

Connecting Quantum and Clean Energy

Quantum Computing, Clean Energy
and the Next Phase of UK Industrial Strategy

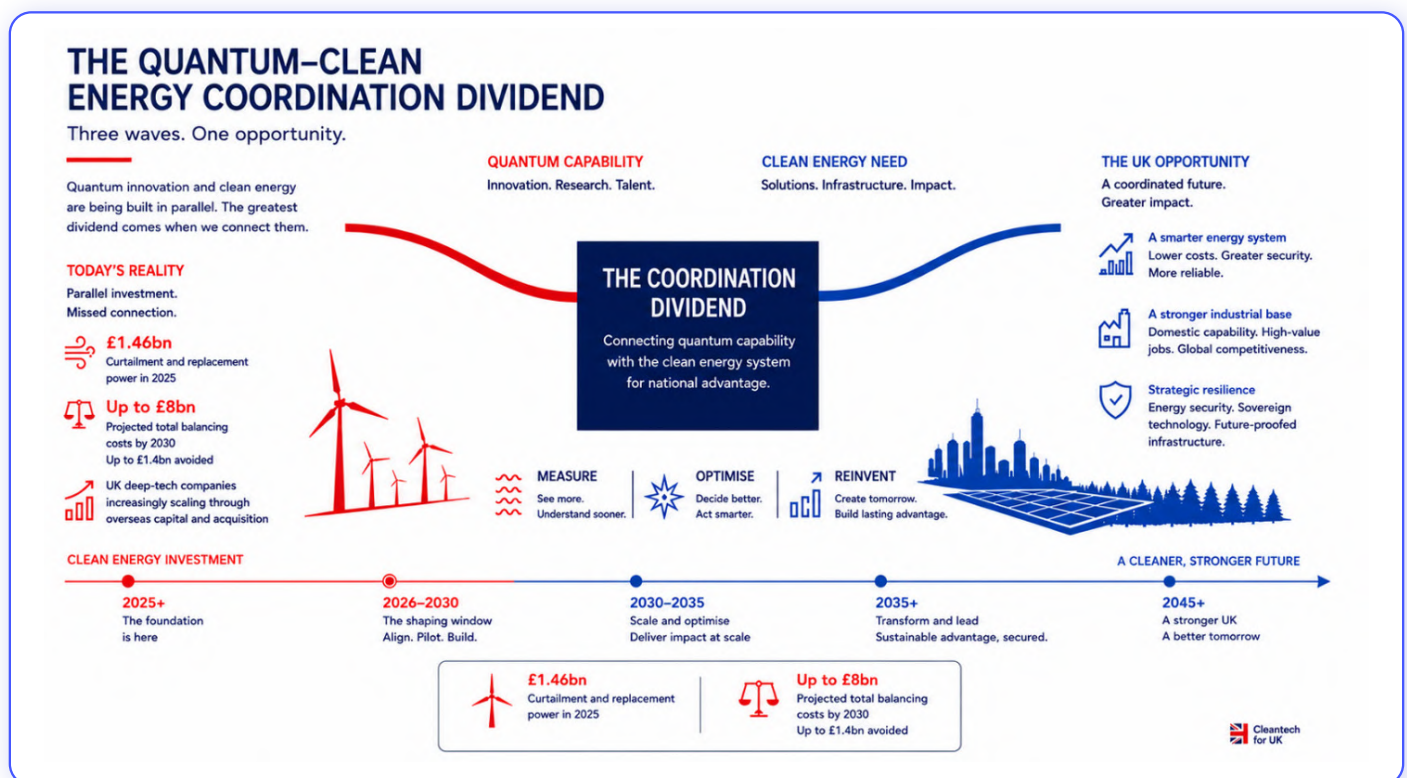
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CONTENTS

Executive Summary	3
1. Why This Report, Why Now	6
2. The Policy Landscape	6
3. The Economic and Strategic Case	10
4. The Energy Sector’s Opportunity	14
5. Understanding the Quantum Landscape	15
6. Three Timelines, Three Cleantech Opportunities	19
7. The Energy Question	26
8. Infrastructure: The Chance to Get It Right	27
9. What Other Countries Are Doing	31
10. Three Recommendations	33
11. Conclusion	35
Key Sources	37

EXECUTIVE SUMMARY

The UK is making serious bets on two technologies that happen to need each other. Every quantum computer needs power to run, and the larger computing machines will draw heavily on clean, stable supply and specialist cooling as they scale. Clean energy needs the optimisation, sensing and simulation capabilities that quantum may be able to provide. The Modern Industrial Strategy names both as priorities. Yet policy still largely treats them as separate agendas.



The Quantum–Clean Energy Coordination Dividend: connecting quantum capability with the clean-energy system. Conceptual and illustrative.

Clean energy systems are generating exactly the kinds of problems quantum technologies may eventually help address. As renewable generation has expanded, the electricity system has become more complex to operate: power is increasingly produced in locations and at times that do not always match demand, requiring the system operator to manage constraints, balance supply and demand, and occasionally reduce renewable output when the network cannot safely absorb it. In 2025, these actions, including turning down renewable generation and procuring replacement power, cost consumers approximately £1.46 billion. NESO projects that total balancing costs could approach £8 billion in 2030, although up to £4 billion could be avoided through faster delivery of critical network projects. Quantum sensors are being developed for methane detection, subsurface mapping

and infrastructure monitoring. Quantum optimisation algorithms, which run on quantum computers, are being explored through early feasibility collaborations on grid problems that become more complex as renewable penetration rises. Longer-horizon quantum simulation capabilities could eventually accelerate materials discovery for areas such as batteries and clean fuels. The UK has companies working at the frontier of all three areas, but policy decisions made by the government over the next few years will influence whether that capability translates into domestic deployment and industrial value.

Quantum will also create new demands on the energy system in which it is deployed. Different quantum technologies have fundamentally different power, cooling and siting requirements. As some architectures scale, they may compete with other industrial loads for constrained grid connections and increase demand for reliable, low-carbon power. Decisions made now about how quantum systems are powered and planned for will influence their long-term environmental footprint and should be considered alongside clean-energy objectives rather than separately from them.

That invites an obvious objection: if the energy draw is significant, is the quantum advantage worth it? The answer depends on which quantum technology, for which problem, and on what timeline. That uncertainty is an argument for planning the build-out now rather than assuming the trade-off will resolve itself. The energy question is examined directly in Section Seven.

Up to £2 billion has been committed to quantum through the former DSIT and UKRI, with the National Wealth Fund, Great British Energy and the British Business Bank deploying additional capital. Energy is an eligible application, but there is no dedicated quantum-clean energy call, shared roadmap or mechanism matching energy-system needs to quantum capability.

The AI build-out showed how quickly compute demand can outpace the grid and the planning system. Quantum is maturing fast enough to take seriously and slowly enough to shape. DSIT's abolition, with science and innovation moving to BIST and AI to the Cabinet Office, could make coordination harder. The response is a named delivery owner for quantum-clean energy coordination, modality-aware planning guidance and a small number of pilots using the existing mandates of the public financial institutions. None requires new legislation, a new institution or a new overall spending settlement.

THREE RECOMMENDATIONS

- 1 BIST should appoint a named Senior Responsible Owner accountable for publishing a quantum-clean energy roadmap within twelve months, with DESNZ and NESO supplying energy-system needs and the evidence threshold as a formal input.
- 2 BIST, DESNZ and MHCLG should publish modality-aware infrastructure guidance through the National Quantum Standards Network.
- 3 Delivery institutions, convened by the Senior Responsible Owner, should jointly fund a small number of quantum-clean energy demonstrators.

01.

WHY THIS REPORT, WHY NOW

The infrastructure decisions being made now about how quantum systems are powered, cooled and sited will have long-term consequences. The data centre sector illustrates what happens when compute infrastructure scales faster than the systems around it: connection queues running into years, grid capacity increasingly constrained by demand from compute, and planning challenges becoming harder to resolve after investment decisions have already been made. Quantum is not yet at that level of maturity, which means there is still an opportunity to design the right frameworks before deployment patterns become established.

One clarification on scope: the term quantum computing is used throughout, but several of the cleantech applications closest to deployment are quantum sensing technologies, some commercially available and others field-testable today without fault-tolerant qubits or the infrastructure associated with large-scale quantum computing. This report covers both, and where the distinction matters it is made explicit.

02.

THE POLICY LANDSCAPE

The UK has developed substantial quantum and clean energy policy infrastructure over the past three years.

The Modern Industrial Strategy (June 2025)

The UK's Modern Industrial Strategy is a ten-year plan built around eight high-growth sectors, the "IS-8". These are advanced manufacturing, Clean Energy Industries, Creative Industries, Defence, Digital and Technology, Financial Services, Life Sciences, and Professional and Business Services. Quantum is identified as a frontier industry within the Digital and Technology sector. Clean Energy is one of the eight sectors in its own right.

The strategy commits to public investment rising from £20.4 billion in 2025/26 to £22.6 billion in 2029/30, with UKRI directed to pivot its programmes toward IS-8 priorities. Quantum and clean energy both sit within the Industrial Strategy as priority sectors. The key implementation question is whether the Industrial Strategy recognises the interdependence between these technologies, or continues to develop and support them in separate silos.

The Clean Energy Industries Sector Plan (June 2025)

The Clean Energy Industries Sector Plan, published alongside the strategy, targets the UK becoming a top three global leader in clean energy by 2035, doubling investment to over £30 billion per year with most of that expected to come from private capital. Its frontier technology priorities cover offshore wind, nuclear, fusion, hydrogen, carbon capture and storage, and heat pumps. Quantum sensing tools and quantum optimisation algorithms, which run on quantum computers, do not yet feature in the plan's delivery framework, despite several of its core challenges being precisely the domain where those tools have the most to offer.

Clean Power 2030

Clean Power 2030 commits to meeting Britain's electricity demand from clean sources by 2030, with 95 percent from clean generation. Delivering that target at pace requires grid optimisation, energy storage management, and flexible

demand coordination of a complexity that strains classical computing at scale. Quantum optimisation algorithms are an active area of exploration for that delivery challenge, but absent from the delivery framework.

UK Quantum Programmes

The scale of the UK's quantum investment commitment has increased significantly in the current spending review period. In March 2026, the former DSIT and HM Treasury announced a package worth up to £2 billion, including an up to £1 billion ProQure programme designed to identify, grow and deploy UK quantum computing capability towards commercial procurement in the early 2030s. Of that total, more than £1 billion is UKRI funding for quantum technologies across 2026 to 2030, announced in December 2025, with an explicit ambition to unlock £3 of private investment for every £1 of public funding in partnership with the British Business Bank. The National Quantum Computing Centre at Harwell, operating on a ten-year footing, sits at the centre of this ecosystem. Innovate UK sits alongside these as the main delivery body for applied quantum, having funded more than £220 million of quantum projects between 2018 and 2024 and run many of the company-facing programmes through which the technology has reached market. That commitment builds on a decade of prior investment. The National Quantum Technologies Programme, established in 2014, delivered over £1 billion of public and private investment in UK quantum research and translation by 2024, and the hubs, skills pipeline and NQCC described below are its direct institutional legacy.

UKRI, the Quantum Hubs and Skills Pipeline

UKRI, principally through EPSRC and Innovate UK, provides the research, translation and skills backbone of the UK's quantum ecosystem. The UK National Quantum Technologies Programme links government, academia, national laboratories and industry. In 2024, UKRI launched five new Quantum Technology Hubs backed by £106 million of public funding and more than £54 million of partner support: Q-BIOMED, led by UCL and Cambridge; QuSIT, led by Birmingham; the Integrated Quantum Networks hub, led by Heriot-Watt; QCI3, led by Oxford; and the Quantum Enabled Position, Navigation and Timing hub, led by Glasgow.

Several map directly onto clean energy and infrastructure. QuSIT covers gas-leak detection and gravity and magnetic-field sensing for critical infrastructure; QCI3 includes materials and chemical simulation; and the Glasgow-led QEPNT hub is developing resilient timing and positioning for transport and critical national infrastructure. The National Physical Laboratory provides the metrology that underpins quantum timing and sensing, while the NQCC provides multi-platform hardware testbeds and a Quantum Software Lab. The skills pipeline is also substantial: EPSRC's 2024 doctoral training settlement included five quantum technology Centres for Doctoral Training, led from Bristol, UCL, Strathclyde, Edinburgh and Southampton. These institutions provide an obvious delivery network for the energy-needs mapping, demonstrators and technical guidance proposed in this paper. The challenge is connecting that capability systematically to clean-energy delivery.

As of July 2026 the institutional picture changed. The government abolished DSIT and folded science and innovation into the new Department for Business, Innovation, Science and Trade (BIST), while moving AI strategy, public-sector AI adoption and the AI Security Institute to the Cabinet Office. This separation matters because AI and quantum are unlikely to develop as entirely separate technology domains: they share infrastructure dependencies, research capabilities and future commercial applications, with hybrid approaches likely to combine both. The funded delivery bodies, the NQCC and the research hubs, sit inside UK Research and Innovation and are largely insulated from these machinery changes. The challenge is therefore not only that quantum no longer sits within a standalone science and technology department, but that closely connected parts of the advanced technology ecosystem now sit across different parts of government. That makes the coordination this paper calls for harder to sustain, and more important to design deliberately.

Three delivery bodies sit alongside UKRI and the NQCC, and each already holds a mandate that reaches both quantum and clean energy. The National Wealth Fund, with more than £100 billion to mobilise, lists both as target sectors. Great British Energy runs a £1 billion Clean Energy Supply Chain Fund alongside its goal of at least 15 GW of generation and storage by 2030. The British Business Bank, whose remit was widened in 2025 to make larger direct investments, invested £40 million in Quantum Motion in May 2026 and committed £100 million to Oxford Quantum Circuits the following month.

None of the three has yet turned that overlap into a coordinated quantum demonstrator portfolio for clean-energy problems, and no joint programme or industrial strategy push currently directs them to try. That is exactly where a small, deliberate programme would sit.

Beyond the delivery institutions, the same gap runs through the government's own quantum programme. Energy appears among the potential application areas within the government's quantum package, including clean-energy research and greenhouse-gas monitoring, but nothing in the programme connects those priorities to net zero delivery, and no route runs from an identified energy-system need to a funded quantum project. Environmental sustainability appears in parts of the funding architecture as a broad principle rather than a scored energy-system outcome. Without explicit coordination, the inclusion of energy as an eligible application does not by itself create a delivery pathway from clean-energy need to demonstration and procurement.

03.

THE ECONOMIC AND STRATEGIC CASE

The economic value of quantum will come less from the quantum industry itself than from its application across the wider economy. Whether the UK captures that value will depend as much on deploying those technologies against commercially important problems, in sectors such as energy, as on developing them in the first place. That will shape economic growth, industrial competitiveness and, ultimately, national resilience.

The economic opportunity

Oxford Economics, in research commissioned by IBM and Oxford Quantum Circuits, estimates that quantum computing could raise UK productivity by up to seven percent by 2045, equivalent to up to £212 billion in gross value added, in a scenario where commercially valuable use cases first emerge in

2035. Almost all of that value comes from other industries using quantum rather than from the quantum industry itself, whose own direct contribution to GDP the same research puts at between £1.7 billion and £3.8 billion by 2045. Its most optimistic employment scenario has the sector supporting around 126,000 jobs by 2045, roughly a quarter of them inside the sector and the rest through its supply chain and the spending of its workforce. These are scenario estimates rather than forecasts, and they overlap.

Energy is one of the sectors where the modelling identifies potential value, and the challenges created by renewable integration illustrate the kinds of complex system problems where better optimisation may eventually help. Constraint and balancing actions cost consumers approximately £1.46 billion in 2025. On NESO's projection those costs could reach around £8 billion by 2030, with as much as £4 billion of that avoidable if critical network projects are accelerated and wider delays prevented. As the system becomes more decentralised and intermittent, the challenge will not only be building new infrastructure but also operating it efficiently, requiring more sophisticated scheduling, forecasting and balancing decisions. Quantum optimisation methods are being explored as one possible approach to some of these challenges, alongside rapidly improving classical and AI-based methods.

Materials discovery is another potential source of value, with the greatest opportunities dependent on the development of fault-tolerant quantum computers. Industrial companies including Mercedes-Benz, BASF and Mitsubishi Chemical are already exploring quantum approaches to chemistry and materials problems, while quantum technology companies such as PsiQuantum and PhaseCraft are developing the hardware and algorithms needed to support these applications. The potential prize is more accurate molecular simulation of materials such as battery components and catalysts, addressing some of the limitations of classical approaches.

The UK will only capture value from these opportunities, in energy and in materials, if the companies developing the technology stay and scale here. US-listed IonQ's acquisition of Oxford Ionics is a case in point: agreed for more than \$1 billion in June 2025, it completed in September 2025. Oxford Ionics was a UK-origin company, spun out of Oxford University, building trapped-ion quantum hardware of genuine international standing. Its acquisition by a US-listed competitor was not a failure of the technology. It reflected the scale-up and capital conditions facing deep-tech companies in highly competitive international markets, as well as the strength of global

demand for leading quantum hardware. The UK government imposed national-security conditions, including continued access to hardware for assessment, but the deal still illustrates the continuing challenge of scaling globally competitive deep-tech companies in the UK. Retention is partly about problems, not only capital. Giving UK firms hard, real-world problems to work on, such as the NESO collaborations described in section six, is itself a reason for them to stay rather than leave for a better-capitalised market.

Sovereign capability and national security

Quantum capability may become strategically important in ways that resemble other foundational technologies such as semiconductors, where control of intellectual property, supply chains and manufacturing capability influences both economic competitiveness and national security. Countries that build capability early are likely to have greater influence over how the technology develops and where the resulting economic value is captured. No country, including the largest economies, is building full-stack quantum capability alone. For the UK, sovereign capability in practice means concentrating investment on the areas where it already has, or could plausibly build, genuine comparative advantage, sensing and positioning-timing being the clearest examples, and securing strategic partnerships and supply-chain access to cover the rest, rather than attempting to replicate every layer of the stack domestically.

The UK already has government-backed investment in quantum capability. The National Security Strategic Investment Fund (NSSIF), the government's corporate venturing arm for dual-use technology, holds positions across sensing, computing, networking and photonics, including in Oxford Ionics and Nu Quantum. The NATO Innovation Fund made its first quantum investment in Aquark Technologies, a UK company in the DIANA accelerator developing resilient positioning and timing technologies. Alongside Innovate UK's applied programmes, this provides a growing base of investment supporting UK quantum capability. The opportunity now is to connect that capability more deliberately to national priorities, including clean-energy challenges, where quantum technologies may have a role.

The clean energy dimension of this argument is underappreciated in current policy discussions. If the simulation breakthroughs that unlock next-generation battery chemistry or green hydrogen catalysis happen

primarily in the United States or China, the UK ends up buying the tools of its own decarbonisation from others, on others' terms and at others' prices. Sovereign quantum capability in clean energy applications is a question of energy security, not only an industrial policy one. That security dimension is not only about who supplies the tools. Resilient timing, positioning and grid monitoring are themselves quantum capabilities that bear on how well the energy system withstands disruption, which makes domestic capacity in them a matter of grid resilience directly.

The national security case is more immediate. The NCSC has published a migration roadmap to post-quantum cryptography with milestones at 2028, 2031 and 2035. Sufficiently powerful quantum computers will threaten the public-key cryptographic systems that underpin much of the UK's digital infrastructure, from banking and healthcare to defence and critical national infrastructure (e.g. the national grid). The primary mitigation strategy is migration to post-quantum cryptography (i.e., encrypting important data in more quantum secure algorithms). Responding effectively depends on domestic capability in cryptographic research, testing, standards, assurance and secure implementation, alongside visibility over the development of the quantum threat. That capability is a security question as much as an industrial one.

Industrial distribution

Quantum hardware manufacturing is high-skilled, well-paid work that does not have to be concentrated in a small number of university cities. The regional innovation clusters being built through the industrial strategy, and Great British Energy's supply chain development ambitions, are mechanisms through which those benefits could be spread with genuine intention. That requires deliberate design rather than assumption, but the institutional infrastructure to act on it already exists. The research hubs already pull on regional strengths, with photonics and position, navigation and timing concentrated around Glasgow and sensing and advanced manufacturing in the Midlands, so the regional scaffolding is partly built rather than hypothetical.

04.

THE ENERGY SECTOR'S OPPORTUNITY

Quantum's potential in the energy system is concentrated in a handful of applications rather than spread evenly across the sector. Some are close to deployment, particularly in sensing and timing, while others remain longer-term research challenges. The opportunities below are illustrative rather than exhaustive.

- **Earlier fault detection.** Quantum magnetometry could improve the detection of anomalies in grid assets, although operational value and deployment models still need to be demonstrated.
- **Faster geothermal exploration.** Atom-interferometry gravity sensing could improve subsurface mapping and speed the identification of viable geothermal resources.
- **Lower balancing costs.** Better dispatch and flexibility optimisation could improve the operation of an increasingly complex electricity system and help reduce balancing costs over time. In 2025, curtailing renewable generation in Great Britain and procuring replacement power cost consumers approximately £1.46 billion.
- **Sharper flexibility markets.** Quantum optimisation methods may improve how flexibility is scheduled and priced as electricity systems become more decentralised and intermittent.
- **Better battery and hydrogen materials.** Over a longer horizon, quantum simulation could accelerate the search for new cathodes, electrolytes and catalysts.

None of these technologies replaces existing engineering, network investment or operational expertise. Their potential lies in improving specific tasks within the energy system. The applications closest to deployment are in sensing and timing. Optimisation remains at the feasibility and algorithm-development stage, while large-scale molecular simulation is a longer-term prospect.

05.

UNDERSTANDING THE QUANTUM LANDSCAPE

The infrastructure implications of quantum depend heavily on the underlying technology. Different hardware approaches require different combinations of cooling, power conditioning, environmental control and specialist equipment. A framework designed around one type of quantum system risks imposing barriers that other technologies do not need, or missing requirements that are real but specific to a different hardware approach.

The table below sets out the main approaches from a policy perspective: what each technology requires to operate, where the UK has capability, and its potential relevance to clean energy. This is not intended as a formal technical taxonomy, but as a practical classification of the technologies most relevant to infrastructure planning and industrial strategy.

Quantum computing uses qubits to perform calculations, with different architectures taking fundamentally different approaches to creating and controlling them. Quantum sensing uses quantum effects to measure physical quantities such as magnetic fields, gravity and gas concentrations, while quantum timing uses ultra-precise clocks and positioning technologies. These categories overlap in the wider quantum ecosystem but have very different deployment models and infrastructure needs.

MODALITY OR SENSING PLATFORM

WHAT IT IS, WHAT IT NEEDS, AND WHAT IT OFFERS CLEANTECH

Superconducting (gate-based)

Computing and sensing. Circuits cooled to near absolute zero using dilution refrigerators. IBM and Google lead globally, with Oxford Quantum Circuits the main UK player. Requires continuous cryogenic cooling, stable environmental conditions and substantial supporting classical infrastructure. Relevant to molecular simulation and optimisation in the medium to longer term, most likely through specialist hosted or co-located facilities.

Trapped ion

Computing. Individual charged atoms held in electromagnetic fields. Oxford Ionics and Quantinuum are UK-connected players. Infrastructure requirements vary by architecture and can include ultra-high vacuum, extensive laser systems, vibration and electromagnetic isolation, and in some designs cryogenic operation. A candidate for materials simulation applications.

Neutral atom

Computing and sensing. Neutral atoms manipulated by lasers. US-based Infleqtion delivered the UK's first 100-qubit system to the NQCC in late 2025. The architecture can have a relatively compact quantum-processing footprint, but still requires complex laser, vacuum and control systems. Promising for optimisation and simulation research, with commercial advantage not yet demonstrated. The same underlying platform is also being developed for gravity and inertial sensing to support navigation, an application still at an earlier stage than the computing use case.

Photonic

Computing and networking. Uses quantum properties of particles of light (photons). Some processing components operate close to room temperature, but sources, control systems and high-performance photon detectors may still require specialised cooling and infrastructure. PsiQuantum is a leading player; ORCA Computing, Nu Quantum and Aegiq are UK players. Important for networking and potentially computation, but a low whole-system energy footprint should not be assumed without architecture-specific evidence.

MODALITY OR SENSING PLATFORM

WHAT IT IS, WHAT IT NEEDS, AND WHAT IT OFFERS CLEANTECH

Silicon spin

Computing. Uses semiconductor processes to create qubits in silicon chips. Quantum Motion is the most prominent domestic player. The approach remains at an early stage, with significant challenges around qubit control, error rates and scalability, and no useful application yet demonstrated. Its long-term attraction is manufacturability: if the technical barriers are solved, it could build on semiconductor supply chains and support a domestic manufacturing base.

Quantum magnetometry

Sensing. Uses platforms including nitrogen-vacancy centres in diamond (element six are UK leads) and atomic magnetometers (Cerca) to detect extremely small magnetic fields. Often operates at or near room temperature. Potential applications include infrastructure monitoring and fault detection, but energy-sector deployment and service models are still emerging.

Atom-interferometry gravity sensing

Sensing. Uses cold atoms to measure tiny variations in gravity. Relevant to subsurface mapping for geothermal exploration, carbon-storage monitoring and civil infrastructure. Delta-G and Aquark are UK companies developing this technology. UK programmes have funded feasibility and field development, but widespread operational deployment is still emerging.

Quantum-enhanced optical spectroscopy

Sensing. Uses quantum-enabled light sources, detectors or measurement methods to improve the detection of gases and other substances. Relevant to methane monitoring. Some enabling components are commercial, while deployment as an energy-sector measurement service remains at an early stage.

MODALITY OR SENSING PLATFORM	WHAT IT IS, WHAT IT NEEDS, AND WHAT IT OFFERS CLEANTECH
Annealing	Computing. Specialised hardware optimised for particular classes of optimisation problem. D-Wave (Canada) is the primary commercial player. Users can access systems through cloud or hosted services, but the host hardware still relies on specialised millikelvin cryogenics. Limited in scope (not applicable to all computational problems) and commercially accessible now, with no demonstrated commercial quantum advantage for grid applications.
Topological	Computing. Seeks to use topological quantum states to create more stable qubits. Microsoft announced its Majorana 1 device in early 2025, but the architecture remains unproven at useful scale. There is no UK hardware player. If it matures, its clean-energy relevance would be the same longer-term simulation and optimisation role as other gate-based systems.

The infrastructure implications of this diversity are significant and only partly addressed in current planning and standards work. The requirements set out in the table vary so widely between modalities that no single standard can sensibly cover them, which is the problem section eight addresses.

The UK’s hardware ecosystem spans most of these modalities. Oxford Ionics, Quantum Motion, Quantinuum, ORCA Computing and Aegiq are all UK-origin or UK-connected companies. The NQCC at Harwell deliberately hosts multiple hardware architectures, making it a diverse national testbed. The UK has both the commercial interest and the technical standing to lead on infrastructure standards, particularly through the new National Quantum Standards Network, but only if standards and planning guidance develop before deployment patterns become entrenched.

06.

THREE TIMELINES, THREE **CLEANTECH** OPPORTUNITIES

The policy challenge is matching investment and deployment decisions to the maturity of each application. Nearer-term opportunities require routes from demonstration to adoption, while longer-term opportunities depend on building capability today so that UK companies and researchers are positioned when the technology matures.

Three horizons, three kinds of value

Quantum's value to clean energy arrives on different timescales, not all at once.



Three horizons, three kinds of value. Quantum's contribution to clean energy arrives on different timescales, not all at once.

Now: Quantum Sensing (2024 to 2027)

Quantum sensing platforms span a wide maturity range. Some enabling technologies are commercially available; others are being tested through field trials or feasibility programmes. They exploit quantum mechanical properties to achieve measurement precision that classical instruments may not match, and they do not require fault-tolerant qubits. The caveat is that some sensing approaches still rely on cooled detectors, lasers or specialist operating conditions, so the infrastructure burden is lighter than for large-scale computing rather than absent.

- **Grid monitoring:** quantum magnetometers could detect small changes in magnetic fields around grid assets and support earlier fault detection. The technical capability is promising, but the operational value, ruggedisation and service model still need to be demonstrated in real network environments.
- **Methane detection:** quantum-enhanced optical spectroscopy and photon-detection methods could improve the precision and speed of methane-leak measurement. Some enabling components are commercially available, while energy-sector deployment is likely to emerge through managed measurement services rather than direct hardware purchases.
- **Geothermal mapping:** atom-interferometry gravity sensors could improve subsurface mapping and accelerate the identification of viable geothermal sites, relevant to the UK's heat-decarbonisation challenge. Feasibility and field development have been funded in the UK, but this is not yet a routine commercial service at scale.
- **Carbon storage verification:** feasibility work has been funded on atom-interferometry gravity sensing for monitoring carbon dioxide storage and subsurface change, relevant to the UK's carbon-capture ambitions. The near-term opportunity is demonstrator and service development rather than immediate widespread deployment.

The commercial model matters as much as the technology. In several of these cases the energy sector is unlikely to buy quantum hardware outright. The more probable route is a service, where a provider operates the sensing and sells the measurement, which lowers the barrier to adoption and gives UK sensing companies an earlier revenue base than a hardware sale would.

Soon: Hybrid Optimisation (2026 to 2030)

Optimisation represents a different challenge. The opportunity is not to replace existing computing approaches, but to test whether quantum methods can improve specific difficult problems within increasingly complex energy systems. Any near-term value is likely to come from hybrid approaches combining classical computing, AI and quantum methods.

- **Grid optimisation:** managing a decarbonised grid with high penetrations of intermittent renewables creates increasingly complex optimisation problems across unit commitment, flexibility coordination and network planning. A 2024 review in Joule identified promising research opportunities for quantum-accelerated optimisation, but no quantum system has yet demonstrated a commercially significant advantage over the best classical methods on a live electricity-system problem. In the UK, Phasecraft has worked with NESO on energy-network problems including network partitioning, critical-node identification and the siting of renewable storage and monitoring equipment. The STFC Hartree Centre has worked with E.ON and IBM on decentralised grids and peer-to-peer energy trading. These are early-stage algorithm-development and feasibility collaborations, not evidence of operational quantum advantage, but they are exactly the sort of hard, real-world problems that can keep capable companies working in the UK.
- **Clean Power 2030 planning:** the pace of renewable deployment creates coordination challenges across permitting, grid connection, and supply chain management. Quantum optimisation speaks to the computational layer of this, network expansion and reinforcement planning under uncertainty, not to the binding constraints, which are mostly institutional, regulatory and financial. It is a potential accelerator for specific optimisation problems, not a fix for the planning system, and in most of these areas classical and AI-based solvers are strong and improving fast.

- Industrial decarbonisation: quantum optimisation applied to industrial supply chains could identify emissions reduction pathways that are computationally intractable at scale for classical approaches.
- Convergence with AI: the nearest-term gains are likely to come from quantum and AI working together, with classical machine learning carrying most of a problem and quantum methods targeting the hard sub-problems where they add value. The realistic policy framing is quantum as part of the AI-and-optimisation stack, not a rival to it.

Later: Molecular Simulation (2030 onwards)

Accurate molecular simulation is both the furthest out and the most consequential of the three timelines. Classical computers face fundamental limitations in modelling electron behaviour in complex molecules from first principles, limitations that additional processing power does not straightforwardly resolve. Fault-tolerant quantum systems are expected to model certain molecular interactions more efficiently and accurately than classical approaches, representing a different computational method rather than simply a faster one.

- Battery chemistry: discovering genuinely new cathode and electrolyte materials, rather than incrementally optimising existing ones, is one of the areas where fault-tolerant quantum simulation could provide a meaningful advantage over classical approaches. BASF, Johnson Matthey, and Mitsubishi Chemical are already investing in this application area in partnership with quantum hardware vendors. On the algorithms side, UK companies including Phasecraft, Riverlane and Quantinuum are developing the simulation and error-correction methods this depends on, which is where domestic capability in this timeline is most likely to sit.
- Green hydrogen catalysis: designing more efficient catalysts for green hydrogen production depends on quantum mechanical understanding of electron behaviour that AI models can only approximate.

- Next-generation materials: simulation of novel photovoltaic materials and low-carbon construction materials at quantum accuracy could unlock performance improvements that lie beyond the reach of classical optimisation.

Mapping Needs to Capability

A useful way to assess quantum’s potential is to start with the problems the energy system needs to solve, then map those against the quantum capabilities that could help address them and the timescales on which they may become relevant.

The table below is a first pass at that mapping. It is deliberately clear about where quantum is unlikely to be the right tool. Maintaining and updating this assessment is one of the roles proposed for the SRO.

Energy need	Quantum type	Horizon	Realistic status
Methane leak detection on gas infrastructure	Sensing	Now	Enabling platforms are commercial; energy-sector deployment and service models are emerging
Grid fault detection and monitoring	Sensing	Now	Field-testable; operational value and ruggedisation still to be proven
Subsurface mapping for geothermal siting and carbon dioxide storage verification	Sensing	Now	Atom-interferometry gravity sensing; feasibility and field development funded
Resilient timing and positioning for grid synchronisation and rail signalling	Timing	Now to Soon	Mainline rail trial completed; operational deployment and cost savings not yet proven
Grid dispatch, flexibility and network planning	Computing: optimisation	Soon	Feasibility and algorithm development; no demonstrated commercial quantum advantage

- Next-generation materials: simulation of novel photovoltaic materials and low-carbon construction materials at quantum accuracy could unlock performance improvements that lie beyond the reach of classical optimisation.

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Energy need	Quantum type	Horizon	Realistic status
Grid dispatch, flexibility and network planning	Computing: optimisation	Soon	Feasibility and algorithm development; no demonstrated commercial quantum advantage
New battery chemistries, electrolytes and hydrogen catalysts	Computing: simulation	Later, 2030+	Most consequential; needs fault-tolerant machines
Asset monitoring, predictive maintenance and demand forecasting	Not a quantum problem	n/a	Dominated by machine learning and data quality, not computation

Table 1: A first-pass map of energy-system needs against quantum type and horizon. It is indicative, and keeping it up-to-date is exactly what the SRO would own.

The Wider Industrial Opportunity

Clean energy is where this report concentrates, but the case does not stop at the energy system. The same quantum capabilities matter across cleantech and heavy industry wherever optimisation, sensing or materials discovery are the binding constraint.

- Industrial decarbonisation: catalyst and process modelling for cement, steel, chemicals and refining, where quantum simulation may eventually complement increasingly resource-intensive classical methods.
- Advanced materials: simulation of low-carbon materials, batteries and industrial compounds beyond classical modelling limits.
- Transport and logistics: optimisation of freight, supply chains and electrified transport. Rail is the clearest near-term sensing and timing case. In March 2026 Network Rail ran the first mainline trial of a Rail Quantum Inertial Navigation System; MoniRail, Transport for London, Imperial and Sussex are developing a related approach for the Underground. The potential prize is lower-cost, more resilient positioning and signalling, although operational performance and cost savings remain to be proven.

As capability matures, its value could extend into wider industrial competitiveness and advanced manufacturing.

THE ENERGY QUESTION

Quantum is not only a tool for the energy transition. It is also a new load on the energy system, and the data centre build-out described in section one is the obvious warning: capacity scaled quickly, the energy implications were addressed only afterwards, and the UK is still living with the consequences.

Superconducting quantum systems operate at approximately fifteen millikelvin, colder than deep space, using dilution refrigerators that run continuously and consume significant power. Data centres have two decades of accumulated energy-efficiency standards and regulatory frameworks. Quantum lacks mature, widely adopted energy and resource standards, although the new National Quantum Standards Network is beginning to address that gap. A 2026 paper in *Nature Reviews Clean Technology* found that the energy and physical-resource demands of quantum-accelerated data centres remain largely unknown. Superconducting machines are singled out here because their demands are among the most exacting and architecture-defining, not because they are the only draw. Other modalities have their own requirements, and the wider compute estate that quantum sits within, including classical data centres and AI clusters, dwarfs quantum's current load. The point is not that quantum is uniquely power-hungry, but that architecture-specific requirements are arriving before comparable standards and measurement practices are mature.

The helium supply chain is a particular risk that deserves more attention. Dilution refrigerators rely on helium-3 and helium-4 mixtures, with helium-3 exceptionally rare and geographically concentrated. Closed-cycle and cryogen-free systems can reduce dependence on externally supplied liquid cryogens, but they do not necessarily eliminate helium isotopes from the refrigeration system. UK procurement and R&D criteria could support cooling approaches that reduce supply-chain exposure and improve efficiency before dependencies become structural. The cooling hardware is its own exposure. Oxford Instruments NanoScience, the UK maker of dilution refrigerators used by superconducting quantum systems, was sold

to the US firm Quantum Design in a deal completed in early 2026. The cryogenic-engineering base matters alongside the feedstock. The exposure is not unique to quantum: helium is also important to semiconductor manufacturing and other advanced industries, so secure supply is a systemic industrial question rather than a quantum-specific one.

There is a counterargument worth naming: as quantum scales, it may actually reduce net compute energy demand for certain workloads by displacing more energy-hungry classical processing. Meier and Yamasaki, writing in PRX Energy in 2025, prove that quantum computation can achieve an exponential energy-consumption advantage over any classical equivalent for a specific benchmark problem, derived from the thermodynamics of computation rather than assumed. They also set out criteria for demonstrating that advantage experimentally, which has not yet been done. Whether the displacement effect is large enough, and general enough, to offset quantum's own energy costs depends on deployment choices that are being made now. That is an argument for planning carefully, not for assuming the energy question will sort itself out.

08.

INFRASTRUCTURE: THE CHANCE TO GET IT RIGHT

Co-location changes the picture

Most discussions of quantum infrastructure assume it means new specialist facilities: secure campuses, dedicated cooling infrastructure and separate grid connections. One emerging deployment model is hosted or co-located quantum processing within existing compute facilities, sitting alongside classical systems and accessed on site or through the cloud. That can change the planning question, because some deployments may involve upgrades to an existing facility rather than a wholly new site. It may reduce land-use impacts, but additional equipment, cooling and supporting infrastructure still carry embodied-carbon and operational implications.

Co-location does not remove the need for careful power conditioning and environmental control. Dilution refrigerators and quantum-control systems can be sensitive to electrical noise, vibration and electromagnetic interference. Co-locating quantum hardware with conventional compute may therefore require active engineering mitigation, backup power and isolation measures. These requirements vary by architecture and facility design. Current data-centre planning guidance does not systematically address them, which creates an anticipatory standards and capability gap rather than proof that co-location is unworkable. The direction of travel points towards hybrid compute rather than standalone quantum facilities, a shift reflected in the Office for Quantum's own infrastructure thinking. The EuroHPC Joint Undertaking offers a live example of what that looks like at scale: it has procured quantum processors across several architectures, including superconducting, trapped-ion and neutral-atom systems, and co-located each one with an existing national supercomputer, so that hybrid classical-quantum workflows run on infrastructure that already exists rather than on new standalone sites. The UK framework need not replicate that model exactly, but it is evidence that co-location can be the default deployment pathway rather than the exception.

A framework that reflects the diversity of the technology

The modalities and sensing platforms described in section five have fundamentally different infrastructure requirements. Superconducting and annealing systems rely on millikelvin cryogenics. Trapped-ion and neutral-atom systems require different combinations of vacuum, lasers and environmental isolation. Photonic processing may operate closer to room temperature, while some sources and detectors still require cooling. Field sensing platforms can have far lighter site requirements, although deployment conditions vary.

A single planning standard applied uniformly across all quantum hardware types will produce the wrong result in most cases, either imposing unnecessary burdens on lower-demand modalities or failing to capture the genuine requirements of higher-demand ones. Where other countries have set sustainability conditions on data centre development, as section nine describes, they have generally acted only once the problems had accumulated. The UK has a genuine opportunity to design equivalent conditions for quantum proactively, before the build-out begins in earnest.

Planning systems that can theoretically distinguish between modalities in written guidance often struggle to operationalise that distinction in practice. Local authorities and regulators rarely have dedicated quantum–infrastructure expertise, and without it guidance risks being applied inconsistently. Building that capacity through the NQCC, the wider National Quantum Technologies Programme and the new National Quantum Standards Network, supported by BIST and MHCLG guidance notes, is as much a part of the planning framework as the standards themselves.

Modality	Cooling requirement	Power quality	Siting model	Planning questions
Superconducting	~15 millikelvin at the quantum processor; continuous dilution refrigeration	High. Power conditioning, backup and environmental control are important	Specialist hosted, co-located or standalone facility	Grid connection; cryogenics; backup power; vibration and noise; retrofit versus new build
Trapped ion	Architecture-dependent; ultra-high vacuum, lasers and sometimes cryogenic operation	High. Sensitive to vibration and electromagnetic interference	Specialist lab, hosted facility or co-location	Vibration and EM isolation; lasers; cooling; backup power; building services
Neutral atom	Near room-temperature chamber with laser cooling and ultra-high vacuum	Moderate to high, depending on control architecture	Specialist lab or compact hosted facility	Lasers and vacuum; space; cooling; vibration; service access
Photonic	Processing often near room temperature; some sources and detectors require cooling	Architecture-dependent; optical stability and control matter	Data centre, networking facility or specialist site	Detector cooling; optical stability; fibre integration; supporting classical compute
Quantum sensing (magnetic fields)	Often room temperature; some detectors and atom systems require cooling, vacuum or lasers	Low to moderate, depending on platform	Field deployment, mobile service or laboratory	Usually low burden; deployment, safety and calibration vary by platform
Annealing	~15 millikelvin at the processor; specialised dilution refrigeration	High at the host facility; customer access may be via cloud	Specialist hosted system in a data-centre environment	Cryogenics; power conditioning; cooling; backup; host integration

Table 2: Indicative infrastructure requirements and planning questions by quantum modality. Requirements will evolve as architectures mature; the table is a starting point for guidance, not a statement of current planning law.

Denmark's experience with heat recovery from large compute facilities is a useful reference point. Quantum and supporting classical systems consume energy and reject heat, but the quantity, temperature and recoverability of that heat vary by architecture and facility. UK guidance should require facilities above an appropriate threshold to assess heat-recovery and heat-network integration where technically and economically viable, rather than assume that useful export is always available.

The coming competition for grid capacity

There is a wider strategic context that the infrastructure planning argument needs to address. The UK is entering a period in which compute infrastructure, energy infrastructure, and industrial policy are converging in ways that have no recent precedent. AI data centres, quantum facilities, EV charging networks, electrified industrial processes, and the renewable generation needed to power all of them are simultaneously making claims on a grid that was not designed to accommodate any of them at current and projected scale.

Quantum infrastructure may add a further layer to competition for grid capacity as the sector scales. Superconducting systems and their supporting classical estate can have demanding power-quality and resilience requirements, but power conditioning, backup systems and engineering design can mitigate many fluctuations. The issue is therefore not that only a rare class of grid connection can host quantum, but that future facilities may compete for both capacity and high-reliability connections in regions already under pressure. This is an anticipatory risk.

Alongside grid capacity there is a quieter dependency on semiconductors, though it works differently from the pressure the AI build-out has created. A quantum computer does not consume chips in anything like the quantities a data centre does, yet it cannot be built without them, because the qubits are often semiconductor devices in their own right: silicon-spin machines are fabricated in silicon, superconducting machines are patterned onto wafers in the same plants that make conventional chips, and every system also depends on custom control electronics installed in the cold alongside the qubits. The constraint is one of precision rather than volume, since the material has to be extraordinarily pure and the fabrication extremely exact, and only a handful of suppliers anywhere are capable of it. In that sense semiconductors sit closer to helium and the critical minerals discussed earlier, as a question of secure supply and sovereign capability, than to

the competition for grid capacity, and they warrant the same forward planning rather than being left to resolve themselves.

The United States, China and the EU are all making strategic investments in advanced compute infrastructure, and the ability to host, power and plan for that infrastructure is increasingly a component of industrial and economic sovereignty. Quantum is an early and visible case of this dynamic, but the underlying logic is broader: countries that secure reliable access to clean power for advanced compute will have strategic options that others will not.

Compute infrastructure is becoming energy and industrial policy, not merely a planning matter. The decisions made now about where quantum facilities are permitted, what grid-connection and performance standards they are expected to meet, and how their energy demands are managed are likely to have consequences beyond the quantum sector. A policy approach that treats quantum infrastructure planning as a niche technical issue risks creating avoidable constraints in grid capacity, siting and system integration as deployment grows.

09.

WHAT OTHER COUNTRIES ARE DOING

Several countries have built models worth borrowing from, some for connecting computing capability to clean-energy outcomes and others for setting conditions on compute infrastructure, so the UK does not need to design its approach from first principles.

- **United States:** ARPA-E: The US Advanced Research Projects Agency for Energy has funded specific programmes at the intersection of quantum computing and clean energy, covering sustainable industrial catalysts, next-generation superconductors for more efficient electricity transmission, and improved battery chemistries. The institutional model is instructive: a dedicated cross-departmental funding instrument with an explicit mandate to connect computing capability to energy outcomes. The UK equivalent would sit in BIST with input from DESNZ.

- **Germany: Fraunhofer Institutes:** Germany's Fraunhofer Institutes are actively embedding quantum applications within sector-specific decarbonisation programmes, rather than treating quantum as a standalone technology domain. The integration of quantum research into manufacturing decarbonisation in particular offers a model for how the UK's Catapult network could develop a similar role.
- **Canada: Quantum for Climate:** The Canadian government has run a specific funding call for small and medium enterprises to demonstrate quantum computing applications in climate-related domains. This is a direct precedent for one of the early actions a UK quantum-clean energy SRO could commission within its first year, at relatively low cost and with rapid signal value.
- **Singapore and the Netherlands:** Conditional planning: Both countries moved from blanket restrictions on data centre development to sustainability-conditioned frameworks that set explicit standards for energy efficiency, renewable power sourcing, and water use. The quantum build-out gives the UK an opportunity to design equivalent conditions from the outset, before the industry reaches a scale where regulation becomes reactive and contested.
- **Denmark: Waste heat integration:** Danish policy on heat recovery from large compute developments is the closest available reference for the architecture-specific assessment proposed in section eight.

The common feature across all of these approaches is not new institutional architecture but coordination across existing institutions.

THREE RECOMMENDATIONS

The UK already has most of the institutional and financial instruments needed to connect its quantum and clean energy ambitions. What follows are three specific recommendations, each actionable within the lifetime of this parliament and each reinforcing the others.

1 Appoint a Senior Responsible Owner for Quantum-Clean Energy Delivery

BIST should appoint a named Senior Responsible Owner accountable for publishing a public roadmap that starts from energy-system needs and maps them against quantum capability timelines across sensing, timing, optimisation and simulation. DESNZ, NESO, network operators and major industrial users should supply the energy-system needs and the evidence threshold for adoption as a formal input, not as co-owners of the output. The roadmap should be published within twelve months, identifying near-term sensing and timing demonstrators, hybrid optimisation feasibility projects tied to NESO planning, and longer-term priorities for battery, hydrogen and materials innovation. No new legislation, agency or fund is required. The natural vehicle for the first output is the next iteration of the Clean Power 2030 Action Plan. Delivery should be tracked externally, either as a Spending Review condition reviewed by HMT or through a reporting requirement to a select committee, so accountability does not rest solely within the two departments. Because quantum timelines shift, the roadmap should be refreshed at least annually rather than produced once, so the mapping keeps pace with technical progress.

2 Publish Modality-Aware Quantum Infrastructure Planning Guidance

BIST, DESNZ and MHCLG should jointly develop quantum-infrastructure planning guidance within the current spending review period, coordinated with the National Quantum Standards Network and informed by the NQCC and wider National Quantum Technologies Programme. MHCLG engagement is operationally critical. The work should review how quantum facilities should be treated under the National Planning Policy Framework and, where relevant thresholds are met, nationally significant infrastructure regimes. Technical annexes should distinguish superconducting, trapped-ion, neutral-atom, photonic, annealing and field-sensing systems. Guidance should cover grid connection and power conditioning, cooling and water use, vibration and electromagnetic control, heat-recovery assessment, embodied carbon and supporting classical compute. Hosted or co-located deployment should be encouraged where appropriate, not imposed as a universal default.

3 Activate the Quantum-Cleantech Co-Investment Mandate

The National Wealth Fund's strategy lists quantum technologies alongside clean energy, Great British Energy's remit covers clean-energy supply chains, and the British Business Bank has demonstrated its ability to invest directly at scale through its £40 million investment in Quantum Motion and £100 million commitment to Oxford Quantum Circuits. Convened by the Senior Responsible Owner named in recommendation one, these institutions should jointly identify and fund a small number of demonstrators, prioritising sensing and timing applications where enabling technology is commercially available or field-testable, and optimisation projects framed explicitly as feasibility and benchmark exercises alongside the best classical and AI methods. GBE's Clean Energy Supply Chain Fund is a plausible instrument, subject to mandate and investment criteria. The aim should be to test operational value, procurement routes and commercial models, not to presume quantum advantage in advance.

The binding constraint may turn out to be capability rather than coordination. Quantum may not work well enough, soon enough, for any of this to matter. Each of these recommendations returns something useful if that proves true. Sensing is already in commercial use and does not depend on quantum computing maturing at all. Modality-aware planning guidance applies to any power-dense, cooling-intensive facility, whether or not the machines arrive. Demonstrators benchmarked against the best classical and AI methods produce a usable answer either way, and learning where quantum does not help is cheaper now than after the infrastructure decisions have been made.

11.

CONCLUSION

The UK has put serious money into quantum and serious money into clean energy. It has not yet built a deliberate delivery architecture connecting the two, and the cost of that gap is starting to accumulate quietly: in planning and standards work that does not yet fully account for quantum infrastructure, in energy-system problem portfolios that do not systematically test where quantum could add value, and in public financial institution capital being deployed into quantum hardware without an explicit route towards clean-energy outcomes.

None of this requires a new institution or a new overall spending settlement. The roadmap needs a named owner and a delivery deadline, not a new committee. The planning guidance needs MHCLG and the National Quantum Standards Network at the table. The demonstrators need someone to convene GBE, the NWF, the BBB, UKRI, energy-system operators and the quantum sector around a small number of well-defined problems. The reason this has not happened is not that the institutional ingredients are absent. It is that no one has yet been given ownership of connecting them.

The spending review period, the Clean Power 2030 delivery window, and the current planning reform cycle all provide natural moments to act. Quantum infrastructure is not yet at the scale where the absence of frameworks becomes acutely painful. That changes within this parliament. The time to design the coordination layer is before the deployment starts, not after the problems accumulate.

The UK has repeatedly demonstrated scientific strength it has then struggled to convert into industrial scale. Quantum is a chance to do it differently, provided deployment pathways are considered alongside research excellence from the outset. The UK is investing early in quantum and expanding clean energy at the same time, and those two strategies now need to become one. If they do, the UK has the chance not simply to lead in quantum or in clean energy, but to define how the two evolve together.

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Thank you
