneous integration. Realising this opportunity depends on translating research capability into scalable, manufacturable, and application-ready systems.

Four priority areas for policy intervention are identified. First, the establishment of a coordinated, systems-level prototyping and scale-up capability that brings together design, fabrication, integration and advanced packaging, and algorithm development within an accessible national framework. Second, the acceleration of technology transfer between complementary sectors, including future telecommunications, semiconductors and defence to support adoption and application. Third, sustained support for, and alignment of, existing sovereign technology platforms with the proposed national centre. Fourth, continued investment in skills and talent development across the full innovation ecosystem.

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[1] **Note on the Institute of Photonics.** The Institute has internationally recognised strengths in semiconductor lasers, photonic integrated circuits, neuromorphic photonics, heterogeneous integration, and system-level photonic hardware. These capabilities sit within a wider Glasgow and Scottish ecosystem that includes the University of Glasgow's James Watt Nanofabrication Centre, the Fraunhofer Centre for Applied Photonics, the National Manufacturing Institute of Scotland's National Advanced Semiconductor Packaging and Integration Centre (NASPIC), and an established base of photonics, semiconductor, quantum and AI companies. This ecosystem provides a strong foundation for UK leadership in sustainable compute, linking research excellence to long-term translational infrastructure and industrial adoption.

These measures would support the development of low-energy computing platforms and strengthen the UK's capacity to deliver advanced semiconductor and photonic systems.

Q1. Can neuromorphic computing and silicon photonics provide a solution to the sustainability challenge of increasing AI-related energy demands? If so, how?

Yes. Neuromorphic computing and silicon photonics can make important contributions to reducing AI-related energy demand, but they do not represent a single, near-term solution to the whole problem. Their greatest impact is likely to be through the deployment of integrated photonic-electronic systems targeted at AI workloads where data movement, high-bandwidth communications, low-latency processing, and sparse or event-driven computation dominate energy use.

Current AI relies heavily on GPU-based architectures in large data centres, where growing model sizes and data volumes drive higher energy demand[1]. Much of this energy is used not only for computation, but also for moving data between processors, memory, accelerators, and servers[2]. Additionally, in edge-integrated AI systems connected to sensor networks, minimizing computation and data transfer energy is essential to reduce overhead and enable deployment within existing infrastructure. Neuromorphic computing and silicon photonics address these pressures at different but complementary levels of the computing stack.

1.1 Neuromorphic computing offers a route to lower-energy AI by changing the computational model. Instead of relying on dense, clocked, synchronous operations, neuromorphic systems draw inspiration from biological neural systems and use event-driven, sparse processing. Computation occurs only when relevant input events arrive. This is especially relevant for real-time sensing, vision, RF processing, autonomous systems, and edge AI, where sparse data streams make it possible to reduce unnecessary computation and, consequently, energy consumption. Neuromorphic approaches bring memory and processing closer together, helping to reduce the von Neumann bottleneck that drives much of the energy cost in conventional AI hardware. Neuromorphic algorithms can also reduce system training costs and overall computational requirements, thereby contributing to lower energy overheads.

1.2 Silicon photonics offers a complementary route to energy efficiency by improving how information is moved and processed. Optical interconnects can provide high bandwidth, low latency, and lower energy per bit than electrical interconnects, especially where communication bandwidth is the main constraint[3]. This is highly relevant to AI data centres, where moving and routing data between servers, accelerators, and memory is a major source of power consumption[4]. At chip and package level, photonic interconnects and co-packaged optics not only can reduce the energy and bandwidth constraints associated with on-chip communications[5], but can provide a platform for novel forms of all-optical neuromorphic computation[6].

1.3 Opto-electronic systems and heterogeneous integration

To deliver the full benefit of photonic technologies for AI, silicon photonics requires the co-integration of active photonic devices and electronics. Photonic AI hardware will require the heterogeneous integration of multiple photonic and electronic material systems and devices.

Efficient light sources, detectors, modulators, nonlinear components, and memory or weighting elements often require III–V semiconductors, germanium, silicon nitride, lithium niobate, polymers, and other functional materials to be integrated with silicon or silicon-compatible platforms[7,8,9]. The key opportunity is therefore the development of scalable multi-material photonic integrated circuits co-designed and co-packaged with advanced electronics.

1.4 In summary, neuromorphic computing and silicon photonics can significantly reduce the energy footprint of AI, particularly for inference, edge AI, real-time processing, optical interconnects, and specialised AI co-processors. Their impact will depend on progress beyond isolated demonstrations towards complete hardware systems that combine neuromorphic algorithms, photonic integrated circuits, optical nonlinearities, heterogeneous materials, co-packaged electronics, and manufacturable system architectures.

Q2. What other opportunities does the combination of neuromorphic computing and silicon photonics create? How well placed is the UK to take advantage of these?

The combination of neuromorphic computing and silicon photonics creates opportunities well beyond reducing AI energy consumption. Together, these technologies could enable new classes of computing, sensing, and communication systems that operate with high bandwidth, low latency, and low power[10]. This is especially important where conventional cloud-based or GPU-centric AI is too energy intensive, too slow, too large in physical footprint, or too dependent on moving large volumes of data to centralised infrastructure. Some key opportunities include:

2.1 Real-Time Signal Processing and Communications

Photonics offers clear advantages in bandwidth, latency, and energy efficiency, making it well suited to real-time signal processing in telecommunications, RF systems, sensing, and other high-throughput data applications. Neuromorphic photonic systems can operate directly on analogue signals, enabling high-speed inference and adaptive processing. Silicon photonics, already widely deployed in communications infrastructure, provides a scalable route to implementing these capabilities at high data rates and low power.

2.2 Hybrid Photonic-Electronic AI Accelerators

Hybrid systems integrating silicon photonics with CMOS electronics and heterogeneous material platforms, including III–V semiconductors, silicon nitride, lithium niobate, and germanium, could create powerful AI co-processors[11]. Photonics provides high parallelism and bandwidth, while electronics provides programmability and system control. Neuromorphic computing improves efficiency through reduced computational overhead and adaptive processing. These systems can deliver specialised acceleration for matrix operations, optimisation, classification, and signal processing.

2.3 Edge AI and Autonomous Systems

Neuromorphic photonic processors enable sensing, classification, and decision-making at the point of data generation, supporting applications such as autonomous vehicles, robotics, aerospace, defence, and distributed sensor networks. Silicon photonics provides high-bandwidth, low-latency data handling, while neuromorphic computing enables energy-efficient, event-driven processing. Together, they support real-time edge intelligence, reducing data transfer, accelerating response times, and improving resilience and privacy.

2.4 New Algorithms for Neuromorphic Photonic Computing Systems

Neuromorphic processing and event-based approaches, such as spiking neural networks, have emerged as a powerful and highly efficient class of algorithms, capable of achieving performance comparable to state-of-the-art AI models while using significantly fewer resources. Developing new algorithms compatible with implementation in high-speed integrated photonics processors represents a significant opportunity for the field.

2.5 High-Value Manufacturing and Sovereign Capability

Neuromorphic photonics supports the development of high-value, differentiated technologies in defence, telecommunications, quantum systems, healthcare, and environmental monitoring. Silicon photonics and compound semiconductor integration build on established strengths in advanced manufacturing and photonics in the UK and could leverage substantial current capabilities to create an accessible sovereign prototyping and scale-up route for the range of critical technology sectors noted above.

2.6 UK Placement

The UK is well placed to take advantage of these opportunities, but only if it connects current research strengths to scalable industrial capability. The UK has internationally recognised leadership in photonics, integrated photonics, compound semiconductors, neuromorphic computing, AI, quantum technologies, and advanced packaging. Relevant academic and innovation activity spans the Universities of Strathclyde, Glasgow, Southampton, Cardiff, UCL, Aston, Edinburgh, Oxford, Manchester, and others.

The UK also has a pioneering legacy in neuromorphic computing, including large-scale electronic neuromorphic systems such as SpiNNaker in Manchester[12]. Although SpiNNaker is not a photonic platform, it demonstrates the depth of UK capability in neuromorphic architectures and creates an important foundation for future hybrid photonic-electronic approaches.

Current UK initiatives, including Innovation and Knowledge Centres in Neuromorphic Computing[13], Silicon Photonics[14] and Heterogeneous Integration[15], the UK Multidisciplinary Centre in Neuromorphic Computing[16] and AI hubs[17], provide a valuable foundation. Future impact will depend on linking these programmes to hardware development, prototype manufacturing, packaging, reliability testing, neuromorphic algorithm development and end-user-led system demonstrations. The UK's opportunity is not only to publish leading research in neuromorphic and photonic computing, but to build a translation pathway that turns these technologies into practical platforms.

2.7 In summary, the combination of neuromorphic computing and silicon photonics creates opportunities in edge AI, autonomous systems, telecoms, defence, sensing, medical diagnostics, photonic-electronic AI accelerators, and high-value semiconductor manufacturing. The UK is scientifically well placed and has strong regional ecosystems that can contribute to this agenda. The main challenge is to convert research excellence into integrated, manufacturable, and deployable systems supported by efficient algorithms and models.

Q3. Where does the UK sit in terms of the scientific research underpinning these developments? Who are our main competitors?

3.1 UK position

The UK is scientifically strong in many of the research areas underpinning neuromorphic computing, silicon photonics, and neuromorphic photonics. It is one of the leading global contributors in this field, with particular strengths in photonic integrated circuits, compound semiconductors, optical communications, AI hardware, neuromorphic architectures, heterogeneous integration, system-level photonic demonstrations, and algorithm development. This breadth of capability matters because future low-energy computing platforms will require close integration of photonics, electronics, materials, software, packaging, and application-specific hardware.

3.1.1 Neuromorphic computing

In neuromorphic photonics, the UK can credibly be considered among the leading global centres alongside the USA, continental Europe and Switzerland, and China. The UK stands out for its breadth across compound semiconductors, devices, photonic integrated circuits, architectures, algorithms, and system-level demonstrations. This breadth is a significant advantage, particularly if it is matched by stronger translational infrastructure and industrial exploitation.

3.1.2 Silicon/Integrated Photonics

The UK has significant national assets and international leadership in silicon photonics and integrated optics. The University of Southampton has long-established expertise in photonic materials, fabrication, and silicon photonic integrated circuits, including the CORNERSTONE open-access silicon photonics foundry platform and related C-PIC Innovation and Knowledge Centre activity. The University of Glasgow hosts the James Watt Nanofabrication Centre which has advanced cleanroom facilities supporting III–V and silicon-based device fabrication, quantum and photonic components, micro- and nano-electronics, and microfluidic and bio-sensing technologies[18]. The University of Strathclyde and the National Manufacturing Institute of Scotland are home to world leading heterogeneous integration laboratories and the National Advanced Semiconductor Packaging and Integration Centre (NASPIC)[19], co-located with a strong industrial ecosystem in industrial photonics systems and critical technologies[20].

3.2 International competitors

The UK faces strong competition in neuromorphic (photonic) computing from the United States, continental Europe including Switzerland, and China, with additional contributions from Canada, Japan, and Singapore. The United States leads in scale and system integration, supported by universities such as Princeton, MIT, and Yale, alongside growing industrial activity in AI hardware. Canada has strong research activities in Neuromorphic Photonic Computing and Silicon Photonics at Queen’s Univ., INRS and UBC. Europe and Switzerland host strong research and innovation clusters at EPFL, ETH Zürich, CNRS and related centres. China is also a major force, with institutions including Tsinghua University, CUHK Shenzhen, and Xi’an/Xi’Dian producing notable work in hybrid neuromorphic chips and photoelectronic AI systems, backed by significant investment and rapid demonstration cycles.

International efforts, supported by the various Chips Acts, are accelerating in integrated photonics and heterogeneous integration. The United States again leads through large-scale industrial investment and companies such as Lightmatter[21] and Ayar Labs[22] targeting photonic AI and data-centre infrastructure, foundry and packaging efforts through the AIMS[23] network and existing foundry infrastructure, e.g. Global Foundries[24]. Europe and Switzerland remain highly competitive, with coordinated ecosystems spanning EPFL, ETH Zürich, Ghent, Eindhoven, CNRS laboratories, HPE Labs, and Trento that combine research, fabrication access, and system-level integration. Industrial fabrication and integration centres include established centres such as IMEC[25] in Belgium, and emerging systems integration efforts including Thema Foundries[26] and PhotonDelta[27]. China continues to expand through strong investment in photonic hardware and integration capabilities, while Japan, through organisations such as NTT, maintains leadership in optical communications and photonic computing. Singapore and Canada also contribute important capabilities in silicon photonics.

The UK is scientifically well positioned in both areas but faces pressure to translate research into scalable systems, requiring sustained support for fabrication access, heterogeneous integration, packaging, testing, and long-term reliability.

Q4. To what extent has the UK developed sovereign capabilities in this area?

The UK has developed substantial, but not yet fully sovereign, capabilities in neuromorphic computing, silicon photonics, and the broader photonic-electronic hardware needed for future low-energy AI systems. The UK is strong in the underlying science, device innovation, photonic integrated circuits, compound semiconductor technologies, heterogeneous integration, neuromorphic algorithm development, and early-stage system demonstrations. However, it does not yet have complete sovereign capability across the full chain from materials, devices, and design to scalable manufacturing, packaging, testing, qualification, and deployment.

4.1 Research Base, Design and Prototyping

The UK's sovereign strengths are most evident in research, design, and prototyping. It has internationally recognised academic and translational capability in integrated photonics, compound semiconductor photonics, neuromorphic computing, optical communications, and specialist AI hardware as detailed in section 3. The UK can design and prototype photonic and neuromorphic chips, develop novel architectures, fabricate advanced devices in university and open-access facilities, create novel training algorithms and demonstrate early-stage systems. These capabilities provide a strong foundation for future low-energy computing platforms, but do not provide for full-stack prototyping and scale-up industrial demands.

4.2 Sovereign Integrated Photonics, HI and Packaging

Future neuromorphic and photonic AI hardware will depend on heterogeneous integration, combining materials such as III–V semiconductors, silicon nitride, lithium niobate, germanium, and associated gain, detection, modulation, and nonlinear elements with electronics on shared platforms. The UK has strong capabilities across these domains, but the challenge is to integrate them into reliable, manufacturable, and deployable systems. Several regional ecosystems already contribute key elements of this capability. Southampton's CORNERSTONE platform provides open-access silicon photonics prototyping, while the University of Sheffield's EPSRC National Epitaxy Facility underpins III–V materials and device development. South Wales remains strategically important through the compound semiconductor cluster around Newport and Cardiff, linking manufacturing, packaging, power electronics, and photonic supply chains.

Scotland provides a particularly integrated set of capabilities. The University of Strathclyde contributes strengths in semiconductor lasers, photonic and electronics integration, and neuromorphic photonics, while the University of Glasgow adds nanofabrication through the James Watt Nanofabrication Centre and expertise in photonic integrated circuits and heterogeneous integration. The National Manufacturing Institute Scotland and the National Advanced Semiconductor Packaging and Integration Centre offer routes to scale.

Q5. How well have the Innovation and Knowledge Centres and other research centres supported by public funds delivered against their initial objectives? What objectives should future IKC activities and other government policy interventions seek to deliver?

Innovation and Knowledge Centres and related publicly funded research centres have played an important role in strengthening the UK's research base, building national communities, and accelerating early-stage translation in strategically important technology areas. In photonics, semiconductors, and neuromorphic computing, these initiatives can help bridge gaps between academic research and industrial application, support spin-outs and licensing, and create more coherent national ecosystems.

We believe that future policy interventions could substantially enable the opportunities detailed above in the following areas:

5.1 Creation of an Accessible Systems-Level Prototyping and Scale-Up Centre

The most impactful intervention would be an accessible systems-level approach that supports both integrated systems prototyping and scale-up. A single point of contact centre would help end-users access advanced technologies and improve compatibility across the supply chain. This would require coordination across design, chip fabrication, heterogeneous integration, electronics, and advanced packaging. Bringing these elements together in a joined-up framework would lower barriers to entry, accelerate development, and create a clearer path from early concepts to production.

5.2 Technology Pull-Through from Complementary Industries

The programme should draw on progress in related sectors and apply it in this domain. Relevant areas include defence, telecommunications, semiconductors, biomedical, and quantum technologies. Stronger links with these industries will help transfer knowledge, adapt proven approaches, and accelerate uptake of emerging capabilities.

5.3 Sustained Support for Existing Sovereign Technology Platforms

A further objective is to connect and sustain long-term support for key sovereign technology platforms. This includes capabilities such as silicon photonics prototyping, III–V devices, heterogeneous integration, and advanced packaging. This also includes aligning their efforts to existing and novel initiatives in Neuromorphic Technologies, including IKCs, CDTs and Centres of Excellence in Neuromorphic Technologies across the UK. Aligning and supporting these areas over time will provide stability and help consolidate existing strengths into a coherent delivery pipeline.

5.4 Skills and Talent Development Across the Ecosystem

The final priority is to build and sustain a skilled workforce across relevant roles, including operators, technicians, engineers, researchers, and future sector leaders. Developing this talent base will ensure the ecosystem has the capacity to design, deliver, and scale advanced technologies. This includes strengthening training routes, supporting career progression, and maintaining a long-term pipeline of expertise. For example, new Centres for Doctoral Training (CDTs) could be targeted to support skills development in Neuromorphic Computing, Integrated Photonics and Heterogeneous Integration.

6. Concluding statement

Neuromorphic computing combined with silicon photonics is a credible pathway to reducing the energy demands of future AI systems and a strategic opportunity for the UK. These technologies could enable low-power AI accelerators, edge-intelligent sensing systems, high-bandwidth optical interconnects, and hybrid photonic-electronic computing platforms when supported by a broader technology supply chain.

The UK possesses significant capability across neuromorphic photonics, integrated photonics, semiconductor laser technologies, photonic integrated circuit architectures, event-driven processing, and neuromorphic algorithm development. These capabilities support the development of novel system-level photonic AI demonstrators that address key challenges in energy-efficient information processing. When combined with strengths in heterogeneous integration, advanced fabrication, and system integration, these foundations provide a credible pathway towards the development of scalable, low-energy photonic–electronic computing platforms aligned with future AI and sensing requirements.

Global competitors are investing heavily, and UK leadership will depend on translating research excellence into manufacturable, deployable systems. With sustained investment, coherent national coordination, open-access prototyping infrastructure, advanced packaging capability, support for hardware demonstrators and algorithm development and a strong skills pipeline, the UK can secure a leading position in sustainable compute and next-generation AI hardware.

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