# Recommendations from the European Quantum Industry Consortium (QuIC) for the EU Quantum Strategy

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# 1 INTRODUCTION

Quantum technologies – encompassing quantum computing, quantum communications and quantum sensing – will revolutionise societies in the next decade. A recent market study by McKinsey & Company[1], a consultancy group, estimates the impact of these technologies by 2035 to reach €2 trillion in value across a wide basket of industry sectors, including chemicals, life sciences, finance, and mobility. Global leadership in quantum technologies (QT) will be determined over the coming decade. The ongoing race offers a once-in-many-generations opportunity for the European Union (EU) to gain global pre-eminence in this transformative sector.

The future global quantum champions are not yet known. More significant breakthroughs in quantum solutions are expected and can be delivered by incumbents and newcomers alike – much like the recent groundbreaking results by DeepSeek in the artificial intelligence (AI) world. Europe must seize the occasion to foster these future quantum champions.

Europe has important strengths in QT on which to capitalise: the EU has a deep pool of talent, leading the world in training and qualifying engineers and other professionals key to QT fields [1]; Europe is a global leader in scientific publications on QT[1], a testament to the EU's creativity and ingenuity; the EU and its Member States are united in their commitment to QT, as demonstrated by the Quantum Pact[2] and pledged funding totalling €7.5 billion[3]; Europe has one of the world's largest industrial bases with about 25% of quantum companies worldwide[4], including dominant specialist companies in several key areas of the global quantum supply chain[5], and Europe is home to ambitious continent-wide infrastructure initiatives (for example: the European Quantum Communication Infrastructure (EuroQCI), the European High-Performance Computing Joint Undertaking (EuroHPC), Chips Joint Undertaking (Chips JU)).

Challenges nevertheless abound. US companies benefit from a deeper and better integrated capital market. American quantum companies have raised about ten times the investments [4] collected by their European counterparts, leaving European quantum enterprises financially vulnerable. Although Europe is a leader in scientific output, data from 2017 – 2022 shows that Europe trails the USA and China in QT patents globally and, alarmingly, trails the USA in its own market[6].

China is also investing heavily in QT developments (though exact numbers remain opaque) and has achieved important milestones, such as the launch of the first quantum-enabled satellite[7].

For Europe to champion the quantum revolution, it must take urgent and significant actions to capitalise on its strengths and overcome existing challenges. The European Quantum Industry Consortium (QuIC) and its nearly 200 members and affiliates enthusiastically welcome the announcement of an EU Quantum Strategy and an EU Quantum Act. By leveraging Europe's heritage in quantum science and research, and the progress spearheaded by the EU Quantum Flagship since 2018, by augmenting recent development and acquisition programmes such as EuroHPC and EuroQCI, and by building on quantum pilot lines introduced in the Chips Act, Europe can position itself as a global leader in QT.

In this paper, we outline a series of recommendations that should be at the heart of the upcoming EU Quantum Strategy.

IMPORTANT NOTES

(1) Quantum Technology Monitor – April 2024, McKinsey & Company
(2) European Declaration on Quantum Technologies
(3) Quantum Initiatives Worldwide – 2025, QURECA
(4) A quantum leap in finance, European Investment Bank & European Commission (2024)
(5) Mapping Quantum Supply Chains, TNO & Quantum Delta NL
(6) A portrait of the Global Patent Landscape in Quantum Technologies, QuIC (2025)
(7) Castelvecchi, D. China's quantum satellite clears major hurdle on way to ultrasecure communications, Nature (2017)

# 2 RECOMMENDATIONS

## 2.1 'Made in Europe' Full-Stack Quantum Computer

### 2.1.1 Quantum Computing Hardware

The EU must set the clear goal of achieving homegrown analogue and gate-based fault-tolerant quantum computing (QC) capabilities by 2030.

Developing powerful quantum processing units (QPUs) for error-free operations will keep the EU at the forefront of QC technology. This involves advancing the development of qubit quality, scalability, interactions, and connectivity, as well as novel QPU architectures for analogue and gate-based QC to establish a robust, fault-tolerant QC capability within this decade.

The EU must sustain its commitment to EuroHPC by investing in standalone quantum computers, quantum emulators, and hybrid high-performance computing - QC systems (HPC - QC). The EU must also support the virtuous convergence of artificial intelligence (AI) and QC, whereby each technology generates significant gain for the other – thus accelerating Europe's progress in both realms ('AI for Quantum' and 'Quantum for AI'). Together, these efforts will enable:

- Development of innovative algorithms and hybrid solutions, driving a thriving ecosystem of use cases that propels the QC revolution across diverse industries.
- Continuous access to best-in-class quantum computers for academic and industry researchers.
- Integration of AI, HPC, and QC capabilities, including cloud services and seamless QC/HPC workflow integration. Emphasis should be placed on co-design, modularity, and interoperability.
- Improved availability of cloud-based emulators. Classical emulators are crucial for developing and testing quantum algorithms, serving as digital twins of QPUs, and for integrating with HPC.

An ideal 'Made in Europe' quantum computer would use only European-made parts. Today, the QC supply chain is already global, and many parts are sourced outside the EU. The EU should proceed to a careful review of its strengths and weaknesses across the QC value chain and take the necessary steps to ensure the resilience of its QC industry (see Section 2.5). Attention should be placed on developing scalable and cost-effective control and readout electronics, advancing cryogenic technology, creating reliable quantum interconnects, and building a robust photonics infrastructure.

To unlock the full potential of QC, it will be essential to develop scalable error correction methods. By achieving logical error rates below physical error rates, it will become possible to ensure reliable operation at unprecedented scales, enabling the widespread adoption of QT.

In light of intensifying global competition and the race for pre-eminence on grounds of national-security interests, it is essential that the EU proactively fosters cooperation with like-minded countries, including standardisation (see Section 2.7), in support of European interests.

### 2.1.2 Quantum Computing Hardware

The evolution of QC is fundamentally intertwined with the development of software that can effectively harness its computational power. Quantum computers operate on fundamentally different principles to classical computers, such as superposition, entanglement, and quantum parallelism, making traditional programming approaches inadequate for QC applications.

To unlock the full potential of QC, the EU must prioritise the development of quantum-specific software stacks, programming frameworks, and algorithmic solutions tailored for hybrid classical-quantum architectures. The current state of quantum software engineering suggests that effective adoption of QC will rely heavily on robust quantum-classical orchestration and seamless integration into HPC infrastructures.

#### THE NEED FOR QUANTUM-SPECIFIC SOFWARE AND ALGORITHM DEVELOPMENT

Most quantum applications use a hybrid approach, with QC accelerating specific tasks and classical computing handling the rest. Effective integration requires new software architectures to dynamically allocate tasks between quantum and classical processors. Developing quantum algorithms involves creating new programming paradigms, optimising techniques to minimise errors, and ensuring reliability through automated testing and error correction. These methodologies will enhance the usability of quantum algorithms and help Europe lead the emerging quantum economy.

#### LIBRARIES FOR CLASSICAL-TO-QUANTUM SOFTWARE CONVERSION

Transitioning from classical to quantum software requires dedicated libraries and middleware to translate code into quantum-compatible workflows. These solutions should provide high-level programming interfaces that support automatic decomposition of problems, integrate with industry standard programming languages, and enable dynamic benchmarking. Establishing quantum software toolchains will bridge the gap and foster innovation in Europe.

#### QUANTUM-CLASSICAL ORCHESTRATION FOR HYBRID COMPUTING

The seamless execution of hybrid quantum-classical applications requires sophisticated orchestration frameworks to distribute workloads between QPUs and classical resources. These frameworks must dynamically allocate computations, optimise communication, and leverage HPC, AI, and cloud infrastructures. Such systems are crucial for real-world deployment, where QC complements classical computing.

#### RECOMMENDATIONS FOR THE EU QUANTUM SOFTWARE STRATEGY

To establish a leading position in quantum software and algorithm development, the EU should:

- Invest in quantum-specific software frameworks that include algorithms, algorithm development tools, debugging environments, and quantum programming languages, as well as ready-to-use application libraries to increase adoption by end users.
- Support the scale-up of software to accommodate increasing qubit numbers, including characterisation, control, error correction, and compilers.
- Fund research into hybrid quantum-classical computing models that integrate QC seamlessly into existing HPC workflows.
- Develop automated tools for classical-to-quantum code translation, ensuring broader adoption by software developers.
- Enhance collaboration between academia and industry to accelerate the development of quantum application ecosystems. Create a European Quantum Software Consortium to standardize quantum software practices, benchmarks, and to create a European software stack with internationally recognized standard interfaces.

These initiatives will ensure that QC is not just a theoretical advantage but a practical tool for European industries, academia, and governments.

## 2.2 Quantum Chips

The forthcoming EU Quantum Act will play a pivotal role in advancing the industrialisation of quantum chip production, ensuring that Europe attains quantum advantage at scale. Despite lagging behind major powers in several sectors of global technology competition, Europe possesses a unique opportunity within the emerging quantum sector. Indeed, Europe has already launched Qu-Test and Qu-Pilot, a pair of open testing and experimental production initiatives; it has issued calls for stability pilot lines for quantum chips under the Chips Act, and it is home to important fabrication sites such as IMEC. The upcoming EU Quantum Act must acknowledge this competitive advantage and pursue industrial-grade quantum fabrication and testing capabilities to strengthen Europe's competitiveness in quantum chip manufacturing.

As QT advance, European leadership in developing quantum chips is vital for maintaining sovereignty, economic competitiveness, and security. The EU must strive to excel in the architectural design, fabrication, and innovative packaging of the quantum chips essential for the quantum revolution.

### RECOMMENDATIONS FOR THE EU QUANTUM CHIPS STRATEGY

To build on its competitive advantage in the emerging quantum sector, the EU should:

- Support European Quantum Foundries with new tools and the design of innovative QC chips and systems, including 'first-of-its-kind' projects (moonshot projects). The support should foster EU-wide innovation collaborations. This would stimulate both public and private investment in manufacturing, reinforce supply chain security, and cultivate a robust quantum ecosystem to enhance Europe's digital and green transitions, as well as forging its pathway to strategic autonomy.
- Incentivise semiconductor companies and specialised equipment manufacturers to invest in QT. The EU should continue to provide tax incentives, funding for collaborative R&D, and innovative procurement tenders. Encouraging public-private partnerships will help scale manufacturing and reduce dependence on non-EU fabrication facilities.
- Promote the development of intellectual property (IP) tied to quantum fabrication and testing, and stimulate IP commercialisation ('IP valorisation') in order to support wealth creation for Europe and further strengthen the ecosystem (see Section 2.8).
- Establish national and European cryogenic testing facilities to accelerate the development of cryogenic systems and electronics. These devices operate at extremely low temperatures and are essential for many quantum solutions (computing, communication, and sensing).
- Finally, advocate for global QT standards and regulatory frameworks that align with European standards development and European interests (see Section 2.7).

## 2.3 Quantum Communications and Quantum-Secure Cryptography

This chapter provides recommendations for the three areas of interest related to quantum communications and quantum-secure cryptography: post-quantum cryptography (PQC), quantum key distribution (QKD) and quantum information networks (QINs).

PQC and QKD are the two main approaches to quantum-secure cryptography, providing cryptographic solutions that resist attacks from large-scale quantum computers. Whereas PQC is software based and exploits an algorithmic approach, QKD relies on dedicated quantum hardware. The two approaches each have their own merits and can complement each other, aspects that are specifically addressed in WG4 of JTC 22[8]. There is an immediate need to encourage development and uptake for both types of systems, in anticipation of 'Harvest Now, Decrypt Later' attacks.

The purpose of QINs is to allow the interconnection of quantum devices via the exchange of qubits by exploiting entanglement swapping and quantum teleportation. Europe is a world leader in this area and should develop this advantage to dominate a potentially large and disruptive market.

### 2.3.1 Quantum Communications and Quantum-Secure Cryptography

As part of the EU Quantum Strategy, the European Commission (EC) should develop a quantum-readiness strategy for European organisations and institutions. A three-step approach is recommended. First, organisations and institutions should create an inventory of their cryptographic components. This systematic overview is essential for effective planning and execution of a quantum-secure transition. Second, European bodies should draw up a transition plan that covers automatic security checks, regular updates of digital assets, prioritisation of risks, and the use of a mix of new quantum-safe and traditional security methods.

Best practice examples could also be highlighted. Finally, these transition plans should be smoothly integrated into network development processes to ensure strong and up-to-date protection. This will streamline the transition process and ensure robust security at every stage.

### 2.3.2 Quantum Communications and Quantum-Secure Cryptography

First, it is important to facilitate tests and validation of QKD solutions developed under the EuroQCI initiative. Establishing a clear regulatory and standardisation framework for QKD will provide the necessary guidelines and support for widespread adoption. Promoting the cross-sector adoption of EuroQCI capabilities and use cases across industry and government will further enhance the integration of QKD into various sectors.

Supporting the rapid deployment of a certified QKD space segment is also critical. This will provide Europe with long-distance secure communication capabilities in a short timeframe. It will additionally enable connections to remote sites, while employing a strict minimum of trusted nodes.

An EU-wide public awareness campaign on quantum security should be launched to educate public authorities, businesses, and critical infrastructure providers about the importance of quantum-safe encryption. Developing targeted guidelines to assist organisations in assessing their quantum risk exposure and implementing appropriate mitigation strategies will also help spread awareness.

Strengthening the European QKD supply chain and industrial ecosystem is another key recommendation. Supporting European manufacturers of QKD components, such as quantum random number generation chips, photon detectors and sources, and key management systems, will reduce reliance on non-EU suppliers. Ensuring the certification of these components will further strengthen strategic autonomy for both government and industry use.

IMPORTANT NOTES

(8) CEN-CENELEC topics – Quantum Technologies, CEN-CENELEC

### 2.3.3 Quantum Information Networks Recommendations

To advance QINs, it is essential to foster research and maturation of core and enabling technologies such as quantum memories and quantum repeaters. These technologies, along with use cases and applications, interconnection technologies, and system and network software stacks, will extend the range of fibre-based (terrestrial) quantum networks. Quantum repeaters and memories not only extend the network range but also increase the repetition rate of the shared multi-photonstate. Practical large-scale demonstrations of these technologies on the ground, in fibre-based networks, and in space are necessary. This will require significant funding for technology readiness level upscaling.

Implementing operational QIN demonstrators (space and terrestrial) will help kickstart QINs, allowing for the prototyping of real long-range applications. Fostering the maturation of space-based solutions will extend the coverage of quantum networks through ground-to-satellite links and vice versa, as well as inter-satellite links. Satellite networks in quantum communications enable the distribution of quantum resources over longer distances than terrestrial networks.

Finally, it will be crucial to foster the development and qualification of laser sources, single-photon detectors, and processing electronics for space-based applications as well as use on the ground. Ensuring these components are produced in Europe will guarantee European sovereignty in this critical technology.

## 2.4 Quantum Sensing & Metrology

Quantum sensing and metrology cover a wide range of technologies with the potential to provide accuracy beyond current standard limits and introduce revolutionary sensor concepts. To enhance European leadership, it is crucial to promote the development of next-generation quantum sensors and to nurture the surrounding ecosystem that provides essential enabling technologies. Quantum sensing harbours enormous economic potential and will impact every sector, for example industry, defence, space, health, transport, energy, environment, and climate. In particular, funding and support activities should include a special focus on quantum sensors for critical applications where Europe requires sovereignty and resilience.

### 2.4.1 Quantum Sensing & Metrology

On the one hand, well-established quantum sensing technologies – such as nitrogen-vacancy centres in diamond, trapped atoms or ions for magnetometry and electric field mapping, optical clocks and frequency references, or accelerometers – require ongoing development to improve their performance and interface them with classical technologies. On the other hand, less-developed approaches, like levitated nanoparticles or optomechanical sensors, need further research investment. New ideas should be explored to expand the portfolio of available quantum sensor types. To highlight one important example, Rydberg-atom sensors as potential broadband radio frequency (RF) sensors and magnetometers are of particular interest for space and defence applications, and thus require special attention to ensure European sovereignty.

Furthermore, work to develop application-ready quantum sensors must be intensified. Practical quantum sensors must be robust, compact, and capable of ambient operation. The integration of quantum sensors with compact, chip-based electronics, embedded signal processing, laser sources, and photonic-integrated circuits enhances their applicability. Efforts should focus on improving size, weight, and power (SWaP), while lowering costs and enhancing performance. Additionally, it would be beneficial to foster integration with AI and edge computing for real-time data processing in extreme environments, as well as working on integrating quantum sensing into classical systems. Linking quantum sensors via quantum networks or combining quantum sensing with QC before conversion to analogue electrical output signals and subsequent digitisation could facilitate performance improvements and the development of new sensing concepts. Hence, the EU should support exploration of such unconventional approaches.

### 2.4.2 Industrialisation & Market Uptake

First-generation quantum sensors are already on the market or close to actual products, with many more soon to follow. Hence, the EU should support work to build a strong and diversified quantum sensor industry. The implementation of measures aiming for compatibility with established production processes will help to penetrate the sensor market. Supporting European semiconductor and photonics industries will reduce reliance on non-EU suppliers. Continuing and extending initiatives like Qu-Test, Qu-Pilot, or Chips JU, and implementing new ones that focus on identifying and testing use cases will help mature novel sensors from lab to market. The EU Quantum Strategy should support European autonomy in security-relevant quantum sensing technologies, such as optical clocks, quantum accelerometers, quantum gyroscopes, and Rydberg-atom sensors for advanced RF sensing.

Establishing EU-wide metrology and interface standards for quantum sensors will accelerate their adoption on the sensor market. Offering competitive funding, especially for start-ups and SMEs, will stimulate innovation and commercialisation. Shared EU testing facilities, such as open quantum testbeds, should be established to provide a platform for benchmarking quantum sensors and to facilitate cross-sector innovation

### 2.4.3 Infrastructure & Development

The EU is encouraged to foster a quantum sensor infrastructure that provides new capabilities and more accurate data for key sectors, such as aerospace, defence, and healthcare. Examples could include equipping future Copernicus satellites with quantum sensors to enhance climate monitoring, resource management, and disaster response, or integration of optical clocks into the Galileo Global Navigation Satellite System (GNSS) for more precise navigation and timing services. Space-based gravimeter or optical clock networks can provide new services and will also help to build a corresponding quantum sensor supply chain.

## 2.5 European Quantum Supply Chain

To ensure the competitiveness and strategic autonomy of the European QT sector, it is crucial to strengthen the European supply chain through a series of targeted actions. First and foremost, increasing both direct and indirect investments in European suppliers of key enabling technologies, materials, and manufacturing infrastructure is essential. This will bolster the EU's market position and reduce dependence on non-EU suppliers. At the same time, promoting collaborations between start-ups and established firms within the EU will accelerate technology development, which will in turn drive innovation and help bring new products to market more rapidly.

Encouraging the use of European suppliers in public procurement and EU-funded projects will provide a sustainable demand for regional suppliers and stimulate further investment in the sector. The EC should moreover support the implementation of EU standards, which will increase the interoperability of components and thus expand market opportunities for European companies. Over the longer term, it is essential to foster the creation of key European positions in global quantum supply chains, i.e. 'control points', which will increase reverse dependencies and provide geoeconomic leverage.

To gain a more in-depth understanding of QT supply chains, the EC should prepare comprehensive lists identifying dependencies on single or highly concentrated suppliers for critical components, materials, fabrication infrastructure, and software. These will help with understanding and mitigating supply chain risks, as well as to identify new market opportunities for European companies. This work can build on similar previous analyses performed by the Dutch ecosystem[9], QuIC and NATO. The EC should establish a European Quantum Supply Chain Alliance to coordinate industrial efforts, share best practices, and ensure long-term strategic planning. Such an alliance would be instrumental in aligning investment and resources across industry players and Member States. Developing mechanisms to monitor the supply chain using both EU and national data will help identify risks, opportunities, and market trends, thus enabling proactive management of the supply chain. Aligning with EU groups responsible for monitoring supply chains with shared vulnerabilities, such as those in the semiconductor, photonics, and cryogenics sectors, will facilitate a comprehensive approach.

IMPORTANT NOTES

(9) Critical Components and Market Dynamics of Quantum Sensors, Quantum Delta NL (2024)

The QT supply chain should moreover be considered in upcoming legislation adjacent to the Competitiveness Compass, such as the Advanced Materials Act, Chips JU and the Space Act, in order to allow for synergetic and effective investments in other critical sectors of the EU.

Beyond its own borders, the EU should build on existing international accords such as the Digital Partnership Agreements, trade agreements and the NATO Alliance to secure Europe's access to foreign suppliers of key enabling technologies and materials. In addition, the EU should establish new partnerships with key QT ecosystems globally and invest in programmes that will open up markets for European suppliers, in order to limit Europe's vulnerabilities and increase its overall supply chain resilience.

### 2.6 Attractive Investment Environment in Europe

Between 2023 and 2024, private investments in QT start-ups increased threefold in the USA while they decreased by 40% in Europe.

To prevent Europe from falling further behind on investments in quantum companies, an aggressive, multi-pronged strategy is needed to make European QT start-ups and scale-ups more attractive to private investors and build European champions.

The first priority is to de-risk private investments in QT start-ups and scale-ups.

For start-up funding, Europe has several deep-tech VCs investing in QT, supported by direct co-funding instruments such as the European Innovation Council (EIC) Accelerator and indirect funding mechanisms like the European Investment Fund (EIF), which invests in quantum-related VC funds. However, the EC's investment priorities continue to shift, and the budget reserved for quantum-related challenges was removed from the EIC work programme in 2025. At the same time, only a small number of deep-tech VCs in Europe are capable of leading investment rounds in QT.

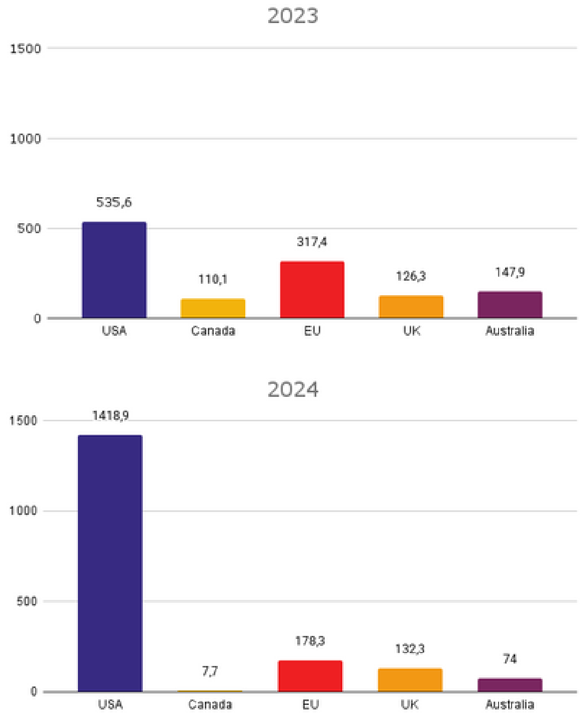


Figure: Private investments recorded by geographical area, in US$M (Source: Quantum Technologies Investment Report 2024, IOGS / Amires / Sonneberg-Harrison as part of EU-funded QU-Test & Qu-PILOT projects)

To address this, it is essential that the EC establishes a ring-fenced budget for QT within the EIC work programme challenges and encourages the European Investment Bank (EIB), which operates the EIC Fund, to lead or co-lead investment rounds in quantum start-ups, rather than merely acting as a 'follower' investor, as is currently the case.

For scale-up funding, Europe lacks VC firms capable of leading large €100M+ rounds, which forces European scale-ups to seek investors in North America or Asia. The EC has recently launched the EIC STEP Scale Up instrument, which is well-suited for QT scale-ups. However, with only €300M per year available for various deep-tech domains – not just quantum – it is unlikely that more than two or three QT scale-ups will receive funding each year. This is insufficient given the number of emerging QT champions in Europe.

Therefore, it is crucial to substantially increase the EIC Scale Up budget in 2026 and 2027, with a portion specifically earmarked for QT. Additional measures could include the creation of a dedicated quantum scale-up fund and/or a pan-European tax relief scheme for VC funds and corporate investors backing quantum ventures. Likewise, the EIB should allocate a larger budget to its high-risk venture debt compartment, which is particularly relevant for quantum scale-ups.

The second priority is to facilitate the emergence of European quantum champions and prevent their takeover by non-EU stakeholders while allowing non-EU investors to support European companies. Achieving this requires:

- Encouraging the implementation of a 28th regime providing a harmonised legal and regulatory framework across EU Member States, reducing fragmentation, and making it easier for innovative companies to scale.
- Defining clear guidelines for foreign direct investments (FDI guidelines) that attract non-EU investment while safeguarding critical technology and intellectual property.
- Protecting intangible knowledge and IP leaks to non-EU competitors in early-stage R&D programmes.
- Exempting all intra-EU cross-border investments from FDI screening.
- Strengthening coordination between the EU and its Member States to encourage and facilitate intra-EU mergers and acquisitions.
- Supporting a Europe-focused IPO framework with streamlined listing processes and reduced regulatory hurdles.
- Fostering 'quantum diplomacy' with key partners (e.g. the USA, Canada, Japan) to promote talent mobility and co-investment opportunities.
- Ensuring public procurement programmes prioritise commercialisation and early adoption of European quantum solutions.
- Positioning the EU as a global leader in sustainable quantum applications by aligning investments with climate, energy, and social-impact goals.

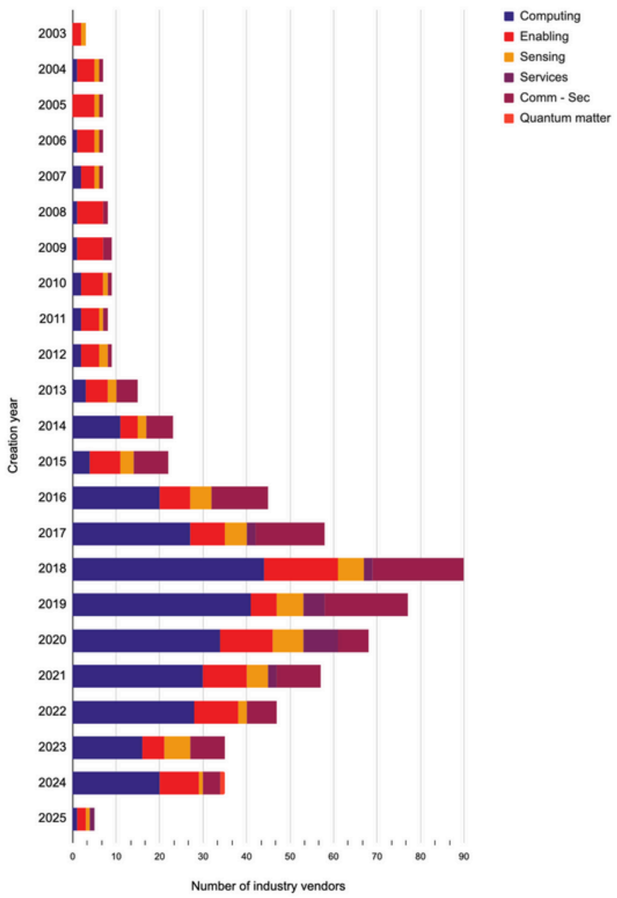


Figure: Quantum technology start-ups founded per year (SOURCE: Understanding QT 2024, Olivier Ezratty)

The third priority is to support the emergence of a 'second wave' of quantum champions, particularly in areas such as software and applications, where North America has traditionally been stronger than Europe. It is important to note that the creation of new QT start-ups has slowed considerably since peaking in 2018. Private investment has primarily focused on the 'first wave' of quantum champions, founded between 2014 and 2020.

A key initiative to support this second wave of start-ups is the creation of a network of quantum venture studios across Europe, bringing together existing initiatives in France, Italy, Germany, and Austria while encouraging similar activities in other Member States. The 'Quantum Launchpad' flagship programme in France, established as a public-private partnership with €6M in private investment and €5M in public subsidies, serves as a promising blueprint. Relevant funding calls could be issued under the third pillar of the Horizon Europe programme, within the 'European Innovation Ecosystems' initiative, to support existing venture studios or establish new ones.

## 2.7 Europe as a Leader in Quantum Technology Standards & Benchmarks

To position Europe as a leader in QT standards and benchmarks, it is essential to implement a series of strategic recommendations. The first step is to launch the Quantum Benchmarking Initiative (QBI)[10] for Europe, which will conduct a global and European evaluation of QC hardware and applications. This initiative should identify industry-driven benchmarks, using the Technical Report on QC benchmarks by Joint Technical Committee 22 (JTC 22)[11] as a starting point. The report distinguishes three categories of benchmarks:

- Hardware-oriented benchmarking: Assess the performance of quantum hardware components, such as qubits, gates, error rates, and coherence times. Compare different quantum architectures, including superconducting qubits and trapped ions, with a focus on scalability and error correction.
- Algorithm benchmarking: Develop metrics to evaluate the efficiency and scalability of quantum algorithms, such as those for optimisation and machine learning, across various hardware platforms. Emphasise resource efficiency, algorithmic complexity, and error resilience.
- Business-oriented benchmarking: Measure the real-world impact of QT in industries like finance, energy, and pharmaceuticals. Use tailored metrics to assess practical value, cost efficiency, and new business opportunities.

The EU must serve as a vector to maximise European interests in European and international JTCs dedicated to QT, specifically JTC 22 in Europe (under CEN-CENELEC) and JTC 3[12] internationally (under IEC / ISO). The EC and EU Member States should recognise JTC 22 as the body responsible for developing and maintaining the European QT roadmap, and for coordinating Europe's interaction with JTC 3

EC-funded QT projects should be required to have and execute an active standardisation strategy from the start of the project. This strategy should include a view of the project's technology supply chain beyond its lifetime, as well as active contributions to European and international standards focused on harmonising that supply chain and growing the associated European market. Funding should not be provided to projects that disconnect EU project work from standardisation efforts or duplicate coordination efforts.

To improve industry expert participation in quantum standardisation activities, the EU should continue to work with national standards bodies across EU Member States. Public dissemination of information enabling industry experts to access national standards organisations should be prioritised. Additionally, the EU and national standards organisations should jointly support and incentivise the direct participation of European industry experts in JTC 22 and JTC 3. This collaboration will foster European alignment and strengthen the promotion of European interests on the global scene.

IMPORTANT NOTES

(10) QBI: Quantum Benchmarking Initiative, Darpa (2024)
(11) CEN-CENELEC topics – Quantum Technologies, JTC 22, CEN-CENELEC
(12) IEC/ISO JTC 3 – Quantum technologies (2024)

Finally, it is important to help EU companies develop awareness of the legal and IP risks tied to foreign funding programmes.
By implementing these recommendations, Europe can establish itself as a leader in QT standards and benchmarks, ensuring a competitive and innovative QT sector (see Section 2.8).

## 2.8 Augment Europe's Intellectual Property and its Commercialisation

A recent study by QuIC shows that Europe is lagging behind other countries, notably the USA, on the international quantum IP landscape[13]. To strengthen Europe's position, the EU must prioritise the creation and commercialisation of IP ('IP valorisation') in all EU-funded quantum projects. Applicants seeking EU funding should present detailed plans on how they will generate and commercialise IP, including clear, concrete strategies for IP valorisation. These plans should also include reporting on successes during the project and strategies for post-project IP management. This approach ensures that the generation of IP is not only a goal but a measurable outcome, fostering a culture of innovation and accountability. Underpinning this strategy, project participants, including those from academia, should receive mandatory training on IP creation and valorisation.

In collaboration with EU Member States, the EU should assess and expand the commercial market use and commercialisation of quantum-related patents held by academic institutions and research and technology organisations (RTOs). By doing so, the EU can ensure that European quantum companies are well-positioned to leverage this IP, maximising the market impact of patents. This collaborative approach will bridge the gap between research and market applications, turning theoretical advances into practical, marketable solutions.

To further support this strategy, the EU should establish and enhance dedicated IP advisory services to help European businesses navigate the IP landscape and facilitate the submission of patents. This includes reviewing existing policies in partnership with knowledge transfer organisations to promote IP valorisation, recognising that the value of IP extends beyond the interests of individual RTOs. Strengthening these advisory services will provide businesses with the necessary tools and guidance to protect and capitalise on their innovations.

Finally, the EU should build on the IP advisory services already available through initiatives such as the European IP Helpdesk, through the European Patent Office, or EU consortia such as Qu-Pilot and Qu-Test. By providing a robust framework for knowledge transfer, IP management (including patents and copyright), and commercial exploitation of quantum-related innovations, the EU can ensure that Europe remains at the forefront of the quantum industry and exploit the substantial investment in this sector. This comprehensive support system will enable continuous growth and adaptation, ensuring that European innovations lead to tangible economic and societal benefits.

Finally, the EU should consider enabling funds that could be made available to projects suitable for private investment, to develop IP from a proof of concept.

IMPORTANT NOTES

(13) A portrait of the Global Patent Landscape in Quantum Technologies, QuIC (2025)

## 2.9 Strengthen Europe's Quantum Workforce

The gap between the talent pool and demand from the job market is expected to widen considerably over the coming years. The required multidisciplinary skill set includes computer science, quantum information basics, experimental quantum science, and engineering skills in electronics, photonics, and lasers, as well as business skills. To secure Europe's position in QT, short-term and long-term measures need to be directed both to industry and academia to align the competencies of both areas and to create synergies and consistent career paths.

Prioritising talent development will strengthen the EU's quantum innovation landscape. Expanding education and training programmes, starting as early as secondary education, will help sustain the EU's leadership in quantum expertise and research. Launching hands-on PhD and postdoc fellowships with academic/industry partnerships will build a skilled workforce ready for the quantum job market.

Short-term measures should also focus on equipping individuals with the skills needed to contribute to Europe's quantum development as soon as possible. The EU and its Member States should establish and promote re-skilling programmes to help professionals transition to the quantum industry. Upskilling, in the form of postdoc and exchange programmes, provides another path to the job market in QT, with RTOs playing a crucial role as facilitators.

Retention and attraction of quantum talent is of the utmost importance. Therefore, the EU and its Member States should support companies to offer competitive conditions. Fast-track work visas for talented professionals with skills adapted to quantum workforce needs could help increase the short-term availability of QT talent, potentially facilitated by a point-based system similar to those in Canada or Australia. Over the long term, the EU must focus on sustainable development of a skilled workforce, in particular by introducing students to quantum early in their school careers and facilitating specialised QT education programmes.

The three key recommendations that will ensure Europe maintains a leading position on the future quantum workforce are thus:

- Promote re-skilling: The EU and its Member States should establish and promote re-skilling programmes to help professionals transition into the quantum industry, ensuring a steady supply of qualified talent.

- Fast-track work visas: The EU should direct individual Member States to devise plans for fast-track work visas – potentially using a point-based system similar to those in Canada and Australia – to attract global talent with the skills needed for the quantum workforce.

- Retain European talent: The EU and its Member States should support companies in offering competitive conditions that attract and retain top European talent within the quantum sector.

## 2.10 European Quantum Sovereignty

As QT advances, it is becoming a crucial strategic asset. For Europe to secure its leadership and sovereignty, it must act decisively to control emerging technologies. Below are the recommended key actions for Europe to maintain its technological future.

### ALIGN EXPORT CONTROLS AND ENSURE SINGLE MARKET INTEGRATION

Harmonise dual-use export controls across Member States to prevent exploitation by non-EU actors and establish a unified regulatory framework for quantum goods. Streamline licensing processes to enable the free flow of QT within the EU, fostering innovation and reducing fragmentation.

### LAUNCH STRATEGIC DEFENVE AND R&D INVESTMENT PROGRAMMES

To secure Europe's technological sovereignty, it is essential to launch a bold, large-scale initiative akin to the Apollo Program, the Manhattan Project, or the Human Genome Project. With fault-tolerant quantum computers on the horizon, Europe must make significant investments in decade-long, high-budget programmes to establish a complete quantum ecosystem. This includes developing enabling technologies, quantum software, and the necessary infrastructure to support these advances. Initiatives like France's PROQCIMA and the US QBI projects showcase the potential for targeted investments to build critical infrastructure and could be replicated at Member State level to help grow their preparedness for QC while supporting the European ecosystem. Specifically, the French PROQCIMA programme has awarded contracts to five French QC start-ups, with a goal of creating two prototypes of universal quantum computers by 2032. The Defence Digital Agency will oversee the programme to develop prototype quantum computers, with a total budget of up to €500 million.

Other Member States could consider a similar involvement of the defence sector in a quantum strategy, as such ambitious quantum programmes will not only reduce Europe's dependence on external suppliers but will also position the EU as a global leader in quantum applications, from secure communications to defence systems. This is a unique opportunity for Europe to take the lead in the digital technologies of the future.

### COORDINATE NATIONAL QUANTUM STRATEGIES

Create a European Quantum Coordination Office to align national strategies and facilitate joint quantum R&D efforts, in line with other European Joint Undertakings. Member States should commit part of their defence budgets to quantum R&D and encourage public-private partnerships to accelerate the development of dual-use technologies.

### ASSERT EUROPE'S LEADERSHIP THROUGH QUANTUM DIPLOMACY

Spearhead international efforts to define global quantum standards, norms, and security protocols. The EU should form strategic alliances with like-minded global partners to facilitate knowledge exchange as well as to ensure its values – privacy, security, and ethical technology use – remain central in quantum policy discussions. This might include implementing systems for monitoring technology transfer and preventing unauthorised proliferation.

### SECURE THE QUANTUM SUPPLY CHAIN AND INDUSTRIAL BASE

Monitor mergers and acquisitions in the quantum sector, encourage foreign investment through a certification or approval process to ensure alignment with Europe's strategic interests. Protect QC centres and create a pan-European Quantum Procurement Programme to support domestic sourcing and strengthen the quantum industrial base.

### FAIR EU PROCUREMENT FOR QT

Streamline public tender processes to allow European start-ups and SMEs to compete on a level playing field, in order to foster innovation and reduce barriers to entry. Conduct thorough market studies in the pre-tender phase, ensuring that procurement requirements are tailored to the specific needs of each project. Prioritise excellence and potential over market share or revenue requirements. Encourage public authorities to ensure that procurement processes are transparent, efficient, and effective.

### IN SUMMARY

Europe must act now to lead in QT and secure its sovereignty. By harmonising export controls, investing in defence and R&D, aligning national strategies, leading quantum diplomacy, and securing the supply chain, Europe can secure its technological future and assert its global position in the quantum age.

## 2.11 Quantum for Environmental and Societal Benefit

Finally, the EU can serve as a global beacon in ethical and sustainable quantum development. Using 'Quantum for Good'[14] as a soft power tool, the EU can engage with global partners on sustainability-driven quantum applications, reinforcing its leadership on the global stage. In the same vein, the EU should seek strategic international alliances and cooperation with like-minded partners.

In alignment with the UN Sustainable Development Goals (SDGs), it is essential to ensure that QT are developed and deployed in ways that minimise their environmental and social impacts. This holistic approach will help achieve broader sustainability objectives while harnessing the transformative potential of QT.

### RECOMMENDATIONS

For the EU to secure its position as a global beacon at the forefront of ethical quantum development, the following measures are recommended:

### ESTABLISH A COMPREHENSIVE FRAMEWORK

The EU should foster the creation of adaptable frameworks to guide the development, export, and transfer of QT with a focus on responsible innovation. This involves advocating for EU-wide policies that integrate quantum governance with broader sustainability and responsible technology frameworks. By encouraging partnerships between policymakers, industry, and academia, it will be possible to co-create governance models for quantum applications that are both transparent and inclusive. Open-access initiatives, citizen engagement, and equitable access to quantum-powered solutions are essential for promoting transparency and inclusivity.

### ENSURE ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability is another critical area where QT can make a significant impact. Supporting research into energy-efficient and resource-efficient QC and quantum materials can help reduce the environmental footprint of information and communication technology infrastructure. Prioritising applications in climate modelling, renewable energy optimisation, and sustainable supply chains will further enhance the role of QT in climate action. Additionally, ensuring sustainable sourcing of materials used in quantum hardware and responsible disposal strategies is crucial for minimising the environmental impact throughout the lifecycle of these technologies.

IMPORTANT NOTES

(14) Quantum for Good – Quantum for Everyone

## PROMOTE OPEN INNOVATION

The EU should draw up clear guidelines for knowledge sharing which can protect strategic advantages while promoting innovation. This will require balancing open-source initiatives with IP protection. Open-access initiatives, citizen engagement, and equitable access to quantum-powered solutions are essential for promoting transparency and inclusivity.

## ENHANCE INCLUSIVE ACCESS

Inclusivity can be addressed by developing comprehensive training programmes for diverse audiences (vocational training), by creating accessible educational materials for increasing public awareness, and by implementing targeted outreach programmes for underrepresented groups.

## FOCUS ON ALIGNMENT WITH SDGs

European companies are already aware of the UN SDGs and understand their importance. The societal impact and inclusion of QT should not be overlooked in this regard and frameworks should be established to leverage quantum advances to help achieve the SDGs, such as water management, precision agriculture, and healthcare.[15]

Promoting educational initiatives to reduce the quantum divide and empower diverse talent pools is essential for fostering digital equity. Furthermore, developing quantum-secure infrastructures will protect vulnerable communities and critical societal functions, enhancing resilience and security.

## SPEARHEAD ‘QUANTUM FOR GOOD’ INITIATIVES

Promoting educational initiatives to reduce the quantum divide and empower diverse talent pools is essential for fostering digital equity. Furthermore, developing quantum-secure infrastructures will protect vulnerable communities and critical societal functions, enhancing resilience and security.

IMPORTANT NOTES

(15) Quantum to Fulfil the SDGs, World Economic Forum (2024)

# 3. CONCLUSION

In this position paper, QuIC proposes a set of recommendations to the EC's upcoming Quantum Strategy to position Europe at the forefront of quantum innovation, ensuring long-term technological leadership, economic growth, and strategic independence in the quantum era. These recommendations can be summarised as follows:

- An intensive, coordinated European effort is required to develop a homegrown full-stack QC ecosystem, ensuring technological sovereignty and economic competitiveness. Investments should focus on modularity, co-design, interoperability, and integration with HPC and AI.
- Strengthening Europe's quantum supply chain is essential to reduce dependence on non-EU suppliers. The EU must invest in key enabling technologies, manufacturing capabilities, and regulatory alignment to secure the entire quantum ecosystem.
- Enhancing European leadership in quantum chips through industrial-scale fabrication and testing facilities, fostering innovation in design, cryogenic electronics, photonics, packaging, and semiconductor technologies, and supporting IP generation for quantum hardware.
- Ensuring secure quantum communications and cryptography by accelerating the deployment of PQC, QKD, and QINs. The EU must act swiftly to mitigate security risks such as 'Harvest Now, Decrypt Later' threats. Key enablers are the funding of a certified QKD space segment and a large-scale QIN demonstrator (terrestrial and space components).
- Driving industrialisation and market uptake of quantum sensing by establishing an EU-wide strategy for research, commercialisation, and deployment of quantum sensors in key sectors, including defence, space, healthcare, and climate monitoring.
- Creating an attractive investment environment for European quantum start-ups and scale-ups by addressing funding gaps, incentivising private investments, and ensuring fair competition for European quantum companies in global markets.
- Positioning Europe as a leader in QT standards and intellectual property by fostering strong European participation in international standardisation bodies, ensuring strategic control over quantum-related patents, and enhancing IP commercialisation mechanisms.
- Building a highly skilled European quantum workforce through education, re-skilling programmes, and talent attraction and retention policies, ensuring that Europe remains competitive in the global quantum race for talents.
- Ensuring European quantum sovereignty through harmonised export controls, strategic defence investments, coordination of national quantum strategies, and securing critical infrastructure.
- Maximising QT for environmental and societal benefits by aligning quantum research with sustainability goals, supporting energy-efficient QC, and leveraging quantum innovation for climate action and the public good.

The European Quantum Industry Consortium and its community welcomes the opportunity to work with the EC in further refining and prioritising these recommendations in support of the European Quantum Strategy.

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# 5 ABOUT QUIC

The European Quantum Industry Consortium (QuIC) is a non-profit industry association, founded in 2021, dedicated to the growth of the commercial QT sector. QuIC operates as a collaborative hub throughout Europe, bringing together hundreds of SMEs, large corporations, investors, RTOs, and academic institutions, to build a strong, vibrant ecosystem. Together, members of the association address topics of common interest, such as standardisation, intellectual property, trade, and workforce development.

Today, QuIC is part of the coordination and support action of the Quantum Flagship – a European project, which aims to make Europe a dynamic and attractive region for innovative research, business, and investments in this field. More information: www.euroquic.org