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Parliamentary Inquiry Response

Centre for Neuromorphic Technologies (CeNT) Written Evidence to the Low-Energy Computing Inquiry

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Written evidence submitted by the Centre for Neuromorphic Technologies (CeNT), University of Southampton (LEC0029)

1. The Centre for Neuromorphic Technologies (CeNT)[#] at the University of Southampton brings together more than 60 researchers across Electronics and Computer Science (ECS), the Optoelectronics Research Centre (ORC), and related disciplines working on low-power brain-inspired computing technologies, spanning materials, devices, photonics, circuits, architectures and AI algorithms. The Centre was established to strengthen interdisciplinary collaboration and accelerate the development of sustainable computing technologies for future AI systems, leveraging existing infrastructure in nanomanufacturing and interactions with Silicon photonics groups.

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

2. Recent analysis from the International Energy Agency (IEA) highlights that AI-related computing infrastructure is becoming a major contributor to energy consumption growth worldwide[1]. Modern AI systems are dependent on hyperscale data centres, each consuming around 100-300 MW of power, comparable to the electricity demand of hundreds of thousands of homes. This trend is economically and environmentally unsustainable. In some regions of the United States, electricity prices have already increased significantly in areas with high concentrations of data centres[2]. As AI adoption accelerates across healthcare, defence, finance, manufacturing, and consumer technologies, the energy demands of conventional computing architectures will continue to rise.
3. A major cause of this inefficiency is the separation of processing and memory in conventional AI computing hardware. Current Graphics Processing Unit (GPU)-based AI accelerators repeatedly transfer data between processors and multiple layers of memory, resulting in substantial energy losses associated with data movement rather than computation itself. Neuromorphic computing offers a different approach inspired by the architecture of the human brain. In neuromorphic systems, memory and information processing are co-located, reducing the energy consumed during data transfer.[3] In recent years, neuromorphic computing has achieved major milestones, including IBM's TrueNorth[4] (a 1-million-neuron programmable neurosynaptic chip) and Intel's Hala Point[5] (the industry's first 1.15-billion-neuron neuromorphic system). However, these systems rely on complementary metal-oxide-semiconductor (CMOS) transistors, which approached their energy-per-useful-operation limit (~100 femtojoules) in 2019[6]. The next breakthrough will likely come from emerging neuromorphic devices based on non-volatile memory technologies, which can retain data without continuous refresh power while enabling ultrafast operation on nanosecond timescales. By exploiting novel physical mechanisms, these devices could deliver orders-of-magnitude improvements in energy efficiency, reaching the attojoule regime (namely over x100 more efficient than incumbent systems), while supporting multibit data storage for efficient AI computation.
4. Neuromorphic technologies could also help decentralise AI computing away from large cloud-based data centres by enabling low-power 'edge AI' directly on personal electronics, medical devices, industrial sensors, and autonomous systems. ***This would reduce***

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pressure on national energy infrastructure, while improving privacy, resilience, and data sovereignty by reducing dependence on cloud computation.

5. At the University of Southampton, CeNT is developing this vision through a vertically integrated approach spanning novel materials and devices, mixed-signal circuit design, photonic systems and AI algorithms. This integration is important because meaningful energy reductions will not arise from innovation within a single sector or discipline, but from co-design across the full computing stack. Combining neuromorphic computing with silicon photonics provides an additional opportunity by enabling ultra-high bandwidth and low-latency communication as light-based (photonic) interconnects can reduce the energy costs associated with data transfer both within chips and between computing systems. Southampton is well positioned through the combination of ECS expertise in neuromorphic hardware and the internationally recognised capabilities of the Optoelectronics Research Centre (ORC) in silicon photonics and optical interconnect technologies. This level of inter- and multidisciplinarity is paramount to accelerate technological impact.

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

6. The combination of neuromorphic computing and silicon photonics creates transformative opportunities across several strategic sectors. Photonic neuromorphic systems could enable ultrafast AI inference with low latency, reduced thermal management requirements, and lower power consumption, supporting real-time intelligent processing. These advances have strong potential to drive growth in advanced manufacturing, defence, and digital technologies, aligning with the UK's Industrial Strategy. Potential applications include:
   - autonomous navigation systems with rapid real-time decision-making
   - low-power healthcare and wearable monitoring technologies
   - secure defence and aerospace platforms
   - intelligent robotics and advanced manufacturing
   - energy-efficient edge AI for consumer electronics and industrial sensing

   By reducing reliance on energy-intensive data centres, neuromorphic computing could also lower the overall energy demand of AI infrastructure, enabling more effective use of power generated by the UK's clean energy sector.

7. The UK is globally recognised for fundamental scientific research in AI and machine learning, neuromorphic materials and devices. Also, the UK has demonstrated leadership through initiatives such as the SpiNNaker neuromorphic computing platform led by the University of Manchester, with contributions from the University of Southampton. ***However, while the UK performs strongly in early-stage research (TRL 1-2), there remains a significant gap in manufacturing capability needed to scale emerging hardware technologies toward deployment.***

8. At the University of Southampton, the Centre for Neuromorphic Technologies (CeNT) also provides an important regional and national coordination role by connecting Southampton researchers with major UK initiatives including NeuroSync, the NeuMat network, NeuroWare Innovation and Knowledge Centre and UKRI AI Centres for Doctoral Training, such as "AI for Sustainability". CeNT is a unique example in the UK that leverages the state-

of-the-art semiconductor fabrication cleanrooms in Southampton to support neuromorphic device prototyping and critical skill-development.

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

9. The UK is internationally recognised as a leader in several areas underpinning neuromorphic computing, particularly neuromorphic architectures, advanced electronic materials, photonic integration, and AI algorithms. The UK has been strong in systems-level neuromorphic computing, exemplified by the SpiNNaker project, and in emerging low-power device technologies including resistive switching memories, ferroelectrics, spintronics, and phase-change materials. The University of Southampton is distinctive in combining world-leading photonics capability through the Optoelectronics Research Centre (ORC) with advanced semiconductor fabrication infrastructure and expertise in emerging electronic materials, enabling research across the full innovation pathway from materials discovery to device prototyping and system-level integration.

10. However, the international landscape is becoming competitive and strategically coordinated. The United States and several European countries are now investing at significant scale in neuromorphic and post-CMOS AI hardware as part of broader national strategies for sustainable AI, semiconductor sovereignty, and edge intelligence. The success of IBM Truenorth has been a result of long-term funding through programmes such as DARPA funded Synapse that allowed coordinated partnerships between academia, national labs and industries. Large-scale European funding such as the recently launched €9 million 10X-Factor(y) programme in Netherlands to establish a national neuromorphic technology ecosystem, the AMO Gmbh 2D pilot line project, Chua Memristor Centre in Dresden and other translational semiconductor support through Fraunhofer-and imec led programmes in Germany and Belgium. These programmes are notable not only for their scale, but because they combine long-term funding horizons (typically 5-15 years), coordinated academia–industry partnerships, pilot fabrication capability and device-to-system integration, and clear pathways toward commercialisation and strategic technologies. By comparison, UK activity remains fragmented and comparatively modest in scale, despite strong underlying scientific capability. ***Without sustained long-term investment, there is a significant risk that UK-led neuromorphic innovations will continue to be manufactured and commercialised overseas, accompanied by the migration of talent and intellectual property in semiconductor technology.***

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

11. The UK has strong sovereign capability in the scientific foundations of neuromorphic and beyond-CMOS computing, particularly in advanced materials, photonics, low-power electronic devices, and neuromorphic hardware architectures. However, sovereign capability in manufacturing, pilot-line prototyping, and hardware scale-up remains limited, meaning many UK-developed technologies still depend on overseas fabrication and commercialisation pathways. Ensuring supply-chain resilience and technological sovereignty will therefore require investment beyond fundamental research, particularly in pilot-line and scale-up infrastructure capable of bridging the gap between laboratory

research and industrial manufacturing. To strengthen technological sovereignty, the UK would benefit from a coordinated national programme in neuromorphic and beyond-CMOS hardware built around shared-access pilot-line facilities and long-term academia-industry partnerships. A realistic first step would be dedicated UKRI infrastructure investment in advanced fabrication, packaging, and device-integration of neuromorphic hardware. Such investment would help UK universities and industry retain intellectual property, talent, and manufacturing capability domestically.

12. The University of Southampton is one of the UK's strongest sovereign assets in this area, combining advanced semiconductor fabrication facilities with world-leading photonics expertise through the Optoelectronics Research Centre (ORC). Southampton's cleanroom infrastructure supports domestic prototyping of emerging neuromorphic technologies at industrially relevant 8-inch wafer scale. These facilities provide critical capability for research into post-CMOS compute-in-memory devices based on ferroelectrics, spintronics, oxide and organic resistive memories, phase-change materials, 2D semiconductors, and photonic interconnects, reducing reliance on overseas fabrication during early-stage development. The nanofabrication competence of Southampton could complement other national semiconductor initiatives such as the South Wales Compound Semiconductor Cluster, the National Epitaxy Facility (Sheffield, Cambridge), and the National Physical Laboratory to support UK's neuromorphic research and translation environment. While these institutions provide the adequate environment, sustained investment is necessary to enable accessible, coordinated and prioritised support for neuromorphic research and achieve success at par with imec in Belgium or the Fraunhofer Institutes in Germany.

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?

13. Innovation and Knowledge Centres (IKCs) and EPSRC-supported centres are playing an important role in building UK capability in neuromorphic computing. Initiatives such as the Neuroware IKC will support collaboration between academia and industry and create a future talent pipeline in this area. Recent programmes such as NeuroSync (UK Multidisciplinary Centre for Neuromorphic Computing), which is co-led by the University of Southampton, and the EPSRC NeuMat Network, demonstrate growing national coordination in neuromorphic technologies for low-power AI hardware. The ECS Centre for Neuromorphic Technologies (CeNT) at the School of Electronics and Computer Science, University of Southampton, is engaging with these initiatives to strengthen collaboration in advanced materials, devices, systems and algorithms research for neuromorphic technologies. These programmes will be effective in supporting early-stage research and interdisciplinary collaboration to define a future roadmap on neuromorphic computing, joint-workshops, ECR training events and conferences such as the upcoming International Neuromorphic Computing Conference (INCC) 2027.

14. Future government interventions should prioritise:
    - long-term support through specific neuromorphic calls from EPSRC for interdisciplinary centres linking materials, photonics, devices, architectures and algorithms for neuromorphic computing

- two shared-access pilot-line semiconductor fabrication infrastructure: a large-scale facility for manufacturing, heterogeneous integration and advanced packaging, and a small-scale agile prototyping facility for emerging neuromorphic and beyond-CMOS devices. Southampton could play a key role in shaping these pilot-lines due to its world-class expertise in electronic and photonic nanofabrication. These pilot lines will enable resilient UK supply chains in future computing hardware and semiconductors
- UKRI funding calls with lower entrance barrier for SMEs
- Centre for Doctoral Training (CDT) and technical skills programmes aligned with neuromorphic computing

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