



Intelligence Report on Quantum Diplomacy in Action 2026-2027

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Foreword

Quantum computing is approaching the point at which it moves from experimental science to practical use. Within this decade, the first devices are expected to outperform classical computers on specific problems in chemistry and cryptanalysis. Yet the rules that will determine who benefits are being set now: export controls are proliferating, patent strategies are taking shape and national strategies increasingly prioritise sovereignty over cooperation.

Previous editions of the *Intelligence Report on Quantum Diplomacy in Action* made the case for anticipation. This edition, informed by the **2026 Quantum Diplomacy in Action Conference**, shows that the challenges coming with this technology are well documented and that the gap now lies in the implementation of mitigating governance approaches. A UNESCO survey of 80 countries, conducted during the *International Year of Quantum Science and Technology*, found that only 22 per cent of institutions have access to quantum computing research facilities, and that cloud access reaches 44 per cent of institutions in Western Europe but around 12 per cent elsewhere. Post-quantum cryptography standards have been available since 2024, yet most regulators have not made migration a compliance obligation. Energy use may differ by a factor of up to 1,000 between hardware modalities, yet vendors do not publish comparable data. In each case, the knowledge exists; the mechanisms to act on it do not.

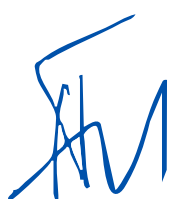
Quantum diplomacy must therefore be judged by what it delivers. This report sets out next steps in four areas: intellectual property and the human right to science, the quantum divide, energy and the environment, and security and dual use. Few of them actually require new treaties. They require trusted settings where governments, experts and industry can test solutions at a manageable scale and make what works available to others.

The Open Quantum Institute (OQI), born at GESDA, hosted at CERN and supported by UBS, was designed as such a sandbox, championing global, inclusive and equitable access to quantum computing. During its pilot phase, it has put into practice what this report recommends in principle: an IP model in which partners license their background IP royalty-free and retain ownership of what they generate, with a fair-sharing obligation should a result become a standard; use cases developed with UN agencies, such as exploring the optimisation of the placement of water leak sensors in Mexico City with UN-Habitat; and hackathons that build talent where the divide is widest, most recently in Pakistan and Kenya. As the pilot phase concludes in December 2026, the next phase should amplify the use of this sandbox with strategic partners deliberately. What proves effective can then be scaled through International Geneva, and its actors such as WIPO, UNIDIR and ITU as well as through UNESCO's Global Quantum Initiative, of which GESDA and the OQI are founding members.

We thank the partners, experts and governments who shaped this edition, including those that shared their national quantum strategies. We commend this report to policymakers, scholars and practitioners, and invite you to bring concrete use cases, data and commitments to this common effort. True to GESDA's ambition to use the future to build the present, the measure of success will be what the international community has put in place before quantum computers operate at scale.

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Table of Content

Foreword	2
1. A Point of Departure for Quantum Computing	5
1.1. Technology maturity.....	5
1.2 How quantum and AI will work together.....	6
1.3 Economic maturity	6
1.4 Policy responses and current investments.....	7
1.5 The Anticipatory Imperative for Quantum Computing Diplomacy.....	8
2. Quantum Computing, Intellectual Property and the Human Right to Science	9
2.1 The human right to science as a governance framework	9
2.2 The current landscape.....	10
2.3 Patenting and licensing for quantum computing	10
2.4 IP governance models relevant to quantum hardware.....	12
2.5 Towards an international framework	14
2.6 The next steps for quantum diplomacy.....	15
3. Multilateral Responses to the Quantum Divide	17
3.1 Understanding the quantum divide	17
3.2 Mapping the divide	19
3.3 Building on the Global Quantum Initiative.....	20
3.4 Investing in human capital.....	21
3.5 Establishing access to infrastructure	22
3.6 Building policy literacy	23
3.7 Creating institutional frameworks.....	24
3.8 The next steps for quantum diplomacy.....	25
4. Environmental and Energy Issues	27
4.1 The challenge of fair comparison	27
4.2 Energy and environmental impacts of quantum computing	27
4.3 Standards, benchmarking and cross-disciplinarity	28
4.4 The next steps for quantum diplomacy	30
5. Security and Dual-Use Dimensions of Quantum Technology.....	31
5.1 Quantum computing's threat to cryptography.....	31
5.2 The response: post-quantum cryptography and quantum key distribution	32
5.3 Near-term dual-use of other quantum technologies.....	35
5.4 How should quantum security be governed?	35
5.5 The next steps for quantum diplomacy	37
6. Concluding Remarks: Actionable Insights for Navigating the Road Ahead in Quantum Computing	38
7. Annexes	39
Annex I How Quantum Computing Works	39
Annex II The Open Quantum Institute, hosted at CERN, born at GESDA, supported by UBS	41
Annex III The Open Quantum Institute and its IP Model.....	42
Annex IV Methodology of the QDiA Conference	42

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1. A Point of Departure for Quantum Computing

Quantum computers represent a complete change of paradigm in the way that computation is practiced. Some key takeaways about how the technology works:

Quantum computing, like other quantum technologies (e.g., quantum sensing, quantum communication), leverages quantum phenomena, such as superposition and entanglement, creating an entirely novel mechanism for encoding information. Quantum information is stored and processed in “qubits” that operate in a different capacity than “bits,” their classical equivalent. That holds the promise for unprecedented performance improvements with specific computational problems.¹

The exact nature of these computational problems is not yet well identified. However, there is a consensus in the scientific community that quantum computing would hold an advantage over classical computing to accelerate discoveries in material science and chemistry, since this involves the simulation of quantum behaviour of matter. With steady, rapid progress, quantum computers may outperform classical computers in real-world applications by the end of this decade. To reach this critical milestone, significant research and development is needed to produce larger-scale, reliable quantum computing devices.

1.1. Technology maturity

Quantum computing is a multifaceted reality, with the potential to be ready at scale within the next decade.

It should be noted that quantum computing technology is still under development as hardware modalities are tested. Many large companies are developing superconducting qubits, while others pursue alternative promising modalities of qubits based on trapped ions, cold atoms, photonics, silicon, and diamonds. Each of these hardware modalities has pros and cons and it is too early to tell which approach will perform the best.

While advancements in a pre-fault-tolerant era have been recently reported, quantum computers are still performing on a small scale and are unreliable.² Further technological development is needed to reach quantum advantage: outperforming conventional computing in terms of execution, speed, accuracy, or energy efficiency when handling real-world relevant problems.

The aim is to create an adequate number of reliable qubits. Researchers expect that it will require thousands, if not millions, of qubits to solve useful tasks — depending on the type of hardware. Quantum properties are highly sensitive to environmental disturbances. Error-correction protocols are being investigated to ensure that quantum processors become more resilient and stable over a long period of time.

While hardware is essential, the implementation of quantum algorithms within the hardware is what will unlock the full potential of quantum systems. As part of the development and testing phase, quantum algorithms today can be implemented on simulators and emulators, which reproduce the quantum properties of quantum computers on classical devices at relatively small-scale. These allow the performance of small-scale, proof-of-concept simulations for practical applications, accelerating the exploration of valid use cases. Simulators and emulators may play an important role in bridging the gap that will remain until quantum hardware becomes available at scale, a milestone that may take another decade to achieve.

Because quantum computers operate in a fundamentally different manner than classical computers, traditional algorithms are not directly transferable to quantum computing. As a result, quantum algorithms are being developed to perform computational tasks, such as quantum simulation and factorisation, as well as quantum-inspired optimisation and machine learning. For further information on how quantum computing works, please refer to Annex 1.

¹CF. Annex I

² Kim, Y., Eddins, A., Anand, S. et al. 2023. Evidence for the utility of quantum computing before fault tolerance. *Nature* 618, 500-505: <https://doi.org/10.1038/s41586-023-06096-3>.

1.2 How quantum and AI will work together

Artificial intelligence (AI) has so far enabled disruptive applications. From efficient analysis and predictive tasks on large datasets to “recommendation” systems and chatbots, AI’s rapid adoption across a spectrum of industries is broadening. Combining classical machine learning (ML) - which is a subset of AI - with quantum computing is, unsurprisingly, a field of growing expectations and hype. The intersection of AI and quantum is still a nascent field, and the effort is at the research and development level. Quantum machine learning, for example, accounts for less than 1% of total machine learning research publications.

The interplay of machine learning and quantum computing can be summarised in three categories:

- **Using classical machine learning to develop quantum computers:** Already in use today, classical machine learning can help to improve experimental control of quantum computers and reduce hardware errors, construct quantum circuits, and simulate the result of quantum computations.³
- **Quantum-inspired machine learning:** Research on quantum computing has inspired the exploration of new techniques and theoretical insights benefiting classical machine learning.
- **Quantum machine learning:** Industry and academic researchers are exploring ways of using classical machine learning techniques on quantum computers. Currently, much of their research focuses on using existing small-scale quantum computers jointly with classical computers (so called “hybrid computing”) to identify potential benefits. Quantum computers also offer some benefits for learning from quantum data (data that itself originates from quantum sensors for instance). **One major challenge is the efficient input and output of classical data to and from quantum data.** It is still too early today to predict if this hybrid approach could realise a quantum advantage for practical applications (i.e. outperforming classical computing), even with future fault-tolerant quantum computing.

Classical machine learning already benefits the development of quantum computers. Despite the early stage of this research field, the intersection of AI and quantum offers possible new avenues that can benefit from more direct collaboration between experts in different disciplines. As the field matures, a transdisciplinary approach should learn from AI governance principles and adapt them to this emerging field at the cross-section of AI and quantum computing.⁴

1.3 Economic maturity

Quantum computing already carries significant economic weight, and is being leveraged as an innovation accelerator in many sectors critical to the world’s major economies.

The timeline to bring quantum computing to full maturity is relatively long compared to other technology development cycles, so its development requires sustained, significant long-term investment.

Governments remain the primary drivers behind quantum R&D. Global public commitments to quantum technologies now exceed approximately \$65-66 billion worldwide as of 2026, reflecting continued strategic investment across North America, Europe, and Asia-Pacific.⁵

Private investment into quantum technology (including quantum computing, sensing, and communication) has rebounded. Global quantum startups attracted nearly \$2.0 billion in funding

³ See for example Liao, H., Wang, D., Iskandar Sitdikov, Salcedo, C., Seif, A., & Zlatko Mineev. 03/05/2024. Machine Learning for Practical Quantum Error Mitigation. IBM Research: <https://research.ibm.com/publications/machine-learning-for-practical-quantum-error-mitigation>; Q-CTRL. 02/08/2024. Making sense of quantum noise with machine learning. Q-Ctrl.com; Q-CTRL. <https://q-ctrl.com/case-study/making-sense-of-quantum-noise-with-machine-learning>; Zeng, Y., Zhou, Z., Rinaldi, E., Gneiting, C., & Nori, F. 2023. Approximate Autonomous Quantum Error Correction with Reinforcement Learning. Physical Review Letters, 131(5) <https://doi.org/10.1103/physrevlett.131.050601>.

⁴ Schuld, M., & Petruccione, F. 2021. Machine Learning with Quantum Computers. In Quantum science and technology. Springer. <https://doi.org/10.1007/978-3-030-83098-4>.

⁵ <https://www.qureca.com/quantum-initiatives-worldwide/>

during 2024, and total quantum-sector investment reached approximately \$12.6 billion in 2025, driven by several large financing rounds and acquisitions.⁶

The quantum computing industry generated more than \$1 billion in revenue in 2025. McKinsey estimates quantum computing revenues could rise to approximately \$4.4 billion by 2028, while broader quantum technology revenues could reach as much as \$97 billion by 2035. While large-scale commercial deployment remains in its early stages, quantum computing is attracting growing interest from industry. Companies across finance, life sciences, energy, manufacturing, and transportation are exploring pilot projects and proof-of-concept applications with quantum technology providers.

The economic potential of quantum computing is now estimated to be substantially higher than earlier forecasts. McKinsey estimates quantum computing alone could create between \$1.3 trillion and \$2.7 trillion in annual economic value globally by 2035 through applications in materials science, life sciences, finance, energy, transportation, and logistics.

1.4 Policy responses and current investments

A growing number of countries are adopting quantum strategies to affirm their sovereignty and competitiveness, while multilateral governance remains nascent.

As of August 2024, at least 29 countries had some form of quantum national initiative or strategy with public funding.²³ The United Kingdom enacted the first one in 2014 and renewed it for ten years in 2023. The United States followed with its adoption of a national approach in 2018.⁷

Key common themes include more support for R&D (foundational and applied research); development of a quantum workforce (education and upskilling programs); preparing future users in the likely fields of application; resilience of the value chain (securing the supply of enabling components and technologies); national security considerations; and international cooperation (in connection with all the above themes, and with standardisation that supports national interests).

Where they differ usually involves the level of financial support and funding mechanism. **A key differentiator is whether a country aims to develop a sovereign infrastructure or competitively rely on the private sector.** The focus can also differ as to priorities among quantum technologies (computing, communication, or sensing) depending on the local expertise; their scope (quantum specific, or quantum as part of deep technology strategies); main drivers (research, industry or government); and the modality of their implementation (top-down or bottom-up approaches) and the stage of development.

Most national strategies support the establishment of national industry consortia to foster ecosystem coordination, fast-track technology transfers, and an acceleration in the industrialisation of sovereign quantum technologies. Quantum industry consortia include QED-C in the U.S., QIC in Canada, QuIC in Europe, and Q-STAR in Japan.

International cooperation on R&D efforts remain mostly at the bilateral level. Some examples of **bilateral agreements** can be found among the United States, Switzerland, Australia, United Kingdom, and Germany.

Multilateral initiatives are nascent at the international level. Closed groups are emerging among like-minded countries that align their roadmaps and discuss internal cooperation. For instance, in May 2022, representatives of 12 countries attended a roundtable meeting on “Pursuing Quantum Information Together” in Washington, D.C. One outcome was the creation of the Entanglement Exchange, a portal for highlighting international exchange opportunities for students, postdocs, and researchers in quantum information science (QIS). This first roundtable

⁶ McKinsey & Company, ‘McKinsey Quantum Technology Monitor 2026: A commercial tipping point’, April 28, 2026, <https://www.mckinsey.com/capabilities/mckinsey-technology/our-insights/mckinsey-quantum-technology-monitor-2026-a-commercial-tipping-point>; Michael Bogobowicz et al., ‘Steady Progress in Approaching the Quantum Advantage’, McKinsey & Company, April 24, 2024, <https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/steady-progress-in-approaching-the-quantum-advantage>.
⁷ CIFAR. 2021. A Quantum Revolution: Report on Global Policies for Quantum Technology, <https://cifar.ca/wp-content/uploads/2021/05/QuantumReport-EN-May2021.pdf>; complemented by GESDA data.

was followed by additional meetings, including in September 2024 on “Multilateral Dialogue on Quantum”. The working group is now composed of 13 countries.⁸

1.5 The Anticipatory Imperative for Quantum Computing Diplomacy

The advancements of quantum technologies briefly described here raise an important question: how can the international community move from anticipation to action while ensuring that benefits are equitably distributed, sensitive applications are responsibly managed and global cooperation is strengthened?

The argument for anticipation rests on a straightforward observation. The standard model of governance — identify a problem, build consensus around it, negotiate a framework — operates on a much slower timescale than the progress of new technology. Technological advances follow their own internal logic, accelerating through research milestones and into early applications. This can happen long before regulators, diplomats and policymakers have developed the conceptual vocabulary, let alone the legal instruments, to respond.

For the most part, scientific breakthroughs do not pause to allow institutions to catch up, and a structural gap opens up between what the political infrastructure is prepared for and what is technologically possible. That gap must therefore be anticipated and addressed upstream.

Anticipatory science diplomacy is the discipline that addresses this structural gap. It uses the lead time that science provides — sometimes five, ten, or even twenty-five years ahead of broad social impact — to understand what is coming and to create the conditions for collective, informed and equitable decision-making before crises emerge.

The global experience with artificial intelligence offers an instructive and cautionary precedent. The social harms, the concentration of economic power and the democratic risks that AI now poses were foreseeable, but the window to act in advance was wasted. Governance frameworks for AI arrived late, remain fragmented and are entirely absent in many jurisdictions.

Quantum computing offers a chance to do better in terms of anticipatory governance. However, while the relevant window is open now, it will not remain open indefinitely. Within the current decade, quantum hardware is likely to cross the threshold from an experimental science to being of practical use for specific classes of problems. Export controls are already proliferating and national strategies are already closing doors from global cooperation. Decisions made today are determining the structure of international quantum governance — or the absence of such structure. In the light of this, it is clear that the “informed” decisions that might eventually be made only once quantum computers are deployed at scale are already becoming irrelevant.

With this **urgency to act now**, this report is centred around four interconnected governance challenges: intellectual property and the human right to science; multilateral responses to the quantum divide; the environmental and energy implications of quantum infrastructure; and the security and dual-use dimensions of quantum technology.

⁸ Entanglement Exchange, <https://entanglementexchange.org/>.

2. Quantum Computing, Intellectual Property and the Human Right to Science

The development of quantum computing relies on collaborations involving governments, research institutions, startups and major technology companies. Every one of those collaborations has the potential to generate intellectual assets, from algorithms and software to potential hardware inventions, and every collaboration therefore forces a choice about ownership, access and reward.

While some of the organisations involved in quantum computing aim to produce knowledge that is open and accessible to all, private sector partners join these projects with a realistic expectation that they can extract commercial value from what they help to create. The tension between these two ambitions cannot be resolved by declaring intellectual property (IP) the enemy of openness. IP covers a spectrum of creations of the mind, which can be legally protected by copyright, patent and trademark, or even hidden as trade secrets. Each of these protections can be used to restrict or to share the IP, and thus it is not their assertion that classifies an organisation's openness, but rather the spirit of their usage. For instance, the patent system exists precisely to draw inventions into public knowledge through disclosure, and it contains balances, exceptions and time limits designed to serve the public interest. **The real challenge is determining exactly where a quantum initiative with global scope should land on the governance spectrum**, and actively making the choice to place it at that point.

2.1 The human right to science as a governance framework

Quantum IP governance builds on legal foundations rooted in the IP treaties of the late 19th century and the codification of human rights law in the aftermath of the Second World War. Article 27 of the Universal Declaration of Human Rights⁹ and Article 15 of the International Covenant on Economic, Social and Cultural Rights¹⁰ codify the human right to science. These instruments impose three obligations on states: governments must support scientific innovation, ensure equitable access to the benefits of scientific progress, and protect the moral and material interests of creators. These interests were first recognised in the Paris Convention of 1883 and the Berne Convention of 1886. Quantum IP policy must therefore manage the apparent tension of these obligations, providing openness for the public and reward for the inventor.

Quantum computing is an exemplar of innovative science that, properly managed, can benefit a broad swathe of humanity without compromising its creators' moral and material interests. There is promise of significant progress in healthcare, food security, climate change mitigation, pharmaceutical development and materials science through the implementation of quantum computing. That the benefits will be shared between nations is ideal because transnational collaboration will be vital to achieving these goals. Bringing the technology to maturity is already demanding a concentration of infrastructure, talent and capital that no single institution or country can assemble alone.

A multilateral quantum initiative therefore sits at the crossroad of a technological necessity and a legal obligation. Therefore, **designing suitable IP governance for the quantum era can be framed as a human rights obligation**, and one that has the potential to narrow global inequality.

This convergence carries practical political value. Policies that foster cooperation in quantum science carry a legal and political legitimacy that purely commercial or purely strategic arguments cannot. The human rights-related facet of the work can deliver broad buy-in across the international system. Framing quantum cooperation as the fulfilment of the human right to science therefore gives science diplomacy a vocabulary that resonates across very different political systems.

Such a framing transforms IP policy choices from administrative housekeeping or negotiation of financial interests into questions of legal and ethical duty in international scientific cooperation. Those duties must include creating appropriate protections for the interests of creators, as

⁹ <https://www.un.org/en/about-us/universal-declaration-of-human-rights>

¹⁰ <https://www.ohchr.org/en/instruments-mechanisms/instruments/international-covenant-economic-social-and-cultural-rights>

guaranteed by the human right to science. The complexity of these requirements necessitates that openness, access and participation are included in the assessment of any governance model.

2.2 The current landscape

The sector is simultaneously defined by rapid technological evolution and high capital intensity. Developing a scalable fault-tolerant quantum computer requires a fully integrated system encompassing hardware, control systems, software layers and cloud-based interfaces for hybrid quantum-classical workflows. Few single actors aim to achieve all of this as a “full stack” offering, and even those that do differ from each other in hardware modalities. Indeed, multiple hardware modalities, including superconducting circuits, trapped ions, neutral atoms and photonic systems, are advancing in parallel with partial convergence on shared architectures or standards, and it remains uncertain which modality — if any — will achieve market dominance. Industry roadmaps remain diverse in terms of hardware and implementations, causing actors to pursue competitive and cooperative IP strategies simultaneously.¹¹ This is producing divergence across the field that amplifies the underlying technical fragmentation.

Patenting in quantum computing remains at a fluid stage, and the patterns that will shape the field have not hardened. This creates a rare (and closing) window of opportunity for the lower layers of the quantum stack. For the upper layers — software, environments, programming interfaces and algorithms — there is a fragmentation by vendor specifics but also a growing ecosystem of modality-agnostic middleware suites. Again, there is an opportunity to encourage sharing of specifications to enable common interfaces to flourish, even if the vendors guard control of their entire quantum stack. “Patent thickets”, the dense overlapping webs of IP rights that famously slowed genomic research,¹² is a risk that may occur in quantum computing development. As we will explore in the next section, there are governance choices that can be made now, before the most valuable patents are filed, that can prevent a repeat of such deceleration.

Similarly problematic is the fact that the system into which quantum computing patents will flow is structurally fragmented. Patents are national rights. Drafting and filing typically costs upwards of \$25,000, and renewal fees run between \$5,000 and \$10,000 per country per year across a twenty-year term. Even the largest pharmaceutical companies file in only three or four of the 194 member states of the international system. The often-imagined picture of IP as a global blocking right is therefore false. The reality is a patchwork of national monopolies surrounded by open territory.

The experience of artificial intelligence can be instructive here. Leading AI developer OpenAI, for instance, held no patents until at least 2022,¹³ relying instead on trade secrets and speed. Only recently has the company begun to use an IP “fortress” strategy, filing significant numbers of patent applications¹⁴ for just a handful of applications; patent activity tends to build when technologies approach commercial application rather than in the phase of exploring its foundational science.

Quantum computing appears to be following the same trajectory: the technology is maturing but the field still lacks decisive commercial patents. That means there is room for governance choices made now and in the near-term to shape the field rather than merely react to it. If these choices are not made in the near-term, before fragmented ownership and proprietary silos emerge, later coordination becomes far more difficult and costly. **The landscape, in short, combines an open window with powerful forces pushing toward closure.**

2.3 Patenting and licensing for quantum computing

Conversations about rights frameworks often use a binary framework of IP versus open innovation. However, the reality is rarely so black and white: **it is possible to create a structured framework where the details open up a middle ground, protecting IP while fostering a culture of**

¹¹ <https://www.euroquic.org/a-portrait-of-the-global-patent-landscape-in-quantum-technologies/>

¹² Heller, M.A. and Eisenberg, R.S., Can Patents Deter Innovation? The Anticommons in Biomedical Research, *Science*, Vol. 280, No. 5364, pp. 698-701, 1 May 1998.

¹³ <https://www.patenttext.com/ip-deep-dives/openai/>

¹⁴ Lysiane Tendil, Artificial Intelligence and Industrial Property: Legal Uncertainty and the Financing of Innovative Firms, SSRN.com (2026), <https://ssrn.com/abstract=6918103>.

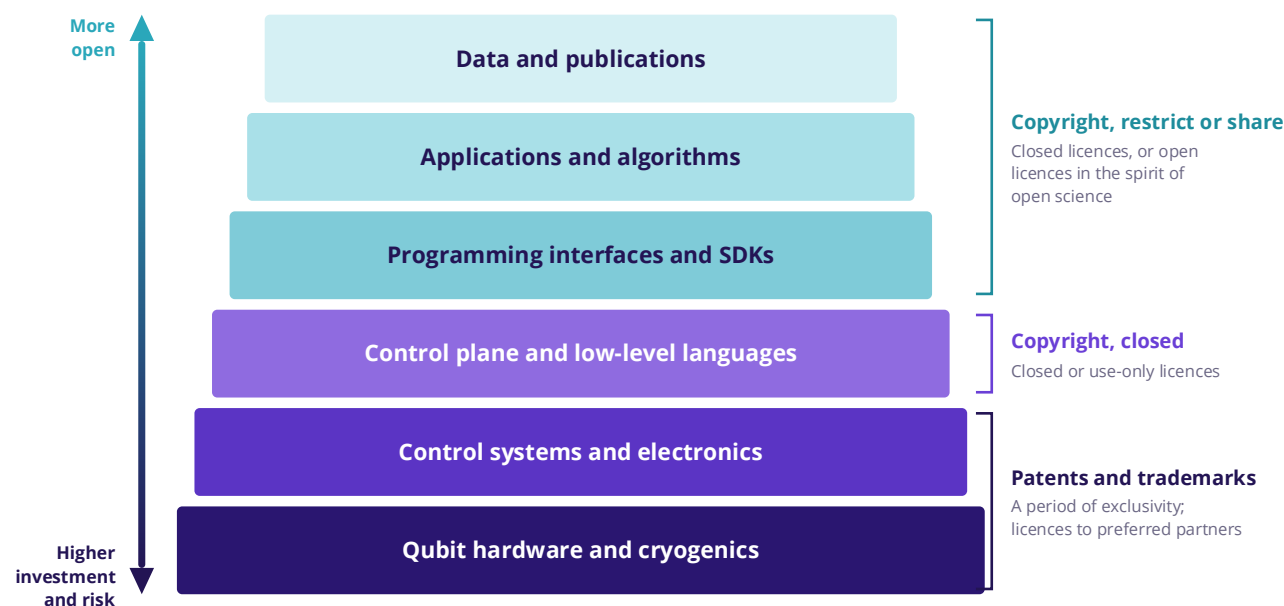
openness and innovation. OQI retains this as a possibility for certain situations, whilst keeping open innovation as its prime strategy.

Innovation can be protected in two different ways. One is Trade Secrets, which last forever and stay hidden from public knowledge. This is generally not the relevant pathway for quantum computing technologies where short-term commercial viability is sought and thus some sort of disclosure is needed. The other is patents, which offer a 20-year monopoly and foster innovation through creating public knowledge.

Who protects what in the quantum stack

Typical intellectual property protection at each layer, from hardware to published results

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Based on Section 2.3 of this report. Layer boundaries are indicative; practice varies by company and modality.

Although patents are generally a helpful pathway to follow, they come with caveats. First, they are regulated nationally and usually only kept in the few countries that deliver 80 - 90 per cent of the revenue. This means that patents tend not to be enforced in middle- and low-income countries. Secondly, mathematical laws or fundamental research are not patentable, since this would stymie fundamental research. This has strong relevance to quantum computing algorithms, which are mathematical routines.¹⁵

To encourage innovation, while protecting opportunities to pursue further research, open science communities often apply IP protection mechanisms aimed at preventing misuse, establishing clear legal rights, and ensuring that the resulting IP remains openly available through permissive licensing. This is how both CERN, where OQI is hosted, and OQI itself, operates. Such mechanisms include open or royalty-free licenses not only for patents but also for data or software.

The legal protections of IP can be used to restrict or to share, depending on the licencing. Patents and trademarks are typically used to guarantee a period of exclusivity especially for the high-investment high-risk lower layers of the quantum stack. Licences may still be issued to preferred partners. Towards the upper software layers of the stack, the protections lean towards copyrights, which are typically used to restrict supply of control planes, interfaces and low-level languages, with closed or use only licences. The top layers of programming interfaces, algorithms, applications, data and publications are copyrighted either to restrict supply, or as a way to assert an open licence and share in the spirit of open science.

¹⁵ https://www.epo.org/en/legal/guidelines-epc/2025/g_ii_3_3.html

2.4 IP governance models relevant to quantum hardware

The high-investment, high-risk lower layers of the quantum stack typically use patents and trademarks in order to guarantee a period of exclusivity (though licences may still be issued to preferred partners). Four distinct approaches to this are possible for a mission defined by the human right to science, where openness, attractiveness to participants, potential for standardisation, and implementation costs are vital considerations. Each involves trade-offs between these considerations; the models can actually be mixed and customised.

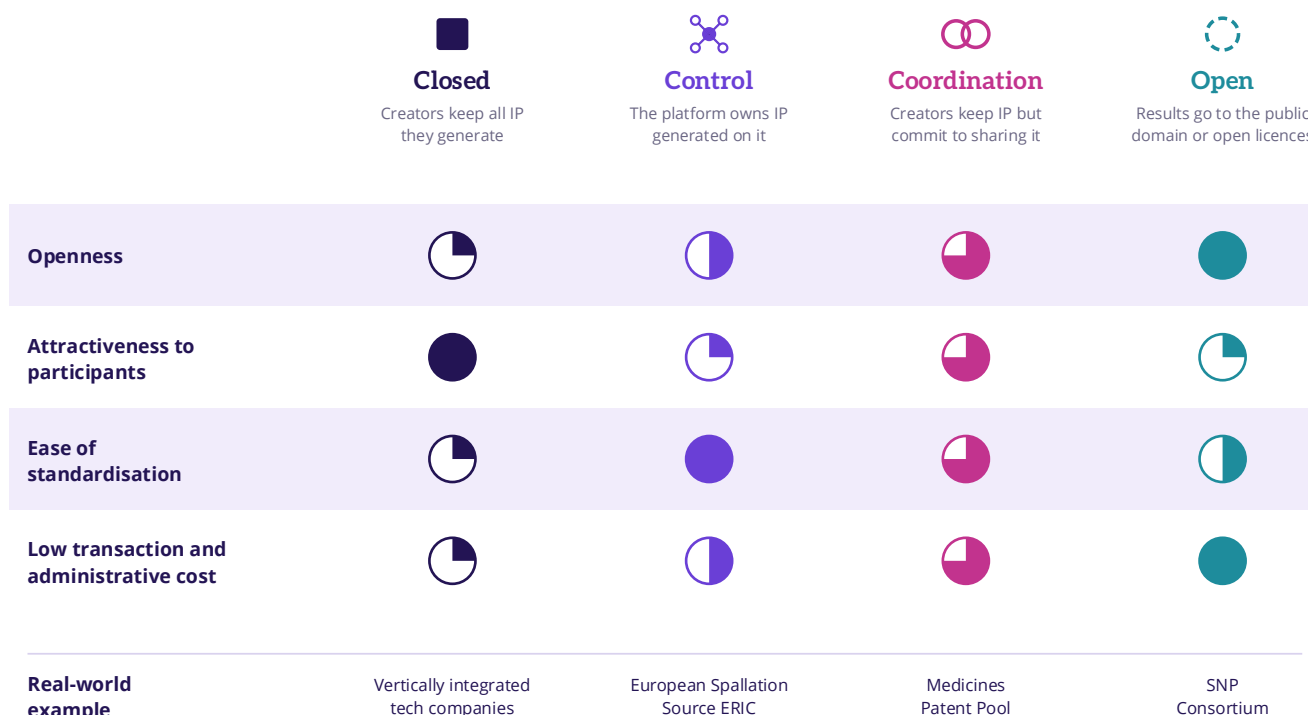
Under the closed model, IP rests fully with the user or creator. Participants bring their background IP — the IP they already own or co-own — into a shared infrastructure, work under prescribed terms and take whatever they generate out as exclusive property. Major technology companies in quantum computing follow this approach by building vertically integrated systems designed to own all (or at least all critical) elements of the technology stack. The model is commercially attractive because it conforms to the expectations of for-profit actors accountable to shareholders and investors.

The weakness of the closed model is fragmentation. Case-by-case licensing creates incoherence, power imbalances and the conditions in which patent thickets may form. Transaction costs are high because IP holders must negotiate and enforce licences individually, and these costs cannot be pooled. Standardisation is also hardest under this model. Fragmented ownership makes coordination among IP holders more difficult, and entities with mature technology may be reluctant to give up competitive advantage by agreeing to a standard they do not control.

Four ways to govern quantum IP

How each model trades off the considerations that matter for a mission built on the right to science

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 Weaker to stronger on each consideration. Models can be mixed and customised.

Ratings are an editorial reading of Section 2.4 of this report, not a formal assessment.

Under the control model, foreground IP generated through a platform transfers to the platform itself while background IP remains with the user.¹⁶ The convening institution holds the rights generated on its infrastructure and controls how they are licensed. This enables standardisation through centralised decision-making: a single party holds all the relevant IP and can direct it toward common technical outcomes. Some European Research Infrastructure Consortia operate on this basis, with the facility owning all IP generated in connection with its activities. A good example is the European Spallation Source ERIC.¹⁷

The trade-off here is loss of incentive. Users and creators lose ownership and control of their creative outputs, which for-profit actors and research institutions increasingly accustomed to owning patents both find unappealing. Furthermore, the model carries non-trivial administrative costs for the institution managing the resulting portfolio.

Under the coordination model, creators retain ownership but commit to structured sharing arrangements. The two principal instruments are the patent pool and the patent pledge. A patent pool operates as a club good in which multiple IP holders agree to license their technologies to one another within the pool, creating a legally cleared space for collaborative work. A patent pledge is a voluntary commitment to refrain from asserting rights against a specified class of users, or to license on fair, reasonable and non-discriminatory terms.

Coordination models occupy the middle ground: participants retain their IP rights, which makes the arrangement more attractive than the control model, while committing to structured sharing, which sacrifices some commercial freedom. The Medicines Patent Pool, established by Unitaid in 2010,¹⁸ demonstrates how durable public-sector-led pools can be. Participating pharmaceutical companies licensed essential medicines to the pool for sub-licensing to generic manufacturers in low- and middle-income countries, balancing access with continued protection of branded markets. In quantum computing, the European Quantum Industry Consortium and the Quantum Economic Development Consortium already appear to be exploring defensive patent pools. Standard-essential patent pools go further, providing a clearinghouse for licensing an agreed technical standard across the whole industry under standard FRAND (Fair, Reasonable and Non-Discriminatory) obligations.

Coordination models reduce transaction costs by centralising licensing and reducing friction, though the coordinating body requires funding and ongoing governance. Critically, the model can be designed to allow new participants from underrepresented regions to benefit from shared IP before they have built their own portfolio to contribute. In this way, coordination becomes a capacity-building tool.

Under the open model, results enter the public domain or circulate under open licences. Creative Commons Zero¹⁹ and similar tools allow inventors and authors to waive their IP claims intentionally, reducing barriers for resource-constrained participants. For patents, the equivalent mechanism is defensive publication: publishing the technical details of an invention in sufficient enabling detail to create date-stamped prior art that prevents any future applicant from patenting the same idea. The SNP Consortium used this approach to map single-nucleotide polymorphisms.²⁰ Formed by pharmaceutical companies and the Wellcome Trust, it anchored foundational genomic data firmly in the public domain and prevented the patent thicket that would otherwise have slowed the field.

Open models impose the lowest transaction and administrative costs and maximise accessibility to newcomers. Their weakness is commercial attractiveness: participants cannot seek IP protection and their creative outputs become freely available to competitors. The trade-off can be mitigated if openness accelerates innovation sufficiently to create first-mover advantages in

¹⁶ Jorge L. Contreras, 2026, The SNP Consortium: Background and Context, Journal of Law and the Biosciences, ahead of print, <https://doi.org/https://doi.org/10.1093/jlb/lsag009>.

¹⁷ European Spallation Source ERIC Intellectual Property Rights and Inventions Policy, Document Number ESS-0036412, 6 December 2016, 2.1, <https://ess.eu/sites/default/files/downloads/2024/03/ESS-0036412%20-%20ESS%20Intellectual%20Property%20Rights%20%28IPR%29%20and%20Inventions%20Policy.pdf>.

¹⁸ <https://medicinespatentpool.org/>

¹⁹ <https://choosealicense.com/licenses/cc0-1.0/>

²⁰ <https://pmc.ncbi.nlm.nih.gov/articles/PMC165499/>

commercialising derivative applications. But the calculation depends on the specific technology and market.

None of these approaches is inherently superior, but the choice of approach is consequential because it shapes the fundamental logic of the arrangement and, once made, becomes progressively harder to reverse. Deploying the control, cooperation or open approaches now, for example, would give the OQI and similar institutions the opportunity to carve out a space for international cooperation that might not exist in the future. It is worth noting that the human right to science suggests that governments have a duty to drive policy in a direction that makes innovation accessible to all.

One further consideration applies to all models except the fully closed one: sideground IP. Derivative and ancillary innovations that emerge from a primary invention may generate independent rights whose enforcement could undermine the cooperative intent of the arrangement. Any governance mechanism must clearly define the scope of creative outputs it covers. The broader the scope, the lower the risk that sideground IP erodes the arrangement's goals.

2.5 Towards an international framework

The obstacles to international coordination on quantum IP are formidable. Intellectual property law is national law. The legal traditions of the United States, Europe and Asian jurisdictions diverge on questions as basic as what counts as patentable subject matter. The history of attempted harmonisation offers little hope: efforts to align patent systems across the world have never really succeeded.

Quantum computing adds a layer of strategic competition to this legal fragmentation. There is very limited appetite for binding multilateral legislation in such a field; states increasingly treat quantum capability as a national economy and security assets, with export controls tightening around hardware. **A single global quantum IP treaty is therefore not a realistic near-term objective.**

However, coordination remains possible under different conditions. Quantum IP governance could follow a soft power strategy, for example. A shared set of principles and ethical commitments to openness and knowledge sharing could be adopted as a condition of participation in multilateral quantum endeavours. This would create real costs for defection in the form of reputational damage and exclusion from cooperative infrastructure.

The coordination models discussed above offer a practical vehicle for this approach. A coordinated, binding patent pledge achieves structured sharing without requiring participants to surrender ownership, for example. It would be administered by an institutional body that maintains a public registry and monitors compliance. The pledge is voluntary, but participation in the cooperative infrastructure depends on it. Members may make different pledges based on the value of their IP, allowing flexibility without abandoning the shared commitment.

Geneva offers the venue this framework requires. The relevant institutions — the UN human rights bodies, WIPO, the standards organisations and the scientific institutions — all sit in one place. WIPO holds patent application data before publication, produces patent landscape reports of the kind already completed for artificial intelligence and operates technology transfer support that could be applied to quantum for the first time.

The IP framework for a field with such a long horizon must face one further question. Every IP system in existence rests on the premise of the inventor being human. But quantum processing may strain that premise to breaking point. Within 15 to 25 years; it may be that machines will generate results no human could derive or observe unaided. An international framework for quantum IP should decide, before the case law decides for it, whether and how far any human direction of machine intelligence can be said to be sufficient grounds for a claim of invention. Anticipating that question is exactly the kind of work a Geneva-based soft framework can begin now.

2.6 The next steps for quantum diplomacy

Discussions at the 2026 Quantum Diplomacy in Action Conference pointed to several avenues that



1. Clarifying IP models.

Stakeholders in quantum computing, together with legal and policy experts, are invited to embark on a structured process to work through the governance variables of openness, attractiveness, standardisation and cost, and to determine which IP model best serves their mission.



2. Openness.

The international community is invited to collaborate in embedding IP policy within a larger framework of accepted and agreed principles and ethical commitments. These should cover openness and the willingness to share knowledge.



3. Anticipate the future.

The international community would benefit from investigations into the implications of future machine-generated results for the traditionally human-centered basis of patenting.



4. Shared IP.

Governments and relevant institutions are encouraged to resolve the fragmentation of ownership that collaborative quantum invention creates, developing clear language for attributing rights when inventions emerge from many cooperating contributors.

National Strategy: Japan

Japan has emerged as one of the world's top government investors in quantum technology. According to both the McKinsey Quantum Technology Monitor (2025) and a Qureca report from May 2026, Japan ranks second globally in government quantum investment (after China), reflecting a sustained strategic commitment. Quantum technology features among 17 priority categories designated under Japan's Growth Strategy, and Japan is building a quantum ecosystem that spans research and development, human resource development and industrialisation.

Japan's approach is characterised by close coordination between government, academia and industry. The Cabinet Office, the Ministry of Internal Affairs and Communications (MIC), MEXT (the science and education ministry), the Ministry of Economy, Trade and Industry (METI) and the Ministry of Foreign Affairs (MOFA) work in close partnership to advance Japan's quantum strategy, giving it strong institutional backing. A nationwide, academia-led service called Quantum Innovation Technology Hubs (QIH) is headquartered at RIKEN, one of Japan's leading research institutions, ensuring tight links between academic research and industrial application.

The main industry body is Q-STAR, the Japanese Quantum Strategic Industry Alliance for Revolution, which has 160 member organisations (as of August 2026). Unusually, approximately half of Q-STAR's members are end-users rather than technology developers, hailing from sectors such as energy, manufacturing, logistics, defence, transport and materials. This strong end-user base gives Japan's ecosystem a distinctive orientation towards applications, accelerating the development of practical quantum use cases.

A central pillar of Japan's quantum strategy is user-driven use-case development. The national quantum computing centre, G-QuAT at the National Institute of Advanced Industrial Science and Technology (AIST), hosts three different hardware modalities and provides integrated access to quantum-HPC hybrid computing environments. In addition, Japan's goal is to develop and supply the specialised materials and components needed to build quantum computers—including for hardware players internationally. This makes Japan a potential strategic partner for countries seeking to build resilient quantum hardware supply chains.

Internationally, Japan is an active partner in bilateral and multilateral cooperation. Alongside government-to-government Memoranda of Cooperation (MoC) on quantum, cooperation between research institutions is also advancing, such as the Memorandum of Understanding (MoU) between AIST's G-QuAT and the UK's National Quantum Computing Centre (NQCC). The Q-Neko project, a Japan-EU collaboration involving CSC (Finland), CEA (France), DLR (Germany) and AIST (Japan), is developing hybrid quantum-HPC platforms for real-world use cases in chemistry, optimisation and simulation. Japan is a leading participant in JTC3, the global quantum standardisation effort led by IEC and ISO.

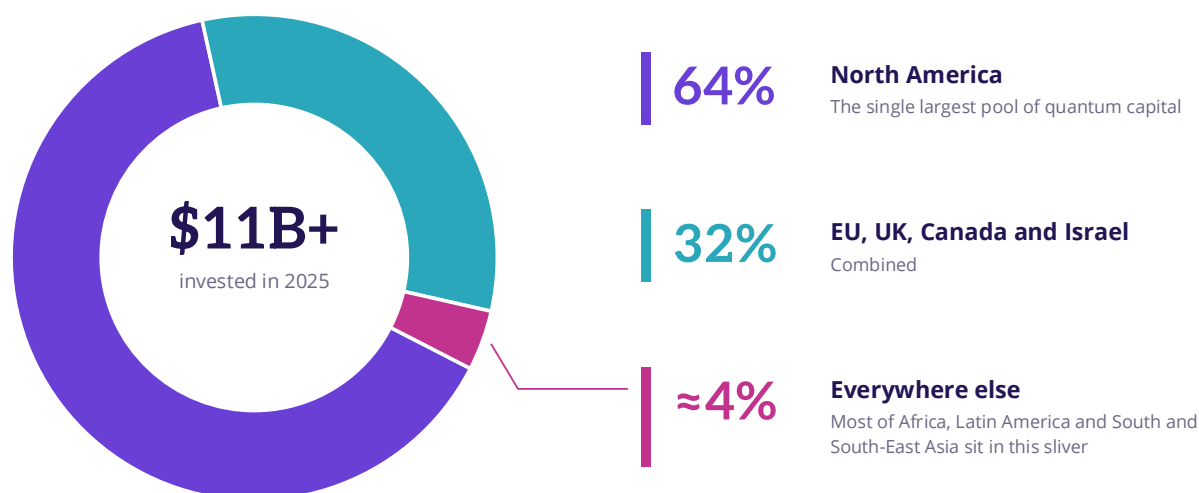
3. Multilateral Responses to the Quantum Divide

The current geographical distribution of quantum computing capabilities is one of the field's biggest challenges. Over \$11 billion was invested in quantum computing startups in 2025.²¹ But the overwhelming majority (64%) of that investment is concentrated in North America, with startups in the EU, UK, Canada and Israel together accounting for 32% of global investment. Although data availability for China is limited, the country is expected to invest significantly in quantum computing over the next four years, especially following the inclusion of development priorities related to quantum technologies into the Outline of the 15th Five-Year Plan (2026-2030) approved in March 2026.²² In much of the world, however, there is relatively little investment or infrastructure, and **without action, there is a looming threat of a structural quantum divide**. The issue was raised in previous editions of our Intelligence Report on Quantum Diplomacy in Action, but new research indicates that the problem is still growing and in need of urgent attention and action.²³

Where quantum startup money went in 2025

Share of the more than \$11 billion invested in quantum computing start-ups

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Source: McKinsey Quantum Technology Monitor 2026. The "everywhere else" share is the residual; China's investment is only partly captured.

3.1 Understanding the quantum divide

National quantum strategies that establish policies (or frameworks) for quantum investment and international partnership remain concentrated in advanced economies. Most of Sub-Saharan Africa, large parts of Latin America and much of South and South-East Asia lack dedicated quantum national frameworks. Without such frameworks, regions cannot set quantum development goals, allocate resources effectively or integrate quantum technology into broader sustainable development agendas.

Quantum hardware is built in very few countries due to the capital-intensive needs. A UNESCO global survey conducted during the International Year of Quantum Science and Technology (IYQ25) found that nearly a third of research institutions that participate in international quantum

²¹ McKinsey Quantum Technology Monitor 2026, <https://www.mckinsey.com/capabilities/mckinsey-technology/our-insights/mckinsey-quantum-technology-monitor-2026-a-commercial-tipping-point>.

²² State Council of the People's Republic of China (2026), Outline of the 15th Five-Year Plan for National Economic and Social Development of the People's Republic of China, Part 3, Chapter 8, Section 2. Available from: < <https://www.ndrc.gov.cn/fggz/fzzlgh/gjfgzh/202603/U020260317369114704096.pdf>. Note: some of the mentioned strategic objectives include the development of an "integrated space-ground quantum communication network", of "fault-tolerant general-purpose quantum computers and scalable specialised quantum computers", and "the achievement of breakthroughs in key technologies for precision quantum measurement".

²³ The Quantum moment: a global report 2026 <https://www.unesco.org/en/articles/quantum-moment-global-report>.

networks worldwide have no access to quantum facilities of any kind.²⁴ Direct access to quantum research infrastructure clusters overwhelmingly in high income countries. Commercial cloud deployments sell access to quantum computers on usage terms for commercially motivated applications in financial services, logistics and drug development, and cloud access is largely routed through facilities in North America, Europe or East Asia. This recreates the dependency relationships of the digital divide rather than transcending them. Even when shared facilities, collaborative arrangements and cloud access were taken into account, one-fifth of respondents to the UNESCO reported being unable to access the facilities they needed.²⁵

The quantum divide is not merely a function of hardware access scarcity. It reflects compounding structural inequalities. Talent shortages are acute, for instance. In the UNESCO survey, 43 per cent of respondents mentioned a shortage of skilled researchers as the primary barrier to their development of quantum technologies. In most surveyed countries, quantum expertise flows outward rather than accumulating domestically, driven by inadequate research funding and limited career pathways. Gender disparities compound the talent gap: in 2023 the EU's QuantERA program reported that women have acted as principal investigators in just 51 of 400 national quantum research teams.²⁶ Similar ventures, such as the ongoing Women in Quantum report,²⁷ reflect an effort to overcome institutional and cultural inertia rather than a pipeline problem.

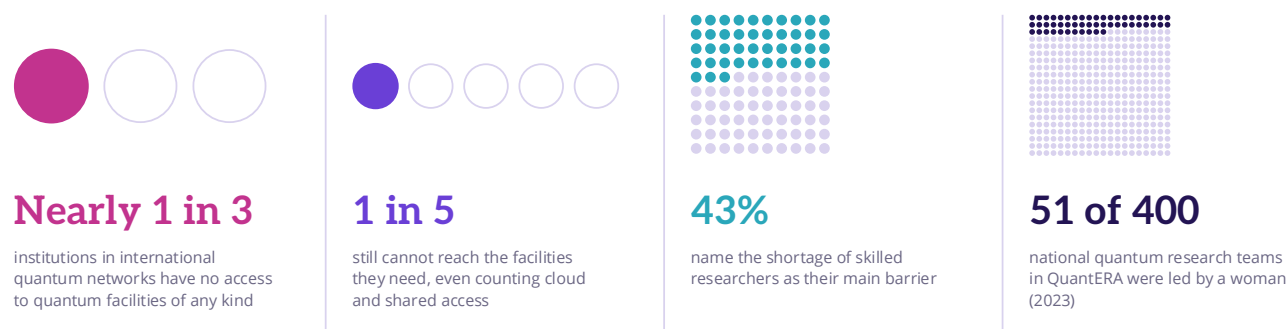
The implications of such a quantum divide are diverse, and extend well beyond scientific capacity. One consequence will be economic disadvantage. The industries most likely to see early quantum advantage, such as pharmaceuticals, materials, advanced manufacturing, financial services, cybersecurity and energy, are the same industries where quantum-underserved regions are most dependent on supply chains and technological infrastructure controlled elsewhere. A quantum-powered restructuring of those value chains threatens to deepen rather than reduce existing economic asymmetries.

A second consequence concerns global governance itself. Meaningful participation in the multilateral processes that will shape quantum standards, export controls and norms requires a

The quantum divide in four numbers

Access, skills and representation in the global quantum research community

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Underneath it all: 2.2 billion people, 27% of humanity, are still offline



Sources: UNESCO, The Quantum Moment: A Global Report (2026); QuantERA (2023); ITU Facts and Figures (2025).

²⁴ Outcomes of the International Year of Quantum Science and Technology <https://unesdoc.unesco.org/ark:/48223/pf0000398055.locale=en>

²⁵ Ibid., p. 62.

²⁶ Women leaders in quantum research, <https://quantera.eu/women-leaders-in-quantum-research/>.

²⁷ <https://www.frontiersin.org/research-topics/78732/women-in-quantum-advancing-research-societal-impact-and-capacity-building-for-inclusive-quantum-ecosystems>

baseline level of quantum literacy that most countries currently lack. **Being outside the conversation about how the technology is governed is not a neutral position.**

However, to declare the quantum divide to be unsolvable would be premature and, thanks to the relative immaturity of this field, anticipatory governance still has time to address relevant issues. Governance frameworks, capacity-building initiatives and equitable access mechanisms put in place before quantum computers are deployed at scale can shape the distribution of quantum capability, for instance.

Various activities are beginning to address this issue, such as regional capacity-building ventures in underserved geographies²⁸ and cloud access programmes opening up hardware to institutions to which these would be inaccessible at current commercial rates.²⁹ Such efforts are a start but scaling them remains difficult. Creating and sustaining a globally inclusive quantum ecosystem requires long-term commitment, structural reform and the kind of political will that anticipatory governance, at its best, can help to generate. It is worth emphasising that this will be far more difficult to achieve after the technology has matured, and is being put to work as a valuable strategic resource.

The quantum divide compounds the problem of the digital divide.³⁰ Indeed, the map of quantum capability already mirrors the map of this digital divide. Preventing permanent disadvantage amongst some countries requires immediate multilateral action on multiple fronts at once, as explained in the subsections that follow.

3.2 Mapping the divide

Effective multilateral action begins with accurate mapping of the problem to be solved. The quantum divide now has such a map: the UNESCO International Year of Quantum Global Report. Titled “The Quantum Moment” and published as the outcome document of the International Year of Quantum Science and Technology, it provides the first systematic picture of who participates in the quantum ecosystem and who stands outside it.

The report surveyed 80 countries, and the responses are striking. A large share of the countries surveyed reported that they do not have access to quantum technology (an umbrella term that includes quantum computing and other quantum-based technologies that are used for tasks such as gravity-sensing, navigation and metrology). **Less than a quarter** (22.3%) of institutions reported possessing quantum computing research facilities. In Western Europe, access to cloud-based quantum computing is possible for 44% of institutions, but is around 12% in all other surveyed regions. The picture that emerges is of regions with dense clusters of quantum activity in North America, Europe and parts of Asia that are surrounded by vast deserts where no quantum research, investment or institutional engagement registers at all.

The divide runs along three dimensions. The first is research capacity: the distribution of laboratories, instruments and trained scientists. The second is investment, where national quantum programmes worth billions exist in a handful of states — in contrast with whole regions that have no quantum line in any budget. The third is governance capacity: the ability of a state to understand the technology well enough to legislate, regulate and negotiate its evolution. This third dimension gives the divide its sharpest formulation. The quantum divide separates not only the haves from the have-nots of quantum technology but those who are governing the second quantum revolution³¹ from those who will be governed by it. A country can survive arriving late to a technology. But arriving late to the rule-making that surrounds a technology makes it far harder to optimise its benefits to suit a nation's particular requirements. An example is the ICANN domain name rules: they were built on the Latin alphabets of the countries that developed the rules.

²⁸ Alexia Yanouli, Quantum Hackathon LATAM explores quantum computing for the SDGs, Open Quantum Institute, <https://open-quantum-institute.cern/quantum-hackathon-latam-explores-quantum-computing-for-the-sdgs/>.

²⁹ First for Africa: Wits-IBM to expand quantum computing in Africa, <https://arua.org/first-for-africa-wits-ibm-to-expand-quantum-computing-in-africa/>

³⁰ <https://www.weforum.org/stories/2024/09/2-5-billion-people-lack-internet-access-how-connectivity-can-unlock-their-potential/>

³¹ Jim Al-Khalili, “Welcome to the Second Quantum Revolution”, The UNESCO Courier, 12 January 2026. Available from: <<https://courier.unesco.org/en/articles/welcome-second-quantum-revolution>>.

Because there was little representation from China or Arabic-speaking countries, their alphabets were not initially permitted for use in domain name registration.³²

The quantum divide also sits on top of an older and unresolved one. As of 2025, 2.2 billion people remain offline.³³ Before the conversation about quantum exclusion even begins, roughly 27% of the world's population stand outside the digital ecosystem that quantum technologies presuppose. It is difficult to convince governments that have not yet completed the digital transition to invest their already stretched attention in quantum technologies. Worryingly, the pattern of quantum capability retraces the pattern of already existing digital divide and, without deliberate intervention, the international community may be at risk of exacerbating its negative consequences further.

The dynamics that widen the gap are not only economic. Misconceptions about what quantum technologies can and cannot do circulate freely. Where they go uncorrected, they grow, distorting public expectations and deterring meaningful engagement. Hype and confusing claims (and counter-claims) from parts of the private sector compounds the problem — an example being the 2019 dispute between Google AI and IBM Quantum³⁴ — leaving policymakers and investors unable to separate reality from false promises. Meanwhile, export controls and the intensifying competition over quantum capability restrict the flow of hardware and knowledge precisely where openness would do most good: the technology is not yet mature enough to merit anyone gatekeeping resources, whether physical or intellectual. The stakes are therefore plain: if the gap is unaddressed, knowledge will stay in the hands of a few, and the world will forfeit the novel, creative approaches that wider participation would otherwise deliver.

3.3 Building on the Global Quantum Initiative

The Global Quantum Initiative is UNESCO's implementation and coordination platform to advance inclusive global quantum capacity through partnerships, concrete programmes and multilateral cooperation. The initiative emerged from the International Year of Quantum Science and Technology and now carries its momentum into a permanent structure, arriving at a useful moment: the appetite for multilateral action on quantum technologies is high but available mechanisms for it are scarce.

The GQI's design reflects a deliberate institutional choice. The GQI is an action-oriented initiative with a decentralised approach that seeks to magnify what is already in place rather than replace it. The model invites participation from all and welcomes contributions, small and large. Its founding members are:



Working groups carry the initiative's agenda forward, and participants can join them through a simple expression of interest; this open mechanism is designed to ensure transparency, inclusiveness and broad global participation. Participants do not all join the GQI for the same reasons. Some come for research excellence, some for capacity-building, some for regional representation and some for policy guidance. What converts this heterogeneity into strength is the common ground of shared principles, and that combination of diverse motivation and shared principle is precisely what gives the GQI its potential as a coordination platform. An initiative that demanded uniform purpose would exclude most of the world. An initiative that demanded

³²<https://icann-community.atlassian.net/wiki/spaces/DDDPP/pages/102302027/5-A+Primer+on+Internationalized+Domain+Names+IDNs>

³³ ITU, "Global number of Internet users increases, but disparities deepen key digital divides", Press Release, 17 November 2025. Available from: <<https://www.itu.int/en/mediacentre/Pages/PR-2025-11-17-Facts-and-Figures.aspx>>.

³⁴ <https://www.quantamagazine.org/google-and-ibm-clash-over-quantum-supremacy-claim-20191023/>

nothing would coordinate nothing. The GQI's foundational idea is that shared principles plus diverse motivations can hold a genuinely global membership together. Five strategic objectives define the initiative's scope:

- Advance quantum education and strengthen institutional and human capacity.
- Build sustainable quantum technology infrastructure and enable resource sharing.
- Advance public awareness and societal engagement.
- Strengthen international cooperation between science and diplomacy.
- Foster responsible innovation and anticipatory governance.

Together, these objectives span the full breadth of the quantum divide, from research capacity through investment to governance. They are translated into concrete collaborative programmes implemented through thematic Working Groups, bringing together governments, academia, industry, international organisations and civil society.

Initial activities already under development include remote access to quantum research infrastructure, quantum literacy and policy training programmes, capacity-building initiatives for underserved regions, dedicated activities to increase the participation of women in quantum science, and collaborative work on anticipatory governance and responsible innovation. The initiative is still in its early stages. Its working groups are still populating, and its outreach has yet to reach every region where the divide bites hardest. Its concrete delivery record is short. The promise is nonetheless real, because the **GQI is currently the only mechanism that connects quantum education, infrastructure, awareness, diplomacy and governance under one multilateral roof**. The task now is to convert the political moment of the International Year of Quantum into long-term commitments rather than mere visibility.

3.4 Investing in human capital

No dimension of the quantum divide closes without people, and the human capital challenge now runs from the classroom to the labour market. **The first need is supply**. As quantum technologies become diversified, underrepresented regions require a ready cohort of not only practitioners, PhD graduates and researchers, but also bachelor and master graduates from different backgrounds³⁵ trained in quantum science and its applications. In a study conducted on 21 companies, 90% of interviewed entities considered coding skills and statistical methods as highly valued, followed by laboratory experience (81%), electronics (76%), troubleshooting and problem solving (71%), knowledge of material science and properties (67%), and quantum algorithms and computer science (62%).³⁶ The increased commercialisation of quantum technologies may also drive demand for entrepreneurial and soft business skills alongside technical skills, for a workforce able to communicate the value and application of already existing or frontier quantum use cases.³⁷

The second requirement is coherence. Quantum education today is a patchwork of national curricula, university programmes and online resources. An important step in fostering coherence while bridging industry demands with offered education programmes is the European Competence Framework for Quantum Technologies (CFQT), aiming to offer a comprehensive overview of topic areas which academic curricula may cover and professional competencies quantum jobs may require. The CFQT is starting to appear in educational programmes offered throughout the EU; yet, the extent to which the framework is reflective of skills required on the day-to-day of quantum jobs is decidedly less clear, with researchers calling for the establishment of a “large-scale study of the skills involved in the industry”.³⁸ Aiming for a definition of a global framework for quantum education would make resources comparable across countries and institutions, allowing learners, employers and governments to know what a given qualification means.

³⁵ Ciaran Hughes et al. (2022), “Assessing the needs of the quantum Industry”, IEEE Transactions on Education, 65:592-601. Available from: <<https://doi.org/10.1109/TE.2022.3153841>>.

³⁶ Michael F. J. Fox, Benjamin M. Zwickl and H. J. Lewandowski (2020), “Preparing for the quantum revolution: what is the role of higher education?”, Physical Review Physics Education Research 16. Available from: <<https://journals.aps.org/prper/abstract/10.1103/PhysRevPhysEducRes.16.020131>>.

³⁷ Sydney Quantum Academy (2024). Quantum Industry & Workforce Review. Available from: <https://sydneyquantum.org/quantum-industry-workforce-review/>.

³⁸ Simon Goorney et al. (2026), “The quantum technology job market: data driven analysis of 3641 job posts”, EPJ Quantum Technology, 13:36. Available from: <<https://doi.org/10.1140/epjqt/s40507-026-00477-z>>.

The framework must nonetheless strike a careful balance. A fully harmonised curriculum risks ignoring local needs, while a fully localised curriculum offer limits the inter-regional compatibility necessary for full coherence. Education resources must also be produced in a diversity of languages: a divide-closing curriculum would be one available in a variety of languages, instead of only catering to the Anglophone world. g. Furthermore, the offer must connect to practice, as students engage most readily when their learning is directly applicable to concrete projects.

The question of employment opportunities in quantum technologies also needs addressing. This is perhaps even harder to resolve than the issues with quantum education. It is not yet clear how many jobs quantum computing will assist, empower and bolster; how many jobs it will modify or alter, or how many it will directly substitute. The analysis must also take combination effects into account, as quantum and AI will work in tandem to produce phenomena the impact of which remains undiscovered.

Artificial intelligence is also relevant here as a catalyst. The impact of AI on the working lives of quantum physicists over the past three years has been staggering, and the trajectory points upward.³⁹ Generative AI is a powerful educational tool that is significantly broadening access to knowledge. With the right support, AI can assist with the complexity of quantum computing processes and potentially reshape the space of who participates in quantum science.⁴⁰ The low-hanging fruit here is to build on this by developing a quantum-focused large language model designed to attract students, answer their questions and provide the support system that the most resourceful are already assembling for themselves.

3.5 Establishing access to infrastructure

Education creates capability only where infrastructure allows people to use it, and access to quantum infrastructure is where the divide becomes physical. The requirement has multiple layers. As discussed in Section 2, there are geopolitical IP and copyright barriers that can restrict access to tools such as cloud-based and physical quantum resources. A researcher who cannot access tools will have greater difficulty contributing to the field. But access alone is not the goal. Genuine access means sharing what is open and accessible in a way that lets users interact with the inner workings of quantum computers in order to understand the hardware's capabilities and limitations, ultimately designing and creating hardware and applications of their own.

The current environment makes this kind of openness difficult. Quantum computing has entered a competitive era in which export controls restrict the movement of hardware, components and in some cases knowledge itself. Sharing the inner workings of a quantum computer across borders now runs against the grain of national policy in several leading quantum nations. Practical models nonetheless exist. One initiative is called Schiiq, which is co-led by the Centre for Quantum Science at EPFL in Lausanne and the University of Applied Sciences and Arts in Northwestern Switzerland (FHNW). Schiiq is an open source, education grade quantum computer designed to allow a broad audience to explore the fundamental principles of quantum computing.⁴¹ Another is Qibolab,⁴² a low-cost, open-source quantum computing platform for research and training purposes. The system is not set up to run commercial workloads, but nonetheless lets students and researchers in any country understand the architecture and learn by building quantum software. Its open architecture is precisely what export-constrained flagship systems cannot offer. There is also Open Quantum Design (OQD), a Canadian-led global initiative developing full-stack, open-source quantum computing systems,⁴³ and aQcess, an open-source public quantum computing platform based in Strasbourg.⁴⁴ All these initiatives are most valuable for educational and training purposes, as their scale and quality of qubits remains limited.

Another infrastructure issue has to do with energy. As with all computing technologies, quantum computing will be energy-intensive, and thus expensive. Hardware development issues aside, access will be affected by the ability to generate and finance energy. Countries in underserved

39 Yuri Alexeev et al., 'Artificial intelligence for quantum computing', *Nature Communications* 16: 10829 (2025), <https://doi.org/10.1038/s41467-025-65836-3>.

40 Sourish Wawdhane and Poulami Das, 'Are LLMs Good For Quantum Software, Architecture, and System Design?', *ArXiv.org* (2026), <https://doi.org/10.48550/arXiv.2603.26904>.

41 <https://www.schiiq.org>

42 Qibolab: an open-source hybrid quantum operating system <https://arxiv.org/abs/2308.06313>

43 <https://openquantumdesign.org/>

44 <https://aqcess.cesq.fr/>

geographies that lack the electrical infrastructure to support energy-intensive computing face a structural exclusion from advanced quantum computing even if they have the scientific talent and the policy ambition to participate. Globally, the institutions with the largest energy budgets will enjoy better access to the most capable systems.

Infrastructure policy must also fit local context rather than abstract ambition. **Buying a quantum computer is not always the right answer for a country**, and many lack the economic power to do so in any case. The better starting point is the question of what quantum means for the systems a country already depends on. For example, much of Sub-Saharan Africa relies on a mobile money ecosystem that permeates every aspect of life. The security implications of quantum computing for such ecosystem are significant: these centralised payment systems dependent on network cryptography that will be vulnerable to successful attack by a quantum algorithm developed by Peter Shor.⁴⁵ Shor's algorithm, implemented on a sufficiently powerful quantum computer, can compromise many of today's cryptographic protocols. Governments in the region must therefore understand that, although they may not be actively involved in developing quantum computing, they nonetheless need to implement policies that mitigate any threat from the technology.

Directing quantum resources to these kinds of use cases grounds infrastructure investment in local reality, builds political support for quantum engagement and gives countries outside the quantum core a reason to participate. The infrastructure pillar of the Global Quantum Initiative carries the greatest weight among its five objectives for exactly this reason. Awareness without machines, skills and locally meaningful applications leaves the divide untouched.

3.6 Building policy literacy

Governance capacity is the third dimension of the divide. Its foundations may lie on quantum fluency: that is, the confidence and competence of policymakers, diplomats and international civil servants to advise, deliberate, and act based on their understanding of the global quantum landscape. Three priorities define the path to quantum fluency:

- **Quantum literacy for policymakers**, based on a shared baseline of understanding across governments rather than isolated, geographically-bound pockets of expertise.
- **Real-world application**, enabling literacy to serve as a catalyst for action-oriented policy recommendations holding the potential to engender concrete change.
- **A deliberate focus on anticipatory governance**, equipping officials to shape rules before the technology and its ecosystem matures into a more solid, less pliable entity.

The obstacles to fluency begin inside science itself. Discussions of the status of, and opportunities associated with, quantum technology are frequently littered with misconceptions. When these go uncorrected, they grow, distort expectations and end up increasing the divide rather than reducing it. Correcting them is the job of scientists, while communicating it can become that of diplomats, policymakers, and international civil servants together with scientists — all stakeholders require clarity over what quantum technologies can and cannot do, together with reaching an agreement on basic definitions.

Policymakers face three further issues. Firstly, in academic circles, opinion is rarely uniform, making it more difficult to evaluate the merit of some scientific claims. Secondly, there is often tension between academia and industry in terms of evaluating likely timelines and potential for the development of a technology into a commercially useful product. Thirdly, oversimplifications and the use of hyperbole permeate public discourse around quantum computing, requiring policymakers and investors to employ considerable amounts of knowledge, understanding and discernment in their decision-making.

Two practical responses are possible. The first is training, building basic quantum knowledge among civil servants as several governments have begun doing. The second is structural. This involves convening a platform where startups, quantum companies and academics debate one another openly while diplomats listen in. This would let policymakers glean from the contest of

⁴⁵ Peter W. Shor, 'Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer', SIAM Journal on Computing Vol. 26, Iss. 5 (1997), <https://doi.org/10.1137/S0097539795293172>.

claims where technology readiness truly lies. **Disagreement among experts, displayed honestly, informs better than consensus manufactured for an audience.**

The cost of illiteracy is not hypothetical. Even a quantum computer that does not exist can be weaponised, because the mere possibility of quantum capability can influence other countries and the way they are governed. Misconceptions therefore threaten democratic institutions as well as technology policy.

Two final conditions are needed to enhance engagement. One is that conversations about security and IP (see Section 2) need safe spaces, because formal settings inhibit the candour these subjects require. The other is that the framing of quantum policy needs rebalancing: the current focus on security crowds out the cooperative and developmental dimensions on which closing the divide depends.

3.7 Creating institutional frameworks

The multilateral system has confronted a technology divide before, and the institutional memory of managing the digital divide experience could be an important asset in quantum governance. Though it was managed (partially and unevenly), this digital divide has never closed, and its persistence now shapes the quantum era. Countries that have not completed the digital transition cannot realistically prioritise quantum technologies, but the multilateral system can:

- **find pathways** to include those outside the digital ecosystem in the quantum conversation today;
- **identify the systems** a population already relies on and ask how those systems are affected by quantum;
- **discern whether to tackle the quantum divide** country by country or multilaterally, and whether it is better to offer coordination without centralising, and to magnify national efforts rather than replace them;
- **explore whether quantum adoption can** help close the remaining digital gap, turning the new technology into a lever on the old problem rather than adding another layer above it;
- **support governments** in exploring the value that multilateral cooperation can bring to the specific local, national, regional contexts in which they operate, as well as the specific development stage of their countries. This might be possible through implementation of a compelling shared metric. Such a metric — it could be called the Quantum Cooperative Advantage Index — would combine economic interest, reliability, security, future projection and global impact into a single number that ministers and ambassadors can cite, making the case for supporting initiatives such as the GQI far more easily than any argument from principle.

3.8 The next steps for quantum diplomacy

The conference discussions highlighted several options that could contribute to narrowing the quantum divide:



1. Global Quantum Initiative.

Expand the GQI geographically while accelerating implementation through concrete collaborative programmes, Working Groups, shared infrastructure initiatives and targeted capacity-building activities, particularly in underserved regions.



2. Shared resources.

Define a common framework for quantum education so that resources and qualifications become comparable across countries and institutions, and encourage the consolidation and structured use of existing educational assets.



3. Prepare the future.

Use the momentum of the International Year of Quantum as a political moment to anchor long-term commitments, creating durable funding, partnerships and programmes.



4. Multilateralism.

Establish the Quantum Cooperative Advantage Index, a necessarily multilateral measure expressed as a single number combining economic interest, reliability, security, future projection and global impact, giving policymakers a clear and citable reason to support cooperative quantum

National Strategy: Switzerland

Switzerland is a significant contributor to quantum science and technology. An analysis commissioned by the Swiss government confirmed that the country is a leading global contributor to quantum research publications.⁴⁶ Swiss universities maintain active research groups investigating all major qubit platforms, including ion traps, cold atoms, quantum dots, nanoparticles and superconducting qubits.

Switzerland's start-up ecosystem in quantum stretches back further than almost anywhere else in the world. ID Quantique, founded in Geneva in 2001, is widely regarded as the world's first quantum technology company, commercialising quantum key distribution — a technology itself invented in Geneva. However, a recurring challenge is insufficient domestic financial and strategic support, which eventually lead to ID Quantique passing out of Swiss ownership. Nevertheless, the timeline of Swiss quantum start-ups shows accelerating activity in recent years, with the Swiss Quantum Commission⁴⁷ focused on ensuring that PhD researchers can translate ideas into companies.

Switzerland's relationship with the European Union's quantum research ecosystem has been turbulent. During the Horizon Europe association dispute, Swiss researchers were excluded from EU quantum research calls, a diplomatic setback that had to be resolved at head-of-state level, beyond the reach of science ministries. Switzerland has now been reintegrated into the European quantum programme and will be eligible to participate in defence-relevant quantum projects in forthcoming calls.

An important idea behind the country's strategy is that smaller countries should have the principal ability and knowledge to build large-scale quantum computers to participate meaningfully in the quantum economy. The actual building of such a machine may or may not be beyond the resources of smaller communities. Switzerland has never produced cars, for example, yet one in ten Swiss jobs depends on the automotive sector. What is essential is technological literacy: the ability to understand and engage with quantum developments independently, rather than deferring entirely to the United States or China. This framing of quantum competence as a prerequisite for sovereign policy-making underpins Switzerland's investment in the field.

⁴⁶ Switzerland: A hub for quantum, https://swissnex.org/app/uploads/2025/10/Switzerland_Hub_Quantum_Oct2025_web.pdf.

⁴⁷ Swiss Quantum Initiative, <https://www.sbfi.admin.ch/en/swiss-quantum-initiative-en>.

4. Environmental and Energy Issues

Digital technologies account for up to 13% of global electricity consumption.⁴⁸ Quantum computing will add to that but, **because the technology is not yet deployed at scale, there is still scope to minimise its impact.** Energy-based arguments and propositions have already been generated by the Quantum Energy Initiative (QEI),⁴⁹ which originated as an academic effort to embed energy awareness early in system design. However, the evolving nature of the field makes decision-making challenging. The parts of this section that follow lay out the relevant issues.

4.1 The challenge of fair comparison

Unlike conventional data centres, which operate on stable and well-understood hardware architectures, quantum computing prototypes currently span multiple competing hardware modalities: superconducting circuits, trapped ions, neutral atoms, photonic systems, etc. each operate on different physical principles, require different operating environments and carry different energy profiles.

One analysis of vendor data reveals that some **quantum computing hardware modalities might use 1000 times more energy than others** when running the same quantum computation.⁵⁰ That wide-ranging spread means that energy efficiency is already a differentiating factor among existing quantum hardware modalities. The most energy-efficient modalities will carry lower operating costs, and in an environment of rising energy prices, that advantage compounds. To assess these modalities more fairly in the future providers are also going to have to provide more transparent information on their hardware which is not currently readily available.

However, the relevant question for problem-solving computation systems is not necessarily which system uses less energy to arrive at the same answer, but what the **energy cost of the solution is and whether the value of the result justifies it.** When quantum computers tackle problems that classical computers can solve, for example, fair comparison requires normalising for problem type, problem size and solution quality (several efforts to standardise benchmarking are in development). Furthermore, error correction protocols introduce a workload-dependent energy overhead that have no direct classical analogue.⁵¹ Some quantum algorithms require longer computational runs, and therefore more error correction operations. Because of this, energy consumption does not scale with problem size in the way that classical energy metrics assume.⁵²

Developing governance frameworks for a technology in this state of flux requires a different approach to regulating a mature industry. That difference is precisely what standards bodies (e.g. ISO/IEC JTC 3,⁵³ CEN-CENELEC,⁵⁴ or IEEE Standards⁵⁵) working in this space are attempting to address.

4.2 Energy and environmental impacts of quantum computing

Quantum computing's most direct potential contribution to energy and environmental challenges include optimisation of complex systems and simulation of relevant molecular processes. Extensive applied research is done to identify the specific instances that, applied to energy and environmental applications, could realise quantum advantage on future fault-tolerant quantum computers. While the deployment of these quantum solutions in real-world are still in a distant future, the policy window for shaping how the technology develops is open now.

48 Hannu Jaakkola, The Fast Growing Role of ICT in Global Electricity Consumption, Information Modelling and Knowledge Bases XXXVII, 18 (2026), <https://doi.org.10.3233/FAlA251716>.

49 <https://quantum-energy-initiative.org/>

50 Olivier Exratty, Understanding Quantum Technologies 2025, arXiv.org (2021), <https://arxiv.org/abs/2111.15352>.

51 Marco Fellous-Asiani et al., Optimizing Resource Efficiencies for Scalable Full-Stack Quantum Computers, PRXQuantum 4, 040319 (2023), <https://doi.org.10.1103/PRXQuantum.4.040319>.

52 Oliver Knitter et al, Measuring Accuracy and Energy-to-Solution of Quantum Fine-Tuning of Foundational AI Models, ArXiv.org (2026), <https://arxiv.org/html/2605.02798v1>.

53 <https://www.iso.org/committee/10138914.html>

54 <https://www.cenelec.eu/>

55 <https://standards.ieee.org/>

On the optimisation side, energy grids incorporating high proportions of renewable generation face a more complex management problem than grids dominated by dispatchable generation. Solar and wind are intermittent, and balancing supply and demand across a distributed network of variable sources requires continuous simultaneous real-time optimisation across production, transmission, distribution and storage. The unit commitment problem, the puzzle of deciding which power plants to switch on and when, is one of the biggest computational challenges in grid management. Experts indicate that optimisation via quantum computing could bring significant benefits here.⁵⁶ Other impactful quantum applications that rely on solving complex optimisation problems include also forecasting extreme weather events for disaster prevention.⁵⁷ A recent study of quantum machine learning was applied to large-scale typhoon trajectory prediction, offering a potential scalable and energy-efficient approach to climate modelling.⁵⁸

On the molecular simulation side, quantum computing's potential impact on energy challenges is more specific. The industrial Haber-Bosch process, which underpins global fertiliser production and therefore food security, is extraordinarily energy intensive because it operates at high temperature and pressure; a process that nature does with enzymes at room temperature and standard pressure. The reaction mechanism for biological nitrogen fixation by the enzyme nitrogenase can be described in theory but not simulated accurately by classical computers. However, a sufficiently powerful quantum computer could perform these simulations, potentially elucidating the chemical reaction and enabling discovery of novel energy-effective catalysts.⁵⁹ Analogous arguments apply to battery chemistry, where the quantum mechanical behaviour of novel materials determines performance characteristics that classical simulation approximates rather than resolves.⁶⁰ These applications will require large scale fault-tolerant quantum computers not yet available, but they represent the clearest examples of quantum computing offering significant impact.

Other relevant quantum computing use cases related to energy and environment can be found in the OQI use case repository, featuring work done by OQI members and like-minded institution to advance solutions to SDGs 7 and 13.⁶¹

Beyond electricity consumption, the full environmental footprint of quantum computing encompasses resources such as cooling water, helium and other specialised materials used in cryogenic systems, and the challenges of recycling and disposing of components. These **dimensions have received almost no governance attention and represent a significant research gap.** Researchers are beginning to study the factors of materials and water alongside energy,⁶² but the work is early and fragmented. Any real environmental audit of quantum computing will have to track all of these resources. That means the governance frameworks being designed now should be flexible enough to handle this bigger picture. The conversation between quantum computing governance and climate and energy governance communities thus needs to begin in earnest, and the organisations that sit at the intersection of those agendas, including the UNFCCC, are natural conveners.

4.3 Standards, benchmarking and cross-disciplinarity

The standards landscape for quantum energy is under development, and the choices made now will shape the transparency and comparability of the field for a generation. The IEEE Standard Working Group 3329,⁶³ developed together with the Quantum Energy Initiative, is the leading initiative currently developing a standard to evaluate the energy consumption of quantum computing systems. Its approach reflects a deliberate response to the measurement difficulties

⁵⁶ Jonas Blenninger et al., Quantum Optimization for the Future Energy Grid: Summary and Quantum Utility Prospects, arXiv.org (2024), <https://arxiv.org/abs/2403.17495>.

⁵⁷ Kin Tung Michael Ho et al., Quantum Computing for Climate Resilience and Sustainability Challenges, 2024 IEEE International Conference on Quantum Computing and Engineering (QCE), Montreal, QC, Canada, 2024, pp. 262-267, doi: 10.1109/QCE60285.2024.10289.

⁵⁸ Chen-Yu Liu et al., Quantum-Enhanced Parameter-Efficient Learning for Typhoon Trajectory Forecasting, ArXiv.org (2025), <https://doi.org/10.48550/arXiv.2505.09395>.

⁵⁹ Markus Reiher et al., Elucidating reaction mechanisms on quantum computers, PNAS 114, 7555 (2017), <https://doi.org/10.1073/pnas.1619152114>.

⁶⁰ Isaac H. Kim et al., Fault-tolerant resource estimate for quantum chemical simulations: Case study on Li-ion battery electrolyte molecules, Phys. Rev. Res. 4, 023019 (2022), <https://doi.org/10.1103/PhysRevResearch.4.023019>.

⁶¹ <https://open-quantum-institute.cern/use-cases/>

⁶² David L. McCollum et al., Uncertain quantum computing futures and potential energy and physical resource impacts at scale, Renewable and Sustainable Energy Transition, 9 (2026), <https://doi.org/10.1016/j.rset.2026.100140>.

⁶³ IEEE P3329 Standard for Quantum Computing Energy Efficiency, <https://standards.ieee.org/ieee/3329/11162/>.

described above. Rather than defining energy metrics tied to specific hardware architectures or qubits, **the working group is developing a task-based framework:** the standard specifies the problem to be solved and the quality of solution required, without prescribing how to solve it. This hardware-agnostic design will allow the standard to remain relevant as quantum hardware architectures evolve.

A critical design principle of the IEEE Standard effort is the requirement to embed all energy sources in the evaluation: not only the quantum processor but classical pre-processing and post-processing, compilation, error correction and the cooling infrastructure. The working group draws on classical computing's experience with Power Usage Effectiveness (PUE),⁶⁴ the ratio of total energy entering a data centre to the energy consumed by the computing equipment itself. Current high-performance computing (HPC) centres can achieve PUE values close to 1.05, reflecting decades of optimisation in cooling efficiency.⁶⁵ Quantum computers will initially have much higher overhead ratios, but an established metric provides a reference point and a trajectory. The question of how PUE and analogous metrics translate to quantum computers, where some cooling operates at temperatures close to absolute zero and others at room temperature, is an active area of work.

Standardisation efforts also include the European CEN-CENELEC Joint Technical Committee 22,⁶⁶ and the international ISO-IEC Joint Technical Committee 3,⁶⁷ which are developing quantum technology standards, with several dimensions including energy and interoperability. The openQSE initiative⁶⁸ is developing an open, modular ecosystem to define specifications enabling seamless integration between HPC and quantum computing through interoperable, vendor-neutral technologies. These complementary efforts share the goal of ensuring that quantum computing standards are compatible with existing HPC standards rather than creating a parallel and incompatible framework.

Nevertheless, **premature adoption of unsuitable metrics or benchmarks can negatively influence technology development.** Classical computing provides a cautionary example in that hardware developers routinely optimise their systems to score well on published benchmarks rather than optimising overall performance and efficiency. Governance frameworks should therefore build in explicit mechanisms to update metrics as technology evolves, and policymakers should be careful not to lock procurement criteria or regulatory requirements to standards that may be superseded. The cross-disciplinary character of this work compounds the challenge. Quantum scientists, cryogenic engineers, classical computing architects, energy measurement specialists and policy analysts must all contribute to standards that are technically rigorous, practically implementable and appropriately flexible. Building and sustaining those interdisciplinary collaborations is itself a governance task.

To note an alternative path, UNFCCC focuses on Methodologies rather than standards.⁶⁹ The carbon market is a good example where there are existing methodologies, but not existing clear benchmarks. The estimation of the emission reduction is based on the following: the more emission reduced, the more carbon credits. In the case companies earn carbon credits they can sell them for financial gain, which creates financial benefits as incentives.

⁶⁴ https://en.wikipedia.org/wiki/Power_usage_effectiveness

⁶⁵ Jian Sun et al., Energy dataset of Frontier supercomputer for waste heat recovery, Sci Data 11, 1077 (2024), <https://doi.org/10.1038/s41597-024-03913-w>.

⁶⁶ <https://www.cenelec.eu/areas-of-work/cen-cenelec-topics/quantum-technologies/>

⁶⁷ <https://www.iso.org/committee/10138914.html>

⁶⁸ <https://openqse.org/>

⁶⁹ <https://unfccc.int/process-and-meetings/the-paris-agreement/article-6/article-64-pacm/methodologies>

4.4 The next steps for quantum diplomacy

There are several avenues that could help move these issues forward:



1. Exploring applications.

Encourage quantum application developers to work collectively with institutions such as the UNFCCC to identify complex environmental and energy problems aligned with UN priorities.



2. Support standards and shared data

Quantum hardware vendors, with the active support of governments and intergovernmental bodies, are encouraged to publish their energy consumption data in standardised and transparent ways. Alongside this transparency requirement, the international community is invited to contribute to the ongoing development of relevant standards, such as the IEEE Standard Working Group 3329 and the parallel European and international standardisation efforts.



3. Environmental footprint.

The international community is invited to study the full environmental footprint of quantum computing — including water, materials and component disposal as well as energy — drawing on the methodological tools that bodies such as the UNFCCC have developed for environmental accounting in other technology domains.

5. Security and Dual-Use Dimensions of Quantum Technology

Developments of and improvements to technology have always raised concerns about “dual-use”. Dual-use is often viewed through the traditional binary lens of civilian versus military applications of a technology. However, this hides a more nuanced picture. There exists a broad spectrum of uses, contexts and intentions where the same technology can serve radically different purposes depending on who holds it and how it is deployed.

While quantum computing has a number of prospective applications that will be helpful to science, agriculture, healthcare, environmental protection and other areas of human endeavour. However, there are dual-use concerns. Most urgently, **future large-scale quantum computers pose a threat to global economic and political stability**, as they have the potential to compromise the cryptographic infrastructure on which the entire digital world rests.

Although this report focuses mostly on quantum computing, here we will point out that there exist other quantum technologies, such as quantum sensing and quantum communications, which leverage some of the same principles. Their applications are therefore also subject to dual use scenarios. Quantum sensing for positioning, navigation and timing are already commercially available in some forms, for example,⁷⁰ and are simultaneously attracting serious defence investment.

5.1 Quantum computing’s threat to cryptography

Widely used cryptographic schemes, such as the Rivest-Shamir-Adleman (RSA) algorithm and Elliptic Curve Cryptography (ECC),⁷¹ rely on mathematical problems that classical computers cannot solve efficiently. However, Shor’s algorithm provides a means by which, if implemented on sufficiently powerful quantum computers, could solve cryptographically relevant mathematical problems within a reasonable time.

The scope of the threat becomes clear when cryptography’s roles are catalogued. Cryptography keeps sensitive data confidential, from individual healthcare records to the IP of pharmaceutical and aerospace companies worth billions. It ensures the integrity of financial transactions so they cannot be silently altered. It authenticates software updates so that the firmware running aircraft, electric vehicles and industrial control systems can be trusted to come from legitimate sources. It underpins property registries, legal records and every form of authoritative digital document. It enables the routing of internet traffic and the operation of every secure network connection. An enterprise sending a single parcel through a logistics network may use five to six million cryptographic keys in the process. **Every one of those keys is potentially vulnerable to a cryptographically relevant quantum computer.**

Although no one yet has a cryptographically-relevant quantum computer (CRQC) — that is, one that poses an immediate threat to state-of-the-art encryption protocols — some of these issues are already urgent. That is because of so-called “harvest-now-decrypt-later” strategies, where malicious actors may be storing encrypted data and communications already, with the aim of decrypting them as soon as a CRQC is available. This is a problem for any businesses, financial institutions and governments who have an interest in, or a duty to, protect secrets for multiple decades. The fact that this also applies to financial and health records means that it is not just a threat to national security and business operations, but also a matter of individuals’ human rights to privacy.

⁷⁰ <https://q-ctrl.com/topics/introduction-to-quantum-sensing>

⁷¹ Michal Krelina, Military and Security Dimensions of Quantum Technologies: A Primer, https://www.sipri.org/sites/default/files/2025-07/0725_military_and_security_dimensions_of_quantum_technologies_0.pdf

5.2 The response: post-quantum cryptography and quantum key distribution

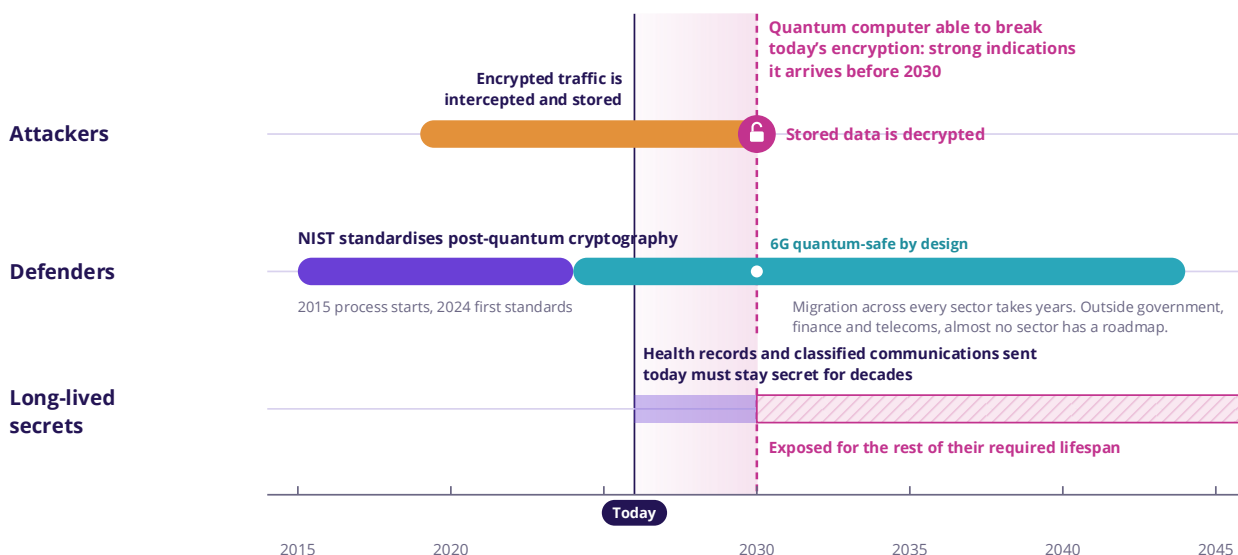
While today's quantum computers are not sufficiently powerful to break current best encryption using Shor's algorithm, there are strong indications that this capability will be available before the end of the decade.⁷²

One of the responses to this vulnerability exists in the form of post-quantum cryptography (PQC). PQC is not a new form of encryption, but rather a form of protection against cryptanalysis protocol that would be deployed on quantum computers. Such a quantum safety effort has been in development for nearly two decades. The United States National Institute of Standards and Technology (NIST) progressed a standardisation process that began in 2015 and issued the first post-quantum cryptographic standards in 2024.⁷³ The telecommunications industry has a roadmap for making its next-generation mobile standard, 6G (due to launch in 2030) quantum-safe by design. Several national governments, including those of the United States, European Union member states, the United Kingdom, Canada, Japan, Singapore and China, have issued quantum-safe guidance to industry. The Quantum Readiness Index, published by the Cyber Security Agency of Singapore, helps organisations assess their readiness for quantum-safe migration, identify capability gaps, and prioritise actions.⁷⁴ Financial services have the guidance of the G7 framework⁷⁵ and the Bank for International Settlements.⁷⁶

Harvest now, decrypt later

Why data encrypted today is already at risk from quantum computers that do not yet exist

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Sources: NIST (2024); Babbush et al., Google Quantum AI (2026); Section 5 of this report. Timeline is schematic.

The political challenge is ensuring that PQC standards are adopted internationally, not just in the wealthy countries and blocs that produced them. Otherwise the risk is a two-tier world divided into quantum-safe and quantum-vulnerable states. This risk entails a cyber decoupling between privileged and underserved geographies in which PQC-equipped states operate in a different security environment from those still running vulnerable cryptography.

⁷² Ryan Babbush et al., Securing Elliptic Curve Cryptocurrencies against Quantum Vulnerabilities: Resource Estimates and Mitigations, Google Quantum AI (2026), <https://quantumai.google/static/site-assets/downloads/cryptocurrency-whitepaper.pdf>.

⁷³ NIST Releases First 3 Finalized Post-Quantum Encryption Standards, NIST.gov (2024), <https://www.nist.gov/news-events/news/2024/08/nist-releases-first-3-finalized-post-quantum-encryption-standards>.

⁷⁴ <https://www.csa.gov.sg/resources/publications/quantum-safe-handbook-and-quantum-readiness-index/>

⁷⁵ Advancing a Coordinated Roadmap for the Transition to Post-Quantum Cryptography in the Financial Sector, Gov.uk (2026), <https://www.gov.uk/government/publications/advancing-a-coordinated-roadmap-for-the-transition-to-post-quantum-cryptography-in-the-financial-sector/g7-cyber-expert-group-statement-on-advancing-a-coordinated-roadmap-for-the-transition-to-post-quantum-cryptography-in-the-financial-sector-january-20>.

⁷⁶ BIS Innovation Hub, Quantum-proofing payment systems, bis.org (2025), <https://www.bis.org/publ/othp107.pdf>.

These are genuine achievements. However, a further misconception compounds the difficulty. Because standards have been published and the technical community has converged on solutions, there is a widespread belief that the problem is effectively solved. It is not. **Publishing the standard is the starting point. Migration at the scale required across all of the global digital infrastructure is a task measured in years.** That means sorting potential vulnerabilities by risk and rolling out quantum-safe measures carefully to avoid accidentally creating fresh loopholes. Crucially, it also requires strict regulatory mandates that most governments have not yet issued. Regulators for some of the sectors that most need to act, including energy, healthcare and high-value manufacturing, have yet to make quantum-safe migration a compliance obligation.

The number of keys that need to be replaced across all digital infrastructure is effectively uncountable. Changing every cryptographic key in an enterprise, and then doing this across governments, regulated industries and critical infrastructure globally, is a management problem of unprecedented scale. In other words, **the technical solution exists, but the organisational, regulatory and policy frameworks to deliver it at speed do not.** The situation is made more urgent by the “harvest now, decrypt later” dynamic: adversaries are collecting encrypted data today with the intention of decrypting it when quantum computers are available. Data encrypted now but required to remain confidential for decades, such as healthcare records or classified government communications, faces a vulnerability that cannot be deferred. The problem is present even if the quantum computer that will exploit it is not.

Although not a direct solution to the threat of Shor’s algorithm, the cryptographic technique known as quantum key distribution (QKD) offers a promising route to provably secure communication in certain circumstances. QKD uses the quantum properties of entities such as photons (which can be transmitted through fibres or via orbiting satellites) to expose any eavesdropping on the distribution of cryptographic keys. Any interception attempt necessarily alters the quantum states being transmitted, making it instantly detectable. The technology is currently deployed at scale in China, which has built a quantum communication network exceeding ten thousand kilometres,⁷⁷ and launched satellite-based quantum communication capabilities now being extended to a third generation.⁷⁸ The European Union is developing EuroQCI, a quantum communication infrastructure connecting member states with plans for operation at security levels appropriate for sensitive government communications.⁷⁹

⁷⁷ Marin Ivezić, China’s Quantum Networking and QKD, *postquantum.com* (2026), <https://postquantum.com/china-quantum-ambition/china-quantum-networking-qkd/>.

⁷⁸ Matt Swayne, China Establishes Quantum-Secure Communication Links With South Africa, *thequantuminsider.com* (2025), <https://thequantuminsider.com/2025/03/14/china-established-quantum-secure-communication-links-with-south-africa/>.

⁷⁹ European Quantum Communication Infrastructure – EuroQCI, <https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci>.

National Strategy: United Kingdom

The United Kingdom has one of the world's longest-standing national quantum programmes, having launched its first dedicated effort in 2014. Its National Quantum Strategy⁸⁰ was published in 2023. Quantum is one of six frontier technologies prioritised under the UK's broader industrial strategy, which seeks to make Britain a top-three destination for technology company creation, secure its first trillion-dollar business, and lead the world in commercial research and development investment.

The most recent phase of the UK programme, launched in 2025-2026, includes five major research hubs distributed across a national network of universities, and is underpinned by the National Physical Laboratory (NPL) — the UK's centre for metrology and standards. The ecosystem spans the full quantum technology stack, including multiple qubit modalities, and an expanding community of end-users.

The centrepiece of the new phase is a £2 billion package of support for the quantum sector, anchored by a flagship government procurement programme known as "ProQure".⁸¹ This programme is designed to create the clear market opportunity that policymakers have identified as the primary barrier to private investment. The first phase focuses on testing, evaluation and benchmarking; the second phase aims to bootstrap the development of computers capable of million-qubit operations with large government contracts conditional on milestone achievements and engagement from healthcare, energy and defence departments as end-users. The programme is explicitly customer-led, placing real government departments as the primary customers.

The UK maintains a dual-use investment fund for quantum technologies and is actively building quantum skills and attracting international talent. The UK remains committed to multilateral cooperation, citing UNESCO's International Year of Quantum initiative — through which the UK reached over one million people — as well as engagement through the OECD, G7 and NATO. The UK recently hosted an international government-to-government summit with the Quantum Development Group on shared policy objectives.

The UK has also taken a leading role in NATO's Transatlantic Quantum Community (TQC), chairing it until May 2026. The UK's bilateral quantum cooperation with Japan has been formalised through the Hiroshima Accord, under which the two countries hold regular "2+2" economic and technology ministerial meetings, and the G-QuAT/NQCC MOU signed in October 2025.

⁸⁰ UK National quantum strategy, <https://www.gov.uk/government/publications/national-quantum-strategy>.

⁸¹ ProQure, <https://www.gov.uk/government/news/uks-quantum-leap-to-help-beat-disease-deliver-high-paid-jobs-and-strengthen-national-security-as-first-country-in-the-world-to-roll-out-quantum>.

5.3 Near-term dual-use of other quantum technologies

Two examples of applications of quantum technologies are presented below. They carry the most immediate relevance in terms of dual-use capabilities, with each one already moving towards deployment.

- **Quantum navigation.** This provides precision positioning that does not depend on satellite signals.⁸² The importance of this capability has grown rapidly because GPS jamming and spoofing have become significant issues in civil aviation and in conflict zones.⁸³ Classical inertial navigation exists as a backup but degrades in precision over time, requiring periodic resynchronisation with external references. Quantum-enhanced inertial navigation is expected to maintain much higher precision for significantly longer periods without synchronisation.⁸⁴ This could enable submarines, for example, to operate for years rather than weeks without surfacing to fix their position.⁸⁵
- **Quantum magnetometry.** A quantum magnetometer, even in its current early form, could in principle detect the magnetic signature of a submarine at ranges substantially exceeding the best classical sensors.⁸⁶ Current estimates place the detection range of optimised classical magnetometers at five to six hundred metres under realistic conditions; quantum versions could extend that to 10km.⁸⁷ Other applications of quantum magnetometry include sensing the Earth's magnetic field for navigational purposes and the ability to scan semiconductor chips for manufacturing defects or unauthorised components. A far-future scenario is provided by the theoretical possibility of placing a magnetometer against a cryptographic device to sniff out an encryption key just by measuring the computation's electromagnetic signature.⁸⁸

5.4 How should quantum security be governed?

Although the security and dual-use dimensions of quantum computing and related technologies are set to shape the geopolitics of the next decade, **the multilateral governance frameworks capable of managing them do not exist.** New governance frameworks will be required, and these must be created before the technology and the threat landscape outpace the international community's ability to respond.

Defence agencies know all of these technologies will have real operational impact, which is why they have funded many of them for decades. The first quantum communication experiments and many foundational discoveries in algorithm design for quantum computers were funded by defence and intelligence agencies. Military funding shaped the early trajectory of the technology, and defence interests remain deeply embedded in the quantum innovation ecosystem. Indeed, several countries' national quantum programmes rely on funding from defence ministries. This is a structural feature that governance frameworks must accommodate rather than deny; the challenge is not to separate military from civilian development, but to manage the consequences of their entanglement from within coherent policy frameworks.

The governance conversation should ask how to build frameworks that account for a spectrum of uses. These need to distinguish between contexts and intentions where possible, and acknowledge where such distinctions break down. This calls for more nuanced and differentiated analysis represents a necessary evolution from earlier approaches that treat dual-use as a binary condition requiring a single policy response.

82 Li, H., Zaminpardaz, S., Kealy, A. et al. Quantum sensors for enhanced positioning and navigation: a comprehensive review. *GPS Solut* 30, 62 (2026). <https://doi.org/10.1007/s10291-026-02030-y>

83 <https://www.nato.int/en/news-and-events/articles/news/2025/05/08/nato-addresses-electromagnetic-interference-threats-to-civil-aviation-safety>

84 <https://www.tudelft.nl/over-tu-delft/strategie/vision-teams/quantum-internet/applications/quantum-enhanced-gps>

85 Marc Habel, 'Quantum Navigation for Submarine Warfare', *US Naval Institute Proceedings* (2024),

<https://www.usni.org/magazines/proceedings/2024/october/quantum-navigation-submarine-warfare>.

86 Ben Doherty, 'Billion-dollar coffins? New technology could make oceans transparent and Aukus submarines vulnerable', *Guardian.com*, 13 September 2025, <https://www.theguardian.com/australia-news/2025/sep/14/aukus-australian-submarines-vulnerable-new-technology>

87 Liam J. Coy, 'Assessing Quantum Magnetometry as an Emerging Detection Modality for Strategic Anti-Submarine Warfare', Thesis submitted to Dept of Nuclear Science and Engineering, MIT (2025), <https://hdl.handle.net/1721.1/159947>.

88 The Cyberagentur, Cybersecurity for Germany's Digital Sovereignty, <https://www.cyberagentur.de/en/>.

Perhaps the toughest question is also the most practical: where does quantum security governance belong, given that no existing multilateral institution is well designed for it? Arms control frameworks were built for weapons capable of mass destruction in recognisable categories. Nuclear, chemical and biological weapons regulation regimes reflect the physical characteristics of those weapons and the verification challenges specific to them. Quantum technologies present a different problem: it is a capability enhancer that makes existing military assets more effective, not a weapon class in its own right.

The institutions closest to this problem are operating at the edges of their mandates. The UN Institute for Disarmament Research (UNIDIR),⁸⁹ for instance, has launched a three-year Science and Technology Watchtower project⁹⁰ to monitor dual-use technology developments, including quantum. It has also organised multi-stakeholder dialogues on quantum and nuclear security. The G7 cyber expert group has begun to engage with quantum risk.⁹¹ The Stockholm International Peace Research Institute (SIPRI) has produced research on military quantum applications.⁹² These are valuable contributions, but they do not add up to a sustained multilateral governance process. In the meantime, the Wassenaar Arrangement on export controls for dual-use technologies already includes provisions that prevent the export of certain quantum technologies.⁹³ Even so, **a structured forum in which states, technical experts, defence institutions and diplomatic actors can address quantum security in an open, coordinated way does not yet exist.**

The governance conversation must also grapple with the asymmetry between countries that can protect themselves and countries that cannot. The concept of a **minimum common denominator** has emerged as a one potential organising principle: identifying the minimum requirements every country needs to meet to avoid being compromised by quantum computers, whether wielded by states or by organised crime. That minimum can then be treated as a universal right rather than a technical aspiration. This mirrors the COVID-19 experience in which establishing a shared priority objective enabled effective coordination across otherwise competing interests.

89 <https://unidir.org/>

90 UNIDIR's Science and Technology Watchtower: Monitoring Innovation for Disarmament, <https://unidir.org/unidirs-science-and-technology-watchtower-monitoring-innovation-for-disarmament/>.

91 G7 Cyber Expert Group Statement on Planning for the Opportunities and Risks of Quantum Computing, <https://assets.publishing.service.gov.uk/media/672e3a8d5437e298ae64cef8/G7-CYBER-EXPERT-GROUP-STATEMENT-PLANNING-OPPORTUNITIES-RISKS-QUANTUM-COMPUTING.pdf>.

92 An Introduction to Military Quantum Technology for Policyholders, SIPRI.org (2025), <https://www.sipri.org/publications/2025/sipri-background-papers/introduction-military-quantum-technology-policyholders>.

93 Matthew Sparkes, Multiple Nations Enact Mysterious Export Controls on Quantum Computers, [newscientist.com](https://www.newscientist.com/article/2436023-multiple-nations-enact-mysterious-export-controls-on-quantum-computers/) (2024), <https://www.newscientist.com/article/2436023-multiple-nations-enact-mysterious-export-controls-on-quantum-computers/>.

5.5 The next steps for quantum diplomacy

Several avenues emerged from the discussions that relevant actors may wish to consider:



1. Building awareness.

Technical and policy institutions are encouraged to collaborate to develop targeted awareness-raising materials designed specifically for diplomats and policymakers. The creation of relevant materials could draw on the expertise of organisations such as SIPRI and UNIDIR alongside science diplomacy bodies including GESDA and OQI. These materials would address both the dual-use landscape and the cryptographic challenge, and be clear about what is known, what is contested and what remains unknown.



2. Priority on UN agenda.

Relevant UN and multilateral bodies could move quantum security higher on their agenda, as a standing item rather than an occasional theme. The international community is invited to identify which delegations are best positioned to champion this issue and with the proper technical and institutional support. UNIDIR's ongoing work on dual-use quantum technologies and nuclear security provides a platform from which quantum could be escalated to the mainstream of disarmament and international security discussions.



3. Role of governments.

Governments and relevant international bodies can build on existing frameworks to develop shared migration timelines, prioritisation guidance and support mechanisms for countries that lack the institutional capacity to undertake migration independently, and for regulators across all critical infrastructure sectors.



4. Shared knowledge.

The international community is encouraged to explore confidence-building measures adapted from the cyber and nuclear domains for the quantum security context, the development of shared definitions for major capability milestones and clear declarations on how quantum tech will be deployed.



5. Quantum security divide.

The international community is invited to treat universal baseline quantum safety as an achievable objective and design the cooperative mechanisms, technology sharing arrangements and capacity building programmes needed to realise it.

6. Concluding Remarks: Actionable Insights for Navigating the Road Ahead in Quantum Computing

The overarching message of this report is that the window for developing effective governance for quantum technologies is still open, but it will not remain so for long. A cautionary lesson comes from artificial intelligence where governance frameworks arrived too late, remained fragmented, and failed to prevent harms that were foreseeable. Quantum technologies offer a rare opportunity to act anticipatorily rather than reactively, responding to these five foundational observations:

1) Intellectual Property requires intentional governance

Quantum IP governance is not a technical legal exercise but a human rights obligation. The field of quantum technologies currently lacks dominant patents, creating a rare and closing window to shape the IP landscape before competitive interests entrench. Four governance models — closed, control, coordination and open — offer distinct trade-offs.

2) The quantum divide is already entrenched

UNESCO's first systematic global survey of quantum access found that a third of researchers worldwide have no access to quantum technologies, and large portions of Sub-Saharan Africa, Latin America, and South-East Asia lack even a national quantum strategy. Crucially, the divide is not just between technological haves and have-nots — it separates those who will govern the quantum revolution from those who will be governed by it. Unless deliberately disrupted, this situation will harden in ways that will be difficult to reverse, echoing the unresolved digital divide that a third of the world's population still lacks internet access.

3) Energy and environment need early attention

The moment to embed energy awareness into system design is now, before fault-tolerant infrastructure is built and incentives calcify. Equitable access to quantum computing will be partly determined by access to affordable energy, making this an overlooked dimension of the quantum divide as much as an environmental concern.

4) Cryptographic migration is an urgent issue

The “harvest now, decrypt later” strategy makes quantum-safe migration an immediate priority. Sectors outside government, finance, telecoms, energy, healthcare and high-value manufacturing can still make quantum-safe compliance mandates a priority. This is the most tractable element of the security challenge.

5) Governance frameworks lag dangerously

Quantum technologies have direct military applications, some already in deployment, yet structured diplomatic forums for addressing these implications do not exist. Priority instruments for closing this gap include confidence-building measures adapted from nuclear and cyber domains.

7. Annexes

Annex I How Quantum Computing Works

Quantum computers exploit quantum mechanics: the laws of physics that govern the behaviour of matter at the tiniest of scales. Quantum mechanics defy all our intuitions about how the physical world operates. It is a world of probabilities rather than clear cause and effect, and it upends our understanding of time and space.

At the most basic level, all information in a classical computer is encoded as sequences of bits — 1s and 0s that represent flicking on and off tiny electrical switches known as “transistors”. Qubits are the quantum equivalent of bits, but because they represent quantum systems rather than simple switches, they have unusual properties that classical bits don’t share. That allows them to store and process much more information simultaneously.

The unusual properties of quantum computers stem from three main quantum effects:

Superposition

In a classical computer, bits exist as either 0s or 1s. They are like flipped coins that are either heads or tails. In a quantum computer, qubits, which are the fundamental information processing units, can exist as a complex combination of the two outcomes. Each outcome has a certain probability of being true. This state, known as superposition, can be maintained until the qubit is measured, at which point it will settle on one of the two values. Qubits in superposition are like coins spinning on their sides.⁹⁴

Entanglement

When two quantum systems are entangled, changing the state of one instantaneously changes the state of the other, no matter the distance between them. This is what Einstein called “spooky action at a distance.” Entanglement makes it possible to connect multiple qubits together so that all their fates are intertwined. The result is a single superposition of all the possible outcomes encoded in each individual qubit. Reading one of these qubits provides information about the states of the others, which means a quantum computer can process information exponentially faster than a classical one.

Interference

How qubits are linked up matters. The probabilities that govern the outcome of each qubit can interfere with those of its neighbours, amplifying or cancelling the other one out. To go from all possible outcomes to the one that is the solution to a problem, a quantum algorithm is needed that carefully choreographs a pattern of interference that leads to the correct solution. There are several options for how to arrange the qubits. The most popular model involves organising them into circuits, like in classical computers. These circuits are built from a sequence of operations on smaller subsets of qubits that together help to solve whatever problem the quantum computer has been set to take on.

⁹⁴ Amit Katwala, “Quantum Computing and Quantum Supremacy, Explained,” WIRED UK, March 5, 2020, <https://www.wired.co.uk/article/quantum-computing-explained>.

While this approach is common to most quantum computers under development today, the physical systems used to implement qubits can vary considerably. The leading modalities are:⁹⁵

- **Superconductors**
qubits encoded in electrical properties of a loop of superconducting wire.
- **Ion traps**
qubits encoded in quantum states of an ion trapped by lasers.
- **Cold atoms**
qubits encoded in quantum states of an atom trapped by lasers.
- **Silicon**
qubits encoded in quantum states of electrons in a silicon chip.
- **Photonics**
qubits encoded in quantum states of photons moving along circuits in silicon chips.

Researchers expect we will need thousands if not millions of qubits to build practical quantum computers that can solve a wide variety of useful tasks. That's partly because of the large number of qubits needed to encode bigger problems into the machine and to deal with the fragility of quantum systems, which makes qubits error prone. To get around this, quantum computers require error-correcting schemes to ensure that mistakes don't pile up too quickly and derail a computation. But to do this, up to 10,000 times as many qubits may be needed to run the error-correction code.

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⁹⁵ Boston Consulting Group (BCG), What Happens When 'If' Turns to 'When' in Quantum Computing, July 2021, <https://web-assets.bcg.com/b6/0d/adab20ab48a1a9fd0dbb6d86dae0/bcg-what-happens-when-if-turns-to-when-in-quantum-computing-jul-2021.pdf>.

Annex II The Open Quantum Institute, hosted at CERN, born at GESDA, supported by UBS

From the 40 emerging scientific topics covered by GESDA, 119 Quantum Technologies is the most advanced in the Anticipatory Situation Room (ASR) pipeline.¹²⁰ Quantum computing is identified as a technology with great transformative capability requiring a science and diplomacy mobilisation to ensure global access and benefits. The related solution idea — the Open Quantum Institute (OQI) — reached the incubation phase in 2023.

In line with GESDA's core mission, the OQI is an anticipatory instrument. We are anticipating the moment when quantum computers will be ready at scale by reflecting now on their future impact on people, society and the planet, and by acting ahead of time to create the conditions for using them in the best interests of humanity. By acting now, we enable human agency and prepare the future multilateral governance so it will be ready when the technology can be effectively deployed.

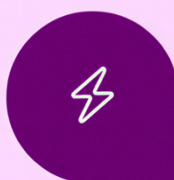
Located in Geneva, the OQI is a multilateral governance initiative, born at GESDA, hosted at CERN, and supported by UBS for its pilot phase (2024-2026). The OQI promotes global and inclusive access to quantum computing and the development of applications for the benefit of all humanity. As a novel science diplomacy instrument, it brings together stakeholders in research, diplomacy, the private sector and philanthropy.

The OQI's mission is divided into four pillars:

A1

Accelerating applications for humanity

We are exploring how quantum computing can accelerate the achievements of the United Nations' Sustainable Development Goals (SDGs), thanks to the combined forces of researchers and developers, entrepreneurs, the United Nations, and large NGOs.



A2

Access for all

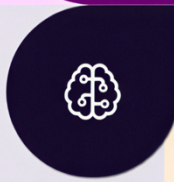
We are providing global, inclusive and equitable access to a pool of public and private quantum computers and simulators via the cloud.



A3

Advancing capacity building

We are developing educational tools to enable everyone around the world to contribute to the development of quantum computing and to make the most of the technology.



A4

Activating multilateral governance for the SDGs

We are providing a neutral forum to help shape the multilateral governance of quantum computing for the SDGs.



Annex III The Open Quantum Institute and its IP Model

The Open Quantum Institute (OQI) is a multilateral governance initiative that champions global, equitable and inclusive access to quantum computing and the development of applications for the benefit of humanity. As a novel science diplomacy instrument, it offers a neutral space for international collaboration between research, diplomacy, private sector and philanthropy stakeholders. The OQI is hosted by CERN during its pilot phase (2024-2026).⁹⁶

The focus of the OQI is on application of existing quantum methods to specific SDG-relevant challenges, rather than developing new quantum methods. This means that, although it is continuously generating IP, it is rarely patentable. The OQI, leveraging CERN's governance, has already developed an IP model for use case exploration done in collaboration with external parties. When a use case begins, the participating entities bring in a list of the relevant background IP. These entities range from universities to startups to large companies and they grant a royalty-free licence to all parties in the specific context of the project. The collaboration then develops the use case, and whatever emerges remains the property of the party that generated it. Within a project each party also grants the other a non-exclusive, royalty free, and perpetual licence to use its background IP to the extent necessary to make use of the results.

This includes processes to identify who generated which output and to make the conversation open and transparent to the outside world.

Documentation is key to this model. The history of collaborative research shows how easily competing claims arise when materials and ideas circulate only informally among research groups. Recording who contributed what, from the first day of a project, is the cheapest insurance available. On licensing, the direction of travel favours established open instruments where they fit. For software, open source licenses serve well, and creative commons licenses cover creative outputs, though ShareAlike licences⁹⁷ impose their own downstream obligations. OQI supports approaches where patented technologies can be made available through open or royalty-free licensing models. One clear rule already applies: if a piece of OQI-derived software or hardware becomes a standard, an obligation of fair sharing follows. This mirrors the FRAND licensing regimes that govern telecommunications standards.⁹⁸

Annex IV Methodology of the QDiA Conference

This report is an output of the 2026 Quantum Diplomacy in Action Conference, organised by the Geneva Science and Diplomacy Anticipator (GESDA)⁹⁹ and the Open Quantum Institute (OQI)¹⁰⁰. It brought together leaders from diplomacy, government, science, industry, and international organisations to address the challenges raised by emerging quantum technologies. This flagship event built on the dialogues with diplomats and intergovernmental organisations initiated by GESDA through its leading contribution to the OQI, and was centred around activating multilateral governance of quantum computing for the SDGs. It encouraged movement from discussion to action, in particular the development of concrete, implementable proposals. Key discussions explored national quantum strategies, security and dual-use considerations, IP and access, environmental impacts, and the quantum divide. The conference had three main objectives: to foster dialogue on quantum diplomacy by sharing national experiences, strategies and policy approaches to quantum computing; to identify priority areas for international cooperation and encourage national and collective actions to advance anticipatory and inclusive governance of quantum computing; and to co-create a knowledge base and policy insights that would inform the 2026 OQI Intelligence Report on Quantum Diplomacy in Action.

⁹⁶ About OQI, <https://open-quantum-institute.cern/who-we-are/>.

⁹⁷ Attribution-ShareAlike 4.0, [creativecommons.org, https://creativecommons.org/licenses/by-sa/4.0/deed.en](https://creativecommons.org/licenses/by-sa/4.0/deed.en).

⁹⁸ Igor Nikolic and Niccolò Galli, Patent Pools in 5G: The Principles for Facilitating Pool Licensing, Telecommunications Policy, Innovation in 5G technology: leadership, competition and policy issues, 46 (4): 102287 (2022), <https://doi.org/10.1016/j.telpol.2021.102287>.

⁹⁹ <https://www.gesda.global/>

¹⁰⁰ <https://open-quantum-institute.cern/>

