European Parliament

Future-proofing the Quantum Europe Strategy for 2040

IN-DEPTH ANALYSIS

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Quantum technologies are developing rapidly. They have extensive uses in secure communications, energy, healthcare, manufacturing, defence and security, and space, and may bring about a change of paradigm in technological capabilities. Their economic and strategic value makes them a high priority for EU strategic autonomy. The new Quantum Europe Strategy intends to establish the EU as a global leader in quantum technologies by 2030.

This paper explores the potential paths the EU can take to establish itself as a global leader in this field. To ensure that the strategy holds in a highly unpredictable world, we have conducted a foresight exercise to 'wind-tunnel' (stress-test) statements taken from the quantum strategy against the European Commission Joint Research Centre's four reference foresight scenarios.

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Executive summary

Quantum technology is emerging as a crucial arena for economic competitiveness and technological sovereignty, with the European Union striving to position itself as a global leader.

The European Commission's recently published Quantum Europe Strategy sets out the EU's key ambitions and priorities in this field. Yet despite substantial current and planned investment, the global quantum landscape presents significant challenges. These include structural issues within the Union itself, such as navigating a complex geopolitical environment, persistent barriers in funding and scaling small and medium-sized enterprises, translating cutting-edge research into industrial applications, and developing a strong talent pipeline to sustain long-term innovation.

Building a thriving quantum ecosystem in Europe will therefore require coordinated and sustained efforts to overcome the fragmentation that has often limited the EU's ability to compete with other global powers. Could quantum technology become a defining moment for Europe and transform ambition into achievement?

This foresight paper explores how the EU can secure global leadership in quantum technologies in an increasingly unpredictable world. To do so, the five main objectives from the Commission's strategy were translated into vision statements for 2040. These statements were tested against the European Commission Joint Research Centre's four 2040 reference foresight scenarios using a participatory 'wind-tunnelling' exercise with policy experts. This explores plausible developments across geopolitical, economic, social, technological and environmental dimensions. The insights from this process offer concrete policy options for policymakers to reinforce the strategy and ensure it remains resilient and future-ready.

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1. Introduction

The rapid advancement of quantum technologies (QT) is transforming a wide range of sectors, including secure communications, energy, healthcare, manufacturing, defence and security, and space, with far-reaching implications. Quantum computing, quantum simulation, quantum communication and quantum sensing and metrology are all fields of global strategic importance that yield a change of paradigm in technological capabilities. The clear economic and strategic value of quantum technologies makes them a high priority for EU strategic autonomy, as highlighted in the European Economic Security Strategy and the Commission Recommendation of 3 October 2023 identifying critical technology areas for economic security.

Against this backdrop, the new Quantum Europe Strategy intends to establish the EU as a global leader in QT by 2030. Similarly, it aims to address significant challenges in a rapidly evolving quantum-powered future, including upscaling and mainstreaming investment in research and development, establishing standards and regulations,[1] and developing a skilled workforce. The EU faces significant competition from other global powers, such as the United States and China, which are also investing heavily in quantum research[2] and development, and key challenges to its competitiveness when it comes to developing a robust quantum ecosystem.[3]

While the EU can build on its tradition of excellence in quantum research, its future role in the quantum domain relies on rapidly evolving technological advancements and geopolitical dynamics, which can range from collaborative innovation to intensified competition or conflict among global powers.

What are quantum technologies?

Quantum technologies (QT) are a new generation of technology that harnesses the power of quantum mechanics to perform tasks that are either impossible to solve or highly inefficient for traditional technologies. These technologies rely on the principles of quantum mechanics to enable new functionalities, such as quantum computing, quantum communication, and quantum sensing. QT have the potential to bring about significant benefits and have a dual-use nature, meaning that they can be used for both civilian and military purposes. This raises important questions about their development, control and regulation.

Cf. EC, OECD.

Despite its significant progress in quantum technology, the EU is currently facing challenges in converting its innovative capabilities and potential into tangible market opportunities. This is further complicated by the lack of cohesion in strategies and road maps among its Member States. The Quantum Europe Strategy seeks to leverage Europe's strengths to establish the continent as a dominant force in quantum technology, by creating a robust and self-sufficient quantum ecosystem

1 Deloitte Center for Integrated Research, Quantum computing over the next five years: Scenario planning for strategic resilience, August 2025.

2 Foreign Affairs, The Race to Lead the Quantum Future, January/February 2025.

3 ECIPE policy papers, Benchmarking Quantum Technology Performance: Governments, Industry, Academia and their Role in Shaping our Technological Future, June 2025.

that promotes start-up development, accelerates the transition of scientific breakthroughs into commercial applications, maintains Europe's position in quantum research and secures its strategic autonomy.

This foresight paper aims to evaluate the quantum strategy before the European Commission submits the proposal for an EU Quantum Act in the first half of 2026.[4] Objectives for Europe's quantum future stated in the five areas covered by the strategy are 'wind-tunnelled' (stress-tested) against four distinct scenario-based contexts for 2040 to identify potential enhancements and policy options to increase resilience. This paper provides an overview of the global QT landscape and the EU's standing prior to positions taken by the European Parliament, as well as a summary of the EU quantum strategy.

2. Current landscape of QT

Many nations have now recognised the importance of QT, which may transform the way we live and work, and are therefore actively developing policies to stay competitive in the global landscape. According to the OECD,[5] QT could create entire new industries, leading to new jobs and further opportunities for economic growth, with potential applications in various sectors.[6]

Despite the vast potential of QT, experts warn that the limits of their application and technology readiness levels should also be considered. Regarding universal quantum computers,[7] for example, technological breakthroughs would be crucial for key QT applications in the aerospace, automotive, energy, finance and pharmaceutical industries, but quantum computers are still at the experimental stage.

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[4] European Commission, communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Commission work programme 2026 – Europe's Independence Moment, COM(2025)870, 21 October 2025.

[5] OECD, A Quantum Technologies Policy Primer, January 2025.

[6] S. De Luca and J. Reichert, Quantum: What is it and where does the EU stand?, EPRS, European Parliament, April 2024.

[7] Universal quantum computers can perform any quantum computation, regardless of the problem. Used to solve a wide range of problems, from simulating complex systems to factoring large numbers, they are considered the most powerful type of quantum computer.

Table 1 – Fields with existing commercial projects for quantum computing (QC)

Sector	Application	Industry collaboration examples
Aerospace	Simulate high-fidelity, optimised designs, improve aerodynamics, increase speed	Airbus (France) and IonQ (US): explore the potential application of QC for developing a prototype aircraft-loading quantum application.
Automotive	Vehicle routing and route optimisation	Classiq (Israel), Nvidia (US) and BMW Group (Germany): optimise mechatronic systems (integrating mechanical engineering, electronics, computer science and control systems) for automotive.
Energy	Enable energy distribution and storage	PsiQuantum (US) and Mitsubishi UFJ Financial Group (Japan): simulate excited states of photochromic molecules to develop efficient energy storage.
Finance	Experimental approaches in fraud detection, portfolio optimisation and accuracy in credit decision algorithms	Quantum Motion (UK) and Goldman Sachs (US): develop a quantum algorithm for improving option pricing in financial services.
Pharmaceutical	Accelerate drug discovery process and development	Japan Tobacco Inc. and D-wave (Canada): leverage QC and AI in the drug discovery process and expand the space for pharmaceutical small compounds.

Source: ECIPE. Quantum Technology: A Policy Primer for EU Policymakers,[8] January 2025.

Therefore, it is essential to recognise that QT are at different maturity levels. A closer look reveals a diverse landscape: some applications, such as quantum sensing, have already reached a high level of maturity, with some technologies like magnetometers[9] being commercially available and fully operational.

However, other areas like radar sensing and inertial navigation are still under development, with validation only taking place in controlled laboratory settings. Quantum key distribution (QKD), a secure communication method that uses quantum mechanics to distribute cryptographic keys, has been successfully tested in real-world environments. Quantum computing remains further behind, with some types, such as annealers,[10] being demonstrated in relevant environments, but universal quantum computers are still in the experimental phase.

8 ECIPE, Quantum Technology: A Policy Primer for EU Policymakers, January 2025.

9 Magnetometer: instrument for measuring the strength and sometimes the direction of magnetic fields.

10 Quantum annealer: a specific type of quantum computer, designed mainly to solve optimisation and simulation tasks. Typically used to tackle complex problems in logistics, finance and energy management, they are often used in conjunction with classical computers to improve the speed and accuracy of computations.

Table 2 – Technology readiness levels for selected QT

Quantum technology	1	2	3	4	5	6	7	8	9
Sensing (magnetometers)									■
Sensing (radar)				■					
Sensing (inertial navigation)				■					
Communication (QKD)							■		
Computing (annealer)					■				
Computing (universal)			■						

Source: OECD. A Quantum Technologies Policy Primer, Paris, January 2025. Readiness levels: 1. Basic principles observed; 2. Concept formulated; 3. Experimental proof of concept; 4. Tech validated in lab; 5. Tech validated in relevant environment; 6. Tech demonstrated in relevant environment; 7. Prototype demonstration in an operational environment; 8. System complete/qualified; 9. Proven in an operational environment.

This disparity in readiness levels underscores the complex and varied nature of quantum technology development, with different areas progressing at different rates towards practical application.

Furthermore, the OECD warns that referring to quantum networks as the 'quantum internet' is not only unhelpful but also misleading, as this comparison suggests quantum networks could surpass today's internet, whereas they are expected to complement rather than replace existing communication infrastructures. In addition, quantum networks are predicted to remain more costly than today's internet and limited in deployment scale.

Significant advancements in QT have been made by various countries, with China pioneering the development of quantum communications, particularly in the area of QKD networks. Meanwhile, the US has emerged as a leader in quantum computing, driven by substantial government support and industry investment, with companies like IBM, which developed its first quantum computer in 2019 featuring a 20-qubit capacity. Its Condor quantum processor rolled out in 2023 was the first to surpass 1 000 qubits, and it now has plans for a 100 000-qubit commercial quantum computer by 2033. Programmes in quantum sensing are also being implemented in India, South Korea and the US.

The EU is also particularly committed to research in quantum sensing, next-generation optical clocks and GPS-free systems, biomedical sensing and imaging, as well as remote sensing for environmental monitoring, resource management and surveillance. Significant progress has been made in developing a genuine quantum policy landscape. Compared to its competitors, the EU has a strong foundation in quantum research and development, boasting several world-class research institutions and a highly skilled workforce. The EU has invested heavily in QT over the past five years, but it faces significant competition from other global powers, such as the US and China, which are also investing heavily in quantum research and development (see Table 3).

The global quantum landscape is home to 441 companies as of 2025, with the EU hosting the largest share (32 %) with 141 companies. The US follows closely with around a quarter (25 %), while China accounts for a smaller but still significant 22 companies (5 %). Despite their numerical advantage, EU-based quantum companies tend to be younger and smaller than their counterparts in the US and China. In terms of company size, the EU lags behind the US and China, since only 13 % of EU-based companies are classified as large or medium-sized, compared to 29 % in the US.[11] China, meanwhile, boasts an impressive 82 % of large quantum companies, indicating a more mature and established industry presence.

The global quantum technology market is expected to experience significant growth in the coming years, with an estimated annual growth rate of 33.4 % from 2020 to 2027, reaching US$64.6 billion by 2027. Further, in a McKinsey report the global QT market is projected to reach US$106 billion by 2040. According to recent reports by Markets and Markets, Research and Markets and IDC, the market is driven by increasing investment in quantum computing, quantum communication and quantum sensing.

As the global quantum effort continues to rise, with current worldwide investment exceeding US$55.7 billion, it is essential to track the investment made by governments and private organisations. The following table provides an overview of the recent investment in QT by the EU and EU national governments and other global players.

The EU also has a strong track record in terms of patent filings, although China dominates quantum patenting activities, owning 46 % of the world patents in quantum. The US follows with a 23 % share of global patents, followed by Japan and the EU, with 6 % of quantum patents each.[12]

Another advantage of the EU is its focus on collaboration and cooperation between research institutions, industry and government. This collaborative approach has helped establish successful quantum research and development projects, such as the EU's Quantum Technologies Flagship. However, the EU also faces significant challenges in developing its quantum ecosystem, including the potential risks of quantum computing and the need for quantum-resistant cryptography[13] to prevent, for example, 'store now, decrypt later' attacks (or 'harvest' attacks, i.e. threat actors collect and store encrypted data to decrypt once they acquire decryption capabilities).

[11] Figures are subject to change and may not reflect the current situation. The definition of quantum-related patents and start-ups may also vary across different sources, such as Startup Genome, Crunchbase or the EU startup database.

[12] A. Lewis, P. Scudo, I. Cerutti, M. Travagnin, C. Marcantonini et al., Future directions for quantum technology in Europe – An analysis of policy questions, Publications Office of the EU, 2025.

[13] A. Brooksby, A. Smith, A. Hickam, M. Manda, A. Rogers, M. LaDuke, A conceptual framework for describing the future impacts of quantum sensors to national security, *Academia Quantum*, 2025/2.

Table 3 – Estimated[14] investment by main stakeholders in QT

Stakeholders	Investment (2020–2025)	Investment (2025–2030)	Sources
EU	**€1.8 billion** (Horizon 2020)	**€1 billion** (Quantum Flagship)	European Commission, Qureca for Europe
EU national governments	**€4.3 billion**	**€6.2 billion**	Qureca for Europe, national government sources
US	**US$2.5 billion**	**US$5 billion**	US National Quantum Initiative, 2025–2029
China	**US$2.2 billion**	**US$10 billion**	Qureca, MERICS, National Quantum Development Plan, 2025–2030
Japan	**US$100 million**	**US$200 million**	Qureca, Japanese Ministry of Education, Culture, Sports, Science and Technology
South Korea	**US$50 million**	**US$100 million**	Qureca, Korean Ministry of Science and ICT
India	**US$20 million**	**US$50 million**	Qureca, Indian Ministry of Science and Technology

Sources: Estimations based on European Commission, Quantum Flagship, US National Quantum Initiative, Chinese Ministry of Science and Technology, Japanese Ministry of Education, Culture, Sports, Science and Technology, Korean Ministry of Science and ICT, Indian Ministry of Science and Technology.

3. European Parliament's position on quantum

The European Parliament has been actively engaged in discussions on QT, holding several policy debates and adopting resolutions and reports focusing on the potential benefits and challenges.

The Committee on Industry, Research and Energy (ITRE) adopted an own-initiative report on European technological sovereignty and digital infrastructure. As the EU is currently heavily dependent on foreign technologies, this report presents recommendations for rapidly achieving technological sovereignty based on competitiveness and protecting strategic markets. These include prioritising capacity building in key areas of hardware, software and services, including high-performance computing, quantum computing, encryption and communication, connectivity, cloud computing, data, web and artificial intelligence ecosystems and digital libraries.

On 23 September 2025, ITRE held a public hearing on Quantum, AI and cloud – technology development and industrial capacity building in Europe to explore the current state and future of

14 Being a fast-moving environment for investment, the figures in this table are merely to demonstrate the enormous amounts needed to advance the technology and illustrate some proportions. Amounts are subject to change and may not add up or be comprehensive: the EU's Quantum Flagship is a 10-year programme with a budget of €1 billion; the US National Quantum Initiative is a 5-year programme with a total budget of US$5 billion; China's National Quantum Development Plan is a 5-year plan with an estimated investment of US$10 billion.

QT, AI and cloud computing in Europe, consider practical solutions to support the European digital ecosystem and examine the potential impact of these technologies on European industry.

In its resolution on quantum and artificial intelligence of 22 October 2020 based on the report by the Special Committee on Artificial Intelligence in a Digital Age, Parliament emphasised the importance of investing in quantum research and development, and called for a comprehensive quantum ecosystem that includes the development of standards and regulations and the creation of a skilled workforce. The European Parliament has also been actively engaged in discussions on the ethical and security implications of QT and has called for the EU to proactively address these challenges.

For more than a decade, the European Parliament's Panel for the Future of Science and Technology (STOA) has carried out technology assessment projects and held high-level discussions on quantum as an emerging technology. Since 2015 there have been many activities on QT, and the EPRS Members' Research Service has also regularly provided updates on this topic.

Overall, the European Parliament is contributing to shaping the EU's quantum policy landscape and has emphasised the need for a comprehensive and collaborative approach to developing QT. A Commission proposal for a European Quantum Act is expected in the second quarter of 2026.

4. Quantum Europe Strategy

The European Commission's Quantum Europe Strategy published in July 2025 outlines the EU's vision for becoming a global leader in QT by 2030. It aims to strengthen the EU's quantum ecosystem, fuel innovation and start-up growth, and enhance competitiveness and technological sovereignty. The strategy is built on five pillars:

- **Research and innovation:** Continue supporting cutting-edge research and development in QT; align EU and national research agendas to maximise synergy and accelerate the innovation lifecycle.
- **Quantum infrastructure:** Develop and connect quantum infrastructures across Europe such as the European quantum communications infrastructure (EuroQCI).
- **Strengthening the quantum ecosystem:** Foster growth by helping start-ups translate innovations into market-ready applications, attract talent and foster a vibrant industrial ecosystem.
- **Space and dual-use technologies:** Focus on the applications of quantum technology in space and for defence and security purposes such as quantum-encrypted communications and GNSS-free navigation.
- **Quantum skills:** Invest in developing the necessary workforce for the quantum industry, including education and training programmes; attract and retain top talent, and create a framework for talent mobility.

This strategy is designed as an evolving framework to guide the EU's quantum future. It comprises a two-level governance framework (for a balanced and effective approach to governing QT, allowing for both European-level coordination and national-level flexibility and autonomy) and international cooperation with like-minded countries, supported by establishing a European quantum international cooperation framework. It contains initiatives such as a European quantum computing and simulation road map and a Quantum Skills Academy. The Commission notes that the EU is currently lagging in translating innovation into real market opportunities but has the potential to become a global leader in QT with the right strategy and investment. The strategy requires collective commitment of the EU, Member States, industry, academia and civil society to achieve its goals. A proposal for a European Quantum Act to provide a legal framework for the strategy is expected in 2026.

Most think-tanks and experts have praised the strategy's ambition and scope. The European Policy Centre (EPC) has noted that the strategy provides a clear and comprehensive framework for the development of QT in Europe. The Centre for European Policy Studies (CEPS) has also praised the strategy, highlighting its focus on the development of a robust and competitive quantum industry. However, other analysts have highlighted that the current funding levels are insufficient to support the strategy's ambitions. Overall, the Quantum Europe Strategy has been widely welcomed as a significant step forward. Nevertheless, its success will depend on the availability of sufficient funding and resources, the effective implementation of its initiatives and measures, and how far it will stand the test of time and be future-proofed against external threats.

5. The foresight methodology

5.1. Approach

To test how future-proof the Quantum Europe Strategy is, we have distilled its five areas (research and innovation; quantum infrastructures; strengthening the EU quantum ecosystem; space and dual-use quantum technologies; and quantum skills) into five statements for 2040. The statements capture the European Commission's ambitions and objectives for each area, striking a balance between aspiration and practicality. Subsequently, we 'wind-tunnelled' them against the European Commission Joint Research Centre's four reference foresight scenarios developed in 2023 for 2040. These reference scenarios allowed us to assess the validity and strength of the strategy across a wide range of conditions. Independent plausible futures can help reveal gaps, weaknesses and blind spots, and shed light on the uncertainties that may arise between now and 2040.

The four scenarios (**storms**, **end game**, **struggling synergies** and **opposing views**) take a holistic view of the EU's future, examining the full range of STEEP (social, technological, economic, environmental and political) dimensions and addressing key uncertainties such as shifts in geopolitical power, environmental degradation, the interconnections between food, water, health and energy, and technological innovation, a crucial aspect when discussing an emerging technology such as quantum. In September 2025, we brought together ten experts from the European Parliament for a participatory foresight workshop. Ahead of the workshop, the participants were provided with adapted, shorter versions of the scenarios that highlighted the most relevant aspects to the quantum strategy, including technology, innovation and geopolitical shifts. We complemented those with four, brief narratives indicating plausible futures for QT in 2040, based on current trends and uncertainties.

Table 4 – Summary of the JRC reference scenarios adapted to QT[15]

Storms A world in turmoil, defined by scarcity and hostility. Global powers form opposing blocks, with wealthier nations exploiting weaker ones. Strategic autonomy is the name of the game. Military strength helps secure influence, and local wars erupt over resources. Innovation is stifled without global collaboration, but investment in security and defence are at an all-time high. Unaddressed, climate change ravages the planet, causing frequent extreme weather events. The development and roll-out of QT is hindered by a lack of global standards and interoperability. Heavy military investment has delivered results in quantum sensing to ensure national security. China's lead in this sector has forced the other regional powers to try to mitigate the risks of quantum-powered cyber-attacks and data breaches, such as by developing more patents or acquiring technologies through industrial espionage.
End game Economic growth trumps social equality, fuelling conflicts and cyber-attacks. Automation replaces jobs, and private interests hold sway over governments. The planet pays the price, with climate change spiralling out of control and global warming reaching catastrophic levels. The pursuit of profit and power is the sole driving force behind innovation. The escalating threat of (cyber) conflicts has accelerated the development of QT, which have become crucial for ensuring the integrity of critical infrastructures. Public-private partnerships have driven the development of dual-use QT, such as quantum sensing, and the integration of quantum computing with artificial intelligence and supercomputing. Weak political institutions have allowed private corporations to reap all the benefits.
Struggling synergies The world is united against climate change, and other aspects of sustainability are not priorities. Cooperation and competition coexist, as nations strive for a greener future with investment in zero-carbon technologies and renewable energy. Global cooperation leads to breakthroughs in fields like artificial intelligence and biotechnology. Challenges persist, including rising social inequalities and conflicts between personal interests and collective values. Quantum technology has become crucial in the global fight against climate change. However, the EU lags behind superpowers like the US and China, hindered by an onerous welfare state that diverts investment, and an increasing brain drain. The prioritisation of low- or zero-carbon QT has led to a slowdown in the development of more resource-intensive quantum applications.
Opposing views Two alliances clash: one prioritising social equality and sustainability, the other pursuing economic growth above all. The regenerative alliance leads in green tech, promoting circular economies and renewable energy. In contrast, the growth-driven alliance focuses on profit, threatening the planet's future with unsustainable practices and environmental degradation. Quantum technology has become a key battleground for the two alliances competing for supremacy. Both have invested in quantum valleys to drive innovation and reduce reliance on external technologies, boosting their own economic resilience. The EU leads the regenerative alliance's efforts to control Arctic quantum communication nodes, seeking geopolitical leverage in secure communications and data sovereignty.

[15] L. Vesnic-Alujevi, S. Muench, E. Stoermer, Reference foresight scenarios on the global standing of EU in 2040, Publications Office of the EU, 2023.

During the workshop, participants engaged in a wind-tunnelling exercise to test the chosen statements against the four scenarios. This paper combines the main insights from the workshop, along with additional research and analysis. In the following sections, we analyse each statement in more detail, exploring the most relevant trends and signals, and discuss how plausible each statement is within each scenario. The Joint Research Centre's reference foresight scenarios were complemented with plausible futures for quantum developed by the authors.

Table 5 – Key characteristics of scenarios most relevant to the Quantum Europe Strategy

	Storms	End game	Struggling synergies	Opposing views
How does Europe function?	EU Member States are functioning democracies. The conservative elderly dominate the political agenda. Disillusioned youth retreated from politics. Internal tensions.	Private corporations dominate, weakened public institutions. Low levels of taxation. The EU is united in protecting its borders. Multi-tier Europe.	The EU is a slow-moving bureaucracy. Regional representatives form a separate chamber in the EP. Governments regulate and monitor environmental performance. Parts of society feel left out by experts and believe in conspiracies.	Green transition has become the compass for EU policy-making. Governments invest heavily in R&D and state-owned technology providers. Governments are responsible for societal equality and redistribution of wealth.
What is the situation of Europe's institutional memberships?	EU expansion in the Balkans, initially contingent on strict control on movement. Decisions are taken by majority.	Some countries enter, some exit the EU. Two-phase membership leads to inner and outer circles of Member States. New community of associated countries align on energy, transport and infrastructure.	EU becomes a looser union as multilateral institutions gain importance. Two south Mediterranean countries leave the EU. The European Economic Area expands.	Some north African countries align with the EU through a southern energy hub. The European Economic Area is open to countries that align with the regenerative alliance.
What technologies are predominant?	Reduction in dependencies (circular economy, new materials). Splinternet. Climate adaptation. Defence. Diversity of national standards and limitations of export opportunities between blocs.	New disruptive technology is stimulated. Biomedicine and human enhancement. Space technologies. Industry 7.0: Virtualisation. Synthetic foods and GMOs.	More mission-oriented innovation. Climate mitigation technologies. Environmental monitoring. Carbon farming (in a global market). Low-cost care for the elderly.	Defence/dual-use technologies. The direction of innovation is different between regenerative and growth-driven alliances. Regenerative alliance: climate mitigation, circular economy. Growth-driven alliance: GMOs and biomedicine.

Source: Authors' work based on the reference foresight scenarios on the global standing of the EU in 2040.

5.2. 'Wind-tunnelling' the strategy statements

Overall assessment

Workshop participants generally agreed that the Quantum Europe Strategy was an ambitious vision for the development of QT in the EU, aiming to establish the region as a global leader. The strategy comprehensively addresses the most critical aspects of quantum, including present challenges and roadblocks. However, its nature as an 'evolving framework' rather than a structured plan with clear, articulated actions may limit its impact. The strategy's success hinges on the commitment of multiple parties, including internal stakeholders (e.g. Member States) and external ones (e.g. industry, academia and global powers). The engagement of diverse stakeholders expands the scope of parties influenced by shifting contextual and transactional uncertainties and competing priorities, potentially undermining the strategy's overall impact and effectiveness.

The overall assessment of the statements across the four scenarios shows that they are more plausible in scenarios characterised by high geopolitical competition and a strong focus on security and defence (**opposing views** and to some extent, **storms**), and high economic growth driven by innovation (**end game**). In contrast, scenarios that prioritise green technologies and international cooperation (**struggling synergies**) pose challenges to the statements' feasibility. The aim of this foresight exercise is to enable more informed decision-making in the face of uncertainty by making the strategy more relevant and resilient across multiple plausible futures.

The following table provides a summary of the evaluation of the statements by participants.

Table 6 – Overview of quantitative assessment of statements within scenarios

World in 2040/ vision statements	Storms	End game	Struggling synergies	Opposing views
1. Research and innovation	Plausible	Plausible	Neutral	Plausible
2. Quantum infrastructures	Plausible	Neutral	Not plausible	Very plausible
3. Strengthening the EU quantum ecosystem	Not plausible	Neutral	Not plausible	Very plausible
4. Space and dual-use	Very plausible	Very plausible	Neutral	Very plausible
5. Quantum skills	Not plausible	Neutral	Not plausible	Plausible

Research and innovation

Statement 1: The EU has bridged the gap between quantum research and industry deployment, and most EU-funded quantum research projects now have tangible applications in sectors like healthcare, logistics and cybersecurity. There is a strong focus on collaboration between academia, industry and research institutions.

The workshop participants identified a strong correlation between the EU's ability to bridge the gap between quantum research and industry deployment and the level of geopolitical competition, which in turn drives state-led initiatives crucial for foundational research and technological development. In scenarios characterised by intense geopolitical competition, such as **storms** and **opposing views**, where autonomy and security are paramount, it is plausible that the statement would perform exceptionally well.

The EU's prioritisation of security and defence, accompanied by investment in quantum technology to secure critical infrastructure with quantum-based communication protocols and quantum sensing, is expected to yield breakthroughs that will trickle down to other sectors of the economy, facilitating scientific advances in real-world applications and impact. However, the lack of knowledge sharing between blocs and alliances in these scenarios may hinder the development of QT and their interoperability, highlighting the need for stronger collaboration between like-minded powers.

In **end game**, the EU's investment in post-quantum cryptography, along with private and public partnerships enhanced by heavy deregulation, make this statement plausible. This push from the EU could, in fact, drive innovation in quantum dual technologies, such as the integration of quantum computing with artificial intelligence and supercomputing. However, participants raised concerns about the potential dominance of external players, such as private tech moguls, who could outpace EU-led efforts and reap the benefits of innovation without sharing breakthroughs with the rest of the EU industry ecosystem, potentially acting like a monopoly.

In contrast, the **struggling synergies** scenario presents a mixed picture. The EU's slow and careful approach to multilateral discussions may lead to increased collaboration between governments, academia and research organisations, driving foundational research and technological development. However, there were concerns that limited investment in quantum technology (unless directly related to climate change purposes or low-carbon technologies) may hinder scientific advances and render the statement's performance uncertain in this scenario.

Quantum infrastructures

Statement 2: The European quantum communication infrastructure (EuroQCI) initiative has expanded to cover almost all the EU's territory, providing secure quantum communication services to all critical infrastructures, governments and a significant portion of the population. There is a strong focus on trusted EU-controlled components and interoperability to enhance technological independence and security.

Public quantum infrastructures should underpin Europe's innovative landscape and be a network that seamlessly connects computing and simulation, communications and sensing capabilities. These are essential to realising Europe's quantum ambitions, stimulating development and accelerating uptake. However, due to the high development and access costs and technical complexity, these infrastructures require significant public investment, which can be justified only if there is strong political unity and a societal push towards security and technological independence. The creation of public quantum infrastructures is therefore contingent upon a shared sense of purpose and urgency among European stakeholders.

In scenarios such as **storms,** characterised by high security concerns and self-sufficiency, it is plausible that the need for autonomy and security would drive secure quantum sensing and communication infrastructure development. However, a politically tumultuous Europe risks ceding leadership in this area to other powers within its bloc, relegating the EU to a customer rather than a driver of these technologies.

Similarly, in the **end game** scenario, it is plausible that the statement would perform well from a (cyber)security angle, with public-private partnerships investing heavily in the military sector. However, the power of deregulated tech companies may hinder the creation of public quantum testbeds if they seek to concentrate technical and human expertise in their own hands, diminishing the EU's ability to implement a strategy for a quantum continent to benefit all.

In contrast, the EU's lead role in the regenerative alliance in **opposing views**, where QT are seen as crucial for gaining geopolitical leverage, would enable the EU to emerge as a quantum leader and champion. The EU's efforts to control its quantum communication nodes and secure communications and data sovereignty makes this statement highly plausible, assuming a strong sense of unity between governments and citizens, thanks to high standards of living and shared values.

In the **struggling synergies** scenario, which depicts the EU as a slow-moving bureaucracy affected by brain drain, the statement is not plausible. Sustaining a comprehensive welfare state and advancing green technologies mean that the EU would not be expected to prioritise investment in QT. The low level of geopolitical competition in this scenario fails to create a sense of urgency around security and autonomy investment, relegating QT to an ancillary role in the fight against climate change, if even deemed useful at all.

Strengthening the EU quantum ecosystem

Statement 3: The EU has established a self-sustaining quantum industry by manufacturing low-cost quantum chips at scale. Thanks to a Europe-wide, centralised network of open-access quantum testbeds, easy access to scale-up capital and high industrial demand, EU-based companies now hold a significant share of the global quantum market.

The statement represents a highly ambitious goal of the European quantum strategy outlined by the Commission. The EU quantum ecosystem is currently fragile and comprised of small start-ups, with Europe attracting only 5 % of global private quantum funding, compared to over 50 % captured by the US. Reversing this trend will be extremely challenging.

This is reflected in the assessment of the statement's plausibility, which is not optimistic. In scenarios like **storms**, for instance, the EU may struggle to catch up with major players in chip manufacturing, such as China and the US, due to strong bloc division and limited sharing of technology and knowledge. Similarly, in **struggling synergies**, it is plausible that the EU remains dependent on other powers for technologies and expertise, as these powers are better positioned to attract top talent and maintain an edge in the development and deployment of QT.

In **end game**, where Member States are drifting towards nationalism and private corporations hold significant influence, it is hard to imagine almost any of the initiatives underpinning this statement, such as expanding quantum competence clusters (QCCs), coming to fruition. Furthermore, improving structural issues in the EU quantum ecosystem, such as the absence of large-scale quantum hardware providers and anchor end-users, seems implausible, due to potential disagreements among Member States over a unified EU quantum agenda. Nevertheless, the scenario's emphasis on deregulation and private sector-driven innovation could create opportunities for increased scale-up capital and investment in QT, prompting governments to prioritise intellectual property (IP) protection mechanisms to safeguard EU know-how.

In contrast, the **opposing views** scenario, where established quantum valleys drive innovation to reduce reliance on external technologies and boost resilience, suggests a strong impetus by EU leadership to drive quantum development and industrial deployment. Under these conditions, the statement appears very plausible, with the EU addressing its structural deficiencies in the quantum ecosystem, such as unstable revenue streams and lack of critical supply chains.

Space and dual-use QT (security and defence)

Statement 4: The EU has integrated quantum innovations into its security and defence, launching a network of quantum-enabled satellites for secure communication, navigation and Earth observation services. It has also developed a range of dual-use QT, including quantum sensing and quantum computing.

The dual-use potential of QT can enhance both Europe's competitiveness and its strategic autonomy in space, security and defence. EU initiatives in this area aim to ensure that QT remain accessible, secure and free from third-country export regulations, while aligning with broad European security goals. This makes the statement highly relevant in an era of intensified power competition and unpredictability.

In scenarios like **storms** and **opposing views**, where division and competition among blocs and alliances are intensifying, QT become critical for securing information and critical infrastructure, as well as transforming defence strategies through breakthroughs in satellite navigation, intelligence and surveillance. Initiatives like NATO's Transatlantic Quantum Community, and the ongoing competition between the US and China for the development of military applications of QT could potentially escalate in these scenarios. As a result, the statement is considered highly plausible, as the push to lead in dual-use QT is expected to intensify, with blocs sharing the burden of investment. However, it is uncertain if innovations in civil QT will trickle down to security and defence sectors. Similarly, the emphasis on military and defence applications might fail to contribute to the growth of a robust civil quantum technology sector, which is a central objective of the Quantum Europe Strategy.

In contrast, it is plausible that, in **end game**, significant investment from public-private partnerships would create cutting-edge companies to help defence actors reinforce Europe's technological edge in capabilities with dual-use potential. However, it is essential to ensure that the technologies developed in this scenario would only be accessible to public defence actors, and not third parties or countries not aligned with EU defence priorities, which may clash with private actors seeking to capitalise on the innovations.

The plausibility of the statement is hindered in the **struggling synergies** scenario due to a lack of focus on security and defence, as well as the slow pace of the EU as a political actor preoccupied with addressing climate change and developing low- or zero-carbon technologies. This limited investment and attention to dual-use QT poses a significant impediment to their development, making the statement less plausible in this scenario.

Quantum skills

Statement 5: The European Quantum Skills Academy has trained thousands of quantum professionals, with a balanced representation of men and women, and has established strong partnerships with industry, ensuring a steady supply of skilled workforce for the EU's quantum ecosystem. Through its generous fellowship schemes, it attracts talent from inside and outside of the EU.

The development of a qualified workforce to support QT is a significant challenge for the sector, as few individuals possess the necessary theoretical knowledge and practical expertise required. Despite the EU's strength in academic quantum programmes and talent, the region suffers from a shortage of skilled professionals who can meet the demands of its growing quantum industry. The planned European Quantum Skills Digital Academy may help close this gap to increase public awareness and engagement with QT, offer practical training, and attract and retain talent.

Overall, workshop participants found this statement to be one of the weakest across the four scenarios, citing various issues to its successful implementation. In the **storms** scenario, the division between blocs, poor scientist mobility and exchange of knowledge, and limited investment in quantum beyond the military sector are expected to hinder the EU's ability to attract outside talent. It is also plausible that its internal turmoil will make it less attractive to top talent, potentially leading to brain drain in favour of other powers in its bloc. Furthermore, the need for security clearance to handle certain types of sensitive information, particularly for individuals with dual citizenship, might pose a regulatory problem among Member States that the EU would have to swiftly address.

In the **end game** scenario, the statement seems only partially achievable. On one hand, the European Quantum Skills Academy could be helped to engage more people in quantum and develop a qualified workforce by having a competitive market of well-funded companies investing heavily in advanced QT. On the other hand, competition among Member States and companies could lead to the creation of 'bubbles' or 'silos,' hindering the free movement of talent and the larger purpose of the EU quantum strategy.

In the **struggling synergies** scenario, the statement is both less relevant and implausible, as the EU is not seen as capable of winning the 'brain war' with the US and China due to competitive incentives. Additionally, quantum plays only a supporting role in the climate change dimension, thus reducing the need for a highly qualified and large workforce.

In contrast, **opposing views** provides the most favourable setting for the statement, highlighting the EU's high quality of life and various freedoms in comparison to competing superpowers. In this scenario, it is very plausible that an initiative like the European quantum talent mobility programme could succeed in attracting international talent and retaining locally qualified staff. Additionally, a quantum-friendly agenda in the EU with thriving 'quantum valleys' may help boost the academy's efforts to train and find employment for talent from academia.

Finally, participants noted that there was not enough detail in the strategy and scenarios to judge the feasibility of creating gender equality in the quantum workforce.

6. Policy options

Foresight enables strategies to withstand a broad range of future challenges and disruptions. In addition to wind-tunnelling the European quantum strategy across four distinct 2040 scenarios, workshop experts identified a set of policy options that could enhance the strategy's resilience and coherence across its five key priority areas.[16]

Research and innovation

Knowledge sharing and collaboration: To safeguard EU ownership of quantum innovations and prevent the outflow of intellectual assets and talent to external actors, such as private corporations or competing global powers, as seen in **storms**, **opposing views** and **end game**, the European Commission could reinforce intellectual property frameworks. Complementing this with stronger open innovation mechanisms would reduce competition among Member States (**end game**) and promote a unified European quantum strategy. As part of the **quantum Europe research and innovation initiative** in the strategy, policymakers could consider supporting collaborative projects and establishing European innovation hubs that facilitate cross-border partnerships. Strengthening intellectual property protection mechanisms could be particularly effective in ensuring that intellectual assets benefit the broader EU ecosystem and remain within Union borders.

Strategic alliances: To reduce isolation risks amid geopolitical tensions (**storms** and **opposing views**) and echo the strategy's 'international cooperation' goal, the EU should deepen alliances with existing tech and trade partners to share knowledge and ensure QT interoperability. The **European quantum standards road map** announced in the strategy is a great step in this direction.

Quantum infrastructures

Public-private partnerships: In **struggling synergies**, weak geopolitical tensions could reduce the national focus on security and defence and related quantum technology investment underpinning the **EuroQCI initiative**. To encourage private sector participation, targeted tax incentives and well-structured public-private partnership frameworks could balance risks and rewards and leverage private sector agility and innovation.

Strengthening the EU quantum ecosystem

Diverse funding mechanisms: Due to the fragile state of the EU quantum ecosystem, introducing diverse funding mechanisms, as outlined in the strategy, is advisable. Across the **storms** and **struggling synergies** scenarios, funding disparities emerge as a key challenge. Programmes such as the **Scale-Up Europe Fund**, targeted measures to stimulate equity investments by institutional investors or publicly backed private funds, and sector-specific initiatives connecting quantum start-ups with established industries represent important steps in addressing these gaps.

[16] For recommendations on particular quantum technologies (communications, computing and simulation, sensing and metrology) or on regulatory, cooperation and investment decisions, refer to: A. Lewis, P. Scudo, P, I. Cerutti, M. Travagnin, C. Marcantonini et al., Future directions for quantum technology in Europe – An analysis of policy questions, Publications Office of the EU, 2025, JRC141050, p. 83-90.

Space and dual-use quantum technologies

Integrated security strategies: Where security and defence are a priority (**storms**, **opposing views** and to some extent **end game**), it may be advantageous to develop an integrated strategy for dual-use QT. This would unify the multiple initiatives outlined and provide greater clarity, agility and well-defined goals for dual-use QT. Explicitly aligning the Commission's efforts with those of partner organisations, such as the **European Defence Agency** and **NATO**, would strengthen strategic coherence and maximise the impact of EU investment.

Civil-military technology transfer: To ensure that innovations in dual-use QT benefit both military and civilian applications, effective technology transfer pathways could be set up using spin-in initiatives that involve civil companies and academia in defence applications. This would facilitate breakthrough-sharing between sectors, mitigating the risk that military advancements overshadow civilian applications, as observed in **storms** and **opposing views**.

Security protocols: It would be beneficial **across all scenarios** to consider stringent security protocols and export controls for dual-use QT to prevent misuse and ensure strategic autonomy.

Quantum skills

Mobility and retention programmes: The **European quantum talent mobility programme** to facilitate the movement and retention of quantum professionals across the EU is crucial. Since the **storms**, **end game** and **struggling synergies** scenarios suggest current measures may be insufficient to achieve the programme's objectives, measures should be complemented with initiatives such as visa facilitation, competitive fellowship schemes and clear professional development opportunities.

Attracting international talent: The geographical scope of the initiatives to develop and attract talent in quantum fields, such as **researchers in residence in quantum technology start-ups,** could be enlarged. Combined with competitive salaries, research grants and career advancement opportunities, this could boost the EU's appeal and address workforce shortages and perceptions of limited competitiveness, as highlighted in **storms**, **end game** and **struggling synergies** scenarios.

Clearance and security protocols for dual nationality: The EU could create standardised clearance and security protocols for EU citizens with dual nationality, an issue in **all scenarios**. A harmonised framework for assessing and granting security clearances in sensitive quantum technology roles would ensure consistency and trust across the EU. Collaboration with national agencies to balance security requirements with inclusivity would help prevent barriers for skilled dual nationals.

Gender parity initiatives: **The virtual academy** outlined in the strategy is committed to enhancing diversity and closing the gender gap in Europe's quantum workforce. This still slightly nebulous ambition could be supported by concrete initiatives, such as scholarships and fellowships for women and mentorship programmes connecting early-career professionals with female leaders in the field.

The strategy will be followed by a Quantum Act proposal, expected in 2026, which further seeks to establish Europe as a global leader in quantum and secure strategic autonomy for the EU. By considering these options, policymakers can reflect on how best to make the act robust and effective in a rapidly evolving landscape, transforming the strategy's objectives into reality.

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Quantum technologies are developing rapidly. They have extensive uses in secure communications, energy, healthcare, manufacturing, defence and security, and space, and may bring about a change of paradigm in technological capabilities. Their economic and strategic value makes them a high priority for EU strategic autonomy. The new Quantum Europe Strategy intends to establish the EU as a global leader in quantum technologies by 2030.

This paper explores the potential paths the EU can take to establish itself as a global leader in this field. To ensure that the strategy holds in a highly unpredictable world, we have conducted a foresight exercise to 'wind-tunnel' (stress-test) statements taken from the quantum strategy against the European Commission Joint Research Centre's four reference foresight scenarios.

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