EUROPEAN
COMMISSION

Brussels, 25.11.2026
SWD(2026) 965 final

PART 1/2

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

Accompanying the document

Proposal for a Regulation of the European Parliament and of the Council

on a framework of measures for strengthening the Union's quantum ecosystem (Quantum Act)

{COM(2026) 965 final} - {SEC(2026) 966 final} - {SWD(2026) 966 final} - {SWD(2026) 967 final}

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1. INTRODUCTION: POLITICAL AND LEGAL CONTEXT

Quantum is widely recognised as a transformative technology breakthrough capable of solving problems and performing tasks far beyond the capabilities of classical technologies. Quantum technologies are mainly divided into three areas: quantum computing and simulation, quantum communication, and quantum sensing and metrology[1].

Quantum has the potential to revolutionise multiple economic and societal sectors, much like the internet and more recently, artificial intelligence (AI). The Draghi report[2] describes quantum as "*the next trailblazing innovation in the computing field, which could open new opportunities for the EU's industrial competitiveness and technological sovereignty*". While many quantum technologies remain in the research or early commercialisation phase, their impact is expected across many critical sectors including healthcare, energy, security, defence, finance, manufacturing, or scientific research, among others. With uses ranging from quantum magnetic resonance imaging (MRI) scanners, advanced sensing (e.g. for geophysics or navigation) and secure communications to quantum computing solutions for sectors such as logistics and finance, these technologies offer significant industrial and dual-use benefits, making them essential for competitiveness, economic security, and the protection of critical infrastructure. Ensuring that quantum technologies deployed in the EU align with European standards and values is of strategic importance.

However, quantum technologies also pose significant security risks. Powerful quantum computers could break widely used encryption, threatening data, communications, digital identities – from critical infrastructure, through banking to government systems. The "harvest now, decrypt later" threat further highlights the need to prepare for future quantum-enabled decryption.

These emerging quantum technologies are developing faster than previously expected, with a rapidly growing yet still nascent ecosystem. The field is at a critical inflection point, where disruptions could occur at any time. Some technologies are transitioning from research-driven development to early industrialisation, deployment, and market formation. This shift is unlikely to follow a linear path: a scientific or engineering breakthrough, combined with sufficient investment and industrial capacity, could rapidly reshape both technological and competitive landscapes. In quantum computing, the real-world problems where a practical advantage will first appear remain uncertain. Competing hardware approaches are still under development, and progress depends not only on scaling hardware but also on advances in error correction, algorithms, and integration with classical computing[3].

Any assessment must reflect this complexity. The sector's nascent nature means that comparable data remain limited, with differences in definitions, samples, geographical coverage, and reporting periods across sources, while quantum-specific trade and usage data are largely unavailable. To address these gaps, the assessment triangulates programme data, external mappings, stakeholder evidence, and selected quantitative indicators. Where evidence is sufficient, impacts are estimated in monetary terms; otherwise, they are assessed using ranges and qualitative scenarios. Dataset coverage and limitations are detailed in Annex 4[4; 5].

[1] See Annex 7 for more details about quantum technologies.
[2] Mario Draghi, The Future of European Competitiveness, Part A, September 2024, pp. 25, 31 and 58.
[3] Geneva Science Diplomacy Anticipator (GESDA) & Open Quantum Institute (OQI), Intelligence Report on Quantum Diplomacy in Action 2025–2026, Third Edition, Geneva, October 2025, pp. 4–5.
[4] Quantum Europe Strategy, COM (2025) 363 final.
[5] OECD and European Patent Office (EPO), Mapping the Global Quantum Ecosystem: A Comprehensive Analysis Based on Innovation, Firm, Investment, Skills, Trade and Policy Data, 2025.

1.1. Quantum in Europe and in the world

Recognising the transformative and strategic importance of quantum technologies, the Quantum Europe Strategy[4] adopted in 2025 aims to position Europe as a global leader in the field by 2030. Europe enters this new era with a strong foundation. It is the home to groundbreaking discoveries and numerous Nobel Prize laureates – from Max Planck, Albert Einstein, Niels Bohr, and Erwin Schrödinger to contemporary pioneers like Theodor Haensch, Albert Fert, Serge Haroche, Anton Zeilinger, Alain Aspect, and Anne L'Huillier.

Today, around one-third of the world's quantum companies are based in the EU, which also boasts significant strengths in research, specialised talent, quantum infrastructures, and key enabling technologies. Although nascent, European quantum companies show strong commercial capabilities delivering roughly half of all procured machines in the world (approximately 150). Europe also holds some key control-points in the quantum supply-chain (e.g. any quantum computer installed worldwide includes European cryogenics or photonics). Over the five years leading up to the Quantum Europe Strategy, the EU and its Member States invested more than EUR 11 billion in quantum technologies, with research increasingly producing breakthroughs with strong industrial and market potential.

However, Europe's leadership in scientific excellence and its thriving start-up ecosystem have not yet translated into **comparable private-scale investment or industrial deployment**.

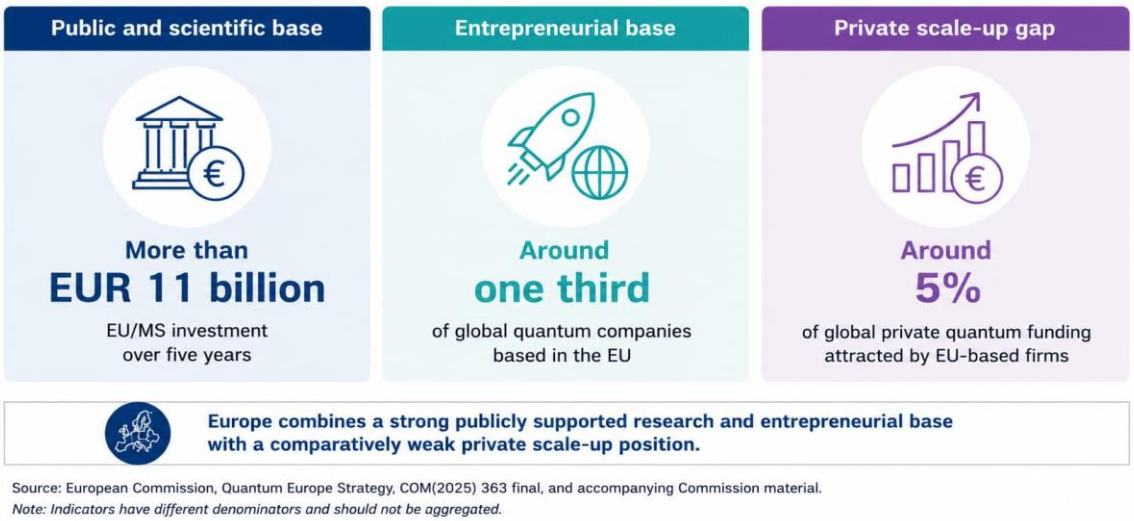

Figure 1.1 *Europe's position in quantum technologies.*

As noted in the Quantum Europe Strategy, EU quantum companies attract only about 5% of global private quantum investment, while US companies secure substantially more, enabling them to scale faster and strengthen their global market position. The OECD-EPO mapping[6] also highlights that the US benefits from a broader financing mix, including stronger later-stage investment, whereas the European ecosystem remains reliant on early-stage funding. This points to a *conversion gap*: Europe has strong scientific and entrepreneurial assets but lacks sufficient later-stage finance, industrial capacity, and predictable early demand to scale quantum technologies effectively.

Europe's efforts must also be viewed in the context of global developments. As recognised in the Quantum Europe Strategy, several major economies, in particular the US and China, but also Australia, Canada, Japan, South Korea and the UK, are making substantial investments in

[6] Idem, pp. 80–89. The analysis found that US-based investors represented on average 52% of global investment in core quantum companies over 2016–2024.

quantum technologies and strengthening their national quantum capabilities[7]. Key regions are increasingly combining research support with industrial infrastructure, public procurement, supply-chain measures, skills development and security policies[8]. By October 2025, governments worldwide had announced an estimated USD 55.7 billion in quantum-related commitments since 2013[9; 10].

As quantum adoption and commercialisation accelerate, the future clear winners are expected to emerge within the next 5-8 years. The window of opportunity for Europe is narrowing, with the US and China leading the race for the moment. The sector is now at a turning point, as major global efforts seek to industrialise scientific and technological (S&T) results and bring concrete products to market. The US benefits from deeper private capital, major investment by Big Tech companies, public support and strong access to knowledge and skills; while China relies more heavily on public investment and state-coordinated support. The global quantum market –covering computing, communication and sensing– remains nascent. Valued at around USD 5 bn in 2025, it could reach up to USD 97 bn by 2035, with quantum computing accounting for the largest share[11].

The differences in the public and private support are already reflected in available financing indicators. Announced public quantum support up to 2025 is estimated at around EUR 8.6 billion in the EU, compared with EUR 5.3 billion in the US and estimates point at twice as much in China, although these figures cover different periods, instruments and stages of implementation and are therefore not directly comparable[12].

Private financing shows a different picture: in 2025, quantum start-ups received around EUR 7 billion in investment in the US compared with EUR 1.1 billion in the EU. Major US technology firms, such as IBM, Google, Microsoft and Amazon, are also investing directly in quantum, while large-scale corporate investment remains far more limited in Europe. Comparable data for China are not available, although evidence points to substantial state-led investment and significant activity in quantum computing and quantum communication, including Quantum Key Distribution (QKD)[13].

Indicator	EU	US	China
Quantum Venture Capital, 2012-2024	EUR 0.862 bn	EUR 2.9 bn	n/a on comparable basis
Investment in quantum start-ups, 2025	EUR 1.10 bn	EUR 7.10 bn	n/a on comparable basis
Announced public quantum support to 2025	EUR 8.6 bn	EUR 5.3 bn	EUR 13.6 bn

Table 1.1. *Public support estimates are based on announced commitments and are not directly comparable with actual expenditure because scope, periods and instruments differ across jurisdictions.*

Recent US measures also point to increased public support for the development and commercialisation of quantum technologies. These include the 2026 Department of Commerce

[7] See the national strategies and the analysis referenced in the Quantum Europe Strategy.
[8] GESDA and OQI, Intelligence Report on Quantum Diplomacy in Action 2025–2026, 2025, chapter 2.
[9] These figures should be interpreted cautiously because they include different time periods, instruments, and stages of implementation.
[10] OECD Publishing, Overview of National Strategies & Policies for Quantum Technologies, 2025.
[11] McKinsey Quantum Technology Monitor 2026
[12] Public-support estimates are based on announced commitments and are not directly comparable with actual expenditure because scope, periods and instruments differ across jurisdictions.
[13] OECD, An Overview of National Strategies and Policies for Quantum Technologies, pp. 28.

announcement of USD 2 billion in proposed federal incentives for quantum companies[14] and Executive Orders 14413 and 14412 of 22 June 2026, which respectively call for an updated US quantum strategy and accelerate the transition of sensitive federal systems to post-quantum cryptography.[15]. The Executive Order 14413 establishes a whole-of-government effort covering quantum computing, sensing and networks. It marks a shift from fragmented research support to coordinated policies aimed at building critical mass, industrial capabilities and market demand[16]. Moreover, the US is tackling the issue of fragmentation through centralising quantum efforts under the Genesis Mission, which aims to develop and deploy a scientifically relevant, fault-tolerant quantum-computing capability[17].

China too has pursued sustained, state-coordinated support for quantum technologies[18]. China has an integrated quantum-communication network of around 4,600 km serving more than 150 users[19]. Chinese applicants accounted for 16,285 quantum patent families between 2005 and 2024, although only 5.8% of them were international[20]. By comparison, the US accounted for around 6,400 patent families, member states of the European Patent Convention (EPC)[21] collectively for 2,690, Japan for 2,636 and Korea for 1,608. While these figures point to China's considerable scale, differences in definitions, reporting practices, data coverage and the degree of patent internationalisation limit direct comparison with the EU[22].

The developments outlined above provide the broader context for assessing whether further action at the Union level may be warranted. The problem analysis below identifies the main challenges that could hinder the Union's ability to achieve its strategic objectives in quantum technologies.

1.2. Relevant EU policy framework, legislation and initiatives

The 2025 **Quantum Europe Strategy** serves as the immediate policy baseline for this initiative. It outlines actions across five key areas—research and innovation; quantum infrastructures; strengthening the quantum ecosystem; space and dual-use quantum technologies; and quantum skills—and announces a future Quantum Act as a principal implementation step[4].

The Quantum Act initiative aligns with the Union's **broader competitiveness agenda**. The Draghi Report identifies quantum computing as a major emerging digital innovation, highlighting Europe's weaker position in private investment, company scale-up and access to critical quantum technologies and components[2]. Building on that diagnosis, the

[14] The proposed funding would provide $1 billion to IBM, $375 million to GlobalFoundries, $100 million each to Atom Computing, D-Wave, Infleqtion, PsiQuantum, Quantinuum and Rigetti, and up to $38 million to Diraq.
[15] Executive Order 14413 of 22 June 2026, Ushering in the Next Frontier of Quantum Innovation; Executive Order 14412 of 22 June 2026, Securing the Nation Against Advanced Cryptographic Attacks.
[16] Executive Order 14413, Ushering in the Next Frontier of Quantum Innovation, 2026. It calls for an updated national strategy, specifications and partnership models for a science-enabling quantum computer, as well as potential advance market commitments, priority sensor projects, strengthened domestic manufacturing and supply chains, new user facilities, workforce developments and ties to national-security applications.
[17] U.S. Department of Energy, Energy Department Announces Initiative to Create and Deploy the World's First Scientifically Relevant, Fault-Tolerant Quantum Computers, 23 June 2026.
[18] Ivezic, M., "China's Quantum Networking and QKD — World's Most Ambitious Quantum Communication Program", Post-Quantum, 7 April 2026.
[19] OECD, An Overview of National Strategies and Policies for Quantum Technologies, pp. 28; Y.-A. Chen, Q. Zhang, T.-Y. Chen et al., An integrated space-to-ground quantum communication network over 4,600 kilometres, Nature 589, 214–219 (2021).
[20] OECD and EPO, Mapping the Global Quantum Ecosystem, 2025, sections 3.3.1 and 3.3.4.
[21] The EPO comprises all 27 EU Member States and 13 additional non-EU countries.
[22] It is essential to point out that raw patent-family counts are not directly comparable indicators of technological leadership, particularly given differences in internationalisation and filing practices.

Competitiveness Compass reaffirmed quantum as strategic for Europe's future competitiveness and announced the Quantum Strategy and a possible **Quantum Act** to address fragmentation, align Union and national programmes and support investment in pan-European quantum infrastructures[23].

This initiative also fits within the **Union's economic-security, preparedness and defence framework**. Following the European Economic Security Strategy[24], Commission Recommendation (EU) 2023/2113[25] identifies quantum technologies as one of four areas presenting immediate risks to technology security and leakage. Likewise, the Union's foreign-direct-investment (FDI) screening and dual-use export-control frameworks[26] address specific risks – for instance, the 2026 FDI Regulation[27] identifies quantum as a critical technology potentially subject to the mandatory investment screening under the relevant national control mechanism. The Niinistö Report[28] and the White Paper for European Defence[29] further emphasise the importance of critical and dual-use technologies for civilian and military preparedness. The European Defence Fund invests in quantum technologies for navigation, cryptography, and sensing to boost the military capabilities of EU armed forces[30;31]. The initiative needs to be also seen in the context of the preparation of the next Multiannual Financial Framework (MFF), the proposed European Competitiveness Fund[32] and the next Research Framework Programme.

Several regulatory initiatives already touch on quantum technologies, including the **Chips Act** and the mandates of the Chips Joint Undertaking (Chips JU) and the EuroHPC Joint Undertaking (EuroHPC JU)[33]. The **Chips JU** (or its successor) will continue to support quantum-chip design, pilot lines, prototyping, testing and validation, while the **EuroHPC JU** (or its successor) will continue to implement Union-level quantum R&I and infrastructure activities across quantum computing and simulation, communication, sensing and metrology. Additionally, the 2024 Critical Raw Materials Act[34] secures sustainable EU supplies of rare-earths, high-purity silicon and other key minerals needed for quantum chips and sensors.

The Quantum Act would not replace existing funding mechanisms or determine funding for individual projects. Instead, it would provide cross-cutting strategic coordination and connect these capabilities to the wider industrialisation pathway.

A quantum-specific initiative, touching also upon Post-Quantum Cryptography (PQC) would need to complement existing **cybersecurity and economic-security instruments** and avoid

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[23] A Competitiveness Compass for the EU, COM (2025) 30 final.
[24] European Economic Security Strategy, JOIN (2023) 20 final.
[25] Commission Recommendation (EU) 2023/2113 on critical technology areas for the EU's economic security for further risk assessment with Member States.
[26] Regulation (EU) 2019/452 and Regulation (EU) 2021/821.
[27] Regulation (EU) 2026/1386 on the screening of foreign investments in the Union.
[28] S. Niinistö, *Safer Together Strengthening Europe's Civilian and Military Preparedness & Readiness*, 2024.
[29] White Paper for European Defence Readiness 2030, JOIN (2025) 120 final.
[30] EU Defence Industry Transformation Roadmap, COM(2025) 845 final. The Roadmap includes quantum technologies among the disruptive technologies relevant to defence transformation.
[31] European Commission, 'From AI to Quantum: How the European Defence Fund shapes the future of EU Defence Technologies', News article, 15 December 2025.
[32] European Commission, 'The 2028–2034 EU budget for a stronger Europe'.
[33] Existing Union instruments already cover parts of the quantum landscape, notably the Chips Act (Regulation (EU) 2023/1781), the Chips JU (Regulation (EU) 2023/1782) and EuroHPC JU (Regulation (EU) 2026/150). The amended EuroHPC mandate covers the full quantum ecosystem and implementation of the Union's quantum-technology agenda, including activities previously financed under HE and the Quantum Flagship. Any quantum-specific initiative should complement these instruments and avoid duplication.
[34] Regulation (EU) 2024/1252.

duplication. The NIS2 directive[35] and the Cyber Resilience Act[36] would continue to govern cybersecurity risk-management and product requirements, while the Cybersecurity Act[37] would remain the Union framework for cybersecurity certification. The Commission Recommendation and subsequent Member State roadmap on PQC[38; 39] would continue to coordinate the transition towards quantum-resistant cryptography. For financial entities, the Digital Operational Resilience Act remains the sector-specific framework for ICT risk management, digital operational resilience testing, ICT-related incident reporting and critical ICT third-party risk[40]. This Impact Assessment (IA) assesses whether quantum-specific coordination, monitoring or referral arrangements are needed for this framework by addressing quantum specific coordination and preparedness needs, without creating parallel supervisory powers or duplicating reporting obligations. Lastly, ProtectEU Internal Security Strategy identifies quantum technologies, the transition to PQC, the European Quantum Communication Infrastructure (EuroQCI), Quantum Key Distribution (QKD), and quantum sensing as relevant to internal-security preparedness[41].

Existing instrument	Contribution relevant to quantum
Quantum Europe Strategy	Common political direction and actions across R&I, infrastructure, ecosystem development, dual use and skills
EuroHPC JU	Union-level quantum R&I, quantum-computing infrastructure, integration with high-performance computing (HPC) and coordination with participating states
Chips Act / Chips JU	Quantum-chip design, pilot lines, prototyping, testing and validation
EuroQCI, CEF and IRIS²	Terrestrial and space components of EuroQCI
European Defence Fund, EDIP/EDPC[42]	Supports collaborative defence R&I and capability development, thereby helping to translate emerging technologies into deployable defence capabilities
EU Inc. Framework[43]	Tackles fragmentation in company law by creating an optional EU-wide corporate regime, easing the establishment and scale-up of European companies.
European Innovation Act[44]	Improves horizontal framework conditions for public procurement of innovation.
Public Procurement Act[45]	Horizontal rules for public procurement.

[35] Directive (EU) 2022/2555.
[36] Regulation (EU) 2024/2847 (Cyber Resilience Act).
[37] Regulation (EU) 2019/881 (Cybersecurity Act).
[38] Commission Recommendation (EU) 2024/1101 on a Coordinated Implementation Roadmap for the transition to Post-Quantum Cryptography.
[39] A Coordinated Implementation Roadmap for the Transition to Post-Quantum Cryptography, June 2025. The roadmap calls for Member States to begin the transition by the end of 2026 and for critical infrastructures to transition no later than the end of 2030.
[40] Regulation (EN) 2022/2554 on digital operational resilience for the financial sector.
[41] ProtectEU: a European Internal Security Strategy, COM (2025) 148 final.
[42] Defence/space-specific quantum activities remain subject to the priorities, work programmes, funding and implementation arrangements of the relevant Union Defence instruments and the competent authorities.
[43] European Commission, Proposal for a Regulation of the European Parliament and of the Council on the 28th Regime Corporate Legal Framework – 'EU Inc.', COM(2026) 321 final, 18 March 2026.
[44] European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing a framework of measures for strengthening the Union innovation ecosystem and amending Regulation (EU) 2017/1001 (European Innovation Act), COM(2026) 567 final, 9 September 2026.
[45] European Commission, Proposal for a Regulation of the European Parliament and of the Council on public contracts and concessions (Public Procurement Act), COM(2026) 590 final, 9 September 2026.

Strategic Tech for Europe Platform (STEP)[46]	Horizontal framework that prioritises support available under existing Union funding programmes and promotes synergies.
Chips Act 2.0[47] / Cloud and AI Development Act (CADA)[48]	These provide relevant digital infrastructures and semiconductor pilot-line support mechanisms
EIC / InvestEU / Future ECF/FP10	Improve access to finance, have general advisory functions and funding
European Research Area Act[49]	Horizontal framework to strengthen the European Research Area, including coordination of EU and national R&I policies and investment, researcher mobility and knowledge circulation.
Cybersecurity[50], PQC and standardisation frameworks	Cybersecurity requirements, certification structures, PQC[51] transition coordination and quantum standards
FDI screening and dual-use export controls	Screening of certain investments and control of listed dual-use items and technologies
Union space instruments[41]	Space R&I, and space-related deployment

Table 1.2. *Existing Union instruments and their contribution to quantum technologies.*

The above mapping shows that the initiative would operate within an already extensive Union policy landscape rather than create a parallel framework. Existing instruments would retain their respective functions: EuroHPC JU and the relevant R&I programmes would implement quantum R&I and infrastructures; the Chips framework would address semiconductor-related capabilities; horizontal innovation, procurement and financing instruments would continue to govern innovation support, public procurement and access to finance; and the relevant cybersecurity, standardisation, economic-security, defence and space frameworks would retain their existing competences. The Quantum Act would therefore reuse these instruments and add quantum-specific arrangements only where residual coordination or delivery gaps remain.

This division of functions also applies to recent and forthcoming horizontal initiatives. The European Innovation Act, Public Procurement Act and European Research Area Act are expected to improve the general conditions for innovation, procurement and coordination of R&I, while Chips Act 2.0 and CADA strengthen relevant semiconductor and digital infrastructure frameworks. These initiatives can address part of the underlying barriers faced by quantum actors, but do not by themselves provide an integrated quantum-specific approach to EU–Member State coordination, links between research and industrial deployment, cross-

[46] European Commission, *Strategic Technologies for Europe Platform (STEP)*, available at: https://strategic-technologies.europa.eu/index_en

[47] European Commission, Proposal for a Regulation of the European Parliament and of the Council on a framework of measures for strengthening the Union's semiconductor ecosystem, repealing Regulation (EU) 2023/1781 (Chips Act 2.0), COM(2026) 504 final, 3 June 2026, 2026/0139(COD)

[48] European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing a framework of measures for strengthening Europe's cloud and AI ecosystem (Cloud and AI Development Act), COM(2026) 502 final, 3 June 2026, 2026/0138(COD)

[49] European Commission, Directorate-General for Research and Innovation, *European Research Area (ERA) Act*, European Research Area Platform.

[50] The Commission's 2026 proposal for a revised Cybersecurity Act also addresses post-quantum cryptography. Its final content remains subject to the legislative process.

[51] In this IA, PQC means classical public-key cryptography designed to resist quantum and classical attacks; quantum communication uses quantum signals, with QKD as one application. PQC and QKD are distinct; "quantum-safe" refers here to PQC.

domain infrastructure and testing, strategic project coordination, financing and first-buyer pathways, or quantum-specific dependency intelligence.

This distinction is carried through into the dynamic baseline and the assessment of the policy options, so that effects already expected from existing or forthcoming frameworks are not attributed to the Quantum Act. Consequently, the initiative does not start from a blank page. The landscape already comprises a range of programmes, infrastructures, regulatory frameworks and policy initiatives addressing quantum-related aspects, although this is not their primary objective. The IA assesses whether additional EU action is needed to strengthen links between these instruments, pool resources around common priorities, facilitate the transition from research to industrial deployment and reduce strategic dependencies, while avoiding duplication and fully respecting the competences and functions of existing structures.

2. PROBLEM DEFINITION

2.1 What are the problems?

The evidence collected for this IA identifies three interrelated structural problems that hinder the Union's ability to translate its scientific strengths in quantum technologies into industrial, market and resilience outcomes[52; 53; 54]. Section 2.1 outlines these problems, their scale and the stakeholders affected. Section 2.2 analyses their root causes, while Section 2.3 examines their likely evolution without further Union intervention. The three problems are:

- **Slow conversion of research excellence into deployable quantum technologies (P1):** Fragmented efforts between the EU and Member States mean that research results and prototypes do not consistently progress into validated, manufacturable and operational products and services.
- **Insufficient conditions for European quantum firms to scale and for early markets to develop (P2):** While the Union has a large and dynamic start-up ecosystem, firms struggle to reach industrial scale, and early demand remains too shallow and fragmented to provide predictable revenue streams or reference customers.
- **Strategic dependencies and insufficient resilience in quantum value chains (P3):** The Union relies on concentrated and, in some cases, non-EU sources for specialised components and enabling technologies, with limited visibility and mitigation of these dependencies.

These problems have a clear cross-border dimension. Research programmes, firms, infrastructures, investors, buyers and suppliers operate across national borders, while capabilities, finance and demand are unevenly distributed among Member States. As a result, fragmented coordination, discontinuities between research and deployment, limited scale-up conditions and dependencies in critical value chains can affect projects, firms and users across the Union[55].

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[52] Lewis et al., Future Directions for Quantum Technology in Europe, 2025; EIB, Investment Report 2025/26, pp. 139, 254; OECD and EPO, Mapping the Global Quantum Ecosystem, 2025, pp. 124, 127; QuIC, Response to the Call for Evidence on the EU Quantum Act, 2025, pp. 5–7. See these sources on fragmented markets, scale-up finance, infrastructure access and discontinuities between R&I and deployment.

[53] Idem, pp. 124, 127, identifying weaker EU translation of innovation into market opportunities and a policy shift towards adoption, commercialisation, and experimentation.

[54] QuIC, *Response to the Call for Evidence on the EU Quantum Act*, 2025, pp. 5–7, calling for continuity from R&D to industrialisation through grants, equity, strategic procurement, and mitigation tools.

[55] Regulation (EU) 2024/2847 (Cyber Resilience Act); see also Sections 2.1 and 2.2; see Annex 4 for the evidence concerning the cross-border operation of research programmes, infrastructures, firms, supply chains and users.

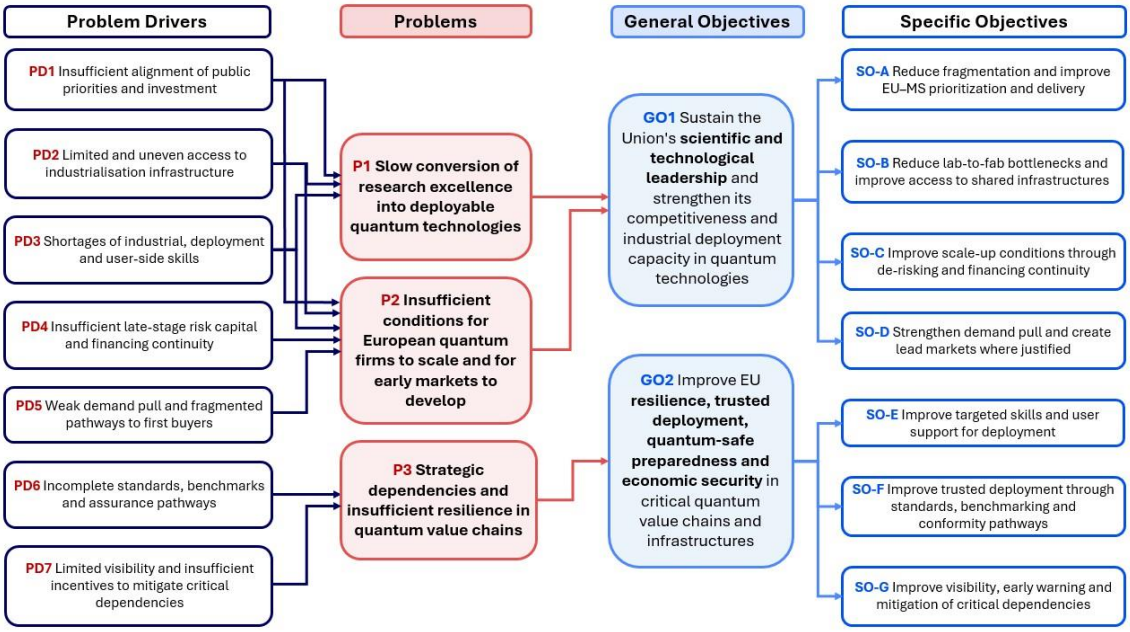

Figure 2.1. *Intervention Framework.*

2.2.1. P1 – Slow conversion of research excellence into deployable quantum technologies

The first problem is that the EU strengths outlined in Chapter 1 do not yet consistently translate into technologies that can be manufactured, integrated, qualified and deployed in operational environments.

EU programme data show progress towards higher Technology Readiness Level (TRL)[56] activities. Of the 283 quantum-related projects mapped under Horizon 2020 and Horizon Europe, 83 (29.3%) were classified as higher-TRL actions. Among concluded projects, this share increased from 21% in 2023 to 45% in 2025, indicating that the shift towards validation and deployment has accelerated since 2023. Separately, among the subset of validated EU quantum technologies, an estimated 65-70% has progressed to a market product, suggesting that the main bottleneck lies earlier in the innovation pipeline, between research and industrial validation[57]. This interpretation is consistent with both OECD/EPO and industry evidence that Europe combines strong quantum innovation capabilities with weaker translation into market opportunities. Discontinuities between R&D, industrialisation and deployment are a constraint to European scale-up[58]. Evidence on patents and value-capture relevant to firm scale-up is only beginning to emerge and is examined under P2[59]. In the lack of sufficient comparable international evidence demonstrating that EU quantum technologies are generally at lower TRLs than comparable technologies in other regions, the available evidence suggests that industrial validation remains uneven.

Technological maturity varies substantially across quantum domains and technological approaches, from specialised applications already on the market to technologies still in early

[56] ESA - Technology Readiness Levels (TRL) measure a technology's maturity on a scale from 1 to 9, progressing from basic scientific research (TRL 1) to fully proven operational use (TRL 9).
[57] See Annex 11, on quantum technologies initiated by EU projects that have led to revenue generation.
[58] OECD and EPO, Mapping the Global Quantum Ecosystem, 2025, pp. 124 and 127; QuIC, Response to the Call for Evidence on the EU Quantum Act, 2025, pp. 5–7.
[59] See Annex 11, section 2.1 on EU-funded quantum R&I projects and section 2.2 on patent activity in quantum technologies .

industrial, R&I or pilot stages. As quantum technologies are still emerging and evolving rapidly, the indicators below provide an indicative picture of technological and commercial maturity across the three domains. The global market estimates provide a complementary indication of the current and expected commercial scale of each domain, although market size should not be interpreted as a direct measure of technological maturity.

Domain	Current maturity / market evidence	Global market[60]
Quantum computing	Current quantum computers remain largely prototypes or early commercial systems, based on different competing hardware platforms[61]. Key challenges are fault tolerance, error correction and scalability. Commercial revenues are emerging, while fault-tolerant quantum computing remains a longer-term objective.	2024: USD 650–750 mln 2025: > USD 1 bn 2035: USD 43–71 bn
Quantum communication	QKD and Quantum Random Number Generators (QRNG) are already deployed in specialised applications, while quantum repeaters, entanglement distribution and advanced quantum networks remain at earlier R&I and pilot stages.	2024: USD 1.3–1.6 bn 2035: USD 11–15 bn
Quantum sensing	Quantum clocks are already deployed and QRNGs are commercially available. Next-generation applications in gravimetry, navigation, industrial and medical sensing are moving from prototypes towards deployment. Europe remains in the race.	2024: USD 2.8–3.1 bn 2035: USD 7–10 bn

Table 2.1. *Comparison of maturity and market evidence across quantum domains.*

This domain-level picture is completed by firm-level evidence on commercialisation. Evidence gathered by the JRC from a sample of 140 EU-based quantum companies indicates that approximately 72 % currently market products, while 21 % do not and the status of the remaining 7% is uncertain. Commercial readiness varies considerably across domains. QKD and PQC are the most market ready, with 80 % and 85 % of firms, respectively, already commercialising products. By contrast, quantum sensing and quantum computing are the least market ready: only 61 % of firms in the quantum sensing segment, 68 % in the quantum computing software segment, and 71 % in the quantum computing hardware segment currently market products[62]. Standardisation also differs across quantum domains. Around 70% of 165 quantum standardisation mapping concerned quantum communication and PQC, while around 20% concerned quantum computing and sensing[63].

Every domain in quantum technology faces overarching challenges that are reflected in the problem drivers below. Across the three domains, there is a mismatch between investment and results: significant investment has not yet been translated into industrial scale and broad market adoption commensurate with Europe's scientific and technological strengths, nor the disruptive effect quantum technologies are expected to have. Supply chain vulnerabilities, as well as talent bottlenecks are also observed across all TRLs of quantum technologies. Each domain also faces specific challenges, albeit these are mostly scientific and engineering challenges and less related to policy and economic conditions.[64]

[60] McKinsey & Company, Quantum Technology Monitor 2026: A commercial tipping point, 2026

[61] These include superconducting circuits, trapped-ion, neutral-atom, photonic systems, and semiconductor/spin-based approaches. These approaches remain competing technological pathways at different levels of maturity, and no single approach has yet emerged as the definitive route towards scalable fault-tolerant quantum computing.

[62] See Annex 11, section 4.1, on the commercialisation status of EU quantum companies.

[63] See Annex 11, section 3, on standardisation.

[64] For instance, Quantum Computing is entering the early fault-tolerant era but still requires millions of physical qubits to generate thousands of logical, error-corrected qubits, which still remains a significant engineering

The relevant gap is therefore not a uniform failure to reach a single TRL, but rather the absence of sufficiently continuous pathways tailored to the maturity and industrial requirements of each technology. The actors most directly affected by this gap include research teams seeking to move results beyond the project stage; start-ups and SMEs unable to finance specialised facilities internally; research and technology organisations operating shared infrastructure; industrial or public users seeking validated solutions.

The observable outcome is a longer and less predictable progression from research results to demonstrators, products, or operational services. This reduces the cumulative industrial return from European research and increases the risk that promising technologies are industrialised elsewhere. Therefore, the initiative cannot eliminate the important constraint of scientific and engineering uncertainty as such, particularly for technologies like large-scale fault-tolerant quantum computing. Therefore, the assessment focuses on policy-addressable conditions (e.g. coordination, access to infrastructure, finance, demand, skills, and assurance) that determine whether sufficiently mature results progress efficiently to validation and deployment.

The causes of this problem, including dispersed prioritisation, limited continuity between funding stages, uneven access to shared infrastructure and shortages of industrial engineering skills, are examined under Problem Drivers PD1, PD2 and PD3 in Section 2.2.

2.2.2. P2 – Insufficient conditions for European quantum firms to scale and for early markets to develop

The Union has one of the world's largest and youngest populations of quantum companies. A Joint Research Centre (JRC) mapping[65] identified 141 EU-based firms out of 441 in a global sample, with around 60% of these EU firms established after 2018. However, the age profile of firms alone does not demonstrate whether they subsequently progress to industrial scale. Between 2020 and 2025, EU27 quantum companies raised around EUR 509 million in early-stage venture capital, compared with EUR 302 million for US firms. At later stages, by contrast, US firms raised around EUR 2.2 billion, 4.5 times the EUR 493 million raised by EU27 firms[66]. This later-stage financing gap is consistent with the EU's more limited pool of private scale-up capital compared with the US. The observed problem is therefore not a lack of entrepreneurial creation, but the limited progression of firms from start-up and prototype stages to sustained industrial scale within the Union.

Scaling a quantum firm requires more than successful R&I. It requires a clear path from prototype to industrial production, including access to patient later-stage capital, specialised testing infrastructure, skilled technical and commercial teams, effective intellectual property management, and lead customers that can turn pilots into reference deployments and repeat demand. In the Union, these conditions remain insufficiently connected: financing is concentrated at earlier stages, industrial capabilities and support are dispersed across programmes and Member States, European patenting activity is dispersed across many actors, and early demand remains narrow and unpredictable.

These weaknesses are mutually reinforcing, making it harder for firms to industrialise and reach sustained scale in Europe[67]. The financing evidence illustrates this discontinuity.

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challenge. In Quantum Communications, quantum signals cannot be amplified using traditional signal boosters, thus being still limited to a couple hundred kilometres of reach. Lastly, a key bottleneck in Quantum Sensing concerns isolating extremely precise sensors from ambient background noise, thermal drift and mechanical vibrations that come when tested in the real-world environment.

[65] Lewis et al., Future Directions for Quantum Technology in Europe, 2025.

[66] See Annex 11, section 4.2, on venture capital investment by finance stage.

[67] See OECD and EPO, Mapping the Global Quantum Ecosystem, 2025, pp. 80–89, 124–127; EIB, Investment Report 2025/26, pp. 139, 254; QuIC, Response to the Call for Evidence on the EU Quantum Act, 2025.

Between 2012 and 2024, EU quantum firms raised approximately EUR 862 million in venture capital, compared with EUR 2.9 billion for US firms[68]. The later-stage comparison above shows that this difference is particularly pronounced as firms move beyond early-stage financing. This financing gap increases the risk that promising EU quantum companies look abroad for growth capital.

According to the 2026 McKinsey Quantum Technology Monitor, government and institutional funding accounted for 19% of global quantum start-up investment in 2022, but only 3% in 2025, as private capital became dominant. It also reports that the top 10 financing or investment transactions involving quantum companies in 2025 totalled EUR 6.6 billion. Of these, eight involved companies headquartered in the US, one in the UK and one in Canada. No EU-headquartered company appeared in the top 10[69]. Furthermore, only 6 EU quantum companies have secured growth rounds exceeding EUR 100 million, compared with 28 globally.

In the EU, limited private scale-up finance makes public instruments especially important for quantum start-ups and scale-ups, notably the EIC Fund and the EIC STEP Scale Up[70]. However, support usually amounts to only a few million or low tens of millions per company and remains fragmented across EU and national programmes. This spreads resources across priorities too thinly rather than targeting key technological bottlenecks, while forcing companies to spend time navigating multiple competitive calls instead of focusing on industrialisation. In addition, fragmented national public funding further weakens Europe's position, as Member States (MS) invest in different priorities and there is insufficient joint programming at EU level. At the same time, US firms benefit from deeper private capital markets and substantial investment by major technology companies. Comparable private-financing data for China are not sufficiently transparent, although available evidence points to substantial state-led investment and significant activity in quantum computing and quantum communication.

As commercialisation gains traction, revenue gaps highlight the EU challenges of industrial scale-up and market development. McKinsey estimates that quantum computing revenues exceeded EUR 0.9 billion in 2025 and are projected to grow to EUR 2.8–3.8 billion by 2028[71].

Patent evidence offers a complementary perspective on scale-up and value-capture conditions. An ad hoc EPO analysis covering more than 31,700 published quantum-related patent families (2005-2024) finds that the European patenting area (the 40 contracting states of the European Patent Convention), has a substantial and diversified inventive base, ranking second only to the US in applicants and international patent families. However, European activity is dispersed across firms and public research organisations, while the largest portfolios are concentrated among a limited number of non-European applicants. This does not indicate weaker patent quality or market power but suggests that smaller European actors may struggle to finance international protection, participate in standardisation activities or negotiate licensing or cross-licensing arrangements as technologies mature[72]. The methodology, definitions and limitations

[68] Ibid, p. 54.
[69] McKinsey & Company, Quantum Technology Monitor 2026: A commercial tipping point, 2026, p. 37.
[70] Between 2021 and 2024, the EIC dedicated around EUR 350 million to quantum-technology start-ups. EIC STEP Scale Up investments can reach up to EUR 30 million per company.
[71] McKinsey & Company (2026), Quantum Technology Monitor 2026, p. 8.
[72] EPO, ad hoc patent analysis prepared for the Quantum Act IA, 2026, unpublished supporting evidence; OECD and EPO, Mapping the Global Quantum Ecosystem, 2025. Patent counts indicate inventive activity and protection strategies; they do not directly measure technological quality, commercialisation, freedom to operate or market power.

of this analysis are detailed in Annex 4, with supporting tables in Annex 11.

Beyond scientific and technical expertise, suppliers and users increasingly require enterprise capabilities, such as product management, business development, communication of use cases, procurement and technology adoption. This reflects the gradual commercialisation of quantum technologies and the need to translate technical capabilities into products, services and demonstrable user value.

The early market remains narrow. Global quantum-computing revenue exceeded just EUR 0.9 billion in 2025[73], with activity focused mainly on public, research and specialised early-adopter markets rather than broad commercial deployment. Within the EU, public investment has created important demonstrators and infrastructures, including the EuroHPC JU quantum-computing procurements[74]. However, the early stage of technology and these early purchases and pilots have yet to develop into a predictable, repeatable Union-wide demand pipeline[75]. This situation affects several groups:

- **quantum start-ups and scale-ups**, which face uncertain revenue, limited reference customers and difficulty financing industrial expansion;
- **industrial and public users**, which encounter uncertain business cases, integration costs and limited access to comparable and validated solutions;
- **investors**, which grapple with technological uncertainty and weak visibility over future demand;
- **public procurers**, which face technological uncertainty, limited reference deployments and insufficiently comparable performance information.

The resulting risk is that the Union finances the creation and early development of quantum firms but captures a smaller share of their subsequent growth, manufacturing, employment and intellectual-property value. This may incentivise firms to seek capital, customers, listings, industrial partners or ownership outside the Union. At the same time, weak supplier scale and weak domestic demand reinforce one another, slowing adoption by European businesses and public authorities.

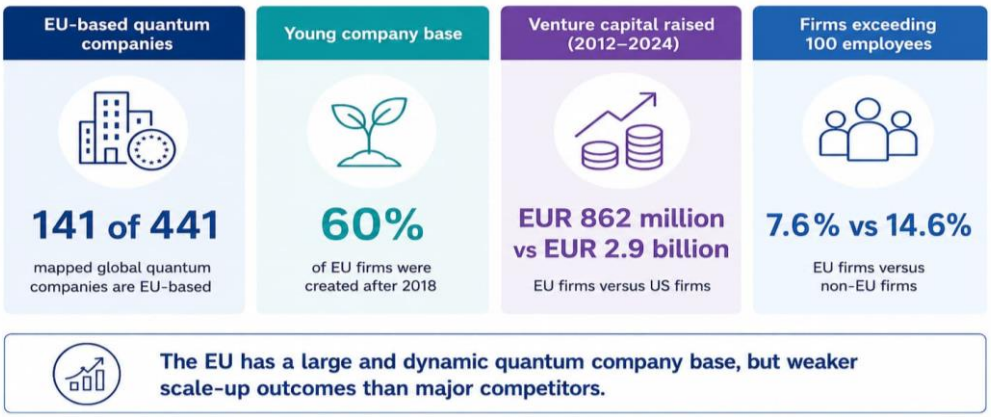

Figure 2.2 *EU quantum entrepreneurship and scale-up indicators. Indicators come from different samples.*

The causes of this combined scale-up and market-formation problem are examined under PD2

[73] McKinsey & Company, Quantum Technology Monitor, 2026.
[74] The EuroHPC JU: Up to now, the EuroHPC JU has procured six quantum computers and co-funded two more. See Quantum Europe Strategy, table 1 for a global overview of quantum computers installed.
[75] See Annex 11, section 4.4, on demand-side support and public procurement. Demand remains concentrated in public, research and specialised early-adopter markets and that pilots do not yet consistently convert into repeat procurement.

to PD6 in Section 2.2**.**

2.2.3. P3 – Strategic dependencies and insufficient resilience in quantum value chains

Quantum technologies rely on specialised materials, components, equipment, software, and services.[76] International sourcing is not inherently problematic, and full self-sufficiency would be neither realistic nor economically desirable. However, a dependency becomes strategically relevant where supply is concentrated, substitution is difficult or slow, and disruption could materially affect deployment or security-sensitive applications.

The supporting study[77] mapped 47 critical components and sub-components used in selected quantum-computing modalities[78] and shared control systems[79]. It assessed whether EU-based suppliers or alternative sourcing options could be identified. Nine components or sub-components had no identified EU-based supplier, while only half of the mapped sub-components had an identified dual-sourcing option. The most acute gaps were found at the sub-component level, particularly in control electronics and specialised materials. Since some inputs are used across multiple quantum modalities, disruptions could simultaneously affect several technology pathways[80]. Programme and stakeholder evidence also highlighted dependencies involving specialised photonic and control components, proprietary non-EU design tools, hardware and cloud services. The mapping is indicative: it covers selected technologies and identifies supplier presence but does not fully assess production capacity, substitutability, ownership, inventories or the probability of disruption. Nevertheless, it demonstrates that concentrated dependencies exist and that their visibility and mitigation require more systematic monitoring[81].

Dependencies may also arise through foreign ownership or investment relationships and be reinforced by the absence of common benchmarks needed to qualify alternative components. These forms of dependency can create technical and commercial lock-in, even where nominal alternative suppliers exist. These dependencies already have operational consequences. Supply constraints are already affecting project delivery[79].

The actors most directly affected include quantum equipment and component manufacturers, start-ups integrating externally sourced inputs, research infrastructures, public procurers and operators of critical or security-sensitive systems. Public authorities are also affected, as no single firm or Member State has full visibility over cross-border, multi-tier supplier dependencies.

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[76] Examples include specialised materials and gases, cryogenics, lasers and photonics, detectors, vacuum equipment, control electronics, RF components, design tools and cloud/computing access.

[77] PPMI and d-fine Commission Study for strengthening the evidence on the IA for the European Quantum Act, Final Report, June 2026. See Annex 11, section 6, on supply chain dependencies and vulnerabilities.

[78] Modalities refer to various technological platforms and associated architectures for quantum computing.

[79] In the documented sample, supply issues accounted for 73% of project extensions; eight affected projects had average delays of 191 days. The sample is illustrative, not representative. Around EUR 747 million of EUR 3.68 billion in mapped EU quantum funding supports domestic capabilities, pilot lines and component suppliers; replacement of critical components can exceed 12 months. See Annex 11, section 6.3 and Annex 2 for more information on the targeted industry survey.

[80] Quantum-specific imports cannot be robustly isolated from broader customs categories; dependency is therefore assessed using supplier location, alternative sourcing, substitutability, lead times and documented delays. Recent ownership changes involving European quantum capabilities are illustrative only., Annex 11.

[81] Documented examples include changes in supply conditions for specialised components, reliance on proprietary non-EU design tools and cloud services, and reduced transparency following the acquisition of a quantum-communication supplier. These cases are illustrative and not representative estimates for the sector. See Annexes 2 and 11, tabs 66, 68, 70, 84; Section 2.2.7.

These vulnerabilities cannot be effectively addressed through isolated national action and therefore require coordinated efforts at Union level. Moreover, public authorities are directly concerned in their role as procurers and operators of critical and security-sensitive systems where supply disruptions can undermine service continuity and security.

The resulting problem is ***insufficient resilience***. Supplier concentration, limited substitutability and incomplete visibility create uncertainty and chokepoint risks. Disruptions, changes in export conditions, acquisitions, supplier exits or technical lock-in may delay projects, increase substitution costs and deepen dependence on non-EU technologies. These consequences are not purely prospective: quantum technologies and quantum-enabled components are already used in established applications such as medical imaging, precision timing and sensing, and are increasingly deployed in communications, navigation, defence and space systems. The consequences could become more significant as deployment expands into further critical infrastructure and other security-sensitive systems. The underlying causes are examined under PD7 in Section 2.2.7.

2.2.4. What are the main consequences?

The scale and timing of further quantum breakthroughs remain uncertain, but this uncertainty does not reduce the potential impact of the problems identified above on the private and public sectors. Given existing applications and the potential for rapid, non-linear progress, these problems may increase the likelihood of four main types of consequences during the assessment period:

- **Lower industrial value capture and competitiveness.** Excellent European research does not automatically translate into EU market uptake; public investment is thus likely to generate smaller returns, fewer scaled suppliers, manufacturing activities, and deployable products than would be expected from the Union's scientific and entrepreneurial base. This could prevent Europe from translating these strengths into sustained industrial leadership and market share, while increasing dependencies.
- **Slower uptake and foregone benefits for users.** Businesses and public authorities will have access to fewer validated European solutions, face higher integration costs and experience slower diffusion of potentially useful quantum applications.
- **Greater strategic and security exposure.** Dependence on concentrated non-EU inputs and platforms may increase the risk of disruption, lock-in and loss of control in sensitive or dual-use applications.
- **Reduced attractiveness for capital and specialised talent.** Limited scale, uncertain demand and delayed deployment may make stronger ecosystems abroad increasingly attractive to investors, companies and highly skilled personnel.

These consequences could reinforce one another. Limited deployment may weaken the revenues of quantum firms and reduce investor confidence; weaker firms may be less able to diversify their suppliers or support users, while continued external dependence may further reduce the Union's capacity to capture industrial value and remain or become leader in this field.

2.3. What are the problem drivers?

The three problems identified in Section 2.1 stem from seven underlying drivers: coordination failures, limited access to shared infrastructure, human-capital constraints, financing conditions, weak early demand, information gaps and trust mechanisms, and the management of strategic dependencies.

These drivers are reinforced by structural features of the global quantum sector, including high technological uncertainty, long development cycles and intensifying international competition.

However, the analysis does not consider these factors as the Union or Member State action cannot realistically influence them.

The drivers are also closely interlinked. Limited access to test and validation infrastructure, for example, raises both technological and financing risk; incomplete standards and benchmarks make procurement and supplier substitution harder; and weak demand undermines firms' ability to attract growth capital. The following subsections set out the main causal mechanism and evidence for each driver.

The evidence base is uneven across problem driver areas. It is strongest for mapped firms, financing rounds, infrastructures, procurement schemes and selected quantum-computing components; it is weaker for infrastructure utilisation, conversion from pilots to procurement, quantum communication and sensing supply chains, user-side adoption and quantum-specific trade flows. As most quantum components fall under broader customs and product classifications, robust estimates of quantum-specific imports are not possible.

2.3.1. PD1 – Insufficient alignment of public priorities and investment

Public support for quantum technologies in Europe is high, but it is spread across many separate EU, national and regional programmes. In the last five years, more than EUR 11 billion has been invested or committed by the EU and its Member States, of which around EUR 9 billion came from Member States[82]. As of March 2026, 14 Member States had a quantum-specific strategy in place and four more were preparing one[83].

This decentralised model is not a problem, because Member States have different strengths and priorities, but separate decisions do not always result in an efficient Union-wide allocation of effort, funding and skills. Additionally, no single authority has the mandate and the full overview to optimise a combined EU and national portfolio. The absence of efficient coordination can lead to an inefficient use of resources and hinders the achievement of common technology targets that require immense investment.

Similar technologies and infrastructures may be funded in parallel, while other areas may remain under-supported or lack continuity and scale. The targeted consultation evidence points to parallel calls addressing similar technologies, different programme conditions and multiple reporting requirements for projects receiving both Union and national support. These examples show the coordination problem even if not all parallel activities are an unnecessary duplication. The evidence suggests extensive parallel support across all three main quantum domains and across major technology platforms using atoms, ions, superconductors, semiconductors, photons or vacancy centres. In quantum computing and simulation alone, 92 national-level actions were identified alongside 34 EU-level actions, with similar patterns in sensing and metrology, communication and enabling technologies[84]. This underlines the need for better visibility and coordination across the full funding landscape.

Existing mechanisms have until recently not provided a regular way to compare Union and national priorities, investments and implementation milestones. The expanded EuroHPC JU mandate now offers a common EU-level implementation platform for many quantum activities. However, because the amended Regulation does not require alignment of all EU and national

[82] The Quantum Europe Strategy reports more than EUR 11 billion of Union and Member State investment whereas the external mapping identified EUR 7.6 billion of commitments in the Member States covered.

[83] Czechia, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, the Netherlands, Austria, Romania, Slovenia, Finland and Sweden. A further four Member States were preparing one: Bulgaria, Greece, Poland and Slovakia. See Annex 11, section 1, on the National Quantum Policy Measures.

[84] PPMI/d-fine mapped 92 national/34 EU-level actions in quantum computing and simulation, 43/18 in sensing and metrology, 24/9 in quantum communication and 11/10 in enabling technologies. See Annex 11.

strategies, programmes or budgets, important coordination gaps are likely to remain. These coordination gaps are reinforced by the structure of funding itself. EU quantum funding is fragmented across many relatively small commitments and is mainly focused on academia rather than industry. This matters because EU firms have fewer alternative private funding sources. The mapped collaboration ecosystem reflects this imbalance: 61% of collaborations are research-to-research, while only 9.6% involve industry. Funding is also less concentrated within established quantum clusters than in the US or China, making it harder to bring together talent, infrastructure, industrial partners and co-investment at the scale needed for commercialisation[85;86].

Overall, PD1 contributes to two core problems: to P1, because dispersed priority-setting weakens the sustained concentration of resources needed to move quantum technologies through successive stages of development; and to P2, because fragmented instruments and funding conditions make it harder to build cross-border projects, combine financing sources and support companies consistently from research to industrial scale-up.

2.3.2. PD2 – Limited and uneven access to quantum industrialisation infrastructure

Quantum industrialisation requires more than proof of concept. Depending on the technology, firms and research teams need access to specialised infrastructure, such as fabrication and cleanrooms facilities, packaging, cryogenic or vacuum environments, advanced testing and experimentation tools, calibration methods, metrology, system integration, security evaluation and technology and system qualification facilities.

Because many of these facilities are expensive and highly specialised, individual start-ups and SMEs cannot finance and operate them alone, making shared access essential. The evidence does not point to a general shortage requiring many new facilities but rather to limited visibility of existing capabilities, uneven access, insufficient user support, weak links between facilities and company development pathways and in some areas missing capability or excess demand. Additional or upgraded capacity would be justified only where European mapping shows a clear gap.

The supporting PPMI/d-fine study shows that only 18 of the 91 mapped testbeds and 8 of the 27 mapped pilot lines were identified as open to start-ups[87]. Where data were available, average waiting times were about six months for Qu-Test[88] testbeds and 3-4 months for mapped quantum-communication testbeds. While not representative for all Union facilities, these figures support stakeholder concerns that timely access can be a bottleneck.

Stakeholders also report practical barriers to access, including unclear or project-specific eligibility criteria, limited capacity, waiting times, costs, IP conditions and insufficient technical support for smaller firms. These barriers vary across facilities and Member States and should not be treated as uniform across the EU.

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[85] Industry participation in quantum collaborations (EU 9.6%, US 23%, Japan 28%). Source: Erixon, F., Dugo, A., Pandya, D. and Sisto, E. (2025), Mapping the Quantum Ecosystems: How Are Economies Positioning Themselves for Innovation Success, ECIPE Occasional Paper No. 08/2025, European Centre for International Political Economy, Brussels, pp. 21–22, Figure 7. 2.2.

[86] Geographic concentration of quantum funding (EU 77%, US 98%, China 99%). Source: Erixon, F., Dugo, A., Pandya, D. and Sisto, E. (2025), Quantum Clusters: Ranking the World's Deep-Tech Epicentres, ECIPE Occasional Paper No. 15/2025, European Centre for International Political Economy, Brussels, p. 45, Annex 2, Figure 15.

[87] See Annex 11, section 5 on the mapping of testbeds and pilot lines.

[88] Qu-Test is a multi-partner project funded under Horizon Europe since 2023 aiming to develop and provide infrastructure for testing and experimentation for quantum technologies in Europe.

Existing EU initiatives partly address this driver. The EuroHPC JU provides access to quantum-computing systems integrated with supercomputers; the EuroQCI initiative supports communication infrastructures and test environments; and the six quantum pilot lines currently under development under the Chips JU will expand fabrication and validation capacity for quantum chips. Despite these activities, the fundamental issues mentioned above remain.

PD2 contributes to P1 by slowing technological maturation and validation. It contributes to P2 because firms that cannot demonstrate reproducible performance, meet customer requirements or qualify production processes face higher financing risk and greater difficulty securing customers.

2.3.3. PD3 – Shortages of industrial, deployment and user-side skills

Quantum industrialisation demands skills far beyond academic quantum science: engineers, technicians, software developers, systems integrators, product specialists, cybersecurity experts and business-development professionals who can bridge quantum knowledge with industrial disciplines. Users and public procurers also need expertise to assess claims, identify use cases, manage procurement and integrate quantum technologies into existing systems.

Europe boasts a strong scientific and doctoral talent with around 40 specialised master's programmes in quantum technologies. However, graduate output is projected to fall short of industrial demand, especially in engineering, software, systems integration and deployment-oriented profiles[89]. There is also growing demand for business and commercialisation skills, such as product management, business development, user engagement or the ability to communicate quantum use cases[90]. The targeted industry survey reinforces this finding: 29 of 41 respondents (71%) considered specialised skills and talent mobility a significant barrier, with gaps in cryogenics, nanofabrication, photonics, control systems, systems engineering and interdisciplinary hardware-software profiles. As the survey was targeted and not statistically representative, these results should be treated as evidence of stakeholder experience rather than an EU-wide estimate[91].

A major challenge is the to keep the education and training offers up to date with the rapid evolution of skill demands. Start-ups and SMEs often lack resources to invest in broadly transferable training, and education providers may not have timely insights and flexibility to constantly adapt to emerging industrial needs. Similar issues affect user-side training.

Mobility and talent retention further strain the supply of experienced personnel. Targeted consultations[92] indicate that better-funded ecosystems and large non-EU technology companies may offer more attractive career prospects. Complementary job-posting evidence also reveals an asymmetry: 7.7% of EU-based quantum vacancies in the study were posted by US-headquartered firms, compared with 1.3% of US-based vacancies posted by EU-headquartered firms, indicating a stronger recruitment presence of US-headquartered companies in the EU quantum labour market.[93].

PD3 contributes to P1 where shortages in engineering and technical profiles delay technology development, processes and products, and the operation of shared infrastructure. It contributes

[89] Strategic Research and Industry Agenda 2030, 2024 (SRIA), p. 168; OECD and EPO, Mapping the Global Quantum Ecosystem, 2025, Chapter 6, on evolving and cross-disciplinary quantum skill requirements; QuIC, 'Response to the Call for Evidence on the EU Quantum Act', 2025, pp. 14–16.
[90] Sydney Quantum Academy, National Quantum Industry and Workforce Development Review, 2023.
[91] See Annex 4 and the corresponding source worksheet in Annex 11, tab 84 on the EU indicators.
[92] More information on the targeted consultation: Annex 3, specifically in sections 3.5, 3.6 and 3.10.
[93] Goorney, S. et al., The Quantum Technology Job Market: Data-driven Analysis of 3,641 Job Posts, EPJ Quantum Technology, 2026. The dataset covered vacancies collected between March 2023 and June 2024.

to P2 where suppliers cannot scale their teams and potential users lack the expertise needed to become customers or move to deployment.

2.3.4. PD4 – Insufficient later-stage risk capital and financing continuity

Quantum companies face long development cycles, high technological uncertainty and significant upfront costs for equipment, engineering and validation before generating predictable revenues. This creates an information asymmetry between firms and investors, who must assess complex technical claims and finance companies over extended periods with unclear commercial outcomes. The gap is especially critical during scale-up, when financing needs grow but technical and market risks remain high. Private investors also fail to capture all societal benefits of quantum investment, such as knowledge spillovers, workforce development and economic-security benefits. IP management, patent portfolios, and freedom-to-operate assessments also affect company valuation and investor confidence, particularly for start-ups, spin-offs and research-intensive SMEs.

This dynamic aligns with observed financing patterns described in Section 2.1. EU firms raised significantly less venture capital than US firms between 2012 and 2024, participating in only 35 of the 188 mapped funding rounds above EUR 25 million. The disparity is most evident in later-stage growth and public-market financing, where EU firms remain underrepresented despite global investment growth in 2025[94]. For firms with a recorded Series A round, EU companies took an average of 4.53 years to reach this stage, compared to 3.76 years for non-EU firms—though this difference should be interpreted cautiously due to sample variations[95].

While existing instruments support early-stage R&I, technology development and selected infrastructure, a critical gap emerges for post grant-funded R&I and prototype development, when firms need substantial, repeated financing for engineering, qualification, production and market entry—amid uncertain revenues. EU initiatives of the European Innovation Council (EIC), InvestEU and EIB Group can help, but do not guarantee a continuous quantum-specific pathway or adequate coverage of capital-intensive later-stage needs.

Indicative bottom-up estimates suggest that the European quantum sector could require around EUR 50–60 billion in financing, mainly equity, to support start-up growth, scale-up and major industrial-capacity investments[96].

This imbalance is compounded by the EU's limited private capital. McKinsey reports that in 2022, government and institutional funding accounted for 19% of global quantum investment, dropping to 3% in 2025 as private capital dominated. In the EU, however, public funding continued to represent the majority of inflows, reflecting a shallower private capital pool[97]. Corporate investment in EU quantum start-ups also lagged: in 2025, EU firms received approximately USD 148 million, compared to USD 1 billion for US firms[98]. This gap is widened by US public support, such as the 2026 Department of Commerce announcement of

[94] Average later-stage venture-capital round sizes increased by 233% between 2024 and 2025, while average reverse-merger and SPAC round sizes increased by 314%. Capital-market transactions, including IPOs, SPACs and PIPEs, accounted for 44% of global private quantum investment. None of the public-market transactions identified among the largest quantum investment transactions of 2025 involved an EU-headquartered company. EU firms received approximately USD 148 million in corporate investment, compared with around USD 1 billion for US firms.

[95] For more information, see Annex 4.

[96] Commission-services bottom-up planning estimate; see Annex 4 for assumptions and limitations.

[97] McKinsey & Company, Quantum Technology Monitor 2026: A commercial tipping point, 2026, p. 36.

[98] Ibid, p. 39.

USD 2 billion in proposed federal incentives for quantum companies[99].

Targeted stakeholder consultations highlighted concerns about the accessibility and suitability of existing financial instruments for capital-intensive quantum firms, including eligibility conditions, continuity between funding stages and the assessment of projects with long commercialisation horizon. These findings are presented in detail in Annex 3.

The financing gap may also restrict European investors' ability to participate in strategically important transactions. A related industrial-policy concern may therefore arise where a strategically important European quantum company lacks viable European financing alternatives and risks relocation or acquisition, potentially reducing Europe's capacity to develop and scale critical quantum capabilities[100]. Foreign investment is not inherently problematic. Where a transaction is subject to FDI screening, any assessment remains governed by the applicable Union and national criteria relating to security or public order. These criteria pursue a distinct objective and do not necessarily address broader industrial-policy concerns, such as preserving European scale-up capacity or strategically important technological capabilities where no security or public-order concern arises.

PD4 directly contributes to P2 by limiting firms' ability to finance industrial teams, production capacity, qualification, market entry and international expansion within the Union.

2.3.5. PD5 – Weak demand pull and fragmented pathways to first buyers

Early-stage quantum markets face a coordination challenge: suppliers need customers, operational feedback and reference deployments to refine their products and attract investment. At the same time potential users hesitate due to uncertain performance, unclear business cases, integration costs and the risk of backing an immature supplier or technology. This creates a first-buyer externality: early adopters bear most of the cost and risk, but successful validation benefits the broader market by generating information, reference value and confidence. As a result, individual public authorities or companies may rationally delay adoption, even if earlier purchasing would benefit the wider ecosystem.

Current demand stems mainly from research infrastructures, specialised industrial users and public purchasers. EU programmes have funded pilots, demonstrators and the first EuroHPC JU quantum-computing procurements. Moreover, lead demand via procurement has proven useful to the ecosystem with the procurement of several quantum computers by the EuroHPC JU. However, there is no systematic Union-wide pathway for successful pilots to progress to reference deployment and repeat procurement. Stakeholders highlight limited anchor customers, fragmented procurement and insufficient end-user involvement in technology-development projects. The mapping of existing quantum procurement schemes and deployments carried out in support of this IA identified only 12 buyers for quantum-computer prototypes and 33 for quantum-communication infrastructure[101], suggesting a narrow buyer base rather than a broad first-buyer market.

Since most EU activities are still early-stage and procurement processes are ongoing[102], it is not yet possible to calculate how many EU pilots progress to deployment. This driver is especially relevant to public authorities and critical-infrastructure operators, which may have

[99] U.S. Department of Commerce, "Department of Commerce Announces Letters of Intent With 9 Companies for $2 Billion to Accelerate U.S. Leadership in Quantum Computing", 21 May 2026.
[100] Regulation (EU) 2019/452 establishing a framework for the screening of FDI into the Union.
[101] See Annex 11, section 4.
[102] At the analytical cut-off, the six Chips JU quantum pilot lines had only recently entered implementation. EuroHPC had procured six quantum systems and co-funded two further systems through HPCQS. The evidence period is therefore too short to calculate a representative pilot-to-repeat-procurement rate.

use cases in secure communications, sensing, navigation, healthcare or computing but may lack the in-house expertise to define requirements, assess offers or compare suppliers using agreed metrics. SMEs on the user side also struggle due to limited resources for evaluating and integrating uncertain technologies.

Comparable firm-level data on access to first customers in the EU, US, and China is unavailable. In the US, Executive Order 14413 aims to coordinate public demand by prioritising quantum-sensing projects, expanding user facilities, and considering advance market commitments for a science-enabling quantum computer—though its impact depends on funding and implementation. Information for China is less available. Thus, while public-demand mechanisms can be compared, no general conclusion can be drawn about easier customer acquisition in either market.

PD5 directly contributes to P2. Weak demand limits revenues, reference customers and investor confidence, while undercapitalised firms reinforce buyer concerns, creating a two-sided coordination failure that hinders both market formation and scale-up.

2.3.6. PD6 – Incomplete standards, benchmarks and assurance pathways

Buyers and investors need reliable information to compare quantum technologies, assess performance and security, and determine integration potential. Suppliers, in turn, need common methods to demonstrate these characteristics. Without agreed terminology, measurement methods, benchmarks, interoperability profiles and assurance pathways, each transaction requires additional technical due diligence and bespoke validation.

This creates a dual challenge: information asymmetry and a collective standard-setting problem. Individual suppliers may push performance metrics that favour their own technologies, while buyers cannot unilaterally establish benchmarks or interoperability requirements that the broader market will adopt. Common methods thus require coordination among suppliers, users, research organisations, metrology bodies and standardisation organisations.

The CEN/CENELEC quantum standardisation roadmap[103] confirms that many international initiatives are underway, but highlights overlaps and significant gaps. It also notes varying maturity across quantum domains: early standardisation can support market development in some areas, while premature standardisation could stifle innovation in others. The issue is twofold: the absence of comprehensive standards for emerging quantum technologies and the lack of agreed reference methods and assurance pathways for more mature technologies ready for procurement and deployment.

A standardisation mapping identified 165 quantum-related items, including published standards, technical specifications and works in progress. Approximately 70% focused on quantum communication or PQC, with around 30% being published formal standards[102]. The methodology, organisations covered and classification of work in progress are set out in Annex 4. As standards evolve, the interaction between patents and standardisation—including access to licensing—may become relevant. Fragmented patent portfolios could disadvantage smaller European actors.

Stakeholder evidence points to practical consequences, such as the need for bespoke test arrangements, difficulties comparing component data, uncertainty about future security-evaluation or certification pathways. Several respondents expressed concerns about the

[103] CEN/CENELEC JTC 22, Standardization Roadmap on Quantum Technologies, Release 1.1, June 2025; See also Annex 11, section 3 regarding standardization in Quantum Technologies.

maturity and practical applicability of existing specifications particularly for QKD.

The international dimension is also important. Strong EU participation in international standard-setting can promote interoperability, mutual recognition and the adoption of European technologies. Stakeholders warn that insufficient European standardisation capacity could increase reliance on external technologies and standards.

PD6 contributes to P2 by increasing the cost and risk of purchasing, integration and supplier substitution. It also contributes to P3, as the lack of comparable specifications and qualification methods can create de facto dependence on incumbent suppliers, even where technical alternatives exist.

2.3.7. PD7 – Limited visibility and insufficient incentives to mitigate critical dependencies

Quantum supply chains are technically complex and multi-tiered. System developers may know their immediate suppliers but often lack visibility into the origin, concentration and substitutability of sub-components, materials, software and services further upstream.

While the evidence does not confirm a general market failure across the entire quantum sector—still in its early commercialisation stage—it does highlight a collective information and coordination gap in strategically relevant supply chains. Limited visibility in this context refers to insufficient EU-level data on quantum-specific dependencies at component, sub-component and supplier levels. Available information is fragmented across companies, projects and programmes, making it difficult to identify shared dependencies or assess concentration, substitutability and disruption risks across firms and Member States. Firms typically have information about their direct suppliers, but no single actor has a comprehensive EU-wide view across supplier tiers, projects and Member States. Additionally, commercially sensitive information is not routinely shared across firms or with public authorities.

Existing mapping exercises already point to supply gaps and long response times, highlighting the importance of earlier identification and coordinated mitigation (see Table 2.1)[104]. Stakeholder evidence also points to vulnerabilities in areas such as specialised amplifiers, cryogenics, control electronics, proprietary design tools and cloud services[105]. Limited visibility can therefore delay the identification of emerging chokepoints and result in diversification and supplier qualification taking place only once risks have materialised. It can also make it more difficult for public authorities to target mitigation, procurement, financing or international partnerships towards the most material risks. The component mapping and documented project delays indicate that these gaps are already impacting R&I and early deployment, even before broad commercial markets emerge.

Key findings (Table 2.2) show that sourcing alternatives are materially weaker at the sub-component level, and supply issues have already caused notable delays in a small, documented sample. The selective mapping covers 31 main components and 16 sub-components across five quantum-computing platforms and shared control systems. Dependency risk is influenced not only by supplier location but also by concentration, substitutability, lead times, and redesign or qualification requirements.

[104] PPMI/d-fine dependency and resilience mapping for the IA. See Table 2.1, Annex 4 for the underlying evidence, methodology and limitations and Annex 11 tabs 42, 55, 56 and 67, while also see Annex 7, section 9 on Dependencies, enabling technologies and resilience"; Annex 8, Table 8.3; and Annex 10, Table 10.3

[105] See Annex 2 for more information on the stakeholder consultation.

Indicator	Evidence	Main interpretation
Components and sub-components mapped	31 main components and 16 sub-components	Selective mapping of strategically relevant inputs; not an exhaustive inventory
Inputs without an identified EU-based supplier	9 of 47 mapped inputs, approximately 19%	Specific gaps were identified in the selective mapping; this is not an estimate that 19% of the entire quantum value chain lacks an EU supplier
Inputs with an identified alternative source	87.1% of main components; 50% of sub-components	Sourcing vulnerability is materially greater at sub-component level
Documented operational effects	Supply issues associated with 73% of documented extensions; 8 affected projects delayed by an average of 191 days	Supply constraints already affect projects, but the sample is too small for sector-wide extrapolation

Table 2.2. *Evidence on sourcing concentration and documented supply-chain effects in selected quantum-computing inputs. Source: external-support component and programme mapping conducted for this IA. Coverage, definitions, supplier-verification methodology and limitations are provided in Annex 4.*

A security externality arises when continuity of supply or control over a technology is essential for the functioning of critical infrastructure, defence, space-related applications or secure communications. Firms typically assess dependencies based on their own risk assessments, often overlooking broader consequences like disruption, technology leakage or the loss of a strategically relevant supplier for other European users.

Existing frameworks address parts of the risk but serve different purposes:

- *FDI screening* evaluates specified inbound investments and acquisitions but does not continuously map component-level supply dependencies;
- *Dual-use export controls* regulate outbound transfers but do not provide early warnings of third-country supplier restrictions;
- The *Critical Raw Materials Act* covers certain materials but not manufactured components, software, or services where many mapped quantum dependencies exist;
- *Programme and project reporting* offers operational insights but lacks a unified quantum supply-chain monitoring system.

Stakeholder evidence highlights risks, including delays due to changes in export conditions for specialised amplifiers, concentration in cryogenic and control-electronics supply, reliance on proprietary non-EU design tools and cloud services, as well as reduced transparency in supply conditions after a change in ownership of a European quantum-communication supplier. These cases illustrate how dependency risks can arise, but do not represent a sector-wide estimate[106].

Foreign investment is not inherently a dependency or negative outcome—it can provide essential capital, commercial networks and industrial expertise. The risk arises when acquisitions, exclusive investment relationships or transfers of decision-making control reduce access to strategically important capabilities for European users or create unacceptable security exposures. Assessments must therefore distinguish between beneficial international investment and transactions posing concrete economic-security risks.

[106] Evidence concerning changes in export conditions, foreign acquisitions and dependencies on specialised components, proprietary software and cloud services is based on documented stakeholder examples. These cases are illustrative and should not be interpreted as representative estimates for the quantum sector.

PD7 directly contributes to P3. The lack of shared visibility delays identifying chokepoints and leaves mitigation largely to individual firms and projects. The relevant issue is therefore resilience and risk-aware diversification, not self-sufficiency or indiscriminate preference for EU suppliers.

2.4. How likely are the problems to persist?

Under the dynamic baseline described in Section 5.1, the Quantum Europe Strategy, the expanded EuroHPC JU mandate, the Chips JU pilot lines, EuroQCI, existing financial instruments and the coordinated PQC roadmap[39] are expected to improve parts of the European quantum ecosystem. However, these measures are at varying implementation stages, and do not collectively address all structural drivers identified in Section 2.2. Thus, the three core problems are likely to persist beyond 2030, though their intensity will vary across technologies and Member States.

P1 – Slow conversion of research excellence into deployable technologies. Quantum activities under the EuroHPC JU, the quantum-chip pilot lines and existing testing and deployment infrastructures will increase available capacity. However, as Union, national and regional programmes will continue to operate under separate planning and funding cycles, access to fabrication, testing, integration and qualification facilities is likely to remain uneven across quantum domains and among stakeholders. Given the long development and qualification cycles involved, discontinuities between research, engineering and deployment may continue to disperse teams, knowledge and industrial partnerships before technologies reach maturity[107]. Although the share of concluded Horizon Europe quantum actions classified as higher-TRL increased from 21% in 2023 to 45% in 2025, indicating progress towards validation and deployment, the period remains too short to conclude that the structural discontinuity between research-to-deployment has been resolved[108].

P2 – Insufficient conditions for firms to scale and early markets to develop. Existing financial instruments and public procurements will continue to support individual firms and projects but they do not create a continuous pathway from research grants and prototypes to later-stage finance, reference deployments and repeat procurement. Investors may wait for customer and revenue evidence, while users may delay adoption until suppliers achieve greater scale and maturity. Some European firms will grow but the gap between company creation and industrial scale is unlikely to close by 2030[109].

P3 – Strategic dependencies and insufficient resilience. Many of the identified dependencies relate to specialised materials, components, software and services supplied by a limited number of providers. Switching to alternative sources may require redesign, qualification and investment and may therefore not be achievable in the short term. Existing frameworks, including FDI screening, export controls, critical raw materials, and programme reporting, address specific risks but they do not provide a continuously updated EU-wide view of component-level dependencies. As deployment expands across communications, space, defence and critical infrastructure, the operational consequences of concentrated or hard-to-replace supply are likely to increase[110].

The problems are interconnected: interruptions in industrialisation make firms harder to finance; weak scale and demand reduce investment in facilities and skills; and a fragmented

[107] See Sections 2.1.1 and 2.2, PD1–PD2.
[108] See Annex 11, section 1 and 2 for funding programmes, section 2 on the Project development periods and higher-/lower-TRL classification and section 5on the quantum support infrastructures in the EU.
[109] See Sections 2.1.2 and 2.2, PD4–PD5.
[110] See Sections 2.1.3 and 2.2, PD7 and Annex 11, section 6.

industrial base has less capacity to identify and mitigate dependencies. Existing measures will generate progress but are unlikely to resolve the underlying research-to-deployment discontinuities, scale-up and market-formation challenges, or resilience risks within the assessment period.

If these problems persist, the consequences outlined in Subsection 2.1.4 will continue to generate lower European industrial value capture, slower uptake of quantum solutions, greater exposure to supply and security risks, and reduced attractiveness for private capital and specialised talent. These consequences would remain mutually reinforcing, as weak deployment reduces revenues and investment, while limited industrial scale constrains the capacity to diversify suppliers and support users.

3. WHY SHOULD THE EU ACT?

3.1 Legal basis

The initiative's main objective is to strengthen the competitiveness and resilience of the Union's quantum-technology industrial ecosystem.

Article 173(3) TFEU is the main legal basis, as it allows the Union to support Member State action in pursuing industrial-policy objectives. Measures on strategic coordination, shared industrialisation capabilities, access to infrastructure, industrial scale-up, ecosystem development and supply-chain resilience may therefore be based on Article 173(3), provided that they support or complement Member State action and do not harmonise Member States' laws or regulations.

Article 114 TFEU may also be used for measures approximating national rules where this is necessary to prevent or remove concrete obstacles to the cross-border deployment of quantum products and services or appreciable distortions of competition in the internal market. This could cover, where justified, common requirements relating to interoperability, conformity assessment, technical documentation or information obligations. Its use should remain limited to provisions for which actual or likely internal-market barriers are demonstrated in the problem definition and impact analysis.

For the initiative assessed in this IA, Article 173(3) TFEU is the main legal basis. Article 114 TFEU should be used only if the final proposal contains clearly separable provisions approximating national rules to address proven internal-market obstacles or distortions of competition. Otherwise, the initiative should rely solely on Article 173(3) TFEU.

3.2. Subsidiarity: necessity of EU action

The initiative concerns industrial policy, an area in which the Union may support, coordinate or supplement Member State action under Article 6(b) TFEU. To the extent that it includes internal-market measures based on Article 114 TFEU, it would also concern an area of shared competence under Article 4(2)(a) TFEU. The principle of subsidiarity therefore applies.

The three problems identified in Chapter 2 have a significant cross-border dimension[111]. As regards **P1**, Member States may finance national research programmes and infrastructures, but national action alone cannot ensure that the European ecosystem reaches critical mass or provides coherent pathways across research, fabrication, testing, qualification and deployment. As regards **P2**, national finance, procurement and business-support measures may assist individual firms and local ecosystems but cannot in themselves create an integrated European scale-up and early-market environment. As regards **P3**, national supply chain monitoring and

[111] Evidence supporting the Union-wide and cross-border dimension is set out in Sections 2.1 and 2.2, and Annex 11. See, for example, footnotes 65, 66 and 69, and Section 2.1.3 for the critical component mapping study.

mitigation measures, where available, cannot in themselves provide a complete picture of EU-level exposure or coordinate responses when the relevant capabilities and alternative suppliers are distributed across the Union.

Member State action therefore remains necessary but is insufficient on its own to address the scale, cross-border effects and coordination failures identified. Union action is necessary to complement national measures where objectives require critical mass, shared infrastructure, cross-border market formation or aggregated supply-chain visibility.

3.3. Subsidiarity: added value of Union action

Union action can add value in four main ways. First, ***alignment***: by aligning Union and national priorities to focus resources where European scale is required, while allowing Member States to support areas reflecting their scientific and industrial strengths. Second, ***economies of scale***: by enabling specialisation and shared access to costly infrastructure (e.g., pilot lines, testbeds), especially for start-ups, SMEs and users located in Member States lacking such facilities. Third, ***market leverage***: by coordinating procurement and strengthening links between firms, users and investors, Union action can create stronger demand and give firms a larger home market in which to scale, while strengthening the Union's collective position[112]. Fourth, ***identifying and managing strategic dependencies***: by aggregating information across firms, infrastructures and Member States, Union action can reveal concentration and chokepoints that would not be visible from a national perspective and facilitate coordinated diversification.

4. OBJECTIVES: WHAT IS TO BE ACHIEVED?

The objectives translate the three problems and seven problem drivers identified in Chapter 2 into the outcomes that the initiative aims to achieve.

4.1. General objectives

The initiative has two mutually reinforcing general objectives:

General Objective 1 (GO-1) – Sustain the Union's scientific and technological leadership and strengthen its competitiveness and industrial deployment capacity in quantum technologies. GO-1 aims to sustain and further develop the Union's quantum scientific and technological (S&T) leadership and turn these strengths into manufacturable and deployable quantum technologies, stronger industrial capabilities, scaled European firms and competitive products and services in global markets. It requires stronger links across the innovation chain so that European quantum breakthroughs can mature and be commercialised.

General Objective 2 (GO-2) – Improve EU resilience, trusted and quantum-safe deployment, and economic security in strategically relevant quantum value chains and infrastructures. GO-2 aims to improve the conditions for trusted and secure deployment, reduce exposure to critical dependencies, disruptions and technology leakage, and strengthen the Union's capacity to anticipate and mitigate risks affecting strategically relevant quantum technologies. It includes preparedness for the security implications of quantum technologies, notably the transition towards quantum-safe solutions where relevant.

Together, these objectives would strengthen the Union's technological sovereignty in quantum technologies.

4.2. Specific objectives

The initiative pursues seven specific objectives:

[112] European Investment Bank, Investment Report 2025/26: Capitalising on Europe's strengths, pp. 7 and 254.

SO-A – Improve EU-Member State R&I alignment and delivery to sustain S&T excellence. Establish one coherent EU-Member State quantum R&I programming framework based on common priorities, with regular alignment and review of relevant Union and national strategies, programmes, investments and implementation milestones.

SO-B – Reduce lab-to-fab bottlenecks and improve access to shared industrialisation infrastructures. Improve continuity from research to industrial deployment by developing or upgrading missing European capabilities, broadening cross-border access to existing infrastructures, and providing the technical support needed to use them.

SO-C – Improve scale-up conditions through de-risking and financing continuity. Improve access to suitable financing and continuity between early-stage public support, private investment and later industrial financing, enabling European quantum firms to enter markets and scale up in Europe.

SO-D – Strengthen demand pull and support pathways to first buyers and wider deployment. Increase the involvement of industrial and public users, improve progression from pilots to reference deployments and repeat procurement, and support early-market formation where EU-level action adds value.

SO-E – Improve targeted skills and user support for deployment. Increase the availability and mobility of the industrial, engineering, software, technical, operational, procurement and user-side skills needed to develop, assess, integrate, operate and adopt quantum technologies.

SO-F – Improve trusted and quantum-safe deployment through standards, benchmarking, testing and implementation support. Improve the comparability, interoperability, security and trustworthiness of quantum technologies through common terminology, measurement methods, performance benchmarks, testing and assurance approaches suited to technological maturity. Support timely and risk-based implementation of the existing PQC transition roadmap.

SO-G – Improve visibility, early warning and mitigation of critical dependencies. Strengthen the Union's capacity to identify, assess and respond to strategically relevant dependencies, supplier concentration, chokepoints and related economic-security risks affecting quantum value chains and deployment, while maintaining open and diversified international supply relationships.

A description of the baseline of the objectives can be found in Annex 8, Section 4.

5. WHAT ARE THE AVAILABLE POLICY OPTIONS?

This chapter defines the dynamic baseline and presents the policy options for assessment. The options, derived from the problems, drivers and objectives in Chapters 2 and 4, stakeholder evidence and a screening of possible policy measures, vary in legal force and implementation intensity. Detailed measure fiches, analytical assumptions and costs are set out in Annex 4.

5.1. What is the baseline from which the options are assessed?

5.1.1. Scope of the dynamic baseline

The dynamic baseline or business as usual (BAU) projects the evolution of the European quantum ecosystem *without* adoption of the Quantum Act, while existing and already planned Union and Member State legislation, strategies, programmes and measures continue to develop and be implemented. It therefore includes the foreseeable contribution of horizontal and sector-specific initiatives relevant to quantum technologies. It includes the foreseeable effects of

existing legislation, strategies, programmes and measures[113]. Additionally, it includes potential synergies and interactions with enabling and complementary technologies, such as AI. Actions that emerge from the Quantum Europe Strategy pillars are summarised below, while the further contribution of the Quantum Act PMs to each of those pillars is listed in Annex 9. Effects accounted for in the baseline are not double counted as benefits of the policy options.

Actions/initiatives under the Quantum Europe Strategy

- The expanded ***EuroHPC JU***[114] (Union-level quantum R&I, development and operation of quantum infrastructures for computing and simulation, communication, sensing and metrology activities);
- The ***Chips Act and the Chips JU***[115] (quantum-chip design, pilot-lines, prototyping, testing and validation activities);
- The **EuroQCI** initiative (terrestrial and space components and integration in IRIS[2;116]);
- Quantum-related activities under ***Horizon Europe, the Digital Europe Programme, the Connecting Europe Facility, the European Defence Fund, cohesion-policy instruments and relevant national programmes*** (e.g., Quantum Flagship R&I actions, dual-use R&I and regional support);
- ***European Quantum Skills Academy***, the Quantum Apprenticeship Programme and related fellowship, mobility, training and talent actions announced in the Quantum Europe Strategy;
- Financing via the EIC, InvestEU, the EIB Group, national institutions, private investors and relevant successor instruments[117], as well as relevant horizontal initiatives supporting private investment, including the Savings and Investments Union;
- ***European and international quantum standardisation and pre-standardisation*** activities;

Other actions/initiatives

- Relevant recent and forthcoming horizontal and sector-specific initiatives, including the ***European Innovation Act, Public Procurement Act, European Research Area Act, EU Inc. framework, STEP, Chips Act 2.0 and Cloud and AI Development Act (CADA).*** These initiatives are expected to improve general framework conditions for innovation and company scale-up, R&I coordination, public procurement, financing, semiconductor capabilities and digital infrastructure, while not providing quantum-specific coordination across the full research-to-deployment pathway.
- The Commission Recommendation and coordinated ***PQC transition roadmap***;
- Member State quantum strategies, programmes, investments and infrastructures;
- Existing Union cybersecurity, critical-entity-resilience, economic-security, foreign-

[113] European Commission, Better Regulation Guidelines, SWD (2021) 305 final, 3 November 2021, Chapter 3; European Commission, Better Regulation Toolbox, 2025, Tool #16, "How to identify policy options".
[114] The EuroHPC amendment is treated as a material improvement to the baseline, but not as evidence that all Member State programmes, investments and infrastructures are already subject to common planning or review. This distinction is consistent with the problem analysis in Section 2.1.1 and Annex 4.
[115] Chips JU work-programme and implementation documentation. The Chips Act and Chips JU support quantum-chip design, prototyping, testing and pilot production, but not the full quantum system stack.
[116] Regulation (EU) 2021/1153 establishing the Connecting Europe Facility; Regulation (EU) 2023/588 establishing the Union Secure Connectivity Programme; European Commission documentation on the European Quantum Communication Infrastructure.
[117] References to future programmes reflect proposals available at the analytical cut-off and do not prejudge the outcome of legislative or budgetary negotiations.

investment-screening, export control and critical-raw-material frameworks[118].

The baseline includes national measures adopted or sufficiently advanced by 19 July 2026. For example, under its national quantum strategy, France is combining public procurement of quantum computers with access to hybrid quantum and high-performance computing facilities for researchers and industrial users through the France Hybrid HPC Quantum Initiative. In the Netherlands, the Quantum Delta NL programme supports research and innovation, investment in shared facilities, skills development and support for SMEs. These measures were already under way at the analytical cut-off and are expected to contribute to the development and use of quantum technologies in the absence of the Quantum Act.

References to successor programmes or implementing bodies do not presuppose their establishment, extension of mandate or additional budget needs. References to forthcoming initiatives likewise do not prejudge their adoption, final design or the outcome of ongoing legislative or budgetary negotiations. The quantitative baseline includes only measures adopted or sufficiently advanced by the analytical cut-off date of 19 July 2026, as specified in Annex 9. Initiatives proposed after the analytical cut-off are considered qualitatively for coherence and additionality but are not included in the quantitative baseline assumptions It also reflects foreseeable technological progress, private investment, industrial consolidation, procurement activity and international competitive developments although their timing, scale and distribution remain uncertain. In particular, horizontal initiatives are expected to improve the general framework for R&I, innovation, company scale-up, access to finance, public procurement and digital and semiconductor infrastructure. These developments are incorporated into the baseline to the extent relevant. However, they do not in themselves establish quantum-specific mechanisms for aligning Union and national priorities, connecting activities across the quantum technology stack and research-to-deployment pathway, coordinating strategic projects and infrastructures, aggregating quantum-specific demand or monitoring quantum-specific dependencies. The policy options are therefore assessed only against these residual quantum-specific coordination and delivery gaps.

The additionality of the Quantum Act, as an enabling legislative framework, would lie in the binding implementation and governance mechanisms it could introduce. The need for additional measures under the Act does not stem from a lack of Strategy commitments, but from the fact that these commitments alone do not address fragmentation between the Member States and the EU programmes. The principal implementation and programming period is 2028-2034 (next MFF). Costs are modelled over 2028-2037 to capture preparatory, start-up and recurrent implementation costs over a 10-year period. Longer-term effects are assessed qualitatively or via scenarios where robust forecasting is not possible.

Potential interactions with enabling and complementary technologies

The three domains of quantum technologies (computing, communications and sensing) depend on common enabling technologies, including photonics, semiconductors, lasers, cryogenics, control electronics and software. Advances in these technologies, including AI, can benefit multiple quantum domains.

Developments in semiconductors, photonics and advanced materials can create new

[118] Regulation (EU) 2021/695 of 28 April 2021 establishing the Horizon Europe Framework Programme, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013; Regulation (EU) 2021/694 of 29 April 2021 establishing the Digital Europe Programme and repealing Decision (EU) 2015/2240; Regulation (EU) 2021/697 of 29 April 2021 establishing the European Defence Fund and repealing Regulation (EU) 2018/1092; Regulation (EU) 2021/523 of 24 March 2021 establishing the InvestEU Programme and amending Regulation (EU) 2015/1017.

opportunities to strengthen European quantum capabilities, reduce lab-to-fab bottlenecks and improve competitiveness, but may also create new dependencies or alter the strategic importance of parts of the quantum value chain. Advances in HPC are particularly relevant, as quantum computing is expected to operate as part of hybrid quantum-classical computing architectures, with classical HPC handling tasks such as pre- and post-processing, optimisation and error correction. Progress in semiconductor fabrication, photonic integration and advanced materials can improve scalability and manufacturability of quantum devices.

AI and other enabling technological developments are expected to increasingly influence the development, industrialisation and deployment of quantum technologies[119]. The relationship is increasingly bidirectional: quantum and hybrid quantum-classical approaches can contribute to AI machine learning and optimisation, although a quantum advantage for mainstream AI workloads has not yet been demonstrated, for example through quantum computing for selected optimisation, simulation and machine-learning tasks. At the same time, AI can accelerate quantum development and industrialisation; AI is already used in quantum for circuit optimisation and quantum error mitigation, the design of novel quantum algorithms, sensor calibration and signal processing, the optimisation of quantum communication networks, and quantum-device control.

5.1.2. Expected development and residual gaps

Existing and announced measures will drive some progress. Public investment, infrastructure deployment and gradual market development are expected to increase R&I activity, early deployment, specialised employment and demand for quantum-related skills. Recent and forthcoming horizontal initiatives are also expected to improve the general conditions under which quantum firms, researchers, investors and public buyers operate. However, these efforts will not resolve the structural problems identified in Chapter 2 the assessment period.

As national programmes are implemented, more researchers and firms are expected to gain access to facilities where they can test quantum technologies. National procurement is also expected to generate initial orders for suppliers and give public buyers experience in specifying and using quantum systems. The pace and reach of these developments will depend on the facilities, priorities and procurement timetables of the Member States concerned. Existing cooperation, including through the EuroHPC Joint Undertaking, can extend the benefits of individual investments across borders, while decisions on access to nationally funded facilities and the timing of national purchases will continue to depend on the arrangements for each programme.

The evidence assessed in Chapters 1 and 2 indicates that significant residual gaps are likely to remain within the assessment period, as summarised in Table 5.1.

Intervention dimension	Expected development under the baseline	Principal residual gap
Strategic coordination and delivery	The Quantum Strategy and EuroHPC JU strengthen Union-level direction and implementation. By July 2026, 14 Member States had adopted a quantum-specific strategy and four were preparing one.	Alignment of Union and national priorities, investments and implementation remains incomplete and uneven. No horizontal initiative provides an integrated mechanism for coordinating quantum priorities, programmes infrastructures and deployment pathways across the

[119] Quantum Flagship, *Artificial Intelligence and Quantum Computing white paper* (2025), prepared by AI and quantum-technology experts.

		ecosystem.
Research, industrialisation and infrastructure	At the analytical cut-off date, implementation arrangements differed across quantum domains (computing, communication, sensing). The baseline reflects the expected implementation of the expanded EuroHPC JU mandate[120] without assuming that all existing EU projects or infrastructures will be transferred to the JU. Chips Act 2.0 and CADA are expected to strengthen relevant semiconductor and digital infrastructure capabilities.	Access conditions, capacity, technical support and links between research projects and industrialisation facilities remain unclear and uneven. Residual gaps concern in particular the connection of full quantum systems, non-semiconductor enabling technologies and cross-domain testing with industrial validation and deployment.
Scale-up finance	EIC, InvestEU, the EIB Group, potential future EU support programmes and national instruments continue to support firms and consortia. STEP, EU Inc. and other horizontal initiatives are expected to improve general financing, visibility and company scale-up conditions.	Technical and financial continuity remains weak between grants, validation, later-stage finance, private co-investment and deployment revenue. Horizontal instruments do not specifically address the capital intensity, long development cycles and specialized infrastructure needs of quantum firms.
Demand and first buyers	Union and national procurement and deployment initiatives continue, including EuroHPC JU and EuroQCI-related actions. The European Innovation Act and Public Procurement Act are expected to improve the horizontal framework for innovation procurement and public purchasing.	Demand remains concentrated among a relatively narrow buyer base, while progression from pilots to reference deployment and repeat procurement remains limited and uneven. The horizontal frameworks do not themselves identify or coordinate quantum-specific strategic demand or connect technology validation systematically with first buyer and reference deployment opportunities.
Skills and user capabilities	Existing education, training and mobility initiatives continue. Europe has a strong scientific base and around 40 specialised quantum master's programmes[121]. Horizontal R&I and mobility initiatives are expected to improve general conditions for researchers and knowledge circulation.	Training remains insufficiently connected to industrial engineering, systems integration, deployment, procurement and user-side needs.
Standards and trusted deployment	European and international standardisation activities, benchmarks and PQC implementation continue to develop. Existing cybersecurity and standardisation frameworks continue to provide the horizontal structures for cybersecurity requirements, certifications and formal standard-setting.	Standards, benchmarks, testing and assurance remain unevenly connected to procurement and deployment, while implementation readiness and PQC migration progress vary across Member States and critical sectors[39].

[120] The expanded mandate covers the Union's Horizon Europe quantum-technology activities.

[121] Quantum Flagship, Strategic Research and Industry Agenda 2030, 2024 (SRIA), section 2.3. The Agenda identified around 40 specialised master's programmes in quantum technologies or quantum engineering in Europe and concluded that expected graduate output would remain insufficient for anticipated industrial needs.

Dependencies and resilience	FDI screening, export controls, project monitoring and other horizontal frameworks including the Economic Security Strategy continue to address individual risks and transactions. Existing Union and Member State quantum-related international partnerships and dialogues also continue. The Chips Act 2.0 framework and other horizontal resilience initiatives are expected to address relevant semiconductor, raw-material and economic- security risks within their respective scopes.	Visibility of strategically relevant dependencies remains incomplete, and identified supply-chain risks are not consistently translated into timely and proportionate mitigation[122]. In particular, no existing horizontal framework provides systematic quantum specific visibility across specialized components, equipment, software and services throughout the wider quantum value chain.

Table 5.1. *Dynamic baseline and residual gaps. Source: Commission services, based on the Quantum Europe Strategy and PPMI/d-fine mappings of Member State strategies, infrastructures, finance, procurement, standardisation and critical components.*
Definitions, coverage and limitations are provided in Annexes 4, 5, 8 and 9[123].

In summary, progress is expected to remain gradual, uneven and insufficient to address the identified structural problems within the assessment period, notably: (i) discontinuities between research and deployment, (ii) insufficient conditions for firm scale-up and early market development, and (iii) strategic dependencies with insufficient resilience. The baseline therefore does not assume that horizontal initiatives have no effect; rather, it incorporates their expected contribution and isolates the quantum-specific gaps that remain. This ensures that only effects additional to the baseline are attributed to the policy options. The detailed assumptions underpinning the baseline scenario, together with the impacts of the policy options, are set out in Annexes 3, 4 and 8, and Chapter 6.

5.2. Description of the policy options

5.2.1. Construction and overview of the options

The residual gaps (Table 5.1) were used to screen potential policy measures for their effectiveness, EU added value, legal and operational feasibility, proportionality, coherence with existing instruments, and administrative and budgetary implications. The selected measures were then grouped into three policy options differing mainly in legal force, coverage and delivery intensity. To address the problems identified, there are **three key intervention areas**: **(i) sustaining and advancing Europe's quantum R&I excellence; (ii) accelerating industrialisation and deployment of quantum technologies and solutions; and (iii) strengthening security and resilience of quantum supply chains, including by monitoring and mitigating critical dependencies**.

[122] Alternative EU-based suppliers were identified for 27 of 31 main-component categories and 8 of 16 sub-component categories. This does not establish technical interchangeability, sufficient capacity or rapid substitutability. See Annex 11, tabs 66–74.

[123] The residual gaps are expressed in functional terms and do not imply a particular instrument, governance model or policy option; alternative approaches to addressing them are assessed in Section 5.2.

All three policy options address the same intervention areas but differ in legal force, coverage and delivery intensity. PO1 relies on voluntary coordination and market facilitation; PO2 introduces structured governance and delivery arrangements with targeted obligations; and PO3 retains the PO2 architecture while applying higher-intensity variants in selected areas. Detailed design principles and safeguards for each of these three policy options are set out in Annex 4.

The options follow the technology lifecycle approach introduced by the Quantum Europe Strategy, covering the progression from research, engineering and validation to industrial scale-up, market deployment and resilient operation, with measures able to operate in parallel. All options build on the dynamic baseline, use existing Union bodies and instruments where possible, and are designed to be technology-neutral and proportionate to technological maturity. Table 5.2 summarises the intervention logic of each option.



Figure 5.1. Indicative lifecycle and interaction of the Quantum Act policy measures.

Scenario / policy option	Intervention logic	Main content
PO1 – Voluntary horizontal framework	Non-legislative, ecosystem-wide and market-enabling approach based on voluntary participation of Member States and other involved stakeholders.	Voluntary cooperation across the three intervention areas: R&I excellence; industrialisation, scale-up, deployment and demand; and security and resilience of quantum value chains. PO1 would not create new legal obligations, formal designations, reserved finance or mandatory reporting.
PO2 – Enabling Quantum Framework Act	Enabling legislative framework establishing structured EU-Member State governance and delivery arrangements, while relying mainly on existing implementing bodies.	A Regulation would establish structured arrangements across the three intervention areas. Obligations would fall mainly on the Commission, Member States and designated or Union-supported actors, while participation by other firms and users would generally remain voluntary. It would create neither a new Union agency nor an automatic entitlement to funding.
PO3 – High-intensity targeted framework	PO2 architecture combined with stronger, binding variants in a limited number of areas where greater implementation certainty may be necessary.	PO3 would retain the PO2 governance and delivery framework and apply higher-intensity variants to selected measures across the three intervention areas. All other measures would operate as under PO2.

***Table 5.2.** Overview of the policy options.*

5.2.2. Policy measures and their configuration across the options

For each of the three main intervention areas outlined above, detailed policy measures have been developed. The 16 policy-measures (PMs) retained for the construction of the policy options are described below. They were retained because they address the identified problem drivers and passed an initial screening of Union added value, legal and operational feasibility, proportionality, coherence and administrative and budgetary implications.

Discarded alternatives are summarised in Section 5.3. The full screening and detailed measure fiches are set out in Annexes 4 and 8.

Intervention area 1: Sustaining and advancing Europe's quantum R&I excellence

PM1: Common programming framework

PO1. PM1a. Provides a voluntary exchange of information on EU and Member State programmes, and voluntary alignment on common priorities, reinforcing coordination compared with the dynamic baseline.

PO2. PM1b. Provides a common EU-Member State framework for developing a shared quantum strategy and aligning EU and national programmes around agreed priorities, identified gaps and coordinated implementation timelines. Funding and budgetary decisions would remain with the competent EU and national authorities.

PO3. PM1c same as PM1b.

The Common Programming Framework would be coordinated by the Commission, in consultation with the Quantum Strategy Board (see PM15 below). Its research goals would be implemented through PhDs and post-doctorates in the fields established in the Programme.

PM2: Quantum Science and Technology (S&T) Excellence Network

PO1. PM2a: Strengthens links across the Quantum Flagship community and European Research Area networks by establishing a voluntary network of quantum labs across Europe that would promote cooperation, including by working on commonly agreed major quantum S&T challenges.

PO2. PM2b: Statutory establishment of a distributed European network of leading and emerging quantum labs, universities, and RTOs to cooperate on commonly agreed S&T challenges, researcher mobility and access to relevant capabilities.

PO3. PM2c same as PM2b.

Under PO2 and PO3, the network would be open, dynamic and based on excellence, rather than a closed club composed of a fixed set of quantum science labs. Participation would be based on an open call for proposals, within the common programming framework (PM1). Selection would be carried out based on transparent criteria covering scientific excellence and relevant capabilities. Appropriate membership modalities will be designed to ensure participation of the best entities. The network would consist of already existing labs, universities, RTOs and infrastructures. The network would provide light coordination between leading centres for quantum, notably under the umbrella of the Common Programming Framework (PM1). Among the advantages of the network would be cooperation around common S&T challenges or facilitating researcher and PhD mobility.

PM3: Quantum Grand Challenges

PO1. PM3a: Voluntary mapping and alignment on grand challenges, which address ambitious objectives for accelerating quantum technology development and system engineering. They would be identified through appropriate stakeholder consultation (e.g. through the European Quantum Alliance – see PM16).

PO2. PM3b: As in PM3a, grand challenges would be identified through stakeholder consultations, and cooperation with Member States (e.g., the Quantum Strategy Board – see PM15). They would then be selected competitively on predefined proposal evaluation criteria.

PO3. PM3c same as PM3b.

A list of potential Grand Challenges would be identified by the Commission, taking into consideration key technological and engineering bottlenecks, available technology roadmaps, stakeholder evidence and international developments. The candidate Grand Challenges would be assessed through a defined procedure, in consultation with the Quantum Strategy Board (see PM15) and the Quantum Alliance (see PM16). The final decision on which Grand Challenge to launch would remain with the Commission. The Governing Board of EuroHPC JU (or its

successor) would take the relevant financing decisions, and the challenges would be implemented through the EuroHPC JU. Implementation would take place through open and competitive calls under the applicable programme. Each Grand Challenge would have a clearly measurable objective, milestones and stage gates. Independent expert review under the applicable programme procedures would assess progress against the predefined milestones and stage gates and provide recommendations on continuation, redirection or termination[124]. Successful Grand Challenges could potentially be followed up by becoming a Strategic Project (PM5).

Intervention area 2: Accelerating industrialisation and deployment of quantum technologies and solutions

PM4: Technology and Innovation Hubs

PO1. PM4a.Voluntary creation of a limited number of specialised Technology and Innovation Hubs. They would focus on start-ups and SMEs, bringing together the expertise, services and infrastructure needed for accelerating their technological development. They would also provide access to infrastructure and test and experimentation facilities.

PO2. PM4b. Statutory designation of a limited number of specialised hubs as described in PM4a. Existing facilities would be used first.

PO3. PM4c same as PM4b.

Under PO2 and PO3, a limited number of specialised Quantum Technology and Innovation Hubs would provide engineering expertise, testing, validation, qualification and access to specialised infrastructures, particularly for start-ups and SMEs. Existing facilities, capacities and structures would be used first, avoiding unnecessary duplication.

PM5: Strategic Quantum Infrastructures and Strategic Quantum Projects

PM5.1 – Strategic Quantum Infrastructures

PO1. PM5.1a. Supporting, on a voluntary basis, the development of existing or new large-scale Strategic Infrastructures to validate quantum technologies at European scale before wider deployment. Examples include the European Quantum Communication Infrastructure (EuroQCI) for quantum secure communications, quantum-enhanced medical imaging, a full-scale European quantum computer, the quantum internet or quantum sensing and gravimetry.

PO2. PM5.1b. A statutory Union framework for identifying and coordinating Strategic Quantum Infrastructures, including the continued development of existing infrastructures and, where justified, new infrastructures, based on Union added value, cross-border relevance, technological maturity and deployment needs. Funding, procurement and access arrangements would remain under the relevant programmes and competent bodies.

PO3. PM5.1c same as PM5.1b.

PM5.2 –Strategic Quantum Projects

PO1. PM5.2a. Voluntary identification and coordination of major industrial projects of European relevance, such as quantum foundries, or other strategic industrial capabilities.

PO2. PM5.2b. The Commission would designate Strategic Quantum Projects through an open process based on predefined criteria, including Union added value, cross-border relevance, strategic importance and implementation maturity, with input from the Quantum Strategy Board (see PM15). Designation would not automatically confer funding or State aid approval.

PO3. PM5.2c same as PM5.2b.

Strategic Quantum Infrastructures would support the development, testing, validation, demonstration and deployment of quantum technologies. Existing infrastructures could be developed or expanded, while new infrastructures would be supported where justified by

[124] At an early stage, PM3 may support several credible pathways in parallel where this is justified by uncertainty and the strategic value of alternative solutions. One possible implementation route under PM3 is pre-commercial procurement, using phased development with predefined technological targets and milestones per phase.

strategic relevance, identified needs and Union added value, including cross-border use.

For Strategic Projects, the added value of designation as such could include Union-level recognition helping projects access relevant Union and national funding instruments. Priorities would be set based on clear criteria[125], developed with advice from the Quantum Strategy Board (see PM15 below), and where appropriate, followed by calls for expressions of interest. Technology pathways for such projects will be assessed against transparent criteria, including expected impact, scientific and technical merit, scalability, time-to-deployment, cost-effectiveness, and contribution to EU policy objectives. The Projects would have a staged, technology-neutral approach to avoid technological lock-in and ensure an optimal choice among competing technologies.

PM6: Competence and Acceleration Centres

PO1. PM6a. A network of distributed voluntary Competence and Acceleration Centres across the Member States that would provide a first entry point to quantum technologies and promote quantum deployment. These centres would support start-ups, SMEs, public authorities and other users in identifying relevant use cases and obtaining initial technical and business support as well as referrals to Technology and Innovation Hubs. They would help reduce quantum adoption barriers without duplicating the specialised engineering role of the Hubs.

PO2. PM6b. The centres, as described in PM6a, would be created with the aim to fulfil a formal role within the support ecosystem. They would ensure the creation of at least one first-level access point (Centre) in each Member State, which may be established nationally or through a joint cross-border arrangement. Centres may be supported under the relevant programmes subject to the applicable funding decisions.

PO3. PM6c same as PM6b.

Under PO2 and PO3, Member States would ensure at least one locally accessible first-level Quantum Competence and Acceleration Centre in each Member State, established nationally or jointly with other countries. Building primarily on existing structures, these Centres would help companies and other users identify quantum applications, access technical and business advice, and obtain referrals to relevant infrastructures, specialised Hubs, skills, financing and procurement opportunities.

PM7: Innovation Procurement

PO1. PM7a. Provide a structured pathway from concept to market, helping public buyers identify promising solutions and prepare for possible future procurement. It would provide for voluntary buyer groups, market consultations, supplier-user matchmaking, model procurement documents and technical guidance.

PO2. PM7b. The Commission and the Member States[126] would coordinate pre-commercial procurement (PCP), public procurement of innovative (PPI) solutions and reference deployments based on common use cases and functional specifications. The measure would strengthen buyer capacity and support progression from experimentation to operational deployment and repeat demand. Procurement decisions would remain with the competent contracting authorities.

PO3. PM7c. PM7b measures combined with common eligibility or sourcing conditions in predefined strategic procurement categories. These would apply where justified by reasons of security of supply, with market-availability tests, proportionate exceptions, trusted-partner participation and compliance with Union and international procurement rules.

[125] Selection criteria may include, but is not limited to, strategic relevance for Europe, the need for upstream S&T advances, potential impact across the quantum ecosystem, European added value, feasibility and structuring effects.

[126] And tentatively international partners, with the appropriate safeguards and reciprocity, pending political steer at the QSB (see PM15).

PM8: Standards and benchmarking

PO1. PM8a. Support for pre-standardisation, measurement, benchmarking and voluntary technical cooperation.

PO2. PM8b. As in PM8a but with financial support to achieve common terminology, measurement methods, performance benchmarks, interoperability profiles and testing procedures.

PO3. PM8c. Same as PM8b.

The Commission would support pre-standardisation, measurement, benchmarking, interoperability and testing activities, building on existing European and international bodies. Formal standards would remain within the recognised European standardisation system. Testing approaches would be introduced only where the technology and assessment methods are sufficiently mature[127]. The European Quantum Alliance (PM16) would contribute to identifying and regularly updating European industry priorities.

PM9: Skills and mobility

PO1. PM9a. Voluntary mapping and exchange on skills needs, training offers, mobility and user-support services.

PO2. PM9b. Coordinated skills intelligence, training, mobility and reskilling activities linked to the common programming framework, infrastructures, Hubs, Grand Challenges, Strategic Projects and existing Quantum Skills Academy. Building on existing frameworks and initiatives, this would allow to address demonstrated skills shortages, while respecting Member States' responsibility for education policy.

PO3. PM9c same as PM9b.

The Commission would identify and address skills shortages through Union-level action, in cooperation with Member States and relevant stakeholders. This could cover training, mobility, skilling and reskilling, supported by relevant Union and national programmes, to strengthen the availability and mobility of the industrial, engineering, technical, operational, procurement and user-side skills needed for the development, assessment, integration, operation and uptake of quantum technologies.

Intervention Area 3: Strengthening security and resilience of quantum supply chains, including by monitoring and mitigating critical dependencies

PM10: Quantum Investment Service Desk

PO1. PM10a. Voluntary investment-readiness guidance and referrals to existing Union, national and private financing instruments.

PO2. PM10b. A Commission-coordinated service desk to help quantum firms and consortia access relevant Union, national and private financing by providing them with advice on existing investment opportunities, connecting them with suitable investors and financial instruments and supporting co-investment. In justified cases, it could facilitate coordination among relevant public and private financing actors where acquisition, relocation or loss of control could materially affect access to a strategically important quantum capability. It would not entail a new financial institution, and investment decisions would remain with the competent financial bodies.

PO3. PM10c. Retains PM10b and adds a dedicated quantum investment mandate or capacity within existing or future Union or national financial instruments, providing greater risk-bearing and rapid-response support for scale-up and strategic capabilities.

Under PO2, the Quantum Investment Service Desk would provide targeted advice and

[127] Sufficient maturity would not necessarily require full technological or market maturity. It would rather mean that results are sufficiently stable, consistent and reproducible, including across laboratories, and linked to recognised references or standards. The Commission would assess maturity of an area, drawing on independent technical expertise where needed.

investment-readiness support to quantum firms, particularly start-ups and SMEs, facilitating access to existing Union, national and private financing opportunities. It would build on relevant existing advisory structures and would not assess individual investments or take financing decisions, which would remain the responsibility of competent financing institutions. The higher-intensity investment-capacity variant is assessed separately under PM10c (PO3).

PM11: Strategic intelligence and dependency monitoring

- **PO1.** PM11a. Collection of information on European quantum supply chains based on public information, and information, which is supplied on a voluntary basis.
- **PO2.** PM11b. Commission to establish a mapping, monitoring and early warning system involving the Member States via the Quantum Strategy Board (see PM15), to identify critical quantum components, suppliers, concentration, substitutability and disruption risks. Identified risks would be referred to existing finance, procurement, supplier-qualification, diversification and economic-security instruments.
- **PO3.** PM11c. PM11b mapping combined with default mandatory information requests for designated projects, infrastructure operators and actors in predefined critical value-chain categories. Identified risks would be referred to existing finance, procurement, supplier-qualification, diversification and economic-security instruments.

Under PO2, the Commission would monitor strategic dependencies across quantum supply chains, including critical components, supplier concentration, technological bottlenecks and disruption risks, in cooperation with Member States and the Quantum Strategy Board (see PM15). Existing information would be reused wherever possible, with additional information requested only where necessary and proportionate, subject to appropriate confidentiality safeguards. PO3 would provide for more extensive mandatory information requirements for defined critical categories.

PM12: Quantum Business Platform

- **PO1.** PM12a. Voluntary participation in a light-touch platform providing company visibility, ad hoc matchmaking and information on capabilities and needs.
- **PO2.** PM12b. An EU-supported platform bringing together quantum companies, users, investors and public buyers for matchmaking, market intelligence and visibility of capabilities, needs and partnership opportunities. Participation in the platform will remain voluntary.
- **PO3.** PM12c same as PM12b.

The operation of the Quantum Business Platform could be contracted to an external or ecosystem operator. Information would be reused where lawful and appropriate, while respecting confidentiality and applicable safeguards. The Platform should connect directly with the Competence and Acceleration Centres and the Quantum Investment Service Desk. The Platform may share non-sensitive data and technical infrastructure with PM11 (Strategic Monitoring) but should remain functionally distinct: participation in the Business Platform is voluntary and market-facing, whereas strategic-intelligence information may be commercially sensitive and, in limited justified cases, subject to proportionate information requests.

PM13: Quantum-safe preparedness

- **PO1.** PM13a. No additional measure beyond the dynamic baseline.
- **PO2.** PM13b. Structured cooperation on PQC between the Commission, Member States and relevant bodies (e.g. the Quantum Strategy Board (see PM15), the NIS Cooperation Group and the European Cybersecurity Certification Group), to coordinate the implementation of the PQC roadmap[39], and monitor its progress.
- **PO3.** PM13c. Make binding the implementation of the PQC roadmap through time-bound migration requirements.

Implementation would build on the existing EU PQC roadmap and cybersecurity governance. Under PO2, the Commission would facilitate regular cooperation with Member States and

relevant Union bodies to monitor implementation, exchange technical guidance and identify bottlenecks, without introducing additional migration deadlines or certification obligations. Under PO3, time-bound requirements would apply to the defined addressees in accordance with the scope established by the initiative and existing Union cybersecurity legislation.

PM14: Strategic international cooperation

PO1. PM14a. Existing partnerships and dialogues would continue, supported by voluntary coordination and information exchange.

PO2. PM14b. Through the Quantum Strategy Board (see PM15), coordination of trusted and reciprocal cooperation with third countries covering research, standards, skills, reciprocal infrastructure and market access, use cases and supply diversification.

PO3. PM14c same as PM14b.

To be implemented by Commission, with advice from the Quantum Strategy Board (see PM15). They may discuss international cooperation on quantum technologies, reducing dependencies, knowledge and skills shortages, and which international partners should be prioritised for strategic partnerships on quantum technologies.

PM15: Quantum Strategy Board

PO1. PM15a: Advisory group bringing together the Commission, Member States and relevant national implementing bodies. It will strengthen the informal EU-Member State coordination of the dynamic baseline, while participation, exchange of information and alignment would remain voluntary.

PO2. PM15b: A high-level advisory body comprising the Commission and the Member States as a permanent coordination platform. It would support coordination of Union and national quantum strategies, facilitate agreement on common priorities, monitor implementation and identify investment, infrastructure and capability gaps.

PO3. PM15c same as PM15b.

Under PM15b, PM15c, the Board would be composed of high-level representatives from all Member States and chaired by a representative from the Commission. The Board would be able to establish other standing or temporary sub-groups for specific topics. Examples include: a group on standards, or a group on skills.

PM16: European Quantum Alliance

PO1. PM16a: Voluntary stakeholder platform bringing together industry, start-ups, research organisations, RTOs, users, investors and standards communities. It would provide evidence and implementation feedback, and structured stakeholder inputs as compared to the informal research and industry networks of the dynamic baseline.

PO2. PM16b same as PM16a, with the Alliance being formally established and linked to the Quantum Strategy Board for the functions detailed in PM16a.

PO3. PM16c same as PM16b.

The Commission would appoint members of the European Quantum Alliance, which should represent the industry across the quantum value and supply chain in the Union. There will be specific criteria for such selection. A representative of the Commission would chair the Alliance. The Alliance would be in regular dialogue with the Quantum Strategy Board and may establish standing or temporary working groups for specific matters – always subject to approval of the Chair.

Figure 5.2 below illustrates the logic and relationship between different PMs and shows how they contribute to the process from research to the adoption of quantum technologies. Detailed descriptions of the PMs can be found in section 4.1.9 of Annex 4.

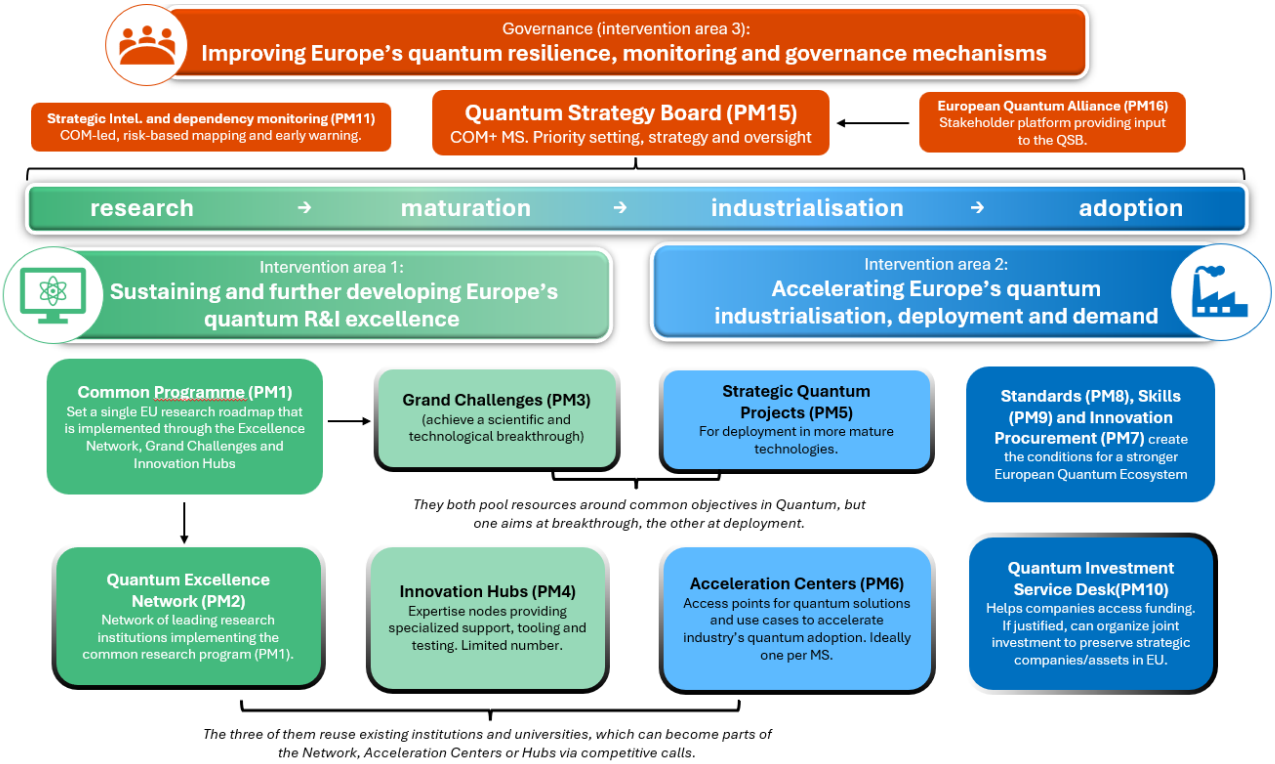

Figure 5.2. *Relations between PMs, intervention areas, and research-adoption process.*

The different PMs are designed as connected following the full quantum technology lifecycle approach (cf. section 5.2.1), from early-stage research to market uptake. However, this is not an automatic linear chain: measures may operate in parallel and participation in one instrument does not confer entitlement to another.

All the measures have been designed to be complementary and to address needs across the quantum supply chain, thereby creating strong synergies between them. For example, a quantum scale-up facing technical and engineering bottlenecks could seek support from a specialised Innovation Hub (PM4); for market deployment and access to end users, from a Competence and Acceleration Centre (PM6); and where looking for financing possibilities, from the Investment Service Desk (PM10), which would orient it to existing Union, national or private funding.

Another key synergy is around the innovation chain. Grand Challenges (PM3) support upstream research and engineering to overcome major quantum technological bottlenecks. Strategic Quantum Infrastructures and Projects (PM5) help bring the most promising results towards validation, scale-up and deployment, through strategic pilot infrastructures (that validate technologies in operational environments, for example Q-MRI[128]) and Strategic quantum Projects that would address more mature industrialisation and deployment needs of European relevance. Innovation Procurement (PM7) supports downstream market uptake by using innovation procurement to create lead markets, provide an initial customer base and accelerate the adoption of quantum solutions. For example, a Q-MRI solution validated under PM5 could later be deployed through PM7 using the innovation procurement instrument for its first operational deployment. In this way, results from PM3 can feed into PM5, and outputs from PM5 can be taken up under PM7, creating a virtuous feedback loop from frontier research

[128] Q-MRI (Quantum Magnetic Resonance Imaging) refers to quantum-enhanced medical imaging using quantum sensors to measure magnetic signals at molecular level.

to strategic implementation.

Stakeholders broadly supported stronger coordination, improved access to cross-border infrastructure, continuity of financing, first-buyer support, skills development and standards. The Top-Level Specialists in the Quantum Technologies group[129] endorsed an integrated pathway combining scientific cooperation, specialised Innovation Hubs, distributed user-access points, Grand Challenges and stronger first-buyer mechanisms. It also stressed that SMEs should not be required to form consortia or disclose commercially sensitive information unless strictly necessary. Views were more divided on the creation of new institutional structures, dedicated financial capacity, binding reporting requirements and broader procurement preferences. These views informed both the design of the options and the alternatives screened out in Section 5.3[130].

The following subsections summarise each option. They do not introduce additional measures; the detailed configuration of each PM under PO1-PO3 is set out above.

5.2.3. Policy Option 1 - Voluntary horizontal framework

PO1 would be a voluntary horizontal, market-enabling approach to improve the framework conditions for the quantum ecosystem through coordination, shared information, common tools, skills, infrastructure access and standards support, as well as improved use of existing Union and national instruments. It avoids mandatory requirements and does not set up systematic structures; so its effectiveness would depend on participation by Member States, implementing bodies and stakeholders.

(i) Sustaining and advancing Europe's quantum R&I excellence. PO1 would establish an informal but regular Commission-Member State dialogue (PM1a), and a voluntary European Quantum S&T Excellence Network (PM2a). These arrangements would facilitate bringing together all relevant public and private stakeholders to exchange on priorities, identify complementarities and define non-binding roadmaps. However, participation and follow-up would remain voluntary, and no new common funding or implementation commitment would be created[131].

(ii) Accelerating industrialisation and deployment of quantum technologies and solutions. PO1 would establish voluntary structures that would connect companies, facilities, investors, financial institutions, public buyers and potential users. All funding, investment, procurement and expenditure decisions would remain with the competent bodies. A skills-intelligence function (PM9a), building on existing Union and national skills initiatives, would map emerging industrial and user needs, relevant curricula, training offers and mobility actions. Pre-standardisation research, measurement methods, performance benchmarks and interoperability profiles would be supported where technological maturity permitted (PM8a).

(iii) Strengthening security and resilience of quantum supply chains, including by monitoring and mitigating critical dependencies. Under PO1, the Commission would collect and analyse publicly available and voluntarily supplied information to create and maintain an overview of European quantum supply chains and their dependencies (PM11a). A voluntary Quantum Business Platform (PM12a) would provide visibility and matchmaking along the

[129] Draft Second Report on Quantum Act Priorities, July 2026, produced by the Top-Level Specialists in Quantum Technologies Commission expert group.

[130] See Annex 2, Stakeholder Consultation Synopsis Report. Consultation evidence was used to assess the problems, feasibility and proportionality of alternative designs and was not treated as an opinion poll.

[131] Strategic Research and Industry Agenda 2030, 2024 (SRIA). The existing Union implementation framework and expected benefits are part of the baseline. The SRIA identifies the need for coordination between research, industrial roadmaps and shared infrastructure, including links to the Chips Act.

value chain and would remain separate from regulatory reporting or funding eligibility. International cooperation (PM14a) would continue through existing partnerships and dialogues. Investor coordination would be supported through voluntary pipeline meetings and referrals among Union, national and private actors (PM10a). Public buyer coordination would be improved through market consultation, training, matchmaking and common model procurement documents. Neither arrangement would reserve funding or bind investment or procurement decisions.

***Delivery characteristics and limitations*.** PO1 could be implemented via recommendations and communications, work programmes, and voluntary cooperation, without creating binding participation, designation, funding or reporting obligations.

5.2.4. Policy Option 2 - Enabling Quantum Framework Act

PO2 would introduce an enabling legislative framework to address coordination, industrialisation, scale-up, deployment and resilience gaps. It would legally anchor a common EU-Member State approach, linking existing Union and national instruments into a continuous pathway from research to industrialisation and deployment. Requirements would primarily apply to the Commission, Member States and designated or Union-supported actors, while participation for private actors would remain voluntary.

(i) Sustaining and advancing Europe's quantum R&I excellence. PO2 would establish a common EU-Member State quantum programme with agreed Union priorities and proportionate national quantum chapters (PM1b). PO2 would formally establish a distributed European Quantum S&T Excellence Network (PM2b) and a portfolio of competitively selected, Quantum Grand Challenges (PM3b).

(ii) Accelerating industrialisation and deployment of quantum technologies and solutions. PO2 would designate a limited number of Technology and Innovation Hubs (PM4b), establish a network of Competence and Acceleration Centres (PM6b) and provide a statutory framework for identifying and coordinating Strategic Quantum Infrastructures (PM5.1b) and a procedure for designating Strategic Quantum Projects (PM5.2b). Together with the PMs in (i), these arrangements would provide support to and connect scientific cooperation, engineering, testing, user support and large cross-border projects using existing capacity first. Designation would not guarantee funding, State aid approval, regulatory exemptions or priority access[132].

PO2 would also coordinate public buyers around common use cases, pre-commercial procurement, public procurement of innovative solutions and reference deployments (PM7b). Procurement decisions would remain with the contracting authorities. It would support common terminology, measurement methods, benchmarks, interoperability profiles and shared testing references, while formal standards would continue to be developed through the recognised standardisation system (PM8b). It would also provide technical advice and implementation support for the PQC roadmap without creating additional migration deadlines or certification obligations. PO2 would connect skills intelligence, training, mobility and user support (PM9b) with infrastructures, Grand Challenges, Strategic Projects and procurement activities[133].

(iii) Strengthening security and resilience of quantum supply chains, including by monitoring and mitigating critical dependencies. A high-level Quantum Strategy Board (PM15b) would set common priorities, monitor implementation and identify investment,

[132] See Annex 4.1.8-4.1.9, fiches PM2–PM6, for the detailed functions, selection criteria, access arrangements and safeguards.
[133] See Annex 4.1.8-4.1.9., fiches PM8 and PM9 for more information.

infrastructure and capability gaps – unlike in PO1, it would constitute a mandatory cooperation framework. A European Quantum Alliance (PM16b) would provide structured advice from stakeholders, including investors. PO2 would also establish structured cooperation on PQC between the Commission, the Member States and relevant bodies, through Commission-facilitated regular exchanges to coordinate implementation and monitor progress under the existing PQC roadmap (PM13b).

PO2 would also establish a Quantum Investment Service Desk (PM10) to address the fragmented financing pathway between grants, scale-up and deployment. It would provide advice to stakeholders for access to finance and connect them with the EIC, InvestEU, the Scaleup Europe Fund, the envisaged Strategic Technologies for Europe Facility (STEF)[134], the EIB Group's financial instruments, national financial institutions and private investors. Lastly, PO2 would also introduce risk-based mapping and early warning for critical quantum components, suppliers and value-chain categories (PM11b), using existing information first and requesting additional information only where necessary and proportionate, subject to confidentiality, data minimisation, secure handling and once-only reuse[135]. Identified risks would be referred to existing finance, procurement, supplier-diversification and economic-security instruments. The Commission and Member States would coordinate cooperation with relevant third countries on research, standards, skills, infrastructure and market access through the Quantum Strategy Board (PM14b).

***Scope and delivery*.** PO2 would be implemented mainly through existing Union and national bodies, without creating a new Union agency, fund or general obligations for all quantum companies.

5.2.5. Policy Option 3 - High-intensity intervention

PO3 would build on PO2's core architecture but introduce higher-intensity measures, including investment capacity, strategic procurement, and PQC preparedness.

(i) Sustaining and advancing Europe's quantum R&I excellence. Same as under PO2.

(ii) Accelerating industrialisation and deployment of quantum technologies and solutions. Procurement (PM7c) would include a minimum level of EU value creation or sourcing as a common eligibility condition for predefined strategic procurement categories, justified by security of supply or resilience, with market-availability tests, proportionate exceptions, trusted-partner participation and compliance with Union and international procurement rules.

(iii) Strengthening security and resilience of quantum supply chains, including by monitoring and mitigating critical dependencies. PO3 would provide a dedicated mandate or capacity within existing or future instruments (PM10c) offering greater risk-bearing and rapid-response support for scale-up and strategic capabilities, with reinforced oversight. It would also make binding the implementation of the PQC roadmap through time-bound migration requirements. (PM13c). Any such obligations would be implemented and supervised through the competent authorities under the applicable cybersecurity and sectoral frameworks, with coordination with critical-entity resilience authorities where relevant; no parallel Quantum Act supervisory structure would be created. PO3 would also extend PM11b by making information contributions mandatory by default for designated projects, infrastructure operators and actors in predefined critical value-chain categories, subject to necessity, proportionality,

[134] COM (2026) 503; page 14. A new strategic investment facility that was announced in the technology sovereignty package of the Union aiming at investing mostly in equity – with a focus on critical technologies, including digital (AI, chips, etc.), energy and biotech.

[135] See Annex 4.1.9, fiches PM11 and PM14. Information requests would be subject to necessity, proportionality, confidentiality and trade-secret safeguards.

confidentiality and data-minimisation safeguards.

These elements would increase administrative, supervisory and compliance costs. Their impacts and proportionality are assessed in Chapters 6 and 7. All other measures would operate as under PO2.

5.2.6. Implementation arrangements and reuse of structures

The implementation of the Quantum Act would be entrusted to existing bodies, the mandate of which already covers quantum aspects. In particular, the EuroHPC JU, or its successor under the next MFF, would implement the quantum R&I and infrastructure actions falling within its legal and budgetary mandate. **The Quantum Act is without prejudice to the current EuroHPC regulation and its governance**[136]. The Chips JU, or its successor under the next MFF, would remain responsible for quantum-chip pilot lines and related semiconductor and photonics capabilities. Decisions on funding, investment, procurement, State aid and regulation would remain with the institutions and bodies competent under the applicable legal bases.

The Quantum Strategy Board would identify common priorities, monitor implementation and issue recommendations for coordinated action. This configuration would ensure visible quantum governance while respecting existing mandates and avoiding institutional duplication. Under PO2 and PO3, the Quantum Investment Service Desk would facilitate access to existing or future Union and national financing instruments. It would not constitute a new financial institution, and investment decisions would remain with the competent financial bodies, such as the EIB/EIF, EIC and Invest EU. Likewise, standard-setting would remain with recognised standardisation bodies; and PQC-related cybersecurity activities with ENISA, the NIS Cooperation Group and existing cybersecurity authorities. New functions under the Quantum Act will be limited to gaps not covered by existing structures, notably cross-ecosystem coordination (PM15), strategic designation (PM5) and quantum-specific dependency intelligence (PM11).

None of the options involve the creation of a new Union body or agency. Expenditure would remain subject to the applicable MFF, programme legislation and budgetary procedures. Detailed responsibilities, staffing assumptions and institutional interfaces are set out in Annex 4.

5.3. Options and measure designs discarded at an early stage

The option-building process considered alternative policy packages and individual measure designs beyond those retained in Section 5.2.2. These were screened against effectiveness, coherence with the intervention logic, EU added value, legal and operational feasibility, proportionality, administrative burden and budgetary implications[137].

An approach was discarded at an early stage only where it was manifestly unlikely to address the identified problems, substantially duplicated existing instruments, lacked sufficient evidence of necessity or raised clearly disproportionate legal, administrative, or financial risks. More intensive measures constituting credible alternatives, including strategic procurement conditions, dependency reporting and binding PQC-preparedness duties, were retained under PO3 for assessment. An economy-wide mandatory certification or assurance regime was not

[136] Any possible change of the Quantum content and governance could be introduced in the framework of the envisaged revision of the EuroHPC regulation or its successor under the next MFF.

[137] European Commission, *Better Regulation Guidelines*, SWD(2021) 305 final, Chapter 3; *Better Regulation Toolbox*, 2025, Tool 16. Options or measures may be discarded if manifestly ineffective, technically or legally infeasible, incoherent with Union law or clearly disproportionate, provided the reasons are transparently explained.

retained because the available evidence does not demonstrate its necessity or proportionality.

5.3.1. Alternative policy packages not retained

Alternative package	Reason for not retaining it
Additional funding without governance or delivery reform	Additional resources alone, without changes to coordination or delivery arrangements would not address fragmented programming, discontinuities between research and deployment, uneven access to industrialisation capacity, weak demand, or limited visibility of dependencies. It could instead reinforce existing fragmentation and duplication.
Immediate full centralisation in a new Quantum JU or Union agency	A new body could duplicate or disrupt responsibilities of EuroHPC JU, Chips JU, the Commission and financial institutions, while adding establishment, transition and institutional-complexity costs. Future decisions on Union implementation bodies would be taken separately under the relevant legal and budgetary framework and are not prejudged by this IA[138].
Separate instruments for computing, communication, sensing and quantum-safe deployment	Separate domain-specific acts would duplicate common provisions on governance, finance, skills, infrastructure and monitoring and could create inconsistent requirements across technologies that increasingly share components, facilities and users.

Table 5.3. *Alternative policy packages screened out.*

The retained set of options therefore reflects the three levels of intervention identified through the screening: a predominantly voluntary framework under PO1, a targeted legislative framework under PO2 and a higher-intensity framework under PO3 testing only those stronger variants considered sufficiently necessary, feasible and proportionate for full assessment.

5.3.2. Individual measure designs screened out

Measure design	Reason for not retaining it
Unconditional economy-wide fixed-date PQC migration and procurement obligations	This measure was not retained because technological maturity, legacy-system complexity and sectoral risk differ substantially and the coordinated PQC roadmap already forms part of the baseline. PO1 adds no PQC-specific measure beyond the baseline, while PO2 provides structured cooperation to support implementation and monitor progress under the existing PQC roadmap. By contrast, PO3 makes implementation of the existing PQC roadmap binding through time-bound migration requirements. Scope and timing would be aligned with the existing roadmap and applicable frameworks[139].
A closed statutory list of third countries eligible to participate in, receive support under or access relevant Quantum Act actions	A fixed country list would be insufficiently adaptable to technological, security and geopolitical developments and could unnecessarily restrict beneficial cooperation. The retained approach instead relies on transparent criteria, reciprocity and the protection of Union interests.
Broad stockpiling or general crisis-intervention powers	Available evidence supports strategic mapping, early warning and targeted mitigation, but does not demonstrate the necessity of broad emergency powers across the emerging quantum ecosystem.

[138] The assessment of institutional alternatives and interfaces with existing bodies is provided in Annex 8.

[139] Commission Recommendation (EU) 2024/1101 (Coordinated Implementation Roadmap for the transition to Post-Quantum Cryptography Directive); (EU) 2022/2555 (NIS 2 Directive); Regulation (EU) 2024/2847 (Cyber Resilience Act); Regulation (EU) 2019/881 (Cybersecurity Act).

A separate quantum-specific FDI-screening or export-control regime	Existing Union frameworks already apply to relevant investments and dual-use technologies. The Quantum Act may provide evidence, monitoring and coordination interfaces but should not duplicate the competent authorities or decision-making procedures established under those frameworks[27].
Automatic statutory step-in, matching or change-of-control rights	Case-by-case European equity investment, co-investment or support for coordinated counteroffers through the Quantum Investment Service Desk provides a more proportionate alternative, subject to independent due diligence and the applicable financial, State aid and competition rules.

Table 5.4. *Specific measure designs screened out.*

Strategic procurement conditions, dependency reporting and binding PQC implementation requirements form part of PO3 and are assessed in Chapters 6 and 7. Horizontal economy-wide certification or assurance requirements do not form part of any retained option.

Other proposals extending beyond the scope of the initiative, including Union-wide measures concerning taxation, company law, legal migration or general accelerated permitting are documented in the full screening matrix but were not developed as measures. The detailed screening scores, evidence, legal considerations and three screening-only variants excluded from the option totals are presented in Annex 4[140].

6. WHAT ARE THE IMPACTS OF THE POLICY OPTIONS?

This chapter assesses the incremental economic, social, environmental, fundamental-rights and implementation impacts of PO1, PO2 and PO3 against the dynamic baseline in Section 5.1. Effects already expected from existing Union and national measures are included in the baseline and are not attributed to the policy options.

In assessing the options, the analysis therefore includes the capacity, skills and initial demand expected from national measures. For example, where a national programme has already provided for a quantum facility or placed an order for a quantum system, the baseline includes the expected use of that facility or the demand generated by that order. The additional effect of an option would arise only to the extent that it enables further use, for example by giving firms in other Member States access they would otherwise lack, or brings together purchases that public buyers would otherwise undertake separately.

Monetisation is limited to impacts supported by sufficiently robust evidence. The assessment distinguishes between regulatory and implementation costs, programme resources subject to future budgetary decisions, and broader economic and societal effects. **Results remain indicative** rather than predictive, given limited granular data and strong dependencies on technological breakthroughs, competition, and future budgets. These outcomes depend heavily on technological progress, global competition, private investment and future Union and national budgets. Detailed assumptions, calculations and sensitivity analysis are provided in Annex 4. The Competitiveness Check and SME Check are provided in Annexes 5 and 6 respectively.

6.1. Overview of the principal expected effects

The three policy options differ in legal force, scope, and in their respective expected benefits, costs and risks. PO1 entails lower costs and fewer adverse effects but depends on voluntary

[140] See Annex 4, full policy-option screening matrix and policy-measure variant assessment. The three screened high-intensity variants excluded from the option totals are: a full-service user-support Centre, unconditional fixed-date quantum-safe obligations and a closed statutory list of international partners.

participation. PO2 provides greater continuity and more secured results across research, industrialisation, finance, demand, skills and resilience, while limiting obligations to specific actors and activities. PO3 extends formal coverage in key areas, but entails higher administrative, compliance, budgetary, competition and proportionality risks (Subsection 6.3.1). Detailed measure-level attribution is provided in Annex 4 Annex 8.

Quantum technologies may generate wider benefits for productivity, innovation, health, security, resilience and the environment, while also creating risks related to cybersecurity, dual use, resource consumption and skills. These broader effects depend primarily on technological development and uptake and cannot be attributed solely to the Quantum Act; the policy options may influence their timing, scale and the Union's ability to capture their benefits. A more detailed analysis is provided in Section 7.2 of Annex 8.

6.2. Economic impacts

6.2.1. Regulatory, administrative and indirect costs

The three policy options generate different levels of incremental implementation, administrative and adjustment costs. PO1 has the lowest costs because it relies mainly on voluntary coordination and information tools. PO2 entails moderate additional public-sector and targeted business costs linked to structured planning, delivery, procurement coordination and dependency monitoring. PO3 is the costliest option because its higher-intensity finance, procurement and reporting measures increase public-sector, business and compliance costs. Detailed cost-bearer allocations and assumptions are provided in Annex 4.

Cost dimension	PO1	PO2	PO3
Administrative and implementation costs	Lowest	Moderate	Highest
Business burden	No administrative burden	Limited and targeted administrative burden	Substantially higher burden
Programme-resource needs	Primarily based on existing instruments	Additional resources, subject to future programme and budget decisions	Greater and more predictable resources, including dedicated financial capacity
Main efficiency risk	Low take-up may reduce value for money	Coordination complexity or insufficient implementation resources may limit effectiveness	Higher programme-resource requirements may reduce flexibility, increase costs and risk crowding out alternative priorities or technological approaches.
Total societal cost, NPV 28-37	EUR 41.44 million	EUR 105.92 million	EUR 163.56 million
Evidenced cost savings (excludes hub/centre service value)	EUR 5.39 million	EUR 13.59 million	EUR 14.04 million
Net modelled cost after savings	EUR 36.05 million	EUR 92.34 million	EUR 149.52 million

Table 6.1. *Qualitative analysis and quantitative overview of costs.*

Under PO2, costs fall predominantly on public authorities and implementation actors, while business-facing costs are concentrated on applicants, beneficiaries, designated Strategic Projects and actors subject to specifically defined information obligations. New business

administrative burden is estimated at EUR 5.46 million NPV over 2028–2037, equivalent to approximately EUR 0.621 million per year; the corresponding estimate is EUR 0 for PO1 and EUR 14.38 million NPV for PO3. Detailed calculations are provided in Annexes 3 and 4.

The monetary assessment is deliberately partial and should not be interpreted as a full welfare balance. Most expected impacts on innovation, industrial capacity, firm growth, skills, resilience, security and productivity cannot be monetised robustly. PO3 is materially more costly than PO2 because of its additional administrative, adjustment and supervisory requirements. Detailed calculations and sensitivity ranges are provided in Annex 4.

6.2.2. Public-budget and programme-resource implications

The public-sector costs reported in Table 6.1 are analytically separate from programme expenditure, such as grants, infrastructure investment, procurement and financial-instrument capital. Programme expenditure depends on future budgetary and investment decisions and is not treated as a societal cost or monetised benefit. Detailed assumptions on the programme-resource estimates, including the Union, Member State and industry contributions, are provided in Annex 4, Sections 4.1.7, 4.4.3, 4.4.4 and 4.4.9.

PO1 would rely mainly on existing instruments, and no separate programme-resource envelope is estimated. For PO2, the indicative Union contribution is estimated at EUR 5.2–6.1 billion over 2028–2034, corresponding to approximately EUR 12.9–18.1 billion in total direct programme resources including Member State and industry contributions. PO3 would be expected to require higher resources for its more intensive measures, but no separate envelope is quantified because this would depend on future programme, financing and budgetary decisions. These figures are indicative planning ranges, not funding commitments or entitlements, and remain subject to the future MFF, programme legislation and individual funding, procurement and investment decisions. For context, the broader financing needs of the European quantum ecosystem are estimated at around EUR 50–60 billion, mainly equity; this is separate from the programme-resource estimates. These figures are further detailed in Annex 4 (Sections 4.1.7, 4.4.3, 4.4.4, 4.4.9).

6.3. Competitiveness, innovation, market development and SMEs

6.3.1. Start-ups and SMEs

Start-ups and SMEs make up most of the mapped European quantum companies. Their main constraints concern access to specialised facilities, later-stage finance, customers and procurement opportunities. The initiative is therefore considered highly relevant for SMEs.

PO1 would impose the lowest burden and could improve information and matchmaking. However, its limited delivery capacity would leave most access, finance and demand constraints unchanged. PO2 would support SMEs through first-level user support, shared facilities, staged procurement, investor preparation, templates and once-only information reuse. Business obligations would arise principally where a firm chose to apply for or receive support, participated in a designated project or fell within a narrowly defined critical reporting category. PO3 could provide stronger financial and procurement support but would extend dependency-reporting requirements to a wider, although still defined, population. The reporting and compliance costs stemming from the measures may weigh more heavily on smaller firms. Scope thresholds, simplified procedures, exemptions, technical assistance and once-only reuse of information would therefore be necessary[141].

[141] Annex 6, SME Check, covering SME prevalence, disproportionate fixed costs, access to facilities and finance, procurement, simplified reporting and avoidance of SME-threshold cliff effects.

The SME check and detailed model indicate that the initiative is overall beneficial for SMEs. Business-facing costs remain limited and targeted under PO2 but rise under PO3 because of its procurement and wider dependency-reporting requirement. Within the partial monetary perimeter, PO2 business costs are broadly offset by evidenced administrative and transaction-cost savings, whereas PO3 produces a substantially less favourable result. Aggregate values, cost-bearer breakdowns and SME-specific limitations are provided in Annexes 4 and 6.

6.3.2. Competition and market structure

The options may affect competition through access to infrastructures, procurement, standards, financing and support for strategic capabilities.

PO1 is expected to have limited effects on market structure, while improved information and access could modestly lower barriers to entry. PO2 could strengthen competition by improving cross-border access to facilities, finance and public buyers, particularly for start-ups and SMEs. However, concentration of support in a limited number of projects, and premature standardisation could reduce the number of suppliers, reinforce incumbents or create technological lock-in. These risks would be mitigated through open and transparent selection, technology-neutral and proportionate criteria, market-availability tests, interoperability and access requirements, and periodic review. PO3 would create higher competition risks because broader procurement conditions and stronger strategic intervention could further restrict supplier participation or crowd out alternative technologies and private investment.

6.3.3. Research, innovation and industrialisation

The main economic effects on research and industrialisation would arise from improved coordination, better access to specialised infrastructure and stronger pathways from research to deployment. PO1 would mainly lower information and search costs and improve use of existing capacity. However, its impact would likely remain limited due to its voluntary participation. PO2 could deliver stronger economic effects by improving access to prototyping, testing, validation and qualification facilities, reducing gaps between R&I and industrial deployment, while strengthening technology transfer and increasing the utilisation of facilities. PO3 would preserve the benefits of PO2 while potentially providing greater certainty of implementation through its higher-intensity measures. These additional gains would, however, require careful design and governance to ensure that stronger intervention does not unduly reduce flexibility, concentrate market power or lock in technology choices too early.

Effects on productivity, market share and aggregate value added cannot be estimated robustly. They depend on whether supported technologies outperform classical alternatives, how quickly markets develop and the scale of future investment[142]. More specifically, continued advances in classical AI and high-performance computing, including for science discovery, could reduce or shift the relative advantage of quantum computing for some applications, raise the performance threshold quantum systems must surpass and influence which quantum use cases become commercially relevant first. Improvements in processors, specialised accelerators, algorithms, HPC architectures and AI could extend the range of problems that can be solved efficiently with classical systems, potentially narrowing the economically relevant niche for quantum computing in some use cases. The assessment of quantum competitiveness and impacts should therefore remain dynamic and account for the evolving performance, cost and

[142] Quantum technologies may create financial-sector transition risks, notably from cryptographic migration, operational disruption and dependence on critical providers, while also offering opportunities in secure communications and advanced analytics. As these effects cannot be robustly quantified, they are assessed qualitatively and should be monitored with the relevant Commission services, European Supervisory Authorities and competent authorities.

energy efficiency of both quantum and classical computing.

6.3.4. Technological lock-in

Given that quantum technologies are still emerging and only a limited number have reached a high level of maturity, the risk of technological lock-in must be taken into account when investing too early in a specific technological approach. The PMs presented are technology-neutral and designed to mitigate this risk as far as possible.

PO1 entails a relatively low risk of technological lock-in, given the voluntary nature of its measures and the absence of ring-fenced financing or mandatory requirements. As a result, this option is unlikely to force the selection of one technology over another, thereby reducing the risk of lock-in.

PO2 increases this risk because it formally establishes initiatives such as Grand Challenges (PM3) and Strategic Projects (PM5), which require choices to be made between competing technological approaches. However, the risks associated with these PMs are mitigated by design: they would rely on regular portfolio reviews, milestone-based assessments and independent expert advice to compare progress across different pathways and determine whether support should continue, be expanded, merged, reoriented or discontinued, in line with Horizon Europe practice.

PO3 is broadly similar to PO2 in this respect, but it introduces a somewhat higher risk due to PM10, which includes a dedicated quantum investment fund (ring-fenced financing). This may increase the likelihood of concentrating resources on a technological pathway that does not deliver the expected results or sufficient added value. To mitigate this risk, eligibility for financial support would be assessed against criteria such as expected results, track record and European added value, among others.

Lastly, more features of PMs to mitigate technological lock-in risk across all options include prioritising open standards and interoperability, in order to reduce the cost of switching systems if one fails to meet the established goals. They also include factoring future migration and disposal costs into the initial financial analysis of options, for instance, for Grand Challenges or Strategic Projects, so as to avoid becoming unintentionally locked into expensive maintenance for years.

6.3.5. Scale-up finance and strategic-capability support

The main scale-up-finance effects arise mainly from PM10, supported by PM5.2 and PM12, through investment readiness, project visibility and access to relevant public and private finance.

PO1 would improve investor awareness, finance readiness and referral, but would not change the volume or risk profile of available capital nor create a structured response to strategically significant transactions. PO2 would establish a Quantum Investment Service Desk providing advisory services on access to grants, equity, quasi-equity, guarantees, debt, procurement and private co-investment through relevant existing or future Union and national instruments. In justified cases, it could facilitate European co-investment or coordinated counteroffers where acquisition, relocation or loss of control could materially affect a strategically important quantum capability[143]. PO3 would add a dedicated mandate within the envelope of existing or future instruments and stronger rapid-response capacity. This could improve visibility and responsiveness for capital-intensive scale-up and strategic-capability cases but would require

[143] The mobilisation range of 1.5–3.5 times Union risk-bearing finance is an illustrative scenario and is deliberately lower than some historical leverage ratios for comparable instruments. It should not be treated as a forecast or added to other benefit scenarios.

greater public risk-bearing and could crowd out other priorities or private investment. Compared with PO2, it could improve visibility and speed, but the incremental financing effect remains uncertain and would depend on additionality, independent due diligence and private-risk sharing.

6.3.6. Demand and procurement

Demand effects arise mainly from PM7, supported by PM5.1, PM6 and PM12, via buyer coordination, reference deployments and progression towards follow-on procurement.

PO1 would improve buyer awareness, identification of use cases and supplier-buyer contacts. It would not create a coordinated procurement pipeline or ensure progression from pilots to repeat demand. PO2 would support coordinated PCP/PPI, reference deployments and follow-on demand. This could give firms customer validation and early revenues, while allowing public buyers to share technical expertise and procurement risk. PO3 would create stronger and more predictable demand through broader procurement-preference requirements. This could strengthen the revenue base of European suppliers but with higher expected procurement premiums and risks of reduced competition, retaliation or supply constraints.

6.3.7. Standards, trusted deployment and resilience

PO1 would support voluntary pre-standardisation and benchmarking but would add no PQC-specific measure beyond the dynamic baseline. The substantive PQC transition and related technical migration costs remain part of the dynamic baseline. PO2 would add structured cooperation between the Commission, Member States and relevant bodies and other relevant existing cybersecurity structures, including monitoring of implementation progress. PO3 would retain this coordination layer and additionally make implementation of the existing PQC roadmap binding through time-bound migration requirements. These conditions could strengthen security of supply and European industrial capabilities where suitable suppliers exist, but may increase prices, reduce bidder participation or limit access to necessary non-European technologies. Market-availability tests, proportionality and appropriate exceptions would therefore be required.

No differentiated avoided-security-loss benefit is included in the central monetary comparison as probability, exposure and causal contribution cannot be estimated with sufficient confidence. No separate substantive PQC migration costs are attributed to PO3, as these implementation costs are already part of the dynamic baseline. Any further avoided-loss effect is treated only as a low-confidence scenario.

6.3.8. Trade and investment

The options may also affect international competitiveness, trade and investment through infrastructure and market access, procurement conditions, standards, financing, dependency mitigation and international cooperation. PO1 would have limited direct effects. PO2 could strengthen the ability of European firms to scale and compete internationally while preserving openness to international investment and diversified supply. PO3 could entail greater risks of restricting supplier participation, raising input costs or triggering reciprocal measures because of its stronger procurement and strategic-intervention conditions. Any such measures would therefore need to be targeted, proportionate and consistent with applicable Union and international obligations.

6.3.9. Fraud and impacts on consumers

No material direct impacts on consumers or consumer prices are expected, as the options do not impose obligations on citizens or consumers. No specific fraud risks beyond those addressed through existing Union financial-control, procurement and anti-fraud frameworks

have been identified.

6.4. Social and territorial impacts

A more detailed analysis of social and territorial impacts is in Section 7 of Annex 8.

6.4.1. Social impacts

The main social impacts arise from PM6 and PM9, supported by training and user-capability inputs under Grand Challenges, Hubs, Strategic Projects and procurement actions in PM3-PM5 and PM7.

PO1 would improve information on training and mobility but have limited direct effects on the supply of industrial, engineering and user skills. PO2 would connect training, mobility and user support to infrastructures, Grand Challenges, Strategic Projects and procurement. PO3 would retain the same skills and user-support arrangements as PO2. Any additional employment effects under PO3 would therefore arise indirectly from its higher-intensity finance, procurement and resilience measures and would depend on actual investment and deployment.

Available global evidence from a survey also points to participation and retention barriers for women and some marginalised groups in quantum[144; 145]. Skills development and mobility measures should therefore include inclusive outreach and, where proportionate, monitor participation and completion by sex[146].

It is also to be noted that quantum applications, often combined with AI, will support public services in areas such as e.g. health diagnostics, drugs discovery, infrastructure and environmental monitoring and secure communications. However, these benefits will depend on affordability, successful deployment and demonstrated performance advantages over classical alternatives. Therefore, they should not be attributed solely to the initiative.

The options would not impose obligations on citizens or consumers and are not expected to have material direct effects on consumer prices or income distribution.

6.4.2. Territorial impacts

Territorial impacts arise mainly from the Hubs and Competence and Acceleration Centres (PM4 and PM6). PO1 would improve information on existing capabilities but would not materially change their geographical accessibility. PO2 would combine first-level user support, aiming at one access point per Member State with specialised capability-based Hubs serving users across borders. PO3 would retain the same territorial architecture. Benefits may initially concentrate in established quantum clusters, but cross-border access to specialised Hubs and first-level support across Member States could broaden participation and diffusion. Transparent selection and access conditions and targeted outreach should mitigate geographical concentration. No robust regional employment or investment forecast can be made before future programme design and budgets are known.

6.4.3. Environmental impacts

Direct environmental impacts arise mainly from infrastructure and deployment activities. PO1 would have minimal direct effects, while PO2 could increase electricity and cooling demand,

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[144] *Key Inclusion Indicators for Quantum Technologies in Europe*, April 2025, p. 5: women represented 24% of project leaders/principal investigators in EU-funded quantum technology projects in 2024.

[145] Propp et al., *Meeting the Needs of the Global Quantum Science Community*, 2025: half of surveyed marginalised quantum scientists had considered leaving the field, vs small minority of non-marginalised.

[146] GESDA and OQI, *Intelligence Report on Quantum Diplomacy in Action 2025–2026*, 2025, pp. 10–13; Propp, T. B. et al., "Meeting the Needs of the Global Quantum Science Community: A Call to Action", 2026. Global, non-representative evidence.

cleanroom activity, specialist-material use and equipment waste. In the central design, PO3 uses the same core infrastructure as PO2 and would have a higher footprint only if additional deployment were financed. The Climate Law consistency check does not identify a significant inconsistency with the Union's climate-neutrality objective. No significant environmental harm is expected at framework level; project-level impacts remain subject to applicable environmental requirements, including the do-no-significant-harm principle where relevant.

Environmental effects[147] may arise from the production, operation and end-of-life treatment of quantum hardware and facilities, as well as from downstream applications. Quantum technologies could support the green transition through advances in materials and energy technologies, logistics and energy-system optimisation, climate modelling and environmental and infrastructure sensing[148]. **Quantum computing could require substantially less electrical power than today's most powerful classical supercomputers.** While leading exascale systems consume tens of megawatts, some energy-efficient quantum-computing architectures are expected to have system-level power requirements two to three orders of magnitude lower, potentially reducing operating costs and pressure on electricity infrastructure.

6.4.4. Impacts on fundamental rights

Quantum technologies can affect fundamental rights depending on their use and level of maturity. Quantum computing could weaken existing encryption, creating risks for privacy and the protection of personal data, while quantum sensing and dual-use applications may raise surveillance and misuse concerns. Existing Union frameworks on cybersecurity, data protection, AI and research security already address part of these risks. The Quantum Act would not authorise specific uses of quantum technologies but would improve preparedness and establish conditions for support.

PO1 would add no PQC-specific measure beyond the dynamic baseline. For PO2 and PO3, the main initiative-specific implications arise from Strategic Project designation, procurement, standards and testing, targeted dependency-information requests and PQC preparedness. PO2 could support the freedom to conduct an improved access to infrastructure, finance, testing and standards, while PQC preparedness could strengthen protection of personal data and digital privacy. At the same time, information requests and support measures may affect confidentiality, trade secrets, intellectual property and procedural rights. Safeguards should therefore ensure necessity and proportionality, purpose limitation, confidentiality, protection of trade secrets and effective procedural rights. PO3 would entail greater fundamental-rights implications because of its binding PQC requirements and broader dependency-reporting obligations[149]. Impacts would mainly concern specific actors and public authorities rather than the wider quantum ecosystem.

6.5. Governance and implementation feasibility

Governance would build on existing mandates: the Quantum Strategy Board would provide advice and support coordination, while implementation would rely on the Commission, relevant Union bodies, including the EuroHPC and Chips JUs within their mandates, and

[147] Environmental assessment covers only the additional footprint of capacity supported by the intervention, including quantum integrated with HPC/AI infrastructure; it does not attribute the overall energy footprint of AI/datacentres to the initiative.

[148] Root, D., Quantum Technologies in the Context of Climate Change, NanoEthics 19 (2025); Auffèves, A., Quantum Technologies Need a Quantum Energy Initiative, PRX Quantum 3 (2022); kiutra & CIRCULAR REPUBLIC, Circularity in the Quantum Industry, 2026.

[149] Charter of Fundamental Rights of the European Union, in particular Articles 8, 13, 16, 17, 41 and 47; Regulation (EU) 2016/679; Directive (EU) 2016/943.

Member States.

Feasibility differs across options. PO1 would be readily feasible, but its effectiveness would depend on voluntary uptake. PO2's feasibility is high since it would be implemented through existing bodies. The main challenge would be securing sufficient administrative capacity and coordination arrangements. PO3 is more complex, as it would require broader planning, a dedicated financial capacity, a broader strategic procurement framework, digital by default implementation, and significantly greater resources, especially at Member State level. Detailed staffing assumptions and peak-resource estimates are provided in Annex 4. Implementation would be digital by default, using interoperable procedures and reusing information in line with the once-only principle where legally possible, thereby limiting additional reporting and administrative burden.

6.6. Uncertainty and sensitivity

As mentioned above, this assessment is subject to significant uncertainty (technology progress, resources, likelihood of supply disruptions, etc.). The values used in the analysis in Annex 4 are scenarios, not statistical confidence intervals. They show how results change under plausible assumptions and should not be read as forecasts. Benefits expressed in different units are not aggregated[150]. The sensitivity analysis in Annex 4 confirms that PO2 is most affected by assumptions on resources required for Hub services, adaptation of existing competence centres, programme implementation and its uptake. PO3 is additionally sensitive to the scope of wider dependency-reporting requirements, procurement costs and the effectiveness of additional risk-bearing finance. The low, central, high and full-build scenarios, together with the probabilistic analysis, are presented in Annex 4.

7. HOW DO THE OPTIONS COMPARE?

This chapter compares PO1, PO2 and PO3 against the dynamic baseline in terms of effectiveness, efficiency and coherence, while also considering trade-offs, uncertainty, subsidiarity, proportionality, implementation feasibility and fundamental rights[151].

The options are alternative packages differing in legal force, scope and delivery. Ratings are reasoned judgements based on Chapters 2, 5 and 6 and Annex 4, not forecasts or aggregated scores. Effectiveness is rated as: **0** no material change; + limited; ++ substantial; +++ significant positive effect. Costs and burdens are assessed separately.

7.1. Effectiveness in achieving the specific objectives

[150] European Commission, Better Regulation Toolbox, Tool #65; Annex 4 assumptions and sensitivity tests.
[151] European Commission, Better Regulation Guidelines, SWD (2021) 305 final, Chapter 3, 2025.

Specific objective	*PO1 / PO2 / PO3*	*Main reason*
SO-A – Coordination and delivery	+ / ++ / ++	*Voluntary alignment under PO1; structured planning and review under PO2/PO3.*
SO-B – Lab-to-fab and infrastructure access	+ / ++ / ++	*Mapping/referral under PO1; targeted hubs, infrastructures and centres under PO2/PO3.*
SO-C – Scale-up finance	+ / ++ / +++	*Finance readiness under PO1; structured pipeline under PO2; dedicated capacity under PO3.*
SO-D – Demand and first buyers	+ / ++ / ++	*PO2/PO3 strengthen demand; PO3 preferences may constrain competition and availability.*
SO-E – Skills and user support	+ / ++ / ++	*PO2/PO3 integrate skills and user support with delivery measures.*
SO-F – Trusted and quantum-safe deployment	+ / ++ / +++	*Voluntary support under PO1; coordinated standards/PQC support under PO2; binding PQC implementation under PO3.*
SO-G – Dependencies and resilience	+ / ++ / +++	*Voluntary visibility under PO1; targeted requests/referrals under PO2; mandatory requests for critical categories under PO3.*

Table 7.1*. Effectiveness against the specific objectives.*

BAU is rated **0** for all objectives, as it represents the baseline against which additional effects are assessed. **PO1** would improve framework conditions across all objectives but remain limited by voluntary participation, with no common access conditions, added risk-bearing capacity, coordinated procurement or complete dependency information. **PO2** would deliver substantial effects across all objectives through common governance, structured delivery and targeted obligations, with broader coverage and continuity than PO1. **PO3** would retain PO2's core arrangements while adding stronger finance, procurement, quantum-safe deployment and dependency reporting. It would therefore be more effective mainly for SO-C, SO-F, SO-G, but with higher costs, complexity and proportionality risks.

7.2. Efficiency

Efficiency compares expected effects with administrative, implementation and indirect costs; monetised estimates cover only effects that can be quantified reliably. PO1 is least costly but leaves key gaps unresolved. PO3 is materially more costly than PO2 and would require significantly greater benefits to justify its higher burdens, which the evidence does not establish with sufficient confidence. PO2 combines moderate costs and targeted burdens with coherent delivery across all seven objectives through existing institutions. Overall, it offers the best balance of effects, costs and implementation risks. Detailed estimates are provided in Annex 4.

Efficiency dimension	**PO1**	**PO2**	**PO3**
Societal costs	*Lowest*	*Moderate*	*Highest*
Business burden	*Non-compulsory*	*Limited, targeted*	*Substantially higher*
Programme resources	*Limited*	*Material*	*Substantially higher*
Main risk	*Low participation*	*Complexity / under-resourcing*	*Premiums, crowding out and lock-in*
Overall	*Low cost, but gaps remain*	***Best balance of effect, cost and feasibility***	*Added coverage does not generally justify higher costs and risks*

Table 7.2. *Efficiency of policy options. Detailed quantitative estimates, assumptions*

and sensitivity ranges are set out in Annex 4.

7.3. Coherence

Coherence assesses the consistency of each option with Union instruments, the internal market and international commitments.

PO1 is broadly coherent and preserves openness, but it does not provide a complete pathway from priority setting to industrialisation, finance, procurement and deployment. PO2 offers the strongest coherence by integrating these elements while complementing existing EU instruments and using targeted resilience, dependency-monitoring and PQC measures. PO3 remains broadly coherent but its wider intervention increases risks of overlap, market distortion, fragmentation and tensions with competition and international commitments. Overall, PO2 provides the best balance of integration, complementarity, resilience and openness.

7.4. Trade-offs and synergies

Trade-offs and synergies mainly arise from how the measures work together within each policy option.

PO1 has a broad horizontal logic: most measures are designed to improve information flows (PM1, PM15, PM16), but also visibility (PM11), networking (PM2), skills intelligence (PM9), investor contacts (PM10, PM12), public buyer coordination (PM7, PM12), standards support (PM8) and supply-chain mapping (PM11). This creates some internal synergies, but they are mostly *soft synergies*, because they rely on voluntary take-up and do not create a structured implementation chain. For example, PM11a (voluntary mapping), PM12a, and PM14a can collectively improve visibility on dependencies and external cooperation opportunities. However, these synergies have limits, notably because the policy measures are not tied together through binding governance, systematic steering and priority setting mechanisms. As a result, the risk of fragmentation remains largely intact across all dimensions: between Member States, in funding, inn procurement and in the visibility and mitigation of supply-chain risks. In short, PO1 maintains high flexibility and a low administrative burden, but creates fewer synergies because coordination, infrastructure access, finance and procurement remain voluntary.

PO2 creates the strongest synergies by connecting programming, infrastructure, finance, skills, standards and procurement, while adding obligations only in specific cases. It shows the strongest internal synergies in a balanced sense, as it establishes a structured chain from research to industrialisation, deployment, finance, procurement, skills and resilience, while still relying mainly on existing bodies and instruments. Its core strength lies in fact that the measures are not isolated: rather, they form a coherent system architecture. For example, PO2 creates strong synergies in terms of strategic governance and coordinated implementation: through PM1, PM15 and PM16, it establishes a governance triangle involving strategic alignment, oversight and stakeholder input. This differs from PO1, where dialogue exists but lacks structured follow-through. Nevertheless, PO2 still relies on voluntary private sector participation and implementation continues to depend on existing programmes and national budgets. In addition, the benefits of PO2 may be concentrated, private investment could be crowded out, procurement may become more costly, and standards could be set too early.

PO3 could improve certainty and resilience in some areas, but it also entails greater risks, such as higher costs, reduced supplier choice, increased administrative burden and constraints on openness. In addition to the synergies already present in PO2, it introduces stronger synergies in strategic and security-sensitive components, namely investment capacity (PM10), strategic procurement (PM7) and binding PQC preparedness (PM13). These measures can be mutually reinforcing: binding PQC migration requirements (PM13c) create predictable demand for

secure solutions; strategic procurement (PM7c) channels that demand towards trusted and resilient suppliers; and dedicated investment capacity (PM10c) enables those suppliers to scale. Overall, while PO3 could reduce fragmentation to a greater extent than PO2 in certain areas, it also creates new risks of fragmentation. In particular, if EU value-creation conditions are too restrictive or too difficult to apply, markets could split between strategic and commercial segments. In addition, smaller firms or less mature actors may face difficulties in meeting compliance, reporting, or procurement eligibility requirements. These points complement the assessment set out in sections 7.1 to 7.3.

7.5. Uncertainty and sensitivity

The policy options differ in how uncertain they are. As explained in Section 6.6, each option is affected by different risks: PO1 depends heavily on voluntary participation. If few join, coverage and effectiveness fall, while coordination costs stay broadly the same. PO2 depends on available programme resources, use of shared facilities and user-support services, and the size of coordinated procurement and investment plans. PO3 is most uncertain, as it depends on administrative capacity, procurement costs, how well risk-bearing finance works and the scope and cost of wider dependency reporting.

The illustrative multi-criteria assessment ranks PO2 first under the central, equal-weight, efficiency-heavy and security-heavy weight sets tested. Under the security-heavy test, the gap between PO2 and PO3 narrows substantially but the ranking is not reversed. The assessment should therefore be interpreted as decision support rather than as a mechanical decision rule. Detailed scores, weights, sensitivity tests and switching thresholds are presented in Annex 4. The probabilistic analysis likewise highlights the limit of the monetised perimeter and should not be used mechanically to determine the preferred option. Complete distributions and methodological qualifications are set out in the Annex 4.

7.6. Subsidiarity, proportionality and overall comparison

As detailed in Chapter 3, the cross-border nature of quantum research, infrastructures, finance, procurement, and value chains justifies action at Union level.

PO1 generates Union added value through voluntary coordination. However, it relies largely on already existing initiatives and remains voluntary in nature, resulting in more limited impacts than the baseline. PO2 introduces additional functions requiring action at Union level, notably common review mechanisms, access to cross-border infrastructure, Strategic Quantum Infrastructures, coordinated procurement and financing, the designation of Strategic Projects and targeted monitoring of dependencies. PO3 also meets the subsidiarity test for certain measures. However, the need or its broader centralisation and more far-reaching obligations is demonstrated less clearly.

From a proportionality perspective, PO1 is the least intrusive option, but it is not sufficiently effective to address the identified needs. PO2 confines binding measures to areas where voluntary coordination is unlikely to ensure adequate coverage, continuity, or effectiveness. By contrast, PO3 would impose more far-reaching obligations, including binding implementation of the existing PQC roadmap, stronger procurement conditions, targeted mandatory dependency reporting and increased public risk-bearing. The available evidence does not demonstrate that this additional intervention intensity is necessary or proportionate.

Criterion	PO1	PO2	PO3
Effectiveness	Limited	Substantial	Highest formal coverage

Efficiency	Moderate	Highest	Moderate to low
Coherence	High, but limited additionality	Highest	Moderate
Implementation feasibility	Easy to put in place but results are less certain because participation is voluntary	Easy to implement and more likely to deliver results, because it uses existing structures, with some targeted binding rules.	Harder to implement because it needs a stronger regulatory framework and more resources.
Business and admin burden	Lowest	Targeted	Highest
Union added value	Positive but limited	Strong	Strong for selected measures
Proportionality and rights	Least intrusive but insufficient	Targeted and manageable with safeguards	Higher risks
Robustness	Vulnerable to low participation	Highest	Vulnerable to higher costs and slower market maturity
Overall	Does not address all residual gaps	**Best overall balance**	Additional effects generally do not justify additional costs and risks

Table 7.3. *Overall comparison policy options.*

Overall, PO2 is materially more effective than PO1 while remaining more targeted, adaptable and feasible to implement than PO3. It contributes to all seven specific objectives, limits obligations to those actors and activities for which EU intervention is justified and relies primarily on existing competent bodies and instruments. PO2 therefore performs best overall in terms of effectiveness, efficiency, coherence, subsidiarity, proportionality, implementation feasibility and robustness. Chapter 8 presents the preferred option and its detailed components.

8. PREFERRED OPTION

The preferred option is **PO2 – Enabling Quantum Framework Act**. PO2 addresses all seven specific objectives more effectively than PO1, while avoiding the additional costs, burdens, and implementation risks of PO3. PO1 remains dependent on voluntary participation and would not provide sufficient continuity and implementation certainty across programming, industrialisation, finance, demand and dependency monitoring. By contrast, PO2 provides a binding coordination framework and structured supply-chain monitoring, giving greater continuity and implementation certainty while keeping obligations targeted and relying mainly on existing Union and national structures. PO3 could provide greater certainty in selected areas, but the available evidence does not demonstrate that its additional binding requirements, stronger procurement conditions, broader dependency reporting and greater public risk-bearing would generate benefits commensurate with their higher costs and proportionality risks. PO2 therefore provides the best overall balance of effectiveness, efficiency, coherence, subsidiarity, proportionality, and implementation feasibility. Its implementation and results would be monitored against the specific objectives in Chapter 4 and the monitoring framework in Chapter 9.

8.1. Content of the preferred option

PO2 would establish structured EU-Member State governance and programming; formalise the S&T Excellence Network, Grand Challenges, Hubs, Strategic Quantum Infrastructures,

Strategic Projects and Competence and Acceleration Centres; coordinate access to finance, innovation procurement, skills, standards and PQC implementation; and introduce risk-based dependency monitoring, a business platform and structured international cooperation. Detailed measure design is set out in Section 5.2 and Annex 4.

Area	Main elements	Implementation
Governance and programming	Quantum Strategy Board, European Quantum Alliance, and common EU–Member State programming framework	Commission and Member States align priorities and review implementation; programme and budget decisions remain with the competent authorities.
Research and industrialisation	S&T Excellence Network, Grand Challenges, Technology and Innovation Hubs, Strategic Quantum Infrastructures, Strategic Quantum Projects and Competence and Acceleration Centres	Primarily implemented through existing programmes, bodies, and facilities; new or upgraded capacity only where justified by identified European gaps or demand.
Finance and market deployment	Quantum Investment Service Desk and coordinated innovation procurement, reference deployments and first-buyer support	Commission coordinates access to relevant financial instruments and procurement cooperation; investment and procurement decisions remain with the competent financial institutions and contracting authorities.
Skills, standards and PQC preparedness	Skills and mobility actions, standards, benchmarking and testing support, and structured cooperation on implementation of the existing PQC roadmap	Delivered through relevant programmes, standardisation structures and existing cybersecurity cooperation mechanisms.
Dependencies, business platform and international cooperation	Risk-based dependency monitoring and early warning, Quantum Business Platform and structured international cooperation	Commission coordinates monitoring and cooperation with Member States; targeted information requests only where necessary and proportionate; international cooperation through existing frameworks.

Table 8.1. *Operational design of the preferred option.*

8.2. Legal framework and implementation

PO2 would rely primarily on existing Union and national implementation structures. The Commission would exercise the functions assigned by the Regulation, with strategic input from the QSB and, where relevant, the European Quantum Alliance. Funding, procurement, and investment decisions would remain with the competent programmes, implementing bodies, contracting authorities and financial institutions.

Implementation would be phased, starting with governance, common procedures and support functions, followed by networks, procurement preparation, infrastructures and Strategic Projects, with subsequent review and adjustment based on implementation evidence and technological maturity.

8.3. Main impacts of the preferred option

Under the central scenario, PO2 has an estimated societal cost of EUR 105.92 million NPV over 2028–2037 and evidenced monetised savings of EUR 13.59 million, giving a net modelled cost of around EUR 92.34 million. Most costs fall on public authorities and implementing actors, while business-facing costs are limited and targeted. There are no direct obligations on citizens or consumers. Chapter 6 and Annex 4 provide the detailed impact assessment. Beyond

the monetised perimeter, PO2 is expected to improve research-to-deployment pathways, firm scale-up, early demand, skills, and supply-chain resilience, while its main risks concern implementation capacity, concentration of support and the resource use associated with infrastructure and deployment.

8.4. Budgetary implications

PO2 would not create automatic funding entitlements. The indicative Union programme contribution is estimated at EUR 5.2–6.1 billion over 2028–2034, corresponding to approximately EUR 12.9–18.1 billion in total direct programme resources when Member State and industry contributions are included. These are planning ranges, subject to the future MFF, programme legislation and individual funding decisions. For context, the broader financing needs of the European quantum ecosystem are estimated at around EUR 50–60 billion, mainly equity; this is a separate sector financing-needs estimate, not a funding commitment and not part of the EUR 12.9–18.1 billion direct programme-resource range. Detailed assumptions are provided in Annex 4.

8.5. Simplification and improved efficiency

The preferred option creates an enabling framework that mainly places obligations on public authorities and designated or EU-supported actors, with targeted information requests only where necessary. It does not introduce broad reporting or certification duties for the wider quantum ecosystem.

To reduce burdens, the framework would use common definitions and templates, digital and interoperable procedures; reuse existing information; allow information to be submitted only once where legally possible; apply proportionate reporting thresholds; consolidate reporting; and provide simpler procedures and technical assistance for SMEs. It would also involve no participation fee, no horizontal mandatory certification and no general reporting obligation for the wider quantum ecosystem.

8.6. Application of the ‘one in, one out’ approach

New administrative burdens on businesses are estimated at EUR 5.46 million NPV over 2028-2037, corresponding to an equivalent annual administrative burden of approximately EUR 0.621 million. Detailed calculations are provided in Annexes 3 and 4.

9. HOW WILL ACTUAL IMPACTS BE MONITORED AND EVALUATED?

9.2. Monitoring arrangements

Monitoring and evaluation will assess whether the preferred option is implemented as intended, meets the seven specific objectives, and remains efficient, proportionate, and coherent with related Union instruments. The Commission, supported by the QSB, will use a common framework with harmonised definitions, reporting and data-quality rules, relying mainly on existing EU, national and programme data and minimising new reporting through digital, interoperable and once-only data reuse.

Results and headline KPIs will be updated annually. The QSB will assess progress, gaps, burdens, and unintended effects and may propose corrective action. A public report will be issued at least every two years, using aggregated data where necessary to protect sensitive information and explaining relevant data or methodological limitations.

9.3. Core monitoring indicators

Specific objective	Core indicators
SO-A – Coordination and delivery	EU–Member State programming/review cycles and follow-up to agreed priorities
SO-B – Lab-to-fab and infrastructure access	Facility participation and utilisation; SME and cross-border access; progression to validation/qualification
SO-C – Scale-up finance	Firms financed; public/private capital mobilised; follow-on financing and Strategic Project progress
SO-D – Demand and first buyers	PCP/PPI actions; reference deployments; progression from pilots to repeat procurement
SO-E – Skills and user support	People trained; mobility; users supported; skills-gap indicators
SO-F – Trusted and quantum-safe deployment	Common benchmarks/testing methods used; standards uptake; PQC implementation-coordination outputs
SO-G – Dependencies and resilience	Critical inputs assessed; alternative suppliers qualified; mitigation actions and supply-related delays

Table 9.1. *Core indicators. Source: Commission-services evidence and external-support mappings. Detailed baselines, milestones, definitions, and methodological specifications are provided in Annex 10. Where robust numerical targets are not yet available, they will be established during the first monitoring cycle.*

Monitoring will cover: (i) **administrative burden**, against the ex-ante estimate of approximately EUR 0.621 million per year; (ii) **SME participation** in facilities, projects, finance and procurement; (iii) **environmental performance**, including relevant resource use and end-of-life effects; and (iv) **procedural safeguards**, including complaints, review requests, confidentiality incidents and delays.

9.4. Evaluation

A full evaluation will be carried out five years after the main provisions begin to apply, assessing effectiveness, efficiency, relevance, coherence, EU added value, proportionality and key economic, social and environmental impacts, including impacts on fundamental rights, SMEs and competition[152]. It will compare results against the baseline, focusing on costs, facility access and use, private investment, procurement, firm growth, dependencies, supply delays and the continued necessity of obligations.

Relevant stakeholders will be consulted. Findings will inform future programme, budget and legislative decisions, including whether measures should be maintained, simplified, expanded or discontinued.

[152] EC, Better Regulation Guidelines, SWD (2021) 305 final, Chapter 3; 2025, Tools 43–47.