McKinsey Technology

Quantum Technology Monitor

April 2026

What can you find in this report?

✓ An overview of the **continuously evolving quantum technology (QT) market** (including investments and market development), covering quantum computing (QC), quantum communication (QComm), and quantum sensing (QS)

✓ An overview of **the QT ecosystem's maturity** (including maturity of industry use cases), based on applications of the technology and academic activity (including patents and publications)

✗ **A definitive and exhaustive list** of start-ups, investments, and commercial readiness in the QT space

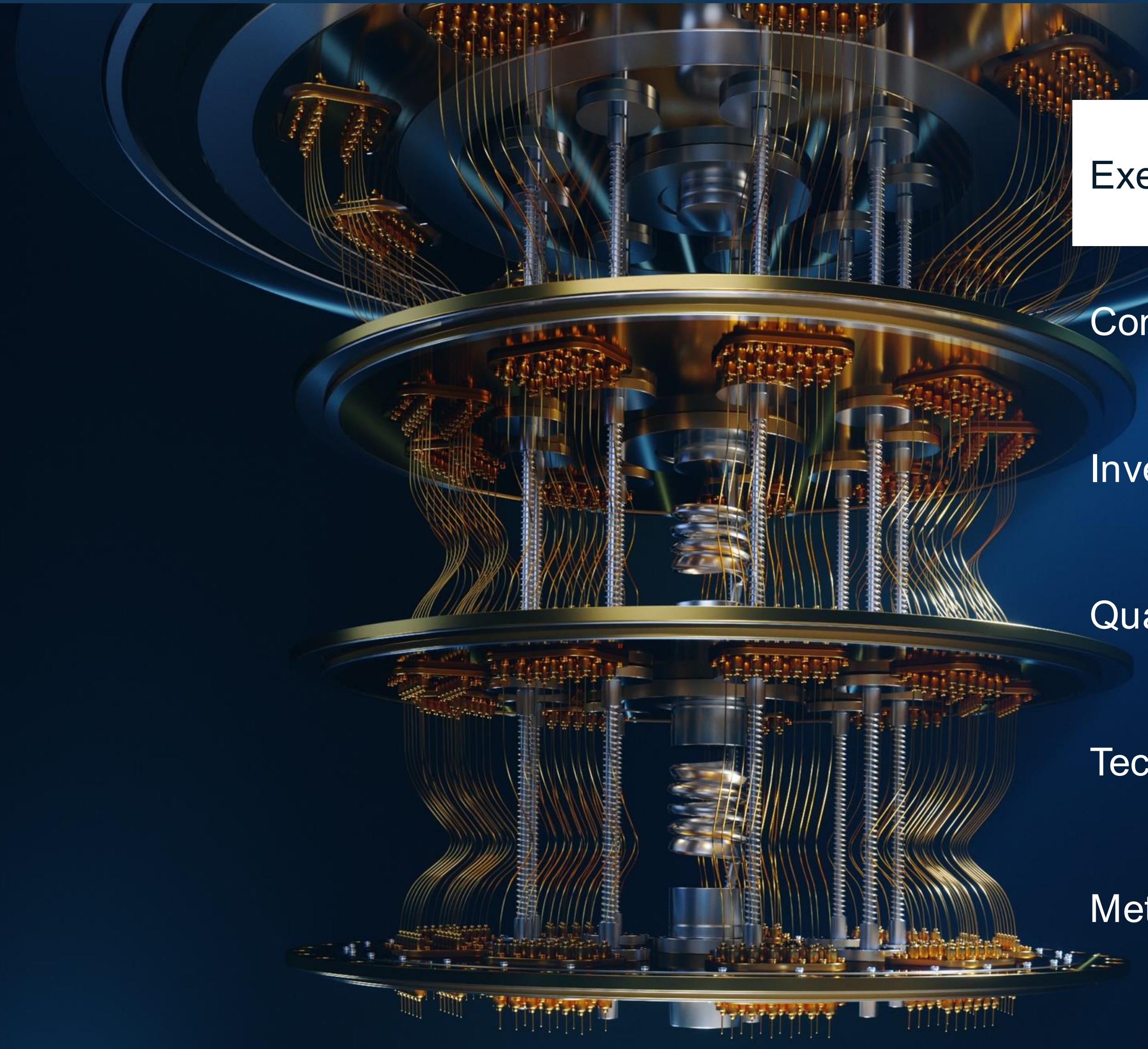
Note: Companies are mentioned as illustrative examples throughout this report; this is purely demonstrative and not representative of the companies' capabilities

Sections of the Monitor

- Commercialization and industry impact
- Investment landscape
- QT market development
- Technological maturity and deep dives, including:
  - — QT intellectual property (IP) and clusters
  - — QT value chain
  - — Cybersecurity
  - — Hybrid computing and integration in data centers
  - — QT emerging ecosystems
- Methodology and acknowledgments

Note: *Quantum Technology Monitor 2026* is based on research from numerous data sources (including, but not limited to, Crunchbase, expert interviews, PitchBook, *Quantum Computing Report*, S&P Capital IQ, and McKinsey analysis); minor data deviations may exist due to updates of the respective databases. Data captured is up to and including Mar 2026.

Contents



Key takeaways from *Quantum Technology Monitor 2026*

>$1B Revenues for QC companies in 2025	**+300** Companies with dedicated quantum efforts	**$1.3T–$2.7T** Value at stake by 2035

QT is becoming strategically relevant as commercialization accelerates

- **QT use cases are expanding across sectors**, with multiple use cases being embedded in end-to-end workflows
- **Improved technical maturity** is enhancing commercially viable use cases
- **As adoption scales**, the window of opportunity before clear winners appear is narrowing

Market momentum
Revenue of QC companies is rising as commercialization gains traction; >$1B in 2025, estimated to grow to $3.2B–$4.4B in 2028

Economic potential
Value at stake for industry is increasing with use case commercialization; total value at stake is estimated to grow to $1.3T–$2.7T in 2035

Investment acceleration
QT investments have accelerated significantly, increasing by 6.3x from 2024 to 2025

Over the next decade, QT will evolve to an industry-defining capability, attracting more investors and growing QT companies.

X Deep dive to follow

1 Industry players

Shift from exploration to scaled value capture: Focus toward securing set of high-impact use cases (eg, optimization, simulation) delivered via quantum-as-a-service

Codevelopment becomes the leading engagement model: Partnerships with QT companies are increasingly structured around joint development

Internal capabilities deliver competitive advantage: Winning organizations invest early in talent, infrastructure, and hybrid HPC[1]–QC integration to industrialize quantum adoption

2 Investors

Window of opportunity before clear winners emerge: No dominant modality or player has been established yet

Holistic investment strategies: Capital is flowing across the value chain (hardware, control, software) to hedge technological uncertainty

Governments accelerating cluster formation and security applications: Public investments, mainly in academia, drive national benefits (eg, PQC[2] development)

Fault tolerance is inflection point: Private investments increasingly hinge on credible paths to error correction and revenue from emerging use cases

3 Quantum technology companies

Market shaping through collaboration and access models: Players are codeveloping standards and platforms while leveraging quantum-as-a-service to accelerate adoption and early revenues

Start-ups and SMEs[3] shifting to commercial validation: Expectations moving from technical progress to business value, with revenue increasingly driven by codevelopment, and focus on commercial milestones and ecosystem partnerships

Big tech scaling through ecosystem and integration: Capability build-up via M&A and strategic investments is accelerating, while cloud and data center access for hybrid (HPC–QC) deployment at scale is leveraged to offer quantum-as-a-service

1. High-performance computer.
2. Post-quantum cryptography.
3. Small and medium-size enterprises.

1. Industry players: There is rapid progress toward commercialization as industry players start to engage in codevelopment for R&D.

Current state

Commercial stages from proof of concept (POC) to scaling of use cases

Build long-term customer relationships

Commercial stages	**POC between QT and industry player**	**Coinvested development for R&D**	**Scaling of use cases**
Description	Collaboration between quantum and industry partners to demonstrate opportunistic use cases	Paid assignment from industry customer to develop and implement use cases	Extension of scope; scaling of use cases of well-developed, commercialized solutions

Value at stake by 2035 for industry players

$1.3T–$2.7T

QC presents a massive use case opportunity, with rapid acceleration expected in the coming 5 to 10 years

Key insights

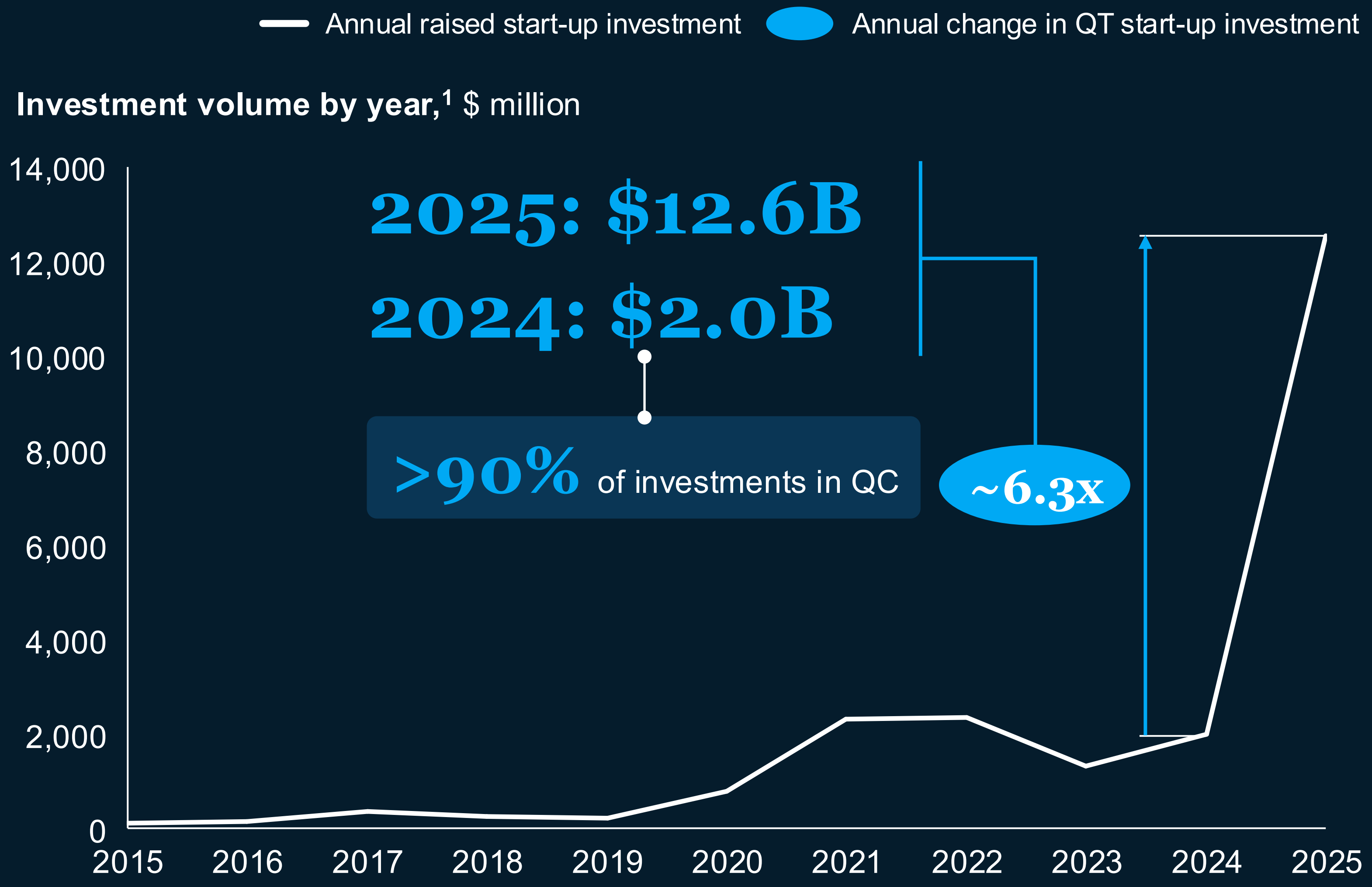
- **Industry players are moving from POCs to paid codevelopment** with QT players (300+ industry players collaborating with leading QC companies)
- Following customer-funded R&D, future sale stages include **scaling of use cases and sales**

Source: Expert interviews; press search; McKinsey analysis

2. Investors: Quantum investment increased by 6.3x from 2024 to 2025.

Key insights

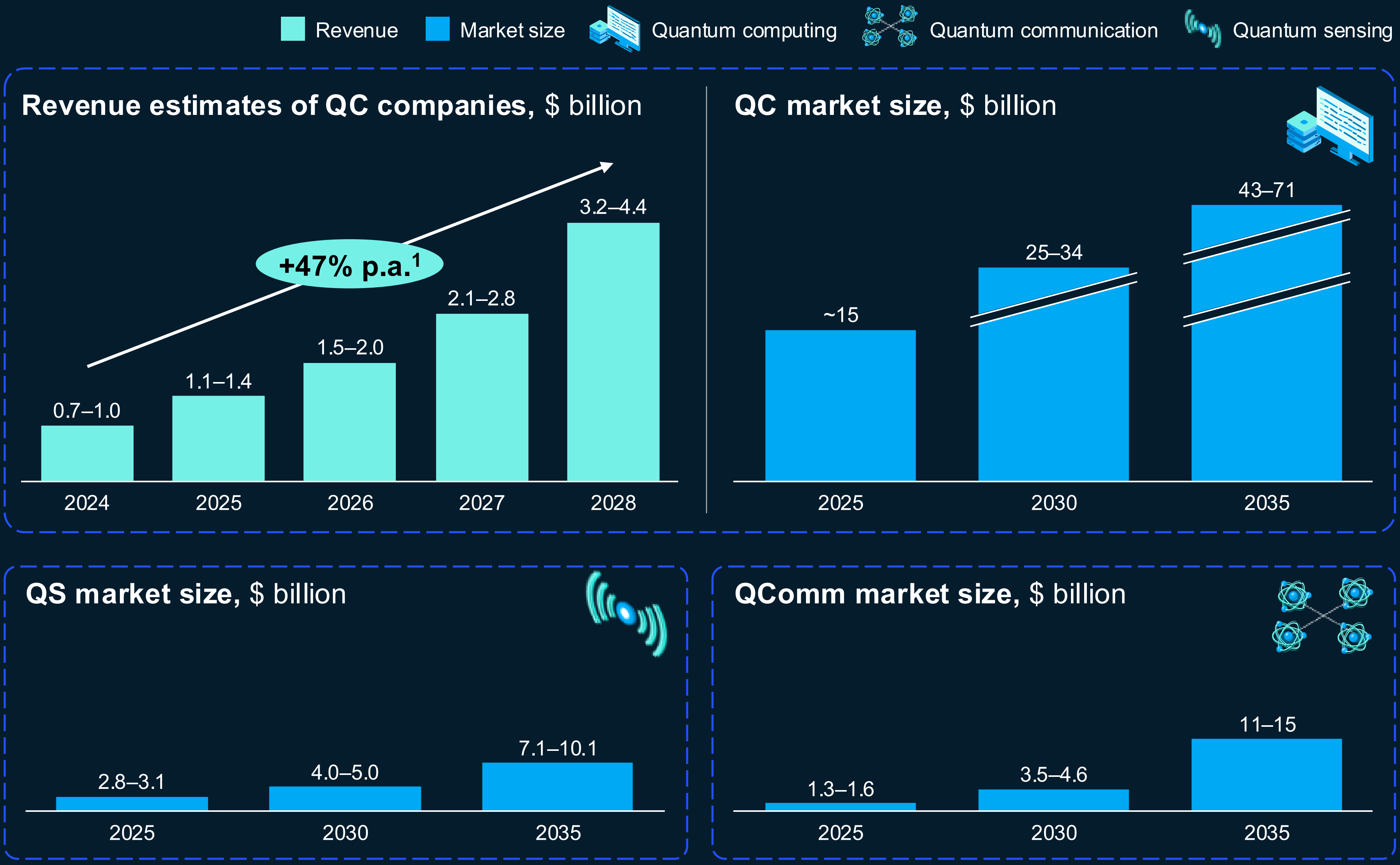
- **Investments in QT accelerated significantly in 2025**, growing by 6.3x from 2024 to 2025
- **Investments are concentrated in QC**, with multiple significant deals driving total investment volume
- **Clear commercialization potential** and corresponding **industry impact** are key drivers for investors



1. Based on investment data recorded in PitchBook, including investments via private markets (eg, venture capital [VC] funding and corporate investments), public markets (eg, IPOs, special-purpose acquisition companies [SPACs], secondary public offerings, and private investment in public equity [PIPEs]), and government and university funding; actual investment is likely higher (excludes investments with missing details on investment types); data availability on start-up investment in China is limited.

Source: PitchBook

3. QT companies: Rising revenues signal accelerating commercialization.



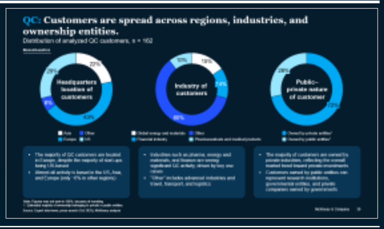
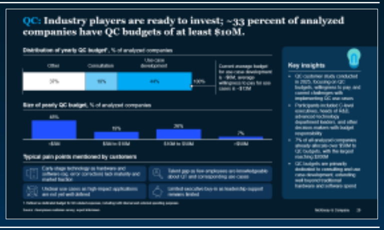
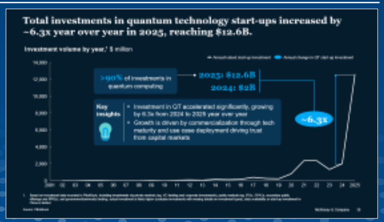
Key insights

- Industry players dedicate an increasing amount of budget to QT (especially QC)
- A significant part of QC budgets for industry players is dedicated to use case development, showcasing a general trust in deploying QC to solve real-world problems
- Revenues are expected to rapidly increase across QT, especially for QC, with an estimated 47% CAGR from 2024 to 2028

1. Per annum.
Source: Expert interviews; press search; *Quantum Technology Monitor 2025*, McKinsey; McKinsey analysis

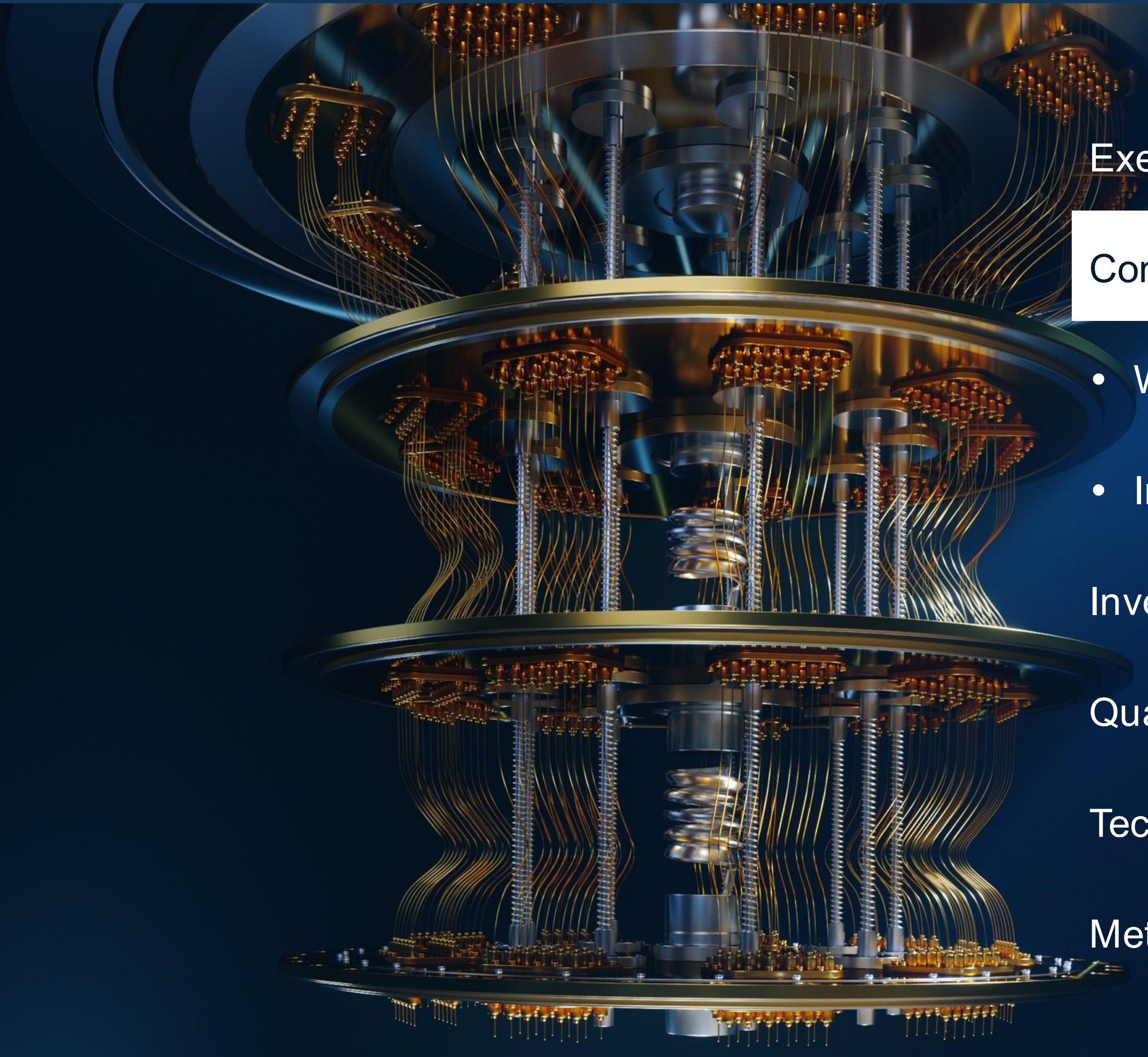
Quantum technology is moving from academic promise to commercial relevance.

Indicative

From ~2015 . . .	. . . to ~2025	
No meaningful commercial adoption	**300+** QT customers globally	
Minor dedicated QT budgets ($1M–$3M) for a few front-runners	**>$5M** Budget for hundreds of industry players	
Few part-time quantum roles	**Dedicated full-time** quantum roles (eg, quantum engineers, quantum algorithm developers, experimental physicists)	
Limited start-up funding	**>$10B** in yearly investment (~$12.6B in 2025)	

Source: Expert interviews; press search; McKinsey analysis

Contents



QT creates value across three distinct economic pools, all expected to grow significantly by 2035.

X Deep dive to follow

Archetypes of economic impact through QT		Expected value by 2035
 1 Industry players	**Quantum economy:** Affected industries Value created through technological advancements defining a post-quantum era	**$1.3T–$2.7T** Value at stake from QC, excluding QS and QComm industry impact
 2 Investors	**Quantum investors:** Beneficiaries of valuation growth Value captured through increased valuation of QT companies and QT-exposed assets	**$1.2T–$2T** Valuation of QT companies[1]
 3 QT companies	**Quantum technologies:** Product and service providers Value generated from selling QT products and services	**$60B–$100B** Market size for QT

1. Assuming valuation multiple of ~20x.

Source: Expert interviews; press search; McKinsey analysis

QT breakthroughs accelerate commercialization as industry players start to engage in codevelopment for R&D.

Current state

Commercial stages from proof of concept (POC) to scaling of use cases

Build long-term customer relationships

Commercial stages	**POC between QT and industry player**	**Coinvested development for R&D**	**Scaling of use cases**
Description	Collaboration between quantum and industry partners to demonstrate opportunistic use cases	Paid assignment from industry customer to develop and implement use cases	Extension of scope; scaling of use cases of well-developed, commercialized solutions
Revenue potential	Low		High

Acceleration of revenue potential once concepts have been proved and industry can significantly benefit from QC in scalable way

Key insights

300+

industry players collaborating with leading QC companies to generate holistic business value from QC

Following customer-funded R&D, future sale stages include scaling of use cases and sales, which generally happens once QC solutions are prepared in well-developed, scalable, commercialized solutions

Source: Expert interviews; press search; McKinsey analysis

Increased QT commercialization is supported by significant announcements.

Selected announcements for business impact and adoption of QT

Nonexhaustive

Signals of commercial progress	Company	Content of announcement	What it means	Announcement[1]
QC – QC players make **significant progress in fault-tolerant computation** and move estimates for Q-Day closer	**Quantinuum**	Launched Helios as the most accurate commercial general-purpose QC with industry-leading 99.921% 2-qubit gate fidelity for 98 physical qubits	Delivers a new performance benchmark for commercial quantum systems accelerating enterprise-grade QC adoption toward real-world application	"Introducing Helios: The Most Accurate Quantum Computer in the World" (2025)
	IonQ	Announced accelerated qubit road map, aiming to reach 2M qubits (80k logical qubits) by 2030	Showcases how the limits of QC are being pushed in a timeline of relatively few years	"Introducing Helios: The Most Accurate Quantum Computer in the World" (2025)
	IBM	Announced plans to develop credible fault-tolerant QC by 2029, presenting detailed end-to-end framework for fault tolerance	Illustrates concrete plans and technical updates to accelerate the path to fault-tolerant QC	"How IBM will build the world's first large-scale, fault-tolerant quantum computer" (2025)
QComm – **Commercialization of QComm accelerates** as QKD[2] integrates with existing telecom and satellite systems	**Quantum Computing Inc.**	Launched commercial quantum secure networking platform, integrating entangled quantum modes with telecom infrastructure	Moves QComm from lab demonstrations to enterprise-grade deployable network solutions for telecom and data center operators	"Quantum Computing Inc. Debuts Revolutionary Quantum Secure Solution at ECOC 2025" (2025)
	IonQ incl Capella Space	Announced plans for the first space-based QKD network to build space-to-space and space-to-ground quantum-secure infrastructure	Enables end-to-end quantum-secure data links extending from terrestrial to orbital networks, supporting global data-security architectures	"IonQ Announces Plans for First Space-Based Quantum Key Distribution Network" (2025)
QS – **Partnerships with government programs accelerate technology adoption**, including first moves for QS in the direction of production at scale	**Honeywell**	Awarded US government contracts to develop quantum sensor-based navigation systems to improve accuracy and resilience in GPS-denied environments	Signifies the commercialization of QS through collaboration between major industry players and government programs	"Honeywell awarded US government contracts to develop sensor-based navigation systems" (2025)
	Quantum Diamonds	Announced investment to build a next-generation quantum chip inspection and testing facility, the first production-scale site dedicated to quantum diamond–based semiconductor inspection	Moves quantum sensing from pilots to industrial scale and strengthens both QS and semiconductor tooling capabilities in Europe	"QD Plans €152 Million Investment in Next-Gen Quantum-Based Chip Inspection Facility in Munich, Germany" (2025)

1. Based on publicly available data on company websites.
2. Quantum key distribution.

Source: Company websites; expert interviews; press search; McKinsey analysis

Europe generally leads in quantum readiness of top-ranked industry players, while the United States leads on QT companies.

(X) Rank of region within industry

Quantum readiness of companies, sum of points assigned to companies in region

Industry	Europe	Rank	North America	Rank	Asia	Rank	Other
Automotive	318	1	113	3	229	2	
Energy	727	1	240	2	92	3	72
Finance	238	2	738	1	108	3	
Life sciences	560	1	370	2			
Total	1,843		1,461		429		72

Key insights

- **Europe leads quantum readiness in most industries** (almost half of top 3 companies are German), supported by strong private initiatives
- **North America shows strong adoption in finance**, reflecting early ecosystem development
- **Asia is building momentum**, with selected companies in top 3 (eg, Hyundai)

Source: Quantum Innovation Index from HorizonX and Resonance

QC: Announcements from industry players illustrate the increased commercialization of QC.

Selected announcements of industry players engaging in QC

Nonexhaustive

Industry players	Content of announcement	What it means	Announcement[1]
JPMorgan Chase	Announced certified quantum randomness by running a quantum protocol on Quantinuum's H2 trapped ion 56-qubit machine	Highlights how industry players are partnering with both QC players and academia to achieve business value	"JPMorganChase, Quantinuum, Argonne National Laboratory, Oak Ridge National Laboratory and University of Texas at Austin advance the application of quantum computing to potential real-world use cases beyond the capabilities of classical computing" (2025)
Aramco	Announced deployment of Pasqal QC—first ever quantum computer in the Middle East dedicated to industrial applications	Showcases how industry players can support national interests by investing in QC	"Aramco and Pasqal make history with Saudi Arabia's first quantum computer" (2025)
AstraZeneca	Developed end-to-end hybrid QC-classical workflow with IonQ, helping to provide solutions to complex pharma challenges	Illustrates how real-world use cases are emerging, especially through hybrid QC-classical workflows	"IonQ Speeds Quantum-Accelerated Drug Development Application with AstraZeneca, AWS, and NVIDIA" (2025)
BMW Group	Announced collaboration with Classiq and NVIDIA to optimize electrical and mechanical architectures of cars of the future	Highlights how hybrid computing and QC algorithms can play together for practical applications	"Classiq Collaborates with BMW and NVIDIA" (2024) "Quantum Computing at the BMW Group" (2025)

1. Based on publicly available data on company websites.

Source: Expert interviews; press search; McKinsey analysis

QC: Several quantum application trends enable business value in a variety of industries.

Industry	Pharmaceuticals	Chemicals	Finance	TTL[1]
Quantum application trends	**From lab demos to targeted R&D pilots** Move from POC partnerships to funded codevelopment that embeds hybrid quantum–classical molecular simulation into drug compound identification and lead-optimization workflows **Initial virtualization of clinical trials** Explore reduced drug testing due to improved simulation capabilities of QC	**Reimagining R&D for chemical companies** Tap into QC for molecular invention, identifying new candidate materials with targeted electronic, thermal, and mechanical properties before moving to synthesis in the lab **Cost-efficient and higher-yield catalyst design** Model and design catalysts with higher precision, enabling higher yield, less-waste reactions	**Innovation beyond AI in search for synergies with QC** Extend AI embedding into workflows, exploring further impact through QC given its synergies with AI, and deploy use cases such as collateral optimization, fraud detection, and derivative pricing **Q-Day as critical shift in security for financial institutions** With the accelerated approach of Q-Day, pressure is increasing to migrate to quantum-safe solutions, driven by attention to systemic cyber risk	**Scale pilots for routing, scheduling, and supply chain optimization to operational tests** Hybrid quantum digital twins are being embedded into pilot transport management systems and last-mile routing systems for hard combinatorial problems **Improved resilience of the value chain with quantum sensors** Unprecedented precision in measuring physical properties increases resilience; eg, in tracking in GPS-denied areas, reduced container load uncertainty

1. Travel, transport, and logistics.

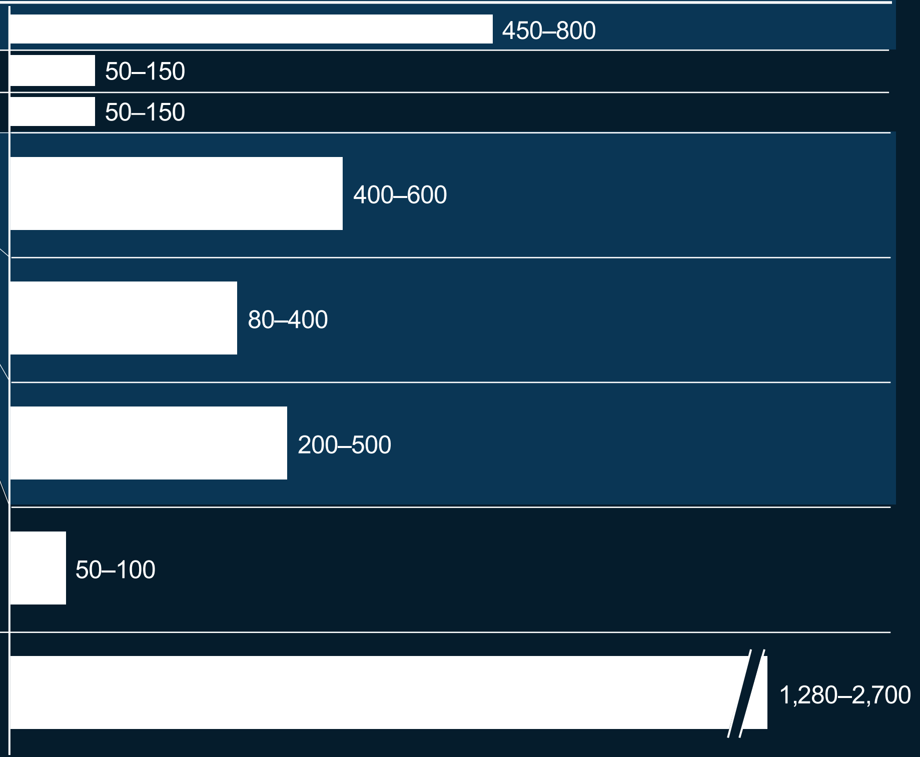
Source: Expert interviews; press search; McKinsey analysis

QC: QC presents a $1.3T to $2.7T use case opportunity, with rapid acceleration expected in the next five to ten years.

Value estimates are approximate and not definitive projections of business value

Deep dive to follow — Economic value: + Low, ++ Medium, +++ High

Industry	Key segment for QC	Economic value of QC[1] ~2025–30	Economic value of QC[1] ~2030–35	Value at stake for QC by 2035,[2] $ billion
Global energy and materials	Chemicals	++	+++	450–800
	Electric power	+	++	50–150
	Oil and gas	+	++	50–150
Financial industry	Financial services	++	+++	400–600
Pharmaceuticals, medical products	Pharmaceuticals	++	+++	200–500
Travel, transport, and logistics	Travel, transport, and logistics	++	+++	200–500
Advanced industries	Automotive	+	++	80–400
	Aerospace and defense	++	+++	
	Advanced electronics	+	++	
	Semiconductors	+	++	
Insurance	Insurance	++	++	50–100
Telecom, media, and technology[3]	Telecom	+	++	
	Media	+	+	
Total				1,280–2,700



The incremental impact of QC exhibits an overlap with the impact of gen AI, meaning the total value at stake is not entirely additive.

1. Defined as impact on revenue and cost savings relative to industry size.
2. Defined as absolute impact in terms of revenue and cost savings.
3. Excluding technology companies and QC players.

Source: Oxford Economics; McKinsey analysis

Progressive QT impact levels bring opportunities for cost reduction, acceleration of existing business, and new opportunities.

Details for selected industries to follow

Impact level of QT	**Incremental innovation**	**Substantial addition to organization processes**	**Disruption of industry**
Description	Application of QT with measurable but limited impact potential	Reshaping entire business units and processes creating systematic advantage—eg, by speedup of simulations	Technology as an asset that revolutionizes the industry

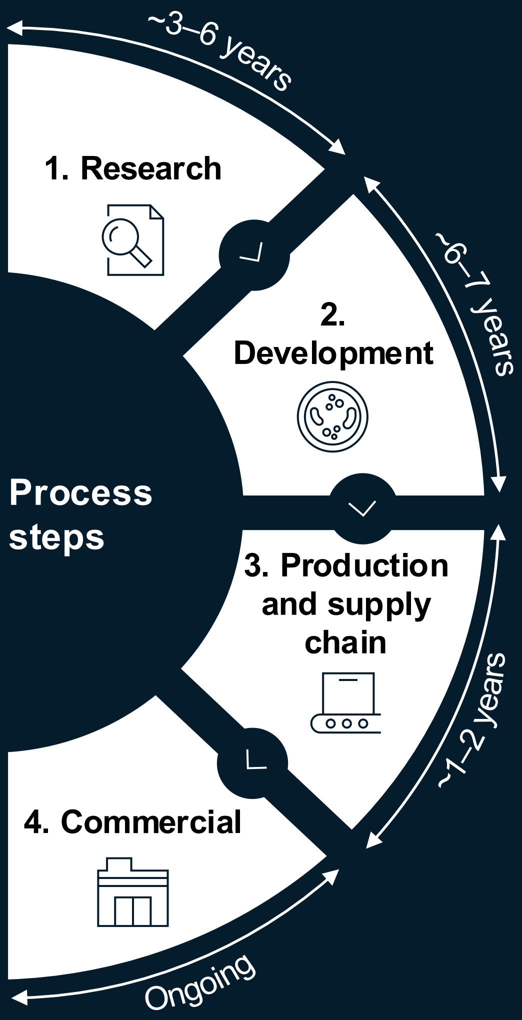
Business opportunity/lever for the company

- **Cost reduction**
- **Acceleration potential (for existing business streams)**
- **New business opportunity**

Source: Expert interviews; press search; McKinsey analysis

QC in pharma: Molecular simulation and computer-aided drug design can reduce costs and time in bringing new drugs to market.

Nonexhaustive



Example impact: AstraZeneca, IonQ, AWS, NVIDIA accelerating drug development through hybrid QC–classical computing[1] (2025)

Individual use case implementation depends on multiple factors unique to each company

Description	Impact levers[2]: Cost reduction	Impact levers[2]: Acceleration potential (existing business streams)	Impact levers[2]: New business opportunity
Identify biological target (eg, protein or gene) linked to a disease and confirm its role using computational tools and experiments Screen thousands of compounds to find "hits" that interact with the target Test optimized leads (drug candidates) in lab to evaluate safety, efficacy, and pharmacokinetics, ensuring readiness for human trials	Cost-intensive step; potential to reduce cost significantly	Reduction of research time from 4–6 years to ~1 year (eg, types of vaccines)	New type of business models (eg, personalized medicine or automated drug recommendations)
Accelerate process of human testing (drug candidate) in three phases (I, II, and III) through simulation Submit a new drug application (NDA) to regulatory authorities for review, which can take 1–2 years	Cost-intensive step; potential to reduce cost significantly	*Limited direct impact*	New type of business models (eg, personalized medicine or automated drug recommendations)
Calculate reaction rates, formulate product, and optimize catalytic processes	Energy and resources speed up through optimization of the production process and catalysis; however, lower impact relative to R&D	*Limited direct impact*	
Launch the drug to market and conduct post-approval studies (phase IV) to monitor long-term safety and efficacy			

1. "IonQ Speeds Quantum-Accelerated Drug Development Application with AstraZeneca, AWS, and NVIDIA," IonQ, June 9, 2025.
2. Impact of QC and AI.

Source: Expert interviews; Matthias Evers, Anna Heid, and Ivan Ostojic, "Pharma's digital Rx: Quantum computing in drug research and development," McKinsey, June 18, 2021; McKinsey analysis

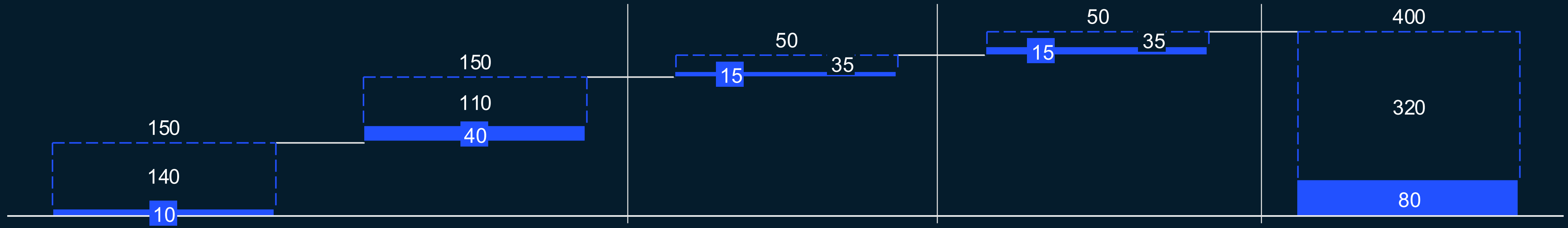
QC in pharma: QC could unlock up to about $400B in value, equal to up to 12 percent of projected industry gross sales.

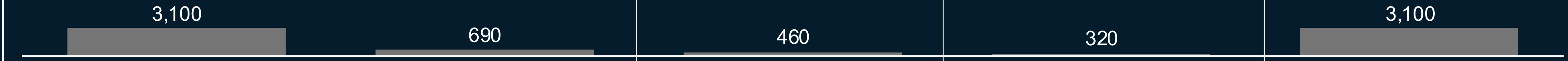
Nonexhaustive | Indicative | Rounded potential impact | Excl black swan breakthroughs

Lower bound | Upper bound

Value chain	Research		Development	Production, supply chain, and commercial	Total
Potential quantum advantage	New businesses via new product development: • personalized medicine or automated drug recommendations • reduce time to market or find new innovative molecules	Augmentation of lab-based R&D with computer-aided drug design to improve R&D productivity and efficacy	Optimization of clinical trials	Savings in energy and resources through: • optimization of the production process • optimization of catalysis	
Impact hypothesis[1] (estimate)	~0.5–5%[3] Increase in revenue	~5–20% Savings	2.5–10% Savings	~5–15% Savings	~2–12%
Financial baseline in 2035, $ billion[2]	3,100 Total global revenue	690 Total R&D spend *(22% of total revenue)*	460 Total spend on clinical trials *(2/3 of R&D revenue)*	320 Total production spend	3,100

Potential impact from QC by 2035, $ billion

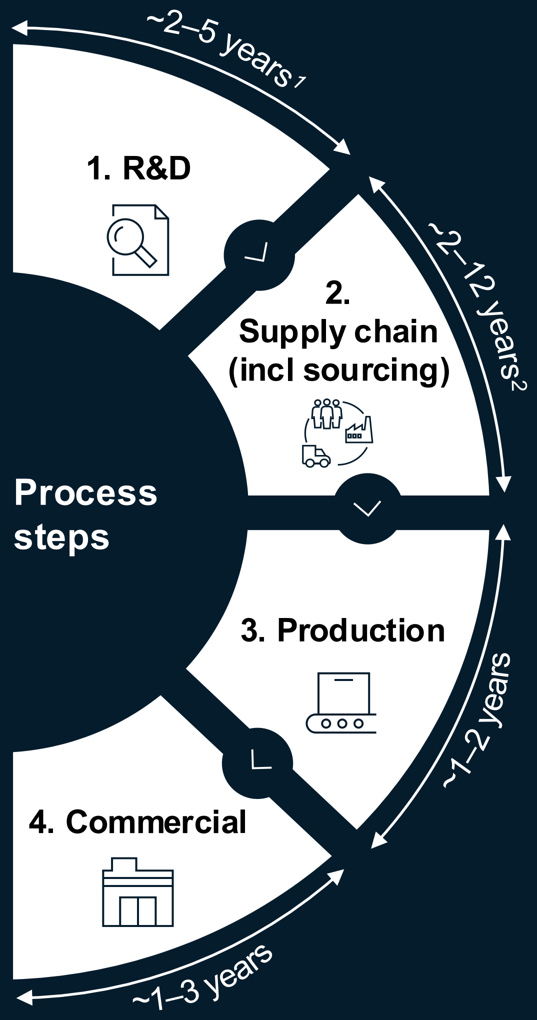




1. Savings are compared to current state, not to future technology alternatives.
2. Baseline from S&P Global Comparative Industry Service—total sales (gross sales) of manufacturing of basic pharmaceutical products and pharmaceutical preparations (C21) in real US $ (2019); percentage spend assessment for R&D (22% of total revenue) and clinical trial spending (2/3 of R&D spending) based on expert input.
3. New businesses impacting entire value chain.
Source: Expert interviews; S&P Capital IQ; S&P Global Comparative Industry Service; web search

QC in chemicals: Quantum simulation and advanced AI enable a priori design and optimization of new molecules and materials.

Nonexhaustive



Example impact: BASF and D-Wave completing a proof-of-concept approach to improve manufacturing workflow efficiency[3] (2025)

Individual use case implementation depends on multiple factors unique to each company

		Impact levers[4]		
	Description	**Cost reduction**	**Acceleration potential** (existing business streams)	**New business opportunity**
1. R&D	Discover and design new molecules and materials; involves computational modeling and laboratory testing	Potential to save spend by 20–50% by 2035 through shorter design cycles, reduced lab testing, and virtualization of R&D	Shorten R&D and supply chain cycle by ~3 years	Revenue generation through chemical invention; eg, for agriculture, energy transition, batteries, new catalysts material, carbon capture
2. Supply chain (incl sourcing)	Focus on scaling up production, sourcing raw materials, and optimizing manufacturing processes to ensure consistent quality and efficiency	Potential to save spend by 1–1.5% of total costs by 2035 from optimized feedstock sourcing	Shorten R&D and supply chain cycle by ~3 years	Limited business opportunity through quantum-enhanced supply chain management software
3. Production	Perform formulation, packaging, and quality control in the actual manufacturing of specialty chemicals	Potential to save spend by 1–1.5% in optimization of the production process and 2–5% in catalysis	*Limited direct impact*	*Limited direct impact*
4. Commercial	Launch the product into the market, manage customer relationships, and optimize product performance in real-world applications	*Limited direct impact*	*Limited direct impact*	*Limited direct impact*

1. 2–3 years for simpler materials or formulation (eg, polyols) and 4–5 years for specialty chemicals.
2. 2–3 years for simpler supply chains and ~7–12 years for scaling up production and supply chain.
3. "BASF and D-Wave Announce Completion of Proof-of-Concept Project, Demonstrating Benchmark in Manufacturing Efficiency," D-Wave, Nov 5, 2025.
4. Impact of QC and AI.

Source: Expert interviews

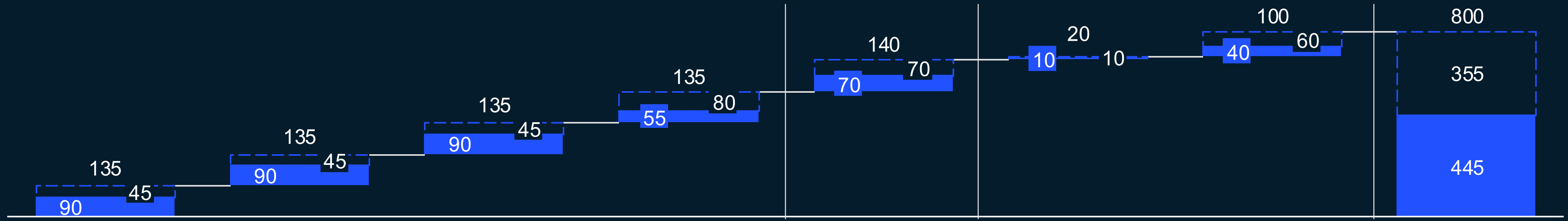
QC in chemicals: By 2035, QC could unlock $450B to $800B in value, representing 5 to 9 percent of projected gross sales.

Nonexhaustive | Indicative | Rounded potential impact | Excl black swan breakthroughs

Upper bound | Lower bound

Value chain: R&D | Supply chain | Production | Total

Potential impact from QC by 2035, $ billion



Value chain	R&D	R&D	R&D	R&D	Supply chain	Production	Production	Total
Potential quantum advantage	Molecular inventions (eg, protein-based crop protection)	Low-cost substitutes based on new synthesis routes (eg, vitamins for animal nutrition, synthetic aromas)	Improved products (eg, high-potency/ multifunctional ingredients due to improved property analysis and design)	Virtualization of R&D, leading to savings in: • development and testing time • materials	Savings in resources through yield increase of raw material	Process planning: production planning for multiproduct, multiline plants to maximize service level	Savings in energy and resources: optimize catalysis, improve selectivity and conversion efficiency	
Impact hypothesis[1] (estimate)	~1–1.5% Increase in revenue	~1–1.5% Increase in revenue	~1–1.5% Increase in revenue	~20–50% Savings	~1–2% Savings	~1–2% Savings	~2–5% Savings	~5–9%
Financial baseline[2] in 2035, $ billion	9,035 Gross sales	9,035 Gross sales	9,035 Gross sales	271 R&D spend	6,859 Cost of goods sold (COGS)	800 Other operating expenditure	2,058 Affected COGS	9,035 Gross sales

1. Savings are vs situation today, not vs future technology alternatives. 2. Baseline from S&P Global Comparative Industry Service—total sales (gross sales) and total purchases of inputs and supplies (COGS) of manufacture of chemicals and chemical products (C20) and of rubber and plastic products (C22)—in real US $ (2019), with percentage spend assessment for R&D (3% of gross sales) and catalysis (30–40% of COGS, assume 30%) based on expert input.

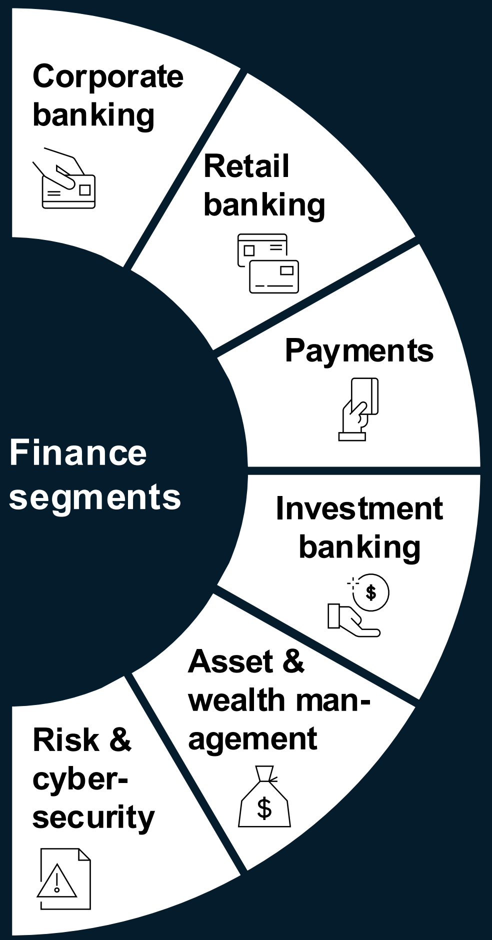
Source: S&P Global Comparative Industry Service; S&P Capital IQ; expert interviews (total spend on R&D, production, supply chain, total production spend associated with catalysis and impact hypothesis)

QC in finance: Optimization, risk modeling, and cryptography security underpin quantum value across finance.

Nonexhaustive

Individual use case implementation depends on multiple factors unique to each company

Example impact: HSBC and IBM demonstrating the world's first-known quantum-enabled algorithmic trading[1] (2025)



	Impact levers[2]		
Description	**Cost reduction**	**Acceleration potential** (existing business streams)	**New business opportunity**
High-value transactions and complex services such as trade finance, collateral optimization, and liquidity management	Optimized collateral allocation, reduced capital buffers	Real-time product decisions (eg, default risk, lending decisions)	Secure smart contracts, communication for trade finance
Serves individuals and small businesses through deposits, loans, and credit products	Limited impact	Faster credit scoring and approvals at scale	Offering new personalized finance recommendations
Involves transferring money across domestic and international networks	Lower fraud losses and compliance costs through better monitoring	*Limited direct impact*	Quantum money, quantum-secure cross-border payments
Advises on and arranges financing, M&A, trading, and derivatives services	Optimized collateral allocation, reduced capital buffers	Fast derivative pricing, real-time trading, acceleration of Monte Carlo simulations	Non-physical assets, secure smart contracts
Manages investment portfolios for individuals and institutions. Covers asset allocation, diversification, and alternative assets	More efficient portfolio allocation and asset modeling	Personalized pricing and better recommendations, leveraging AI	Secure smart contracts, quantum networking for transaction banking
Centers on security, such as accurate and fast fraud detection as well as defense against QC ability to decrypt data	Lower compliance and reporting costs through automated simulation	Faster, broader risk simulations and improved fraud detection accuracy	PQC/QKD will be mandatory to enable secure transactions[3]

Note: Operations and finance is not shown here due to negligible impact.
1. "HSBC demonstrates world's first-known quantum-enabled algorithmic trading with IBM," HSBC, Sept 25, 2025.
2. Impact of QC and AI.
3. Overlap with cyber and security vertical.

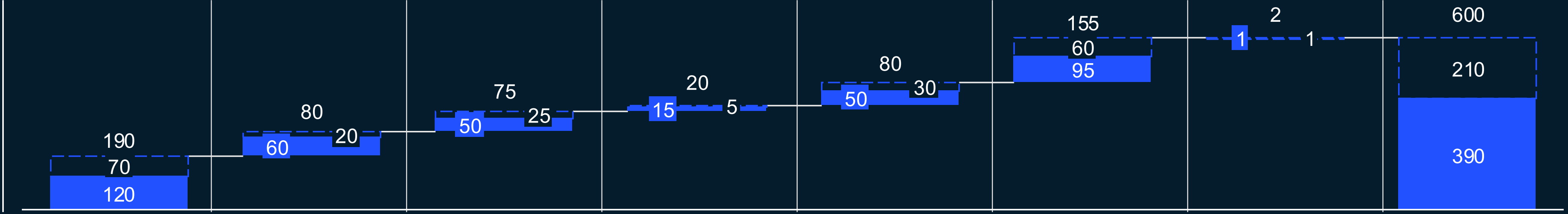
Source: Expert interviews; Martina Gschwendtner, Nicole Morgan, and Henning Soller, "Quantum technology use cases as fuel for value in finance," McKinsey, Oct 23, 2023

QC in finance: The value of use cases could be $400B to $600B by 2035, representing 3.0 to 4.5 percent average impact.

Nonexhaustive | Indicative | Rounded potential impact | Excl black swan breakthroughs

Lower bound | Upper bound

Value chain	Corporate banking	Retail banking	Payments	Investment banking	Asset and wealth management	Risk and cybersecurity	Operations and finance	Total
Potential impact from QC by 2035, $ billion	190	80	75	20	80	155	2	600



	Corporate banking	Retail banking	Payments	Investment banking	Asset and wealth management	Risk and cybersecurity	Operations and finance	Total
Potential quantum advantage	Enabling more efficient collateral allocation (freeing capital for lending), improving default risk prediction for real-time product decisions, and securing cross-border trade finance through smart contracts	Collateral optimization for high account volume and collateral types for improved risk management, leading to incremental changes for high-net-worth individuals	Potential replacement of current blockchain technology and getting rid of fraud and anti–money laundering checking (quantum money)	More efficient portfolio allocation and asset modeling, with improved derivative pricing algorithms, hedging, etc (eg, improved modeling on complex constraints such as transaction costs)	Enabling more efficient portfolio allocation and asset modeling, personalized pricing, and secure transactions	Large impact arising from fraud detection accuracy improvement and replacement of classical risk models	Full-time equivalent (FTE) footprint optimization, tax exposure optimization, and automation of reporting	
Impact hypothesis[1] (estimate)	~3.5–5.5% Increase in revenue	~1.5–2% Increase in revenue	~3–4.5% Increase in revenue	~2.5–3.5% Increase in revenue	~5–8% Increase in revenue	~3–5% Increase in revenue	1–2.5% Savings	3–4.5%[2]
Financial baseline in 2035, $ billion	3,500	4,200	1,600	610	980	3,100	70	
	Total global corporate banking revenue *(50% of division affected)*	Total global retail banking revenue *(50% of division affected)*	Total global revenue of payments *(70% of division affected)*	Total global investment banking revenue *(22% of division affected)*	Total global asset and wealth management revenue *(35% of division affected)*	Total spend on risk and cybersecurity *(30% of division affected)*	Total spend on operations and finance *(50% of division affected)*	

1. Savings are vs situation today, not vs future technology alternatives.
2. Weighted average from all finance contributors.

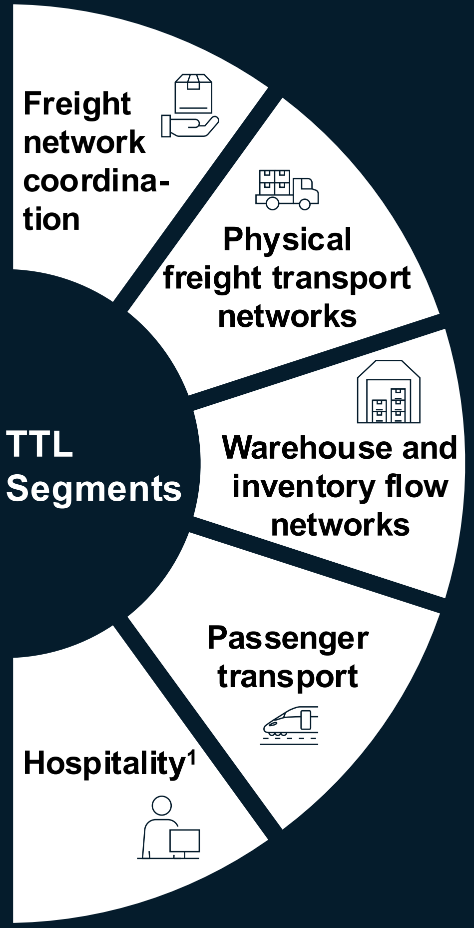
Source: Expert interviews; raw data from Panorama Solutions

QC in travel, transport, and logistics: Network optimization unlocks new routing and scheduling possibilities.

Nonexhaustive

Example impact: Einride and IonQ partnering to develop quantum supply chain and quantum-enhanced logistics[2] (2025)

Individual use case implementation depends on multiple factors unique to each company



Impact levers[3]

Description	Cost reduction	Acceleration potential (existing business streams)	New business opportunity
Coordinating and matching freight demand with available logistics capacity across carriers and routes	**Reduction in procurement and coordination costs** through episodic (eg, annual) optimization of highly granular logistics networks (eg, container shipping where large-scale network flows and assignment problems impose a high computational burden)	**Faster planning and re-matching cycles** via heuristic acceleration of combinatorial optimization across carrier-lane networks	*Limited direct impact*
Operating and routing physical freight flows via trucks, ships, planes, and trains	**Reduction in fuel costs and empty mileage** (eg, in trucking or liner shipping network), enabled by near-real-time re-optimization of freight networks requiring daily matching of routes, assets, and emerging demand under a high computational burden	**Faster real-time rerouting and scheduling** enabled by hybrid classical–quantum heuristics for combinatorial optimization for, eg, traffic, weather, and demand	**QS for cargo monitoring** (eg, tamper detection, high-precision tracking)
Storing goods and managing inventory movements within warehouses and distribution centers	**Reduced disruption- and recovery costs** (eg, compensation, secondary delay effects) through improved solutions to high-dimensional network recovery decisions	**Faster recovery** by enabling near-real-time prediction and re-optimization of cascading disrup-tion effects (eg, weather, assets, and staff availability) using heuristic and hybrid solving framework	*Limited direct impact*
Transporting passengers across air, rail, and ground networks	**Reduced disruption and recovery costs** (eg, asset underutilization) through improved solutions to high-dimensional network recovery and scheduling problems	**Faster recovery and journey times** via heuristic acceleration and hybrid solving frameworks for complex, cascading disruption scenarios	
Managing accommodation supply and travel bookings across customer segments and channels	**Cost savings** through more efficient pricing and marketing decisions	**Faster adaptation of offers and recommendations** via more granular demand optimization and hyperpersonalization	

1. Includes hotels, cruises, and travel booking.
2. "IonQ Partners with Sweden's Einride to Develop Quantum Supply Chain and Quantum-Enhanced Logistics for Autonomous Driving Solutions," IonQ, May 20, 2025.
3. Impact of QC and AI.

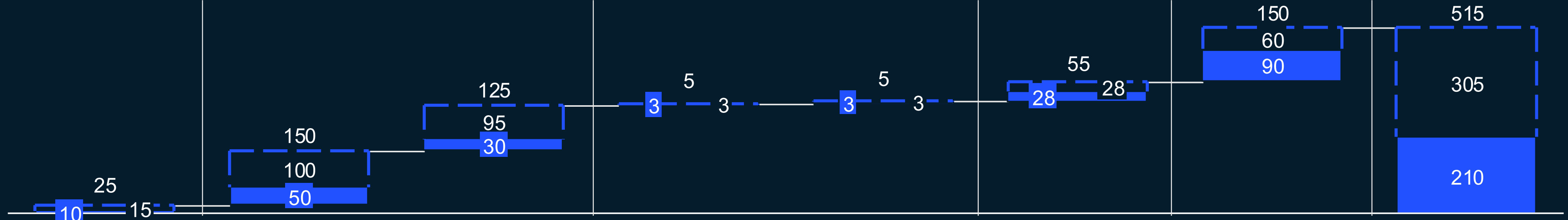
Source: Expert interviews; McKinsey analysis

QC in travel, transport, and logistics: QC could unlock $200B to $500B in value by 2035.

Nonexhaustive | Indicative | Rounded potential impact | Excl black swan breakthroughs

Upper bound | Lower bound

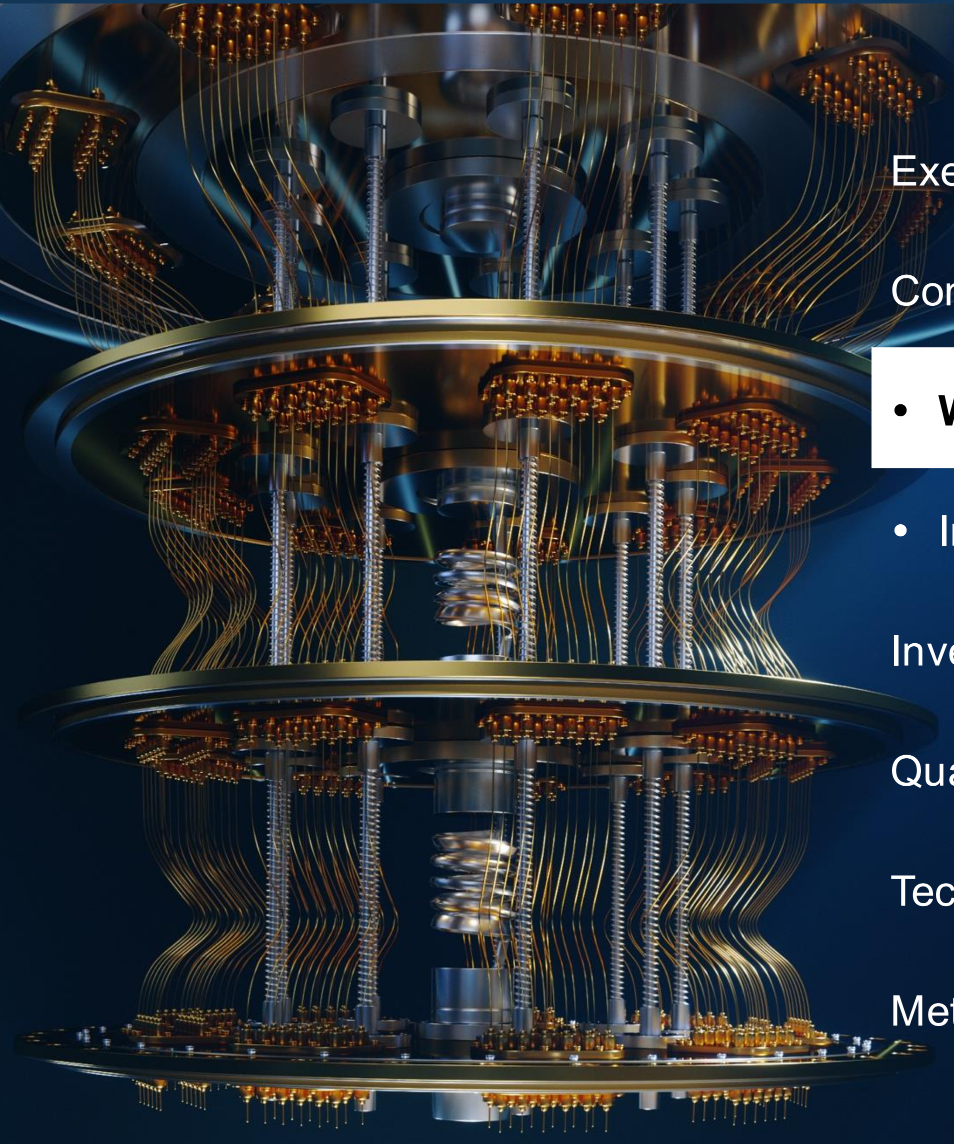
Potential impact from QC by 2035, $ billion



Value chain	1. Freight network coordination	2. Physical freight transport networks		3. Warehouse and inventory flow networks		4. Passenger transport	5. Hospitality	Total
Potential quantum advantage	Multimodal routing optimization	Vehicle routing and scheduling optimization	Cargo loading optimization focused on empty mileage, yet can apply to broader range of transportation modes	Warehouse storage/layout optimization	Order picking and fulfillment scheduling optimization	Vehicle routing, scheduling optimization, and enhanced, high-dimensional disruption management	Revenue increase through enhanced loyalty programs and personalized marketing measures	
Impact hypothesis[1] (estimate)	1–3%	1–3%	2.5–10%[2]	2–4%	2–4%	2.5–5%	3–5%	2–4.5%[3]
Financial baseline in 2035, $ billion	822	5,102	1,273	131	131	1,103	2,999	
	Global COGS in contract logistics and freight forwarder	Global COGS in post and parcel, rail, trucking, air cargo, and maritime logistics	Global COGS in post and parcel, trucking *(30% of empty mileage)*	Global COGS in warehousing		Global COGS in air, rail, and bus passenger transport	Global revenue in hotels, cruises, and online travel booking	

Note: Figures may not sum because of rounding.
1. Savings are vs situation today, not vs future technology alternatives.
2. Based on improvement potential to optimization of empty mileage.
3. Weighted average from all TTL contributors.
Source: Euromonitor; expert interviews; IATA; S&P Global Comparative Industry Service; web search

Contents



QT offers early-stage investment upside before clear leaders emerge.

Why QT, especially QC, can serve as an attractive investment

AI shows how fast leadership can consolidate

- AI leadership positions are largely consolidated
- AI has high capital intensity and valuation multiples
- AI differentiation is increasingly incremental

QT does not yet have a clear leader, providing a unique tech investment opportunity

QT still offers high optionality relative to other tech investments

- QT builds fundamentally new capabilities, highly tailored to specific use cases
- The cost to capture QT IP is low, offering potential to future-proof use cases
- QT investments can be leveraged to improve company perception

Early movers shape use cases, ecosystems, and standards

The cost of waiting is nonlinear and increasing

- Valuations of QC companies have seen drastic increase, with continued increase in year-over-year investments
- Access to cutting-edge hardware tightens as commercialization grows
- Talent scarcity increases

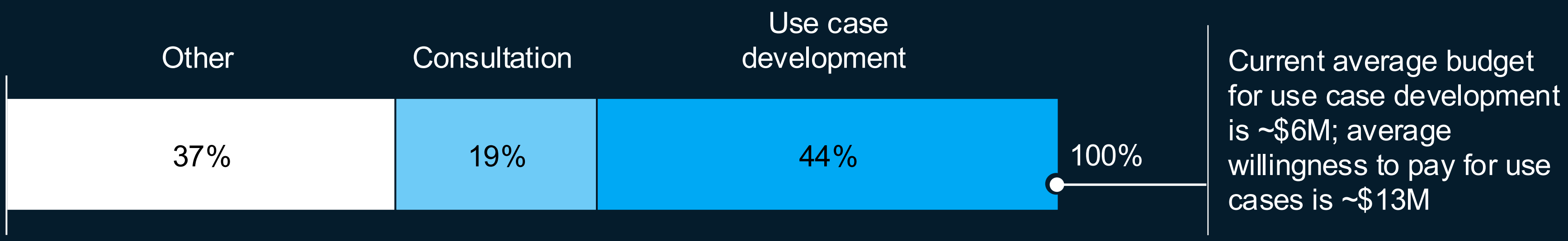
Late AI adopters paid a premium; QC could be at an inflection point

As capital, talent, and access tighten, the cost of waiting is rising

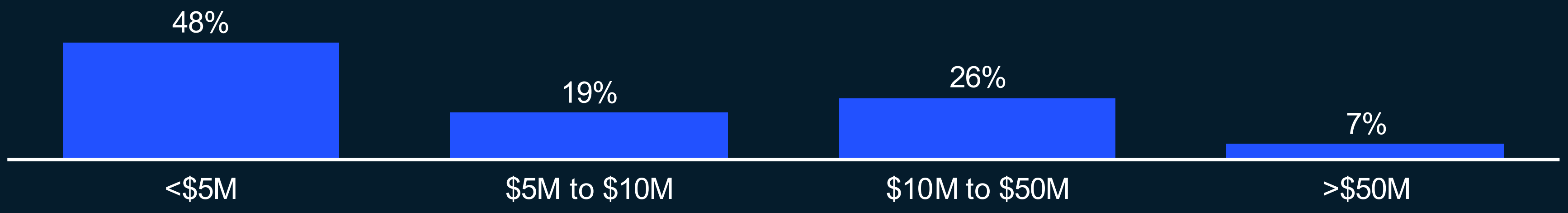
Source: Expert interviews; press search; McKinsey analysis

QC: Industry players are ready to invest; ~33 percent of analyzed companies have QC budgets of at least $10M.

Distribution of yearly QC budget[1], % of analyzed companies



Size of yearly QC budget, % of analyzed companies



Typical pain points mentioned by customers

- Early-stage technology as hardware and software (eg, error correction) lack maturity and market traction
- Talent gap as few employees are knowledgeable about QT and corresponding use cases
- Unclear use cases as high-impact applications are not yet well defined
- Limited executive buy-in as leadership support remains limited

Key insights

- QC customer study conducted in 2025, focusing on QC budgets, willingness to pay, and current challenges with implementing QC use cases
- Participants included C-level executives, heads of R&D, advanced-technology department leaders, and other decision-makers with budget responsibility
- 7% of all analyzed companies already allocate over $50M to QC budgets, with the largest reaching $200M
- QC budgets are primarily dedicated to consulting and use case development, extending well beyond traditional hardware and software spend

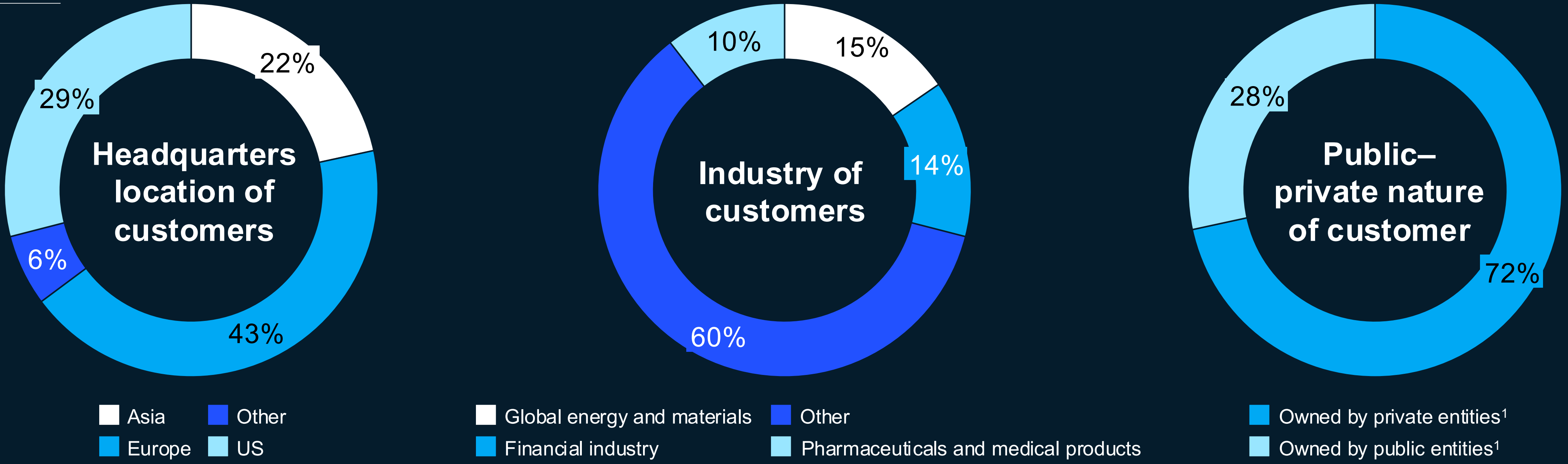
1. Defined as dedicated budget for QC-related expenses, including both internal and external spending purposes.

Source: Anonymous customer survey; expert interviews

QC: Customers are spread across regions, industries, and ownership entities.

Distribution of analyzed QC customers, n = 162

Nonexhaustive



- The majority of QC customers are located in Europe, despite the majority of start-ups being US-based
- Almost all activity is based in the US, Asia, and Europe (only ~6% in other regions)

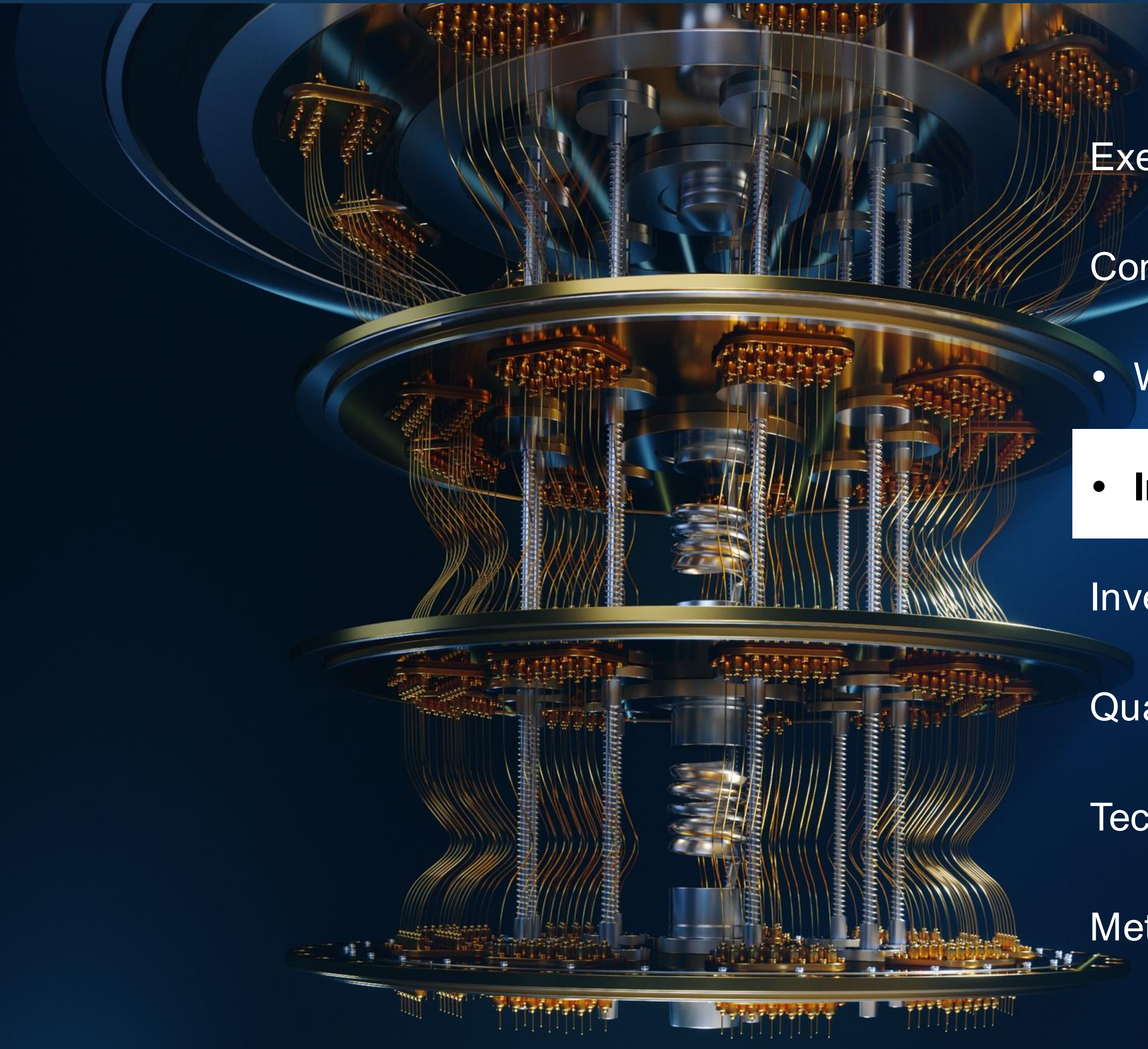
- Industries such as pharma, energy and materials, and finance are seeing significant QC activity, driven by key use cases
- "Other" includes advanced industries and travel, transport, and logistics

- The majority of customers are owned by private industries, reflecting the overall market trend toward private investments
- Customers owned by public entities can represent research institutions, governmental entities, and private companies owned by governments

Note: Figures may not sum to 100%, because of rounding.
1. Estimated majority of ownership belonging to private or public entities.

Source: Expert interviews; press search (Oct 2025); McKinsey analysis

Contents



QC and AI can add value to each other in several areas.

Hypothetical   Indicative

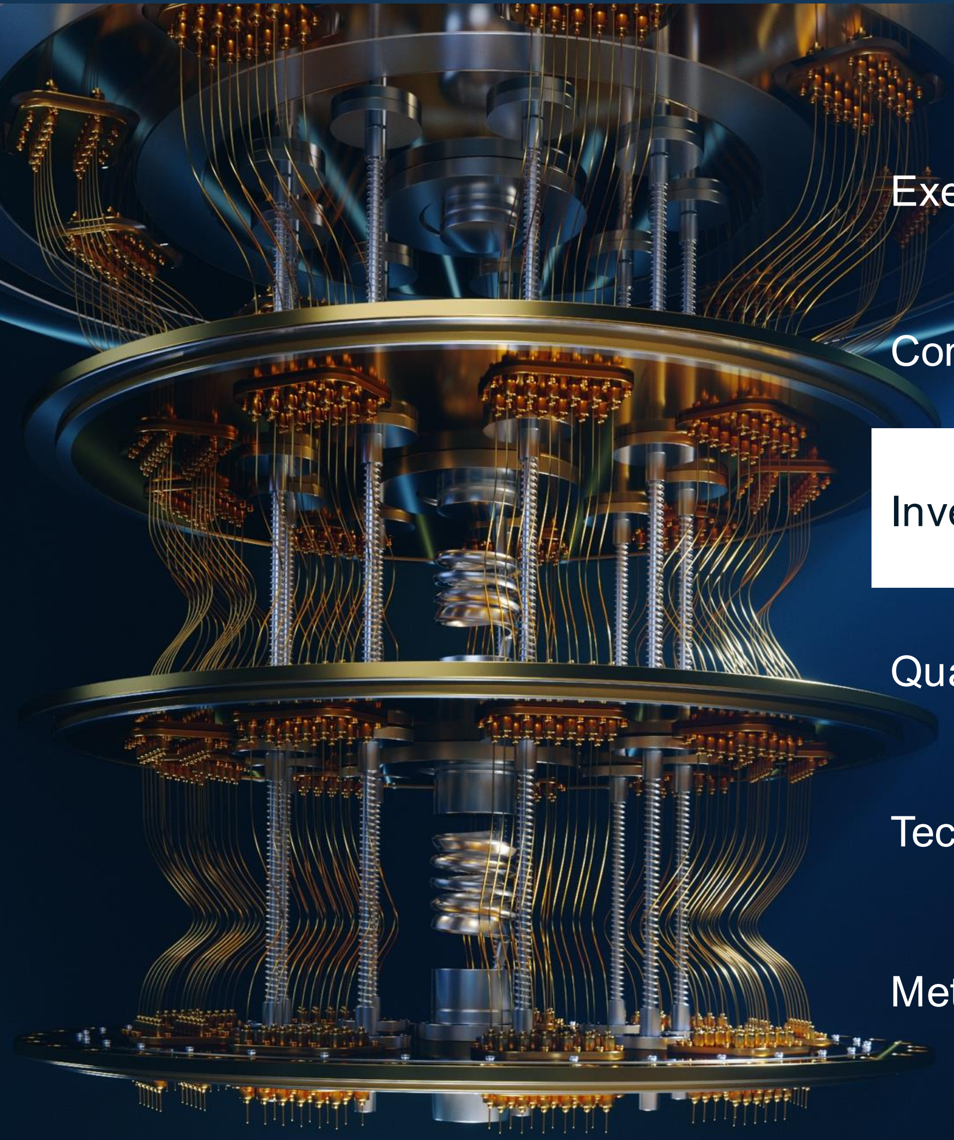
QC will be used for AI in stages after Q-Day

	Q-Day		*+3–5 years*	*Far future*
	Use of QC for new use cases or highly complex AI tasks—eg, model training		**Use of QC for simple AI tasks** (for cost reasons)	**Use of QC for typical classical computing**
Description	Use of QC for tasks that are extremely difficult classically (eg, model training)	Use of QC for problems that cannot be solved classically	Use of QC as an alternative for multiple AI algorithms	Use of QC as cheaper alternative to classical computing
Effect on AI	QC provides capacity where classical compute would otherwise grow too much (energy demand, etc)	New possibilities for AI without cannibalization of existing use cases	Significant reduction in demand for AI data centers	Significant reduction of data center demand

QC will also benefit from improved compute power through better chip design, etc

Source: Expert interviews; press search; McKinsey analysis

Contents



QT creates value across three distinct economic pools, all expected to grow significantly by 2035.

X Deep dive to follow

Archetypes of economic impact through QT		Expected value by 2035
 1 Industry players	**Quantum economy:** Affected industries Value created through technological advancements defining a post-quantum era	**$1.3T–$2.7T** Value at stake from QC, excluding QS and QComm industry impact
 2 Investors	**Quantum investors:** Beneficiaries of valuation growth Value captured through increased valuation of QT companies and QT-exposed assets	**$1.2T–$2T** Valuation of QT companies[1]
 3 QT companies	**Quantum technologies:** Product and service providers Value generated from selling QT products and services	**$60B–$100B** Market size for QT

1. Assuming valuation multiple of ~20x.

Source: Expert interviews; press search; McKinsey analysis

Total investments in quantum technology start-ups increased by ~6.3x year over year in 2025, reaching $12.6B.

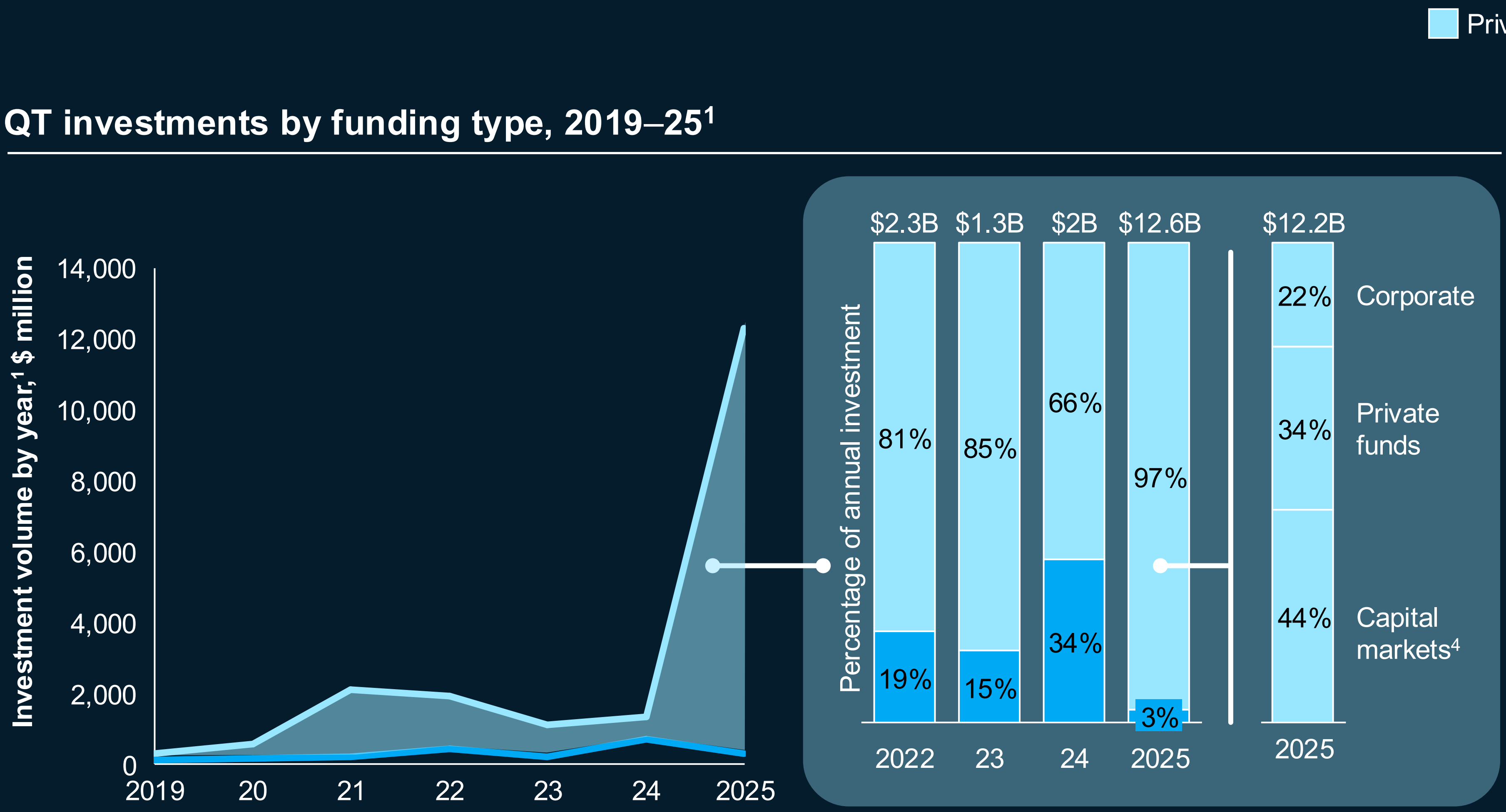
Investment volume by year,[1] $ million

1. Based on investment data recorded in PitchBook, including investments via private markets (eg, VC funding and corporate investments), public markets (eg, IPOs, SPACs, secondary public offerings and PIPEs), and government/university funding; actual investment is likely higher (excludes investments with missing details on investment types); data availability on start-up investment in China is limited.

Source: PitchBook

Private investment in QT start-ups is increasing significantly, particularly driven by capital markets.

QT investments by funding type, 2019–25[1]



Key insights

- Private investments rose by >9x between 2024 and 2025, mainly driven by capital markets (44% of private investments) and private funds (34% of private investments)
- Government and institutional funding declined slightly to ~$350M, roughly half of 2024, while only representing 3% of total investments in 2025 due to strong private growth

1. Based on investment data recorded in PitchBook; actual investment likely higher (excluding investments with missing details on investment types); data availability on start-up investment in China is limited.
2. Includes investments on private markets—ie, financing rounds through VC funds, hedge funds, angel investors, and accelerators; investments from corporations as well as capital markets, eg, IPOs, SPACs, secondary offerings, and PIPEs.
3. Includes investments from governments, sovereign wealth funds, and universities.
4. Includes IPOs, SPACs, PIPEs, and secondary public offerings.

Source: PitchBook

The top ten deals in 2025 were valued at about $7.6B combined, representing about 60 percent of total deal value in 2025.

Top 10 investments in QT start-ups in 2025, by deal size (descending)

Company	HQ location	Segment	Deal size, $ million	Deal type
1 IonQ	US	Hardware manufacturing	1,535	Public investment 2nd offering
2 Oxford Ionics	UK	Hardware manufacturing	1,075	Reverse merger
3 Quantinuum	US	Hardware manufacturing	839[1]	Early-stage VC
4 IonQ	US	Hardware manufacturing	786	Public investment 2nd offering
5 PsiQuantum	US	Hardware manufacturing	750	Later-stage VC
6 Quantum Computing Inc.	US	Hardware manufacturing	750	PIPE
7 Xanadu	Canada	Hardware manufacturing	500	Reverse merger
8 Quantum Computing Inc.	US	Hardware manufacturing	500	PIPE
9 SandboxAQ	US	Application software	450	Later-stage VC
10 D-Wave Quantum	US	Hardware manufacturing	400	Public investment 2nd offering

Total deal value includes IonQ shares (Oxford Ionics, 1,075)

Total ~7,600

~60% of total investments in 2025

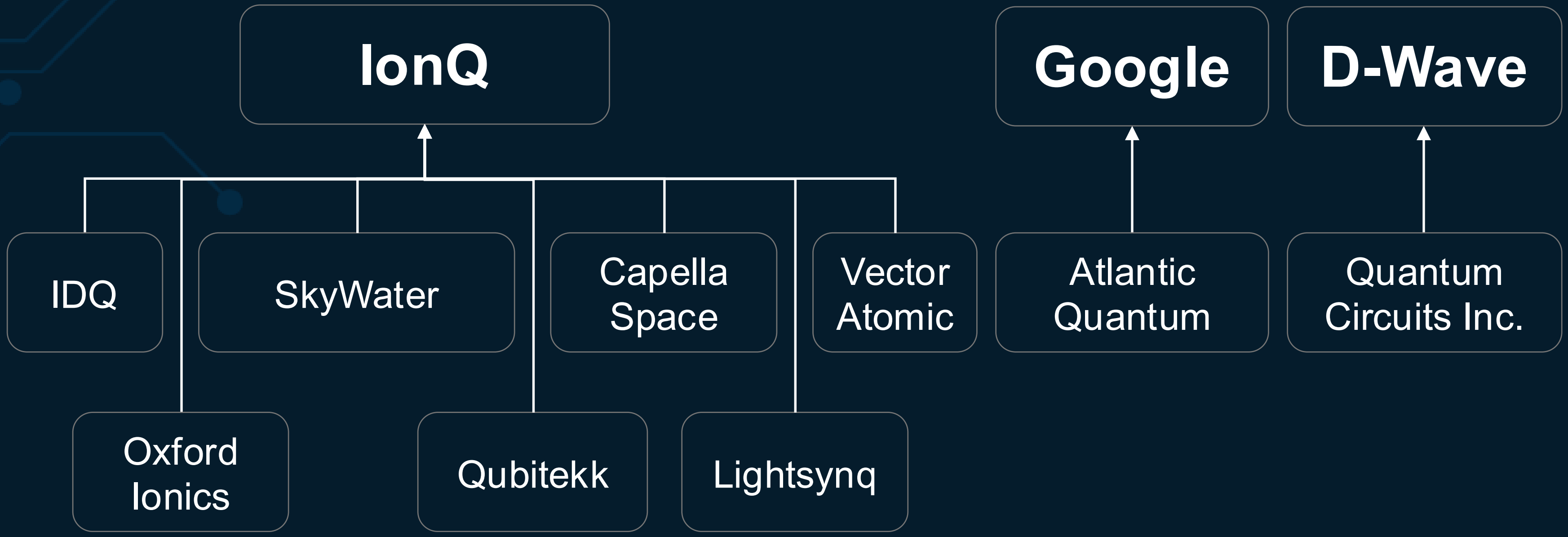
1. https://www.crunchbase.com/organization/honeywell-quantum-solutions#company_funding

Source: Crunchbase; PitchBook; press search

Increased investments are showcased through consolidation of QT companies; multiple major players are not yet activated.

Nonexhaustive

Example of recent consolidation in the QT ecosystem[1]



Key insights

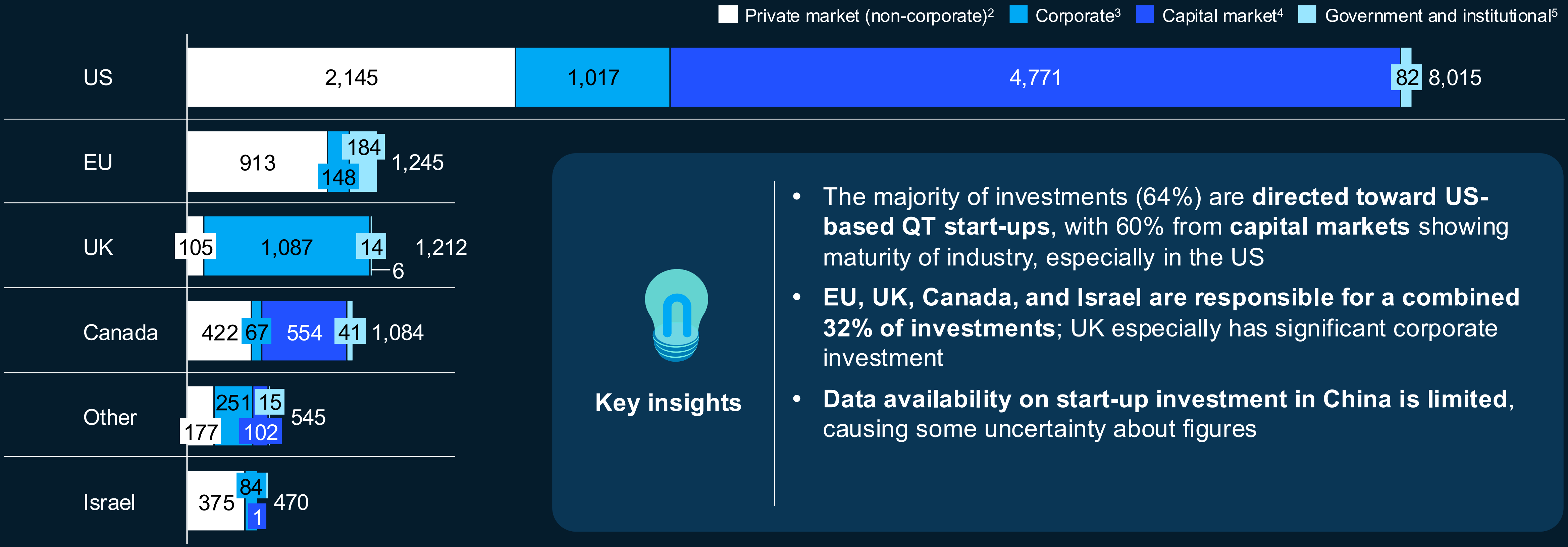
- Recent years have seen a general trend toward consolidation of smaller QT companies, with IonQ being a clear M&A front-runner
- M&A activity is not just access to new hardware—it's also talent, IP, software, know-how, and more
- Multiple significant players, such as NVIDIA, have not yet shown M&A activity, indicating a continued desire to see which technologies mature

1. Includes some 2026 M&A activity.

Source: Expert interviews; press search; McKinsey analysis

In 2025, most QT start-up investment went to US-based companies, with capital markets providing the largest share of funding.

Total investment in QT by start-up location and primary investor type, 2025, $ million[1]



Key insights

- The majority of investments (64%) are **directed toward US-based QT start-ups**, with 60% from **capital markets** showing maturity of industry, especially in the US
- **EU, UK, Canada, and Israel are responsible for a combined 32% of investments**; UK especially has significant corporate investment
- **Data availability on start-up investment in China is limited**, causing some uncertainty about figures

1. Based on public investment data recorded in PitchBook; actual investment is likely higher (excludes investments with missing details on investment types); data availability on start-up investment in China is limited.
2. Investments from VC funds, hedge funds, angel investors, and accelerators.
3. Includes investments from corporations and corporate VC in external start-ups; excludes corporate investments in internal QT programs.
4. Includes IPOs, SPACs, PIPEs, and secondary public offerings.
5. Includes investments by governments, sovereign wealth funds, and universities.

Source: PitchBook

Average round sizes increased significantly from 2024 to 2025, especially for QT companies going public.

Average investment size per funding stage, $ million

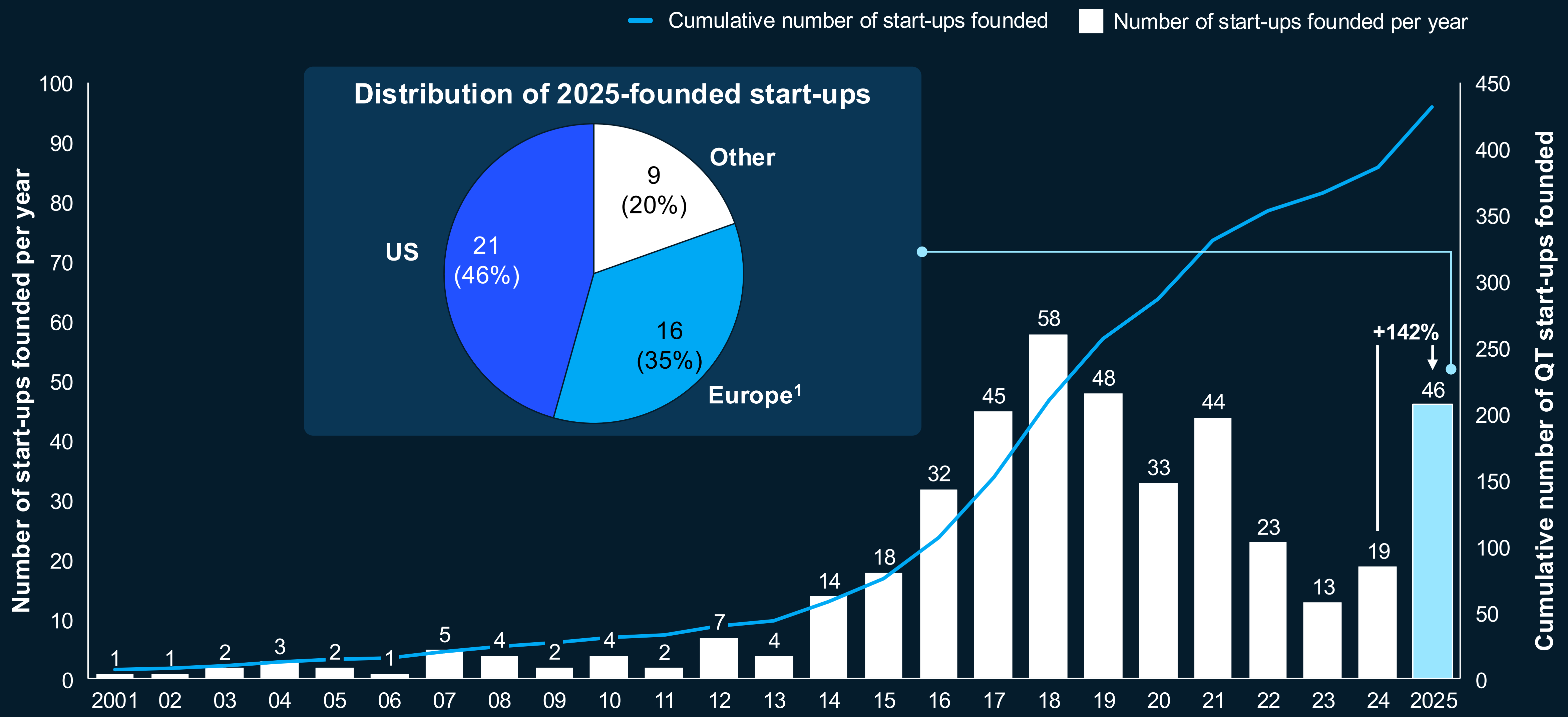
Year	Private: Early-stage VC	Private: Late-stage VC	Capital markets: Reverse mergers/ SPACs	Capital markets: PIPE
2024	88	59	190	N/A
2025	123	195	788	138
Increase	40%	233%	314%	N/A

Key insights

- **Higher average funding round sizes**, especially on capital markets, signal higher maturity of QT companies and **stronger appetite of investors**
- Most significant increase occurred in **reverse mergers/SPACs,** where average round size increased from $190M to $788M
- **Late-stage VC** round sizes also increased significantly, while **early-stage VC** grew more moderately

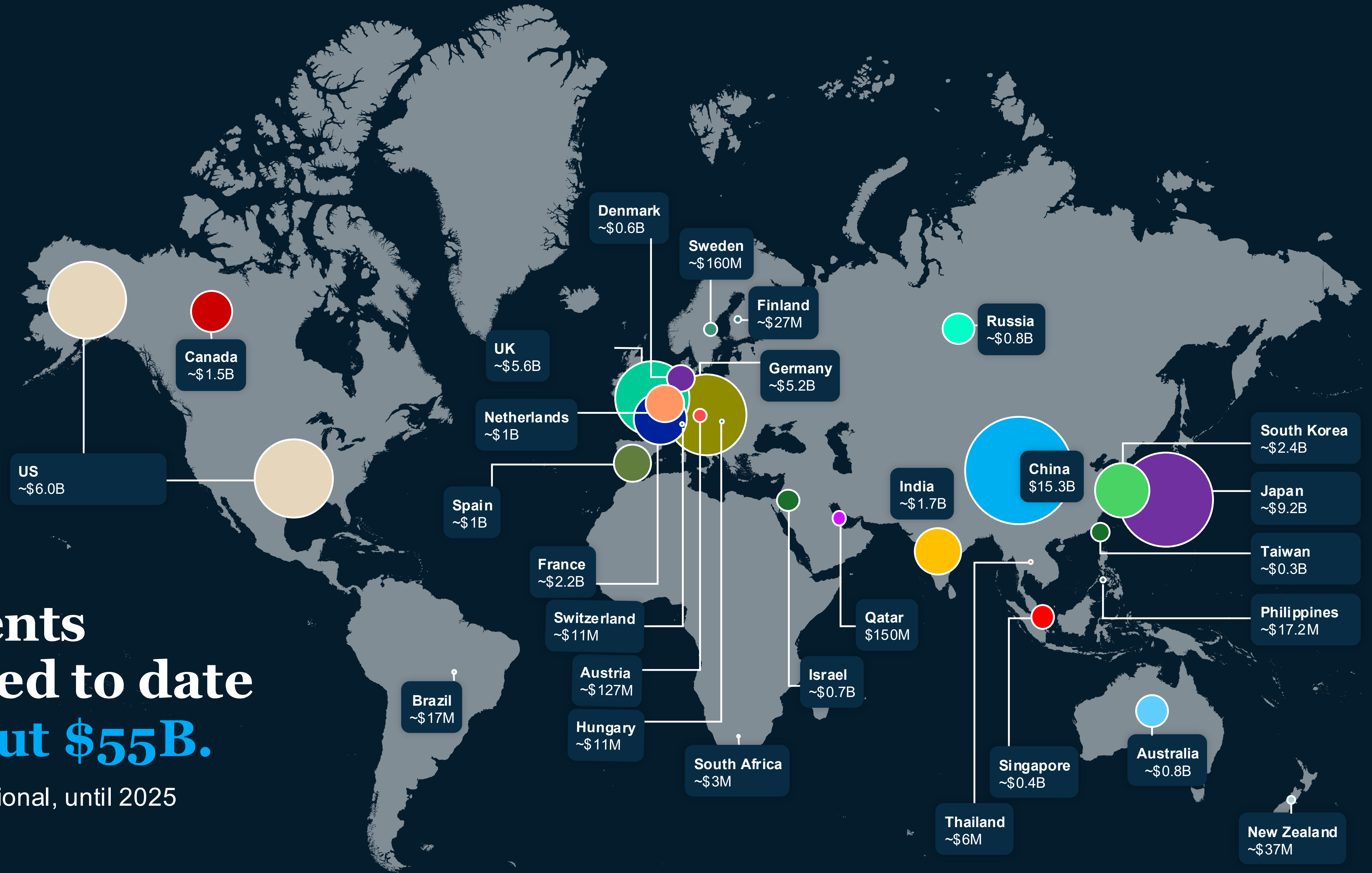
Source: PitchBook

QT start-up formation accelerated in 2025 amid rising investment volumes.



Note: Figures do not sum to 100%, because of rounding.
1. Includes UK and Switzerland.

Source: Crunchbase; PitchBook



National investments announced to date total about $55B.

Estimated and directional, until 2025

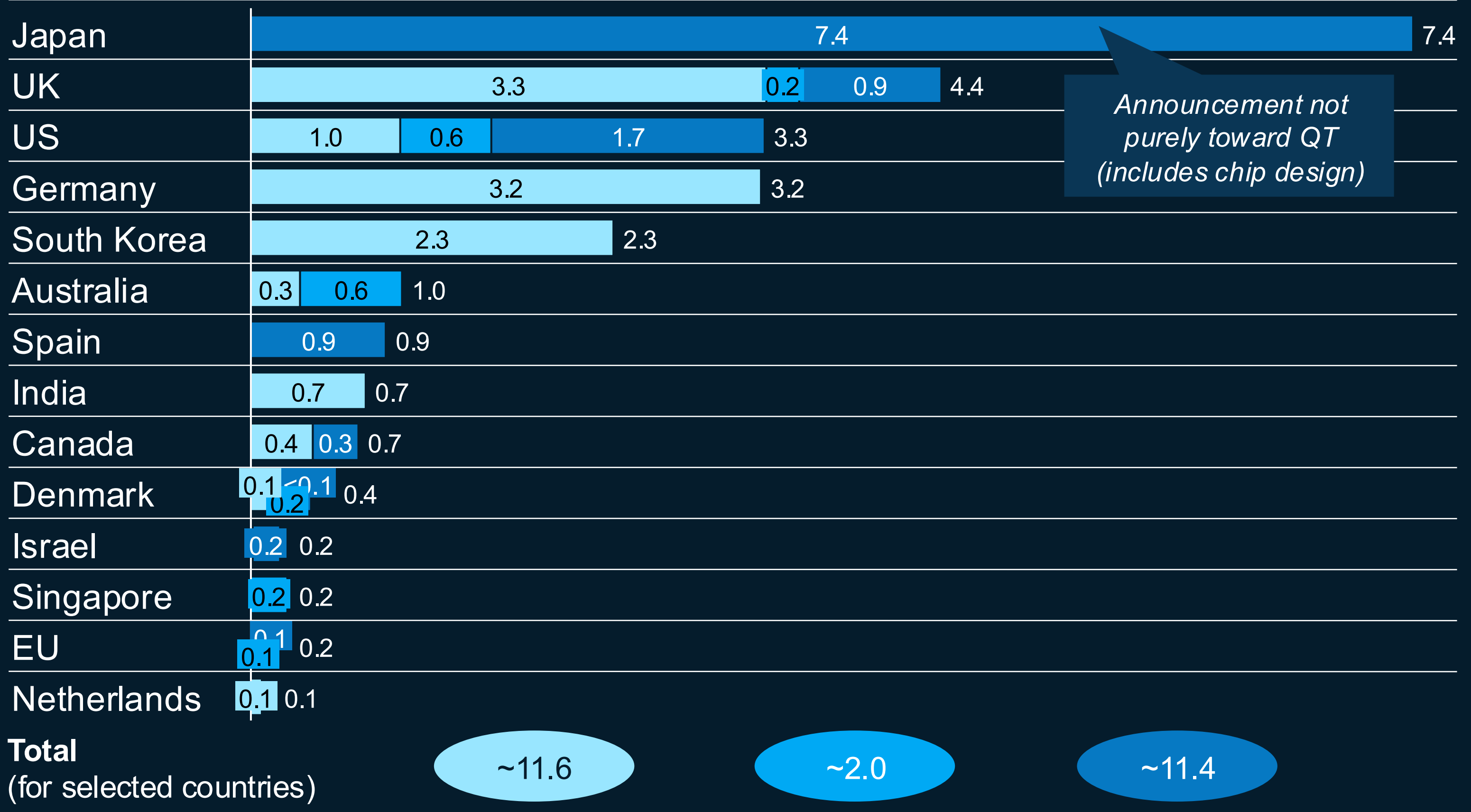
Note: Limited transparency on commercial activity in China; excludes the $136B announced investment toward emerging technologies due to unclear relevance for QT. Excludes $680M Swedish investment toward research and innovation, and US–Swedish investment of $40M toward next-generation networks, AI, quantum technology, and educational science within STEM areas. Excludes Saudi Arabia's $6.4B investment in 2022 toward future tech, as no breakdown for quantum technology is present; excludes Qatar's (QIA) and Bpifrance's investment in Alice & Bob in 2025 due to missing breakdown of investment. Japan's investment is not exclusively toward quantum technology (includes next-generation chip design as well). The boundaries and names shown on the map do not imply official endorsement or acceptance by McKinsey & Company.

Source: Press search

In 2025, QT announcements reached $11.4B, with Japan, the United States, the United Kingdom, and Spain announcing significant investments.

Announced in 2023 | Announced in 2024 | Announced in 2025

Announced government investment, 2023–25, $ billion



Key insights

- Japan announced significant $7.4B investment in 2025 (covering both QT and chip design), illustrating an increased Asian interest in QT
- UK, Germany, and South Korea led investment through 2023–24; in 2025, Japan, US, UK, and Spain led with the biggest announcements
- Despite significant government investment, only a small part goes to private start-ups; the vast majority of governmental investments are directed toward academia

Note: Limited transparency on commercial activity in China; excludes the $136B announced investment toward emerging technologies due to unclear relevance for QT; the ~$15B investment is not shown here, as it was announced before 2023. Excludes $680M Swedish investment toward research and innovation, and US–Swedish investment of $40M toward next-generation networks, AI, quantum technology, and educational science within STEM areas. Excludes Saudi Arabia's $6.4B investment in 2022 toward future tech, as no breakdown for quantum technology is present; excludes Qatar's (QIA) and Bpifrance's investment in Alice & Bob in 2025 due to missing breakdown of investment. Japan's investment is not exclusively toward quantum technology (includes next-generation chip design as well).

Source: Press search

Public announcements are surging in 2025, with about $10B led by major initiatives in Japan, the United States, and Spain.

Largest national and regional funding announcements in 2025

X 2025 announced investment volume

Nonexhaustive

Japan — $7.4B

Japan announced $7.4B for next-generation chip and QC research as part of the pledge for semiconductor and AI development toward 2030, with the quantum portion focused on industrializing QC via hybrid QC–HPC infrastructure and strengthening the broader ecosystem for quantum software and applications

US — $1.7B

The US is accelerating QT investments, led by the Department of Energy's Office of Science making $625M available for the next phase of National Quantum Information Science Research Centers, alongside Maryland's Capital of Quantum initiative designed to catalyze $1B in public–private investment

Spain — $0.9B

Spain announced its National Quantum Technology Strategy, committing $860M through 2030 to advance quantum science—particularly QC, QComm, and QS/metrology—and to attract an additional ~$780M in private investment alongside the public funding

UK — $0.9B

The UK ramped up QT investment in 2025, led by major government funding (including $672M quantum computing commitment over 4 years and a $160M program via Innovate UK and the NQCC) and complemented by targeted commercialization and international collaboration initiatives (eg, UK–CA and UK–GER joint projects)

Canada — $0.3B

Canada has increased quantum funding in 2025, nearly matching the previous two years combined, driven by $52M investment toward QT and a $239M defense-focused push to scale domestic quantum firms and adoption

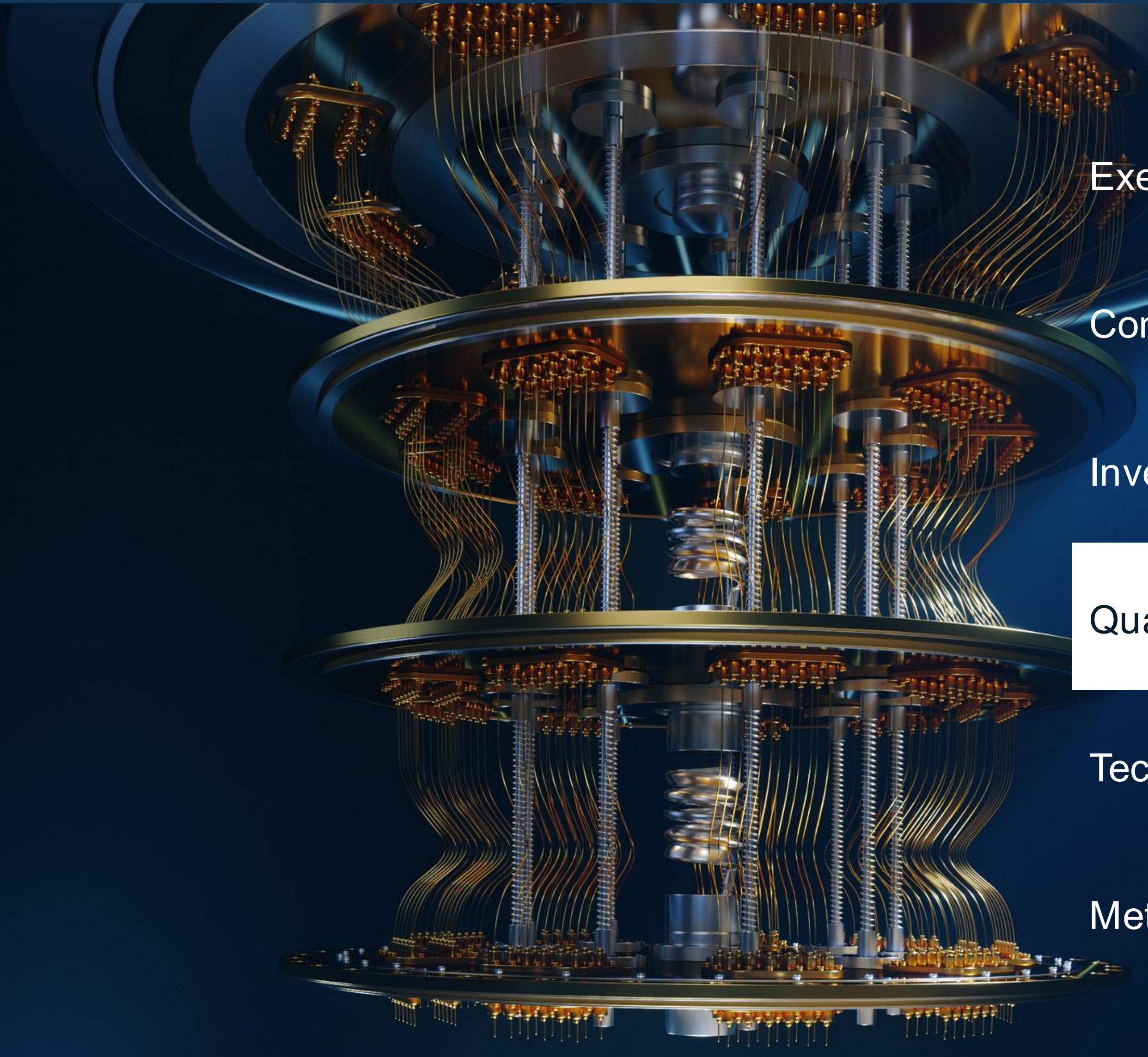
Israel — $0.2B

Israel has announced new public quantum investments in 2025 after no publicly announced funding in 2023 and 2024, led by US–Israel joint quantum/AI fund totaling $200M[1] and a YOZMA deep-tech program at $70M

Note: Limited transparency on commercial activity in China.
1. Each nation will contribute $20M annually, starting in 2026 and through 2030 (counting here as $100M per nation).

Source: Expert interviews; press search; McKinsey analysis

Contents



QT creates value across three distinct economic pools, all expected to grow significantly by 2035.

X Deep dive to follow

Archetypes of economic impact through QT		Expected value by 2035
 1 Industry players	**Quantum economy:** Affected industries Value created through technological advancements defining a post-quantum era	**$1.3T–$2.7T** Value at stake from QC, excluding QS and QComm industry impact
 2 Investors	**Quantum investors:** Beneficiaries of valuation growth Value captured through increased valuation of QT companies and QT-exposed assets	**$1.2T–$2T** Valuation of QT companies[1]
 3 QT companies	**Quantum technologies:** Product and service providers Value generated from selling QT products and services	**$60B–$100B** Market size for QT

1. Assuming valuation multiple of ~20x.

Source: Expert interviews; press search; McKinsey analysis

The total internal market size for QT could reach an estimated ~$100B by 2035 and ~$200B by 2040.

Deep dive to follow | Conservative growth[1] | Optimistic growth

QT market-size scenarios, 2035 and 2040

	Quantum computing (Conservative)	Quantum computing (Optimistic)	Quantum communication (Conservative)	Quantum communication (Optimistic)	Quantum sensing[2] (Conservative)	Quantum sensing[2] (Optimistic)
2035	$43B	$71B	$11B	$15B	$7B	$10B
2040	$77B	$148B	$24B	$36B	$18B	$31B

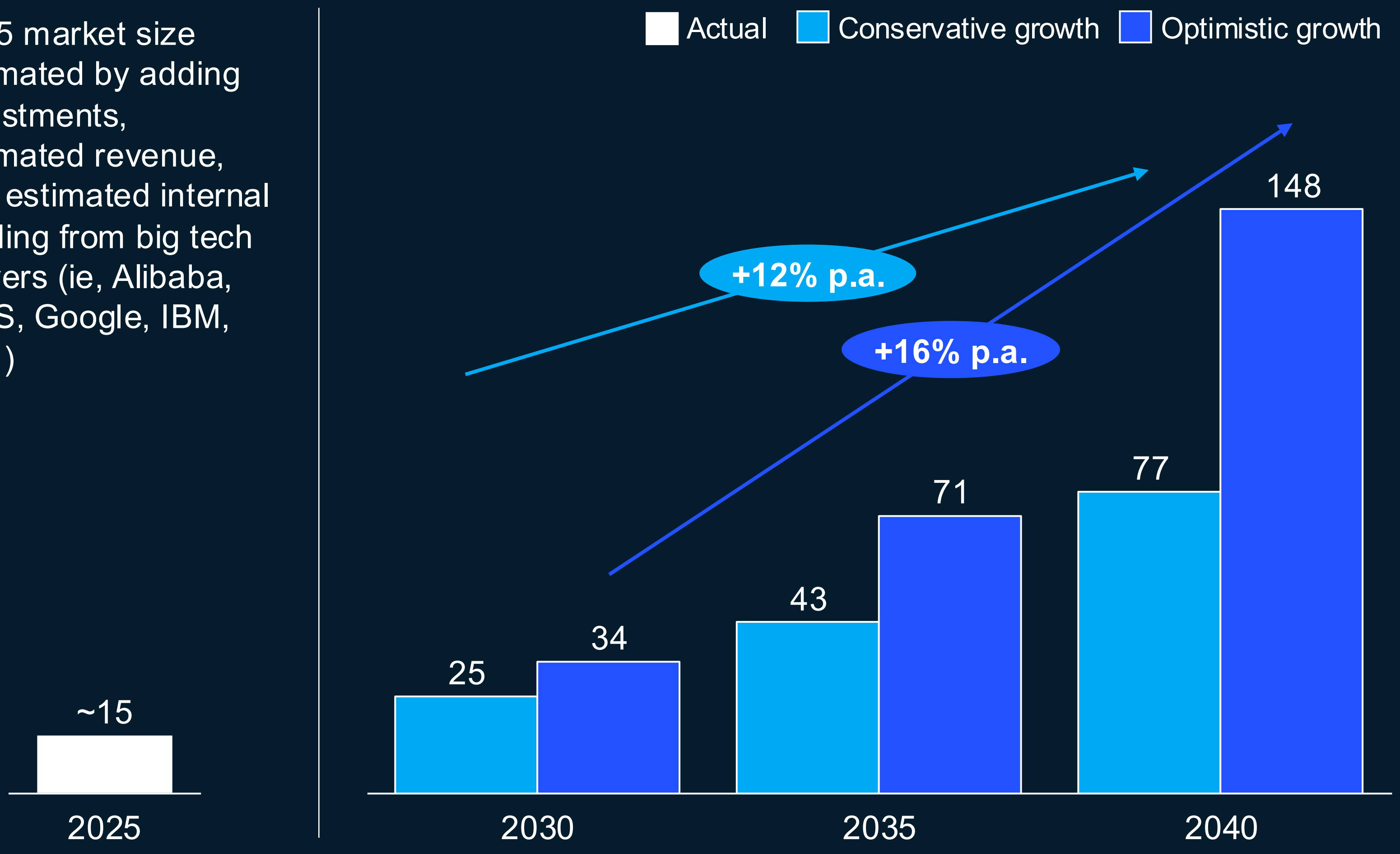
1. Based on existing development road maps and assumed adoption curves per technology.
2. Approach for quantum sensing updated through clusters of use cases based on recent development, announcements, and breakthroughs.

Source: Expert interviews; press search; McKinsey analysis

QC: The QC market is expected to reach $43B to $71B by 2035 and $77B to $148B by 2040.

Expected market size (revenue and funding) in each scenario, $ billion

2025 market size estimated by adding investments, estimated revenue, and estimated internal funding from big tech players (ie, Alibaba, AWS, Google, IBM, Intel)



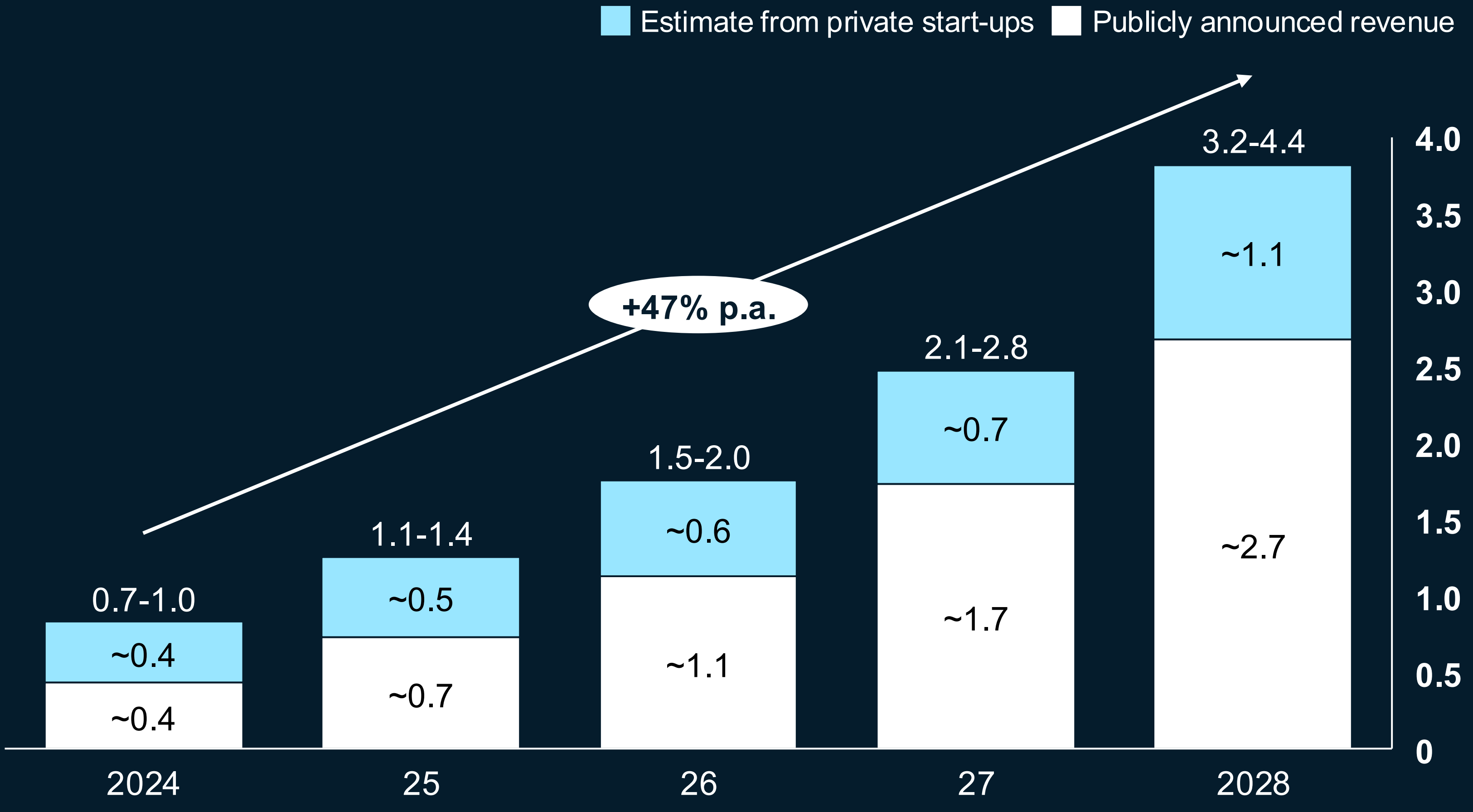
Key insights

- **Expected overall market size of $77B–$148B** in 2040, depending on assumed growth scenario
- **Growth rates are expected at 12–16% per year** in the next decade
- **Q-Day is expected to happen after 2028,** which could generate additional uptake in market growth besides displayed estimates
- **Latest successes and product launches of QT companies** increase confidence of rapid growth

Source: Expert interviews; press search; McKinsey analysis

QC: Revenue of QC companies is expected to rapidly increase in coming years, driven by increased commercialization of use cases.

Revenue estimates of QC companies, 2024–28, $ billion



Key insights

- Rising commercialization through use cases increases deployment of hardware (including cloud access), driving significant growth in revenue
- Latest generation hardware expected to be close to full capacity, while less-advanced machines have leftover capacity and can be accessed through cloud
- Revenue expected to increasingly originate from publicly traded companies, reflecting QC developing from a niche to a billion-dollar industry
- Further revenue increase is projected to start ~2028 based on latest Q-Day expectations for 2028–30 by many QC companies

Note: Estimations increased relative to *Quantum Technology Monitor 2025*. Methodology: Estimated based on the publicly announced revenues of QC start-ups.

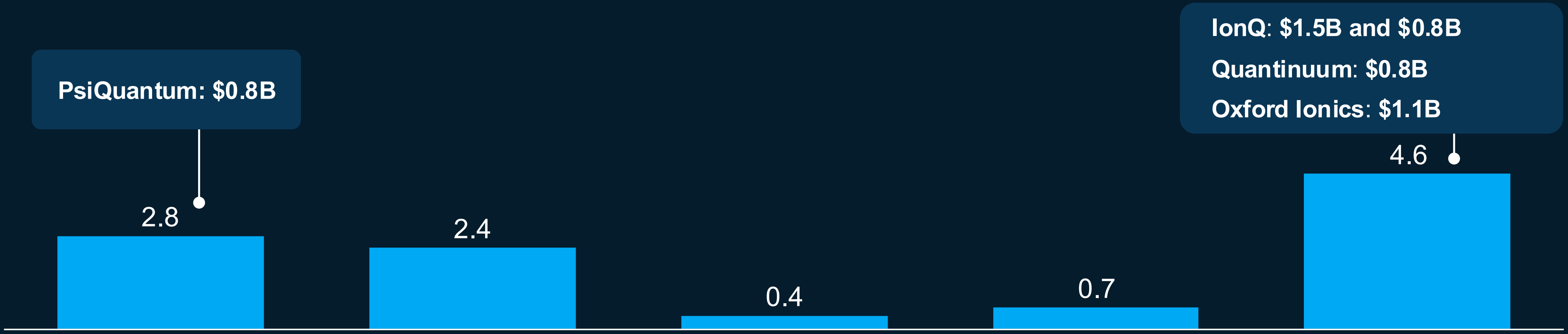
Source: Expert interviews; press search; McKinsey analysis

QC: Photonic networks and trapped ions have seen significant funding in recent years.

Key 2025 investments

Nonexhaustive

Technology	Photonic networks	Superconducting (SC) circuits	Spin qubits	Neutral atoms	Trapped ions
Qubit description	Occupation of a photonic waveguide	Difference in energy states of Cooper pairs between two sides of a Josephson tunnel junction	Electron spins of different materials; eg, an electron trapped within a silicon quantum dot or a color center in an insulator, controlled by laser light or microwave radiation	Internal energy levels of neutral atoms trapped by laser fields	Internal energy levels of ions trapped by electromagnetic fields
Funding, 2023–25,[1] $ billion	2.8	2.4	0.4	0.7	4.6



1. Assumptions: $100M funding per major player per year for SC circuits (Alibaba, AWS, Google, IBM) and $50M per major player per year for spin qubits (Intel).

Source: Capital IQ; Crunchbase; expert interviews, PitchBook; *Quantum Computing Report*; McKinsey analysis

QS: Key players are mostly specialized, with some broadening capabilities across product families.

Nonexhaustive

Overview of QS product families and leading companies

Quantum magnetometers	Quantum electrometers	Quantum inertial and gravimetric sensors	Quantum thermometers/ barometers	Atomic clocks	Quantum imaging and spectroscopy systems
Magnetic field	Electric field	Rotation Gravity	Temperature Pressure	Time	Light
EuQlid	Q-CTRL	Muquans	Infleqtion	TOPTICA	EuQlid
Qnami	M Squared	AOSense	M Squared	M Squared	Photek
Quantum Diamonds	Infleqtion	Infleqtion	Rydberg Technologies	QuantX	Quantum Diamonds
SBQuantum		Exail		Vector Atomic	TeraView
Rydberg Technologies					Qnami
QZabre					IRsweep
					QDTI
					DIASENSE

Key insights

- Most QS companies concentrate on single product family as technologies remain distinct and complex
- A smaller number operate across multiple product families (eg, M Squared, Qnami), reflecting broader engineering integration capabilities
- Significance of QS for global energy companies (eg, BP exploring QS use cases) for precise and noninvasive field exploration; other relevant industries include advanced industries such as aerospace and defense

Note: Product families are directional only; multiple categories have overlap (eg, magnetometers and spectroscopy).

Source: Expert interviews; press search; McKinsey analysis

QS: Quantum sensing shows both short- and long-term use cases across industries.

Nonexhaustive

Futuristic applications

Industries: Life sciences; Energy and materials; Communication and logistics; Microelectronics; Others

QS technologies: Solid state spins; SC circuits; Neutral atoms; Photonics

Existing commercialization

- Wide-field magnetic spectroscopy
- Scanning nanoscale quantum sensors (for research use)
- Navigation enabled by satellite-based atomic clocks
- Monitoring volcano activity
- Underground analysis of pipes/structures/power lines
- Brain injury imaging through magneto-encephalography (MEG)
- Failure analysis and inspection of semiconductors (eg, chips, boards)
- QS-based navigation (when no GPS available)

Near-term commercialization

- In-line metrology and process control of semiconductors (eg, chips, boards)
- Defect inspection and design improvement of batteries
- Monitor corrosion for pipeline integrity and other industrial power systems
- Cardiac diagnostics with biomagnetics
- Temperature measurements in cells and small organisms
- Bioimaging with enhanced MRI, PET
- Better disease understanding through spectroscopy or magnetic signatures at biomarker level (eg, neurological, inflammatory)

Medium-term commercialization

- Targeted photodynamic therapy for cancer treatment
- Long-wavelength communication with atom acting as antenna
- Signal receivers and amplifiers for radar communication
- Monitor temperature in transformers and power plants
- Monitoring stability/integrity of infrastructure (eg, detection of cavities)
- Geophysical surveying through gravity/ electromagnetic imaging for oil, gas, and mineral detection
- Better disease understanding through spectroscopy at single cell level
- Metabolic measurements in living cells

Long-term commercialization

- Efficiency boost for energy conversion in solar cells
- Identifying objects through radio-frequency (RF) camera (eg, position of a drone)
- Calibration and inspection of electrical standards beyond 5G
- Magnetometer for fusion reactors
- Determination of protein structure and dynamics under near-physiological conditions
- Personalized medicine (checking response to drugs with single-cell sensors, measuring drug degradation)
- Understanding molecular structures with spectroscopy at single-protein level
- On-chip monitoring of security and malfunction of chips
- Microscopy for verification of high-value artifacts
- Mind–machine interface

Development timeline

Source: Expert interviews; *Quantum sensing use cases*, Quantum Economic Development Consortium (QED-C), Sept 22, 2022

QS: Core technologies show sensing capabilities across a broad range of physical properties.

Established capabilities | Early research on sensing capabilities | Market sizing per product family to follow

Indicative

Physical platform		Product families (physical property measured)							
		Quantum magnetometers	Quantum electrometers	Quantum inertial and gravimetric sensors		Quantum thermometers/ barometers		Atomic clocks	Quantum imaging and spectroscopy systems
		Magnetic field	Electric field	Rotation	Gravity	Temperature	Pressure	Time	Light
Solid state spins	Nitrogen-vacancy (NV) centers in diamonds	Established	Established	Established		Established	Established		
	SiC-based[1] sensors	Established	Established			Established			
Neutral atoms	Optically pumped magnetometers	Established							
	Cold atomic clouds	Established		Established	Established	Early research			
	Atomic interferometers	Established		Established	Established	Early research			
	Optical/microwave clocks				Established			Established	
	Rydberg atoms		Established			Early research			Established
SC circuits	SQUIDs[2]	Established				Early research			
	Single qubits	Established	Established			Early research			Early research
Photonic systems	Optical crystals, optical fibers, or integrated photonic chips	Early research		Established		Early research	Early research		Established

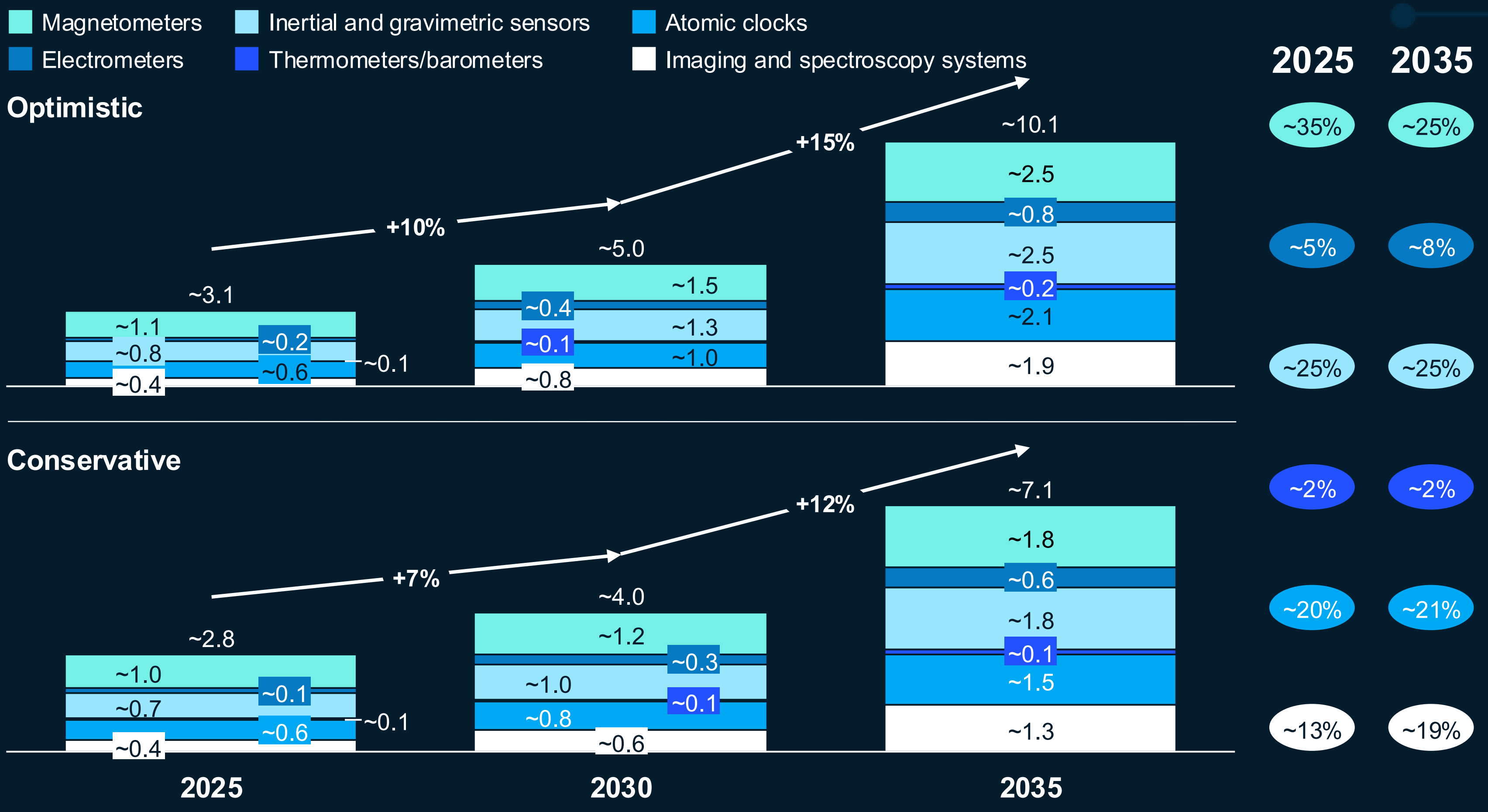
Note: Product families are directional only; multiple categories overlap (eg, magnetometers and spectroscopy).
1. Silicon carbide–based.
2. Superconducting quantum interference devices.

Source: Expert interviews; press search; McKinsey analysis

QS: The quantum sensing market is expected to grow through 2035; magnetometers lead the expansion.

Market share

QS market size, $ billion



Select growth rationales[1]

- Brain imaging, mineral exploration, and predictive maintenance drive segment
- 6G and RF communications create new demand; commercial deployment early stage
- GPS-denied navigation and subsea exploration fuel defense-led adoption
- Niche industrial monitoring and cryogenic calibration applications
- Telecom, GPS, and financial network timing anchor demand
- Semiconductor inspection and medical diagnostics expand commercial use

Note: Product families are directional only; multiple categories overlap (eg, magnetometers and spectroscopy).
1. Nonexhaustive.

Source: Expert interviews; press search; McKinsey analysis

QS: The QS value chain is driven by hardware players providing end-to-end solutions.

Nonexhaustive

Components	Hardware	Application	Services
Lasers: Light sources that cool, trap, manipulate, and read out quantum states in sensors	**Quantum magnetometers:** Sensors that measure magnetic fields with high sensitivity	*Majority of QS applications and services are directly handled by the corresponding hardware players*	
Photon detectors: Detectors that capture optical signals, encoding quantum measurement results	**Quantum electrometers:** Sensors that detect electric fields at high precision via quantum effects		
QS materials: Materials that serve as the active sensing element (eg, diamonds, magnets, etc)	**Quantum inertial and gravimetric sensors:** Sensors that measure acceleration, rotation, and gravity		
Advanced optics: Optical components that route laser light to and from quantum sensors	**Quantum thermometers/barometers:** Sensors that measure temperature or pressure at high precision		
Magnetic shielding: Enclosures that block external magnetic noise from sensitive measurements	**Atomic clocks:** Devices that lock to intrinsic atomic transition frequencies for ultraprecise timekeeping		
Vacuum chambers and cryostats: Environments maintaining vacuum or cryogenic temperatures for stable quantum operations	**Quantum imaging and spectroscopy systems:** Systems that image materials or analyze spectra with quantum-enhanced sensitivity		

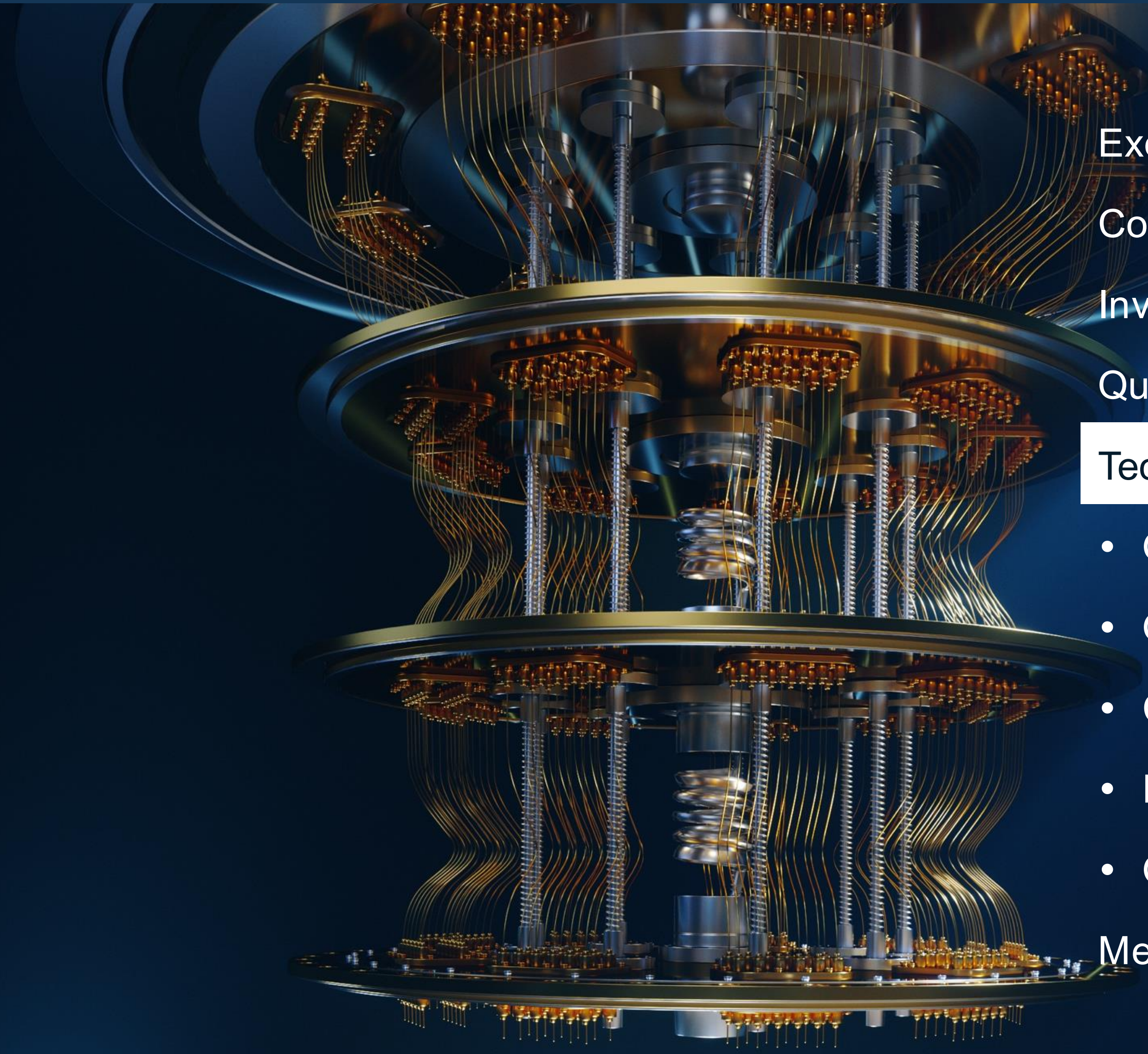
Key insights

- QS hardware often relies on well-studied characteristics of spectroscopy to measure electromagnetic fields, acceleration, rotation, time, etc, steering component requirements
- QS applications and services are driven end to end by hardware players, providing stand-alone solutions
- QS software not considered as separate part of value chain but rather integrated with hardware

Note: Slide with key logos can be shared on request.

Source: Company websites; expert interviews; press search; roundtable discussions

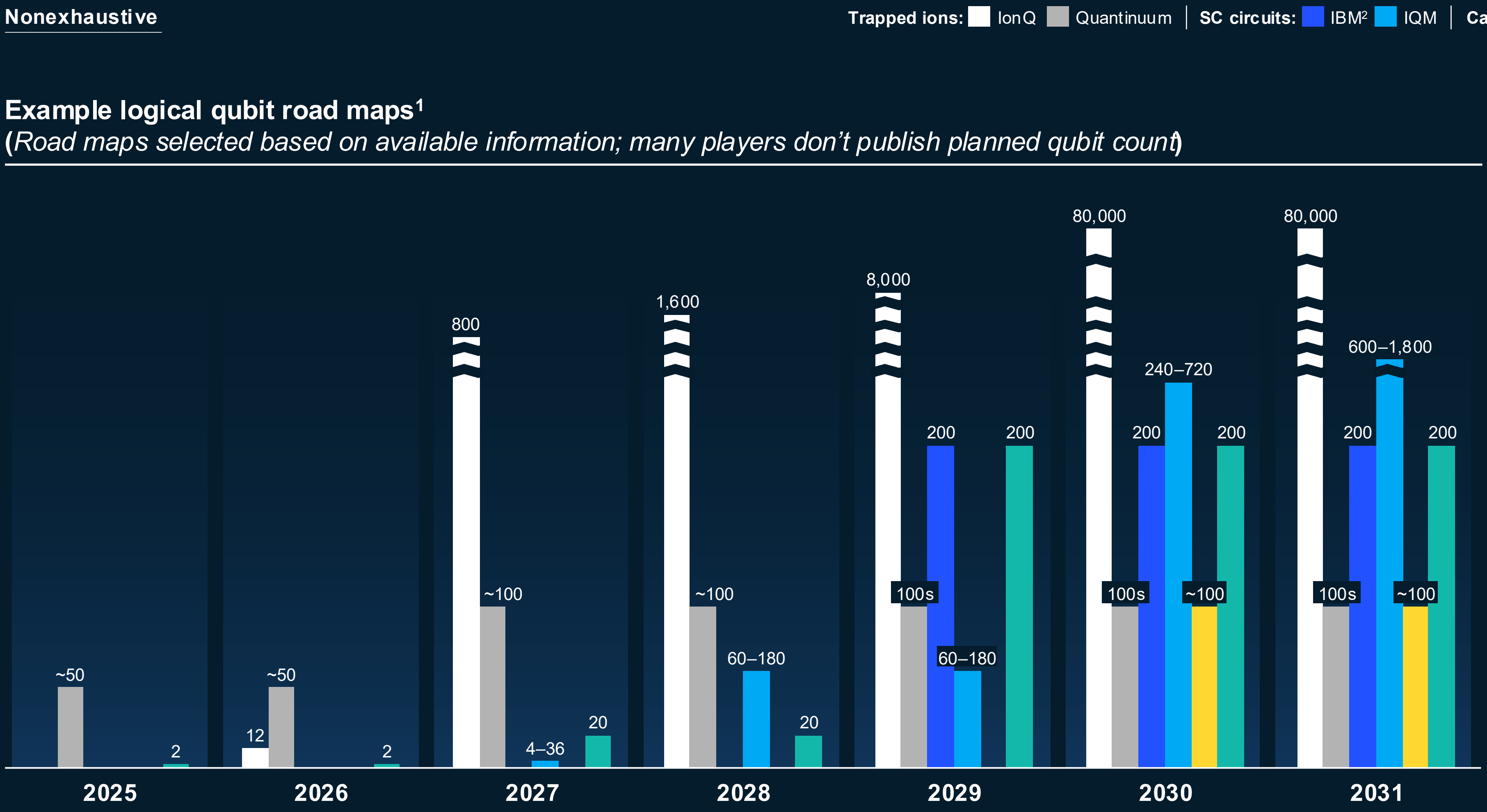
Contents



Qubit road maps predict hundreds of logical qubits; qubit count alone does not fully describe computational capabilities.

Nonexhaustive

Example logical qubit road maps[1]
(*Road maps selected based on available information; many players don't publish planned qubit count*)



Key insights

- Companies are increasingly sharing logical-qubit road maps; goals aren't directly comparable across modalities and aren't a reliable indicator of actual delivery
- Most players target ~100–200 logical qubits by ~2030 but face distinct scaling bottlenecks (eg, error rates, connectivity, cooling, lasers, integrated photonics)
- Progress depends on parallel system scaling, not qubit count alone (hardware, control, error correction, and infrastructure must advance together)
- Leadership by number of qubits does not imply a clear winner: some modalities (eg, neutral atoms) trade speed for scalability, making near-term comparisons incomplete

1. Qubit counts and road maps are selected based on available public announcements and available information as of Jan 2026, assuming that qubit count is kept constant if no further information is provided for years not mentioned in the road maps.
2. IBM reports integration of fault-tolerant systems in Starling (2029) and BlueJay (2033+) machines.
3. Reporting ~100 logical qubits by 2030.

Source: Company websites; expert interviews; press search; McKinsey analysis

QC players push hardware innovation to fuel commercial use cases.

Selected announcements for research and maturity breakthroughs of QC

Key messages

QC

Showcasing speedup in computational power and fidelity, pushing the boundaries of feasibility and pushing faster toward commercialization and real-world applications

Company	Content of announcement	What it means	Announcement[1]
Google	**Deploying the "Quantum Echoes" algorithm** on Willow chip to run molecular simulation tasks faster than classical supercomputers	Marks a practical demonstration of **verifiable quantum advantage** and the move from theoretical benchmarks to real-world computational utility	"Our Quantum Echoes algorithm is a big step toward real-world application for quantum computing" (2025)
AWS	**Prototyping the "Ocelot"** quantum computing chip architecture using a scalable microwave-integrated circuit process with built-in error correction, improving qubit efficiency and hardware stability	Highlights AWS's **entry into quantum hardware**, expanding AWS from cloud access to full-stack quantum infrastructure	"AWS announces Ocelot, a new quantum computing chip" (2025)
Microsoft	**Introducing the Majorana 1** topological qubit processor using topological qubits built on a superconducting nanowire platform designed to enhance qubit stability and reduce error propagation	Represents progress toward more **stable and scalable QC architecture**, with potential long-term implications for fault tolerance	"Microsoft unveils Majorana 1, the world's first quantum processor powered by topological qubits" (2025)
IonQ	**Combining IonQ's scalable trapped-ion architecture**, control software, and cloud integration after acquisition of Oxford Ionics with its **record-setting ion-trap fidelity** and CMOS-compatible chip technology	**Shows prospect to unite** high-fidelity qubit technology with scalable, manufacturable hardware within **a single integrated stack**	"IonQ Completes Acquisition of Oxford Ionics, Rapidly Accelerating Its Quantum Computing Roadmap" (2025)
Quantinuum	**Launching Helios as the most accurate commercial general-purpose QC** with industry-leading 99.921% 2-qubit gate fidelity for 98 physical qubits	**Delivers a new performance benchmark** for commercial quantum systems, accelerating enterprise-grade QC adoption toward real-world application	"Introducing Helios: The Most Accurate Quantum Computer in the World" (2025)

1. Based on publicly available data on company websites.

Source: Company websites; expert interviews; press search; McKinsey analysis

QComm and QS breakthroughs move beyond the lab to real-world applications.

Selected announcements for research and maturity breakthroughs of QComm and QS

Key messages

QComm

Moving from **isolated experiments to national-scale deployable systems,** showcasing applicability across environments (fiber, satellites, etc)

QS

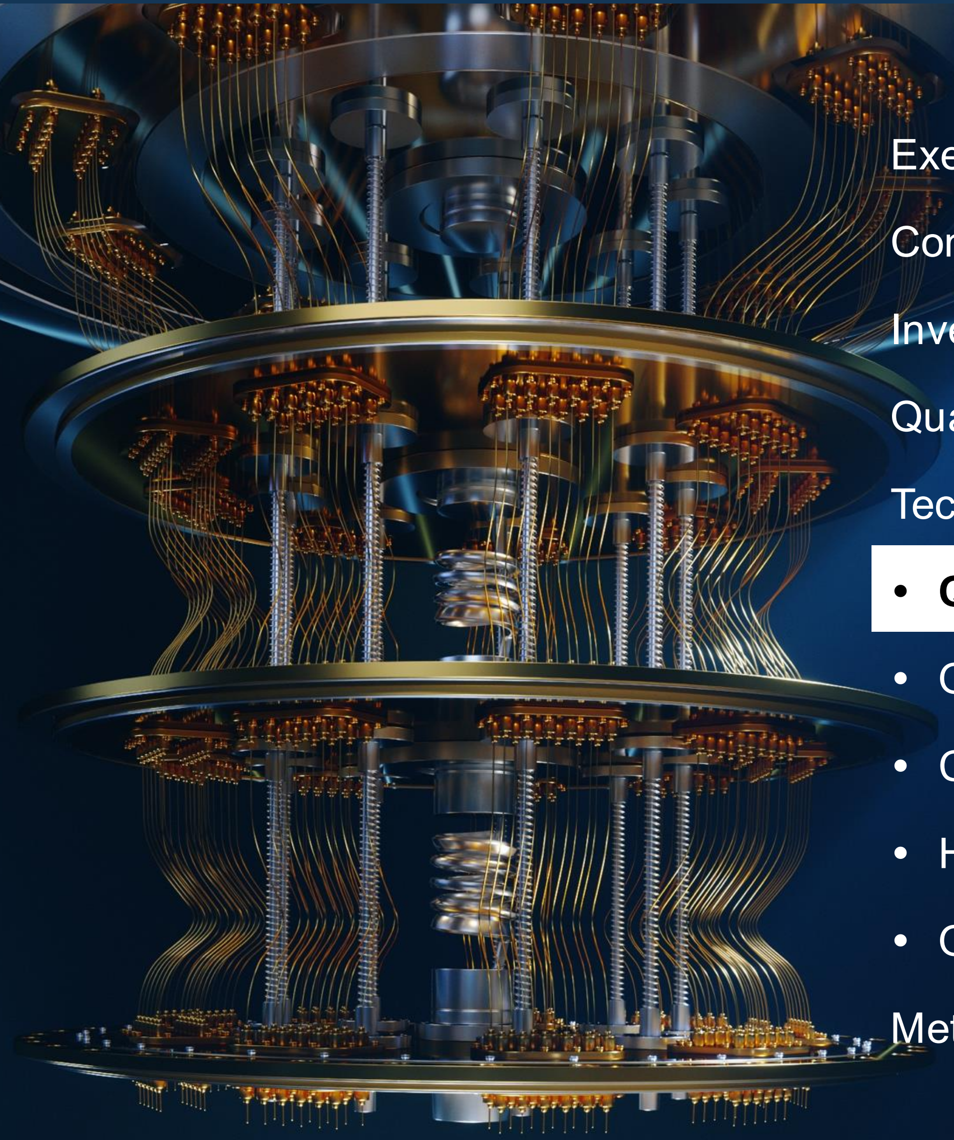
Transitioning **from prototypes to real-world applications;** eg, within defense and navigation

Company	Content of announcement	What it means	Announcement[1]
SpeQtral and Thales Alenia Space	**Established satellite–ground QKD** link for secure global communication (transmitting entangled photons between SpeQtral satellite and Thales ground station)	Advances QComm toward **global, quantum-internet-scale connectivity** through space-to-ground integration	"SpeQtral and Thales Alenia Space Launch Joint Satellite Quantum Communications Program" (2025)
Toshiba	**Demonstrated coherent QComm** national-scale telecom infrastructure	Demonstrates scalable integration of **quantum-secure communication into existing telecom networks**, accelerating readiness for commercial deployment	"Toshiba Demonstrates Coherent Quantum Communication Across National Telecom Infrastructure" (2025)
ID Quantique	Demonstrating **terrestrial intercontinental** QKD over existing telecom fiber	Shows **QComm industrialization** by moving QKD from lab environments to controlled long-distance applications	"World's First Terrestrial Intercontinental QKD Achieved in Istanbul" (2025)
Q-CTRL	**Demonstrated next-generation quantum navigation sensors** for defense platforms to provide navigation and positioning capabilities in environments without satellite signals	Moves QS **from lab prototypes to deployable systems** on airborne, maritime, and ground platforms	"DARPA selects Q-CTRL to develop next-generation quantum sensors for navigation on advanced defense platforms" (2025)
Inflegtion	**Demonstrated a quantum optical atomic clock** in collaboration with the UK Royal Navy on an autonomous underwater submarine to maintain high-precision timing and navigation without satellite connectivity	Shows growing **maturity of QS moving into field-level implementation**; eg, operational vehicles and extreme maritime environments	"Infleqtion and Royal Navy demonstrate world's first quantum optical clock on underwater autonomous submarine" (2025)

1. Based on publicly available data on company websites.

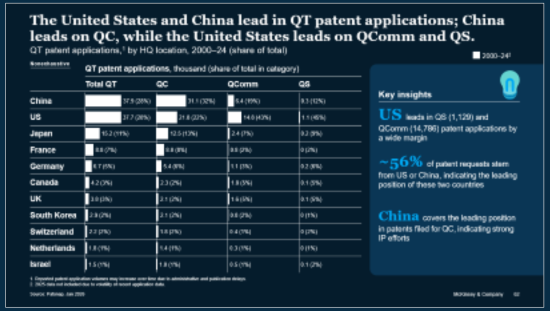
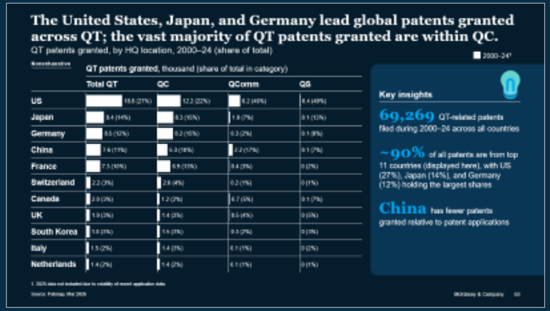
Source: Company websites; expert interviews; press search; McKinsey analysis

Contents



The United States and China generally lead on academic activity and patents, with significant activity in Germany, Japan, and South Korea.

Indicative

	Patent applications[1]	Patents granted[2]	Publications
Key insights	US and China lead in total QT patent applications; China leads on QC patent applications, while US leads on QComm and QS patent applications	US, Japan, and Germany lead global patents granted across QT; vast majority of QT patents granted are within QC	China has the institutions with the most publication shares in 2024, but the majority of corporate publications stem from the US
Analyses			

1. The first step in patenting, the application is a formal request to a patent office, incl detailed documentation of the invention's design, function, and originality.
2. Approved outcome of a patent application, giving the inventor exclusive legal rights; only granted patents are legally recognized and enforceable.

Source: Expert interviews; Nature Index; Patsnap; press search; McKinsey analysis

The United States and China lead in QT patent applications; China leads on QC, while the United States leads on QComm and QS.

QT patent applications,[1] by HQ location, 2000–24 (share of total)

2000–24[2]

Nonexhaustive

QT patent applications, thousand (share of total in category)

	Total QT	QC	QComm	QS
China	37.9 (28%)	31.1 (32%)	6.4 (19%)	0.3 (12%)
US	37.7 (28%)	21.8 (22%)	14.8 (43%)	1.1 (45%)
Japan	15.2 (11%)	12.5 (13%)	2.4 (7%)	0.2 (9%)
France	8.8 (7%)	8.0 (8%)	0.8 (2%)	0 (2%)
Germany	6.7 (5%)	5.4 (6%)	1.1 (3%)	0.2 (6%)
Canada	4.2 (3%)	2.3 (2%)	1.8 (5%)	0.1 (5%)
UK	3.8 (3%)	2.1 (2%)	1.6 (5%)	0.1 (5%)
South Korea	2.9 (2%)	2.1 (2%)	0.8 (2%)	0 (1%)
Switzerland	2.2 (2%)	1.8 (2%)	0.4 (1%)	0 (2%)
Netherlands	1.8 (1%)	1.4 (1%)	0.3 (1%)	0 (1%)
Israel	1.5 (1%)	1.0 (1%)	0.5 (1%)	0.1 (2%)

Key insights

US leads in QS (1,129) and QComm (14,786) patent applications by a wide margin

~56% of patent requests stem from US or China, indicating the leading position of these two countries

China covers the leading position in patents filed for QC, indicating strong IP efforts

1. Reported patent application volumes may increase over time due to administrative and publication delays.
2. 2025 data not included due to volatility of recent application data.

Source: Patsnap, Jan 2026

The United States, Japan, and Germany lead global patents granted across QT; the vast majority of QT patents granted are within QC.

QT patents granted, by HQ location, 2000–24 (share of total)

2000–24[1]

Nonexhaustive

QT patents granted, thousand (share of total in category)

	Total QT	QC	QComm	QS
US	18.8 (27%)	12.2 (22%)	6.2 (46%)	0.4 (40%)
Japan	9.4 (14%)	8.3 (15%)	1.0 (7%)	0.1 (13%)
Germany	8.5 (12%)	8.2 (15%)	0.3 (2%)	0.1 (8%)
China	7.6 (11%)	5.3 (10%)	2.2 (17%)	0.1 (7%)
France	7.3 (10%)	6.9 (13%)	0.4 (3%)	0 (2%)
Switzerland	2.2 (3%)	2.0 (4%)	0.2 (1%)	0 (1%)
Canada	2.0 (3%)	1.2 (2%)	0.7 (5%)	0.1 (7%)
UK	1.9 (3%)	1.4 (3%)	0.5 (4%)	0 (5%)
South Korea	1.8 (3%)	1.5 (3%)	0.3 (2%)	0 (3%)
Italy	1.5 (2%)	1.4 (3%)	0.1 (1%)	0 (2%)
Netherlands	1.4 (2%)	1.4 (2%)	0.1 (1%)	0 (1%)

Key insights

69,269 QT-related patents filed during 2000–24 across all countries

~90% of all patents are from top 11 countries (displayed here), with US (27%), Japan (14%), and Germany (12%) holding the largest shares

China has fewer patents granted relative to patent applications

1. 2025 data not included due to volatility of recent application data.

Source: Patsnap, Mar 2026

QT clusters in 2025 grew through academic institutions and public–private funding; the majority of emerging clusters are in Asia.

Existing clusters; example organizations | Emerging clusters; example organizations

Nonexhaustive

Capital investments
Fund research, scale-up, and commercialization

Accessibility and integration
Allow standardized platforms and easy quantum–classical integration

Physical infrastructure and hardware
Provide advanced labs and quantum facilities

Industry or government partnerships
Support QT players through collaboration

Academic institutions and research organizations, incl talent
Develop critical know-how, nurture and motivate talent, incubate start-ups

QT clusters consist of **QT start-ups, incumbent companies, and public or government organizations**; the trend is moving toward consolidation into quantum hubs across different regions

Examples of QT innovation clusters

Boston	*Harvard University*	*MIT*	*QuEra Computing*	*AWS*	*NVIDIA*
Chicago	*University of Chicago*	*University of Illinois*	*EeroQ*	*IBM*	
Delft	*TUDelft*	*QBlox*	*Intel*		
Oxford	*University of Oxford*	*Oxford Quantum Circuits*	*Element Six*		
Tel Aviv	*Tel Aviv University*	*Classiq*			
Hefei	*University of Science and Technology of China*	*CIQTEK*	*Tencent*		
Seoul	*Sungkyunkwan University*	*Yonsei University*	*Seoul National University*	*Norma*	
Singapore	*National University of Singapore*	*Nanyang Technological University (incl Nanyang Quantum Hub)*	*Center for Quantum Technologies*	*SpeQtral*	

Source: Company websites; expert interviews; press search; McKinsey analysis

China has the institutions with the most publication shares in 2024 and also the institutions with the biggest increase in publication shares.

Scientific publications by institutions

Publications from institutions within physical sciences, based on publication shares[1]

Publication shares, 2024

		Publication shares
China	CAS	1,126
China	USTC	438
China	Tsinghua University	409
Germany	Max Planck Society	350
China	UCAS	338
China	ZJU	336
China	NJU	334
China	PKU	334
China	SJTU	311
France	CNRS	263

Increase in publication shares, 2021–24

		Increase
China	CAS	498
China	USTC	212
China	Tsinghua University	197
China	ZJU	171
China	SJTU	163
China	NJU	162
China	UCAS	158
China	PKU	150
China	JLU	142
China	XJTU	132

Increase in publication shares, 2021–24, non-Chinese

		Increase
South Korea	SNU	37
Singapore	NUS	34
South Korea	KAIST	34
US	University of Chicago	33
South Korea	SKKU	27
US	Johns Hopkins University	27
Saudi Arabia	KAUST	24
US	University of Washington	23
US	Yale University	23
Canada	McGill University	23

Key insights

- Chinese institutions had the most publication shares in 2024 and the biggest growth in 2021–24
- Non-Chinese institutions in South Korea, Singapore, US, Saudi Arabia, and Canada are growing significantly, indicating the emergence of new clusters
- Number of publications is not equivalent to technological progress, but is insightful as proxy for scientific progress

1. Share of publication is a fractional measure that splits credit among coauthoring institutions (eg, for a publication authored by 5 authors, 4 of whom are affiliated with the same university, that university has a share of 0.8, while the other has a 0.2 share).

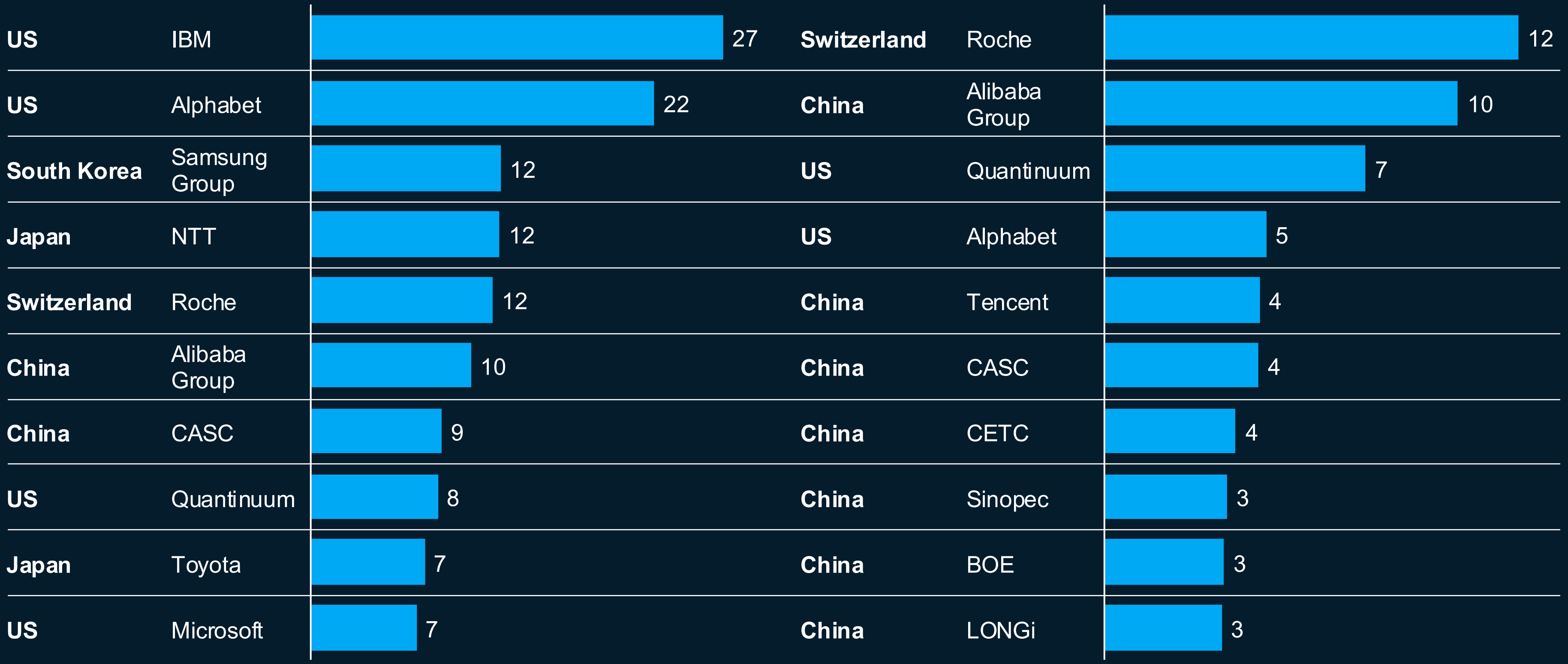
Source: Nature Index (used to approximate number of QT-related publications)

The majority of corporate publications stem from the United States, but China saw a significant increase in publications from 2021 to 2024.

Scientific publications by corporations

Publications from institutions within physical sciences, based on publication shares[1]

Publication shares, 2024 | **Increase in publication shares**, 2021–24



Key insights

- IBM leads all corporate institutions in publication shares for 2024
- Roche, Alibaba, and Quantinuum show the biggest increases in publication shares from 2021 to 2024
- Strong contributions also come from tech leaders such as Alphabet, Samsung, and Microsoft
- Chinese companies including Tencent, CASC, and LONGi are also expanding their research output, reflecting increased Chinese academic activity

1. Share of publication is a fractional measure that splits credit among coauthoring institutions (eg, for a publication authored by 5 authors, 4 of whom are affiliated with the same university, that university has a share of 0.8, while the other has a 0.2 share).

Source: Nature Index (used to approximate number of QT-related publications)

Access to IP is expected to increasingly become a strategic pillar as commercialization of QT grows.

Nonexhaustive

Forms of intellectual property

- **Patents:** Legal ownership; visible but often nonoperational
- **Know-how:** Tacit knowledge and experience
- **Software and control stacks:** Firmware, compilers, orchestration layers

Illustrative examples of IP as a strategic pillar

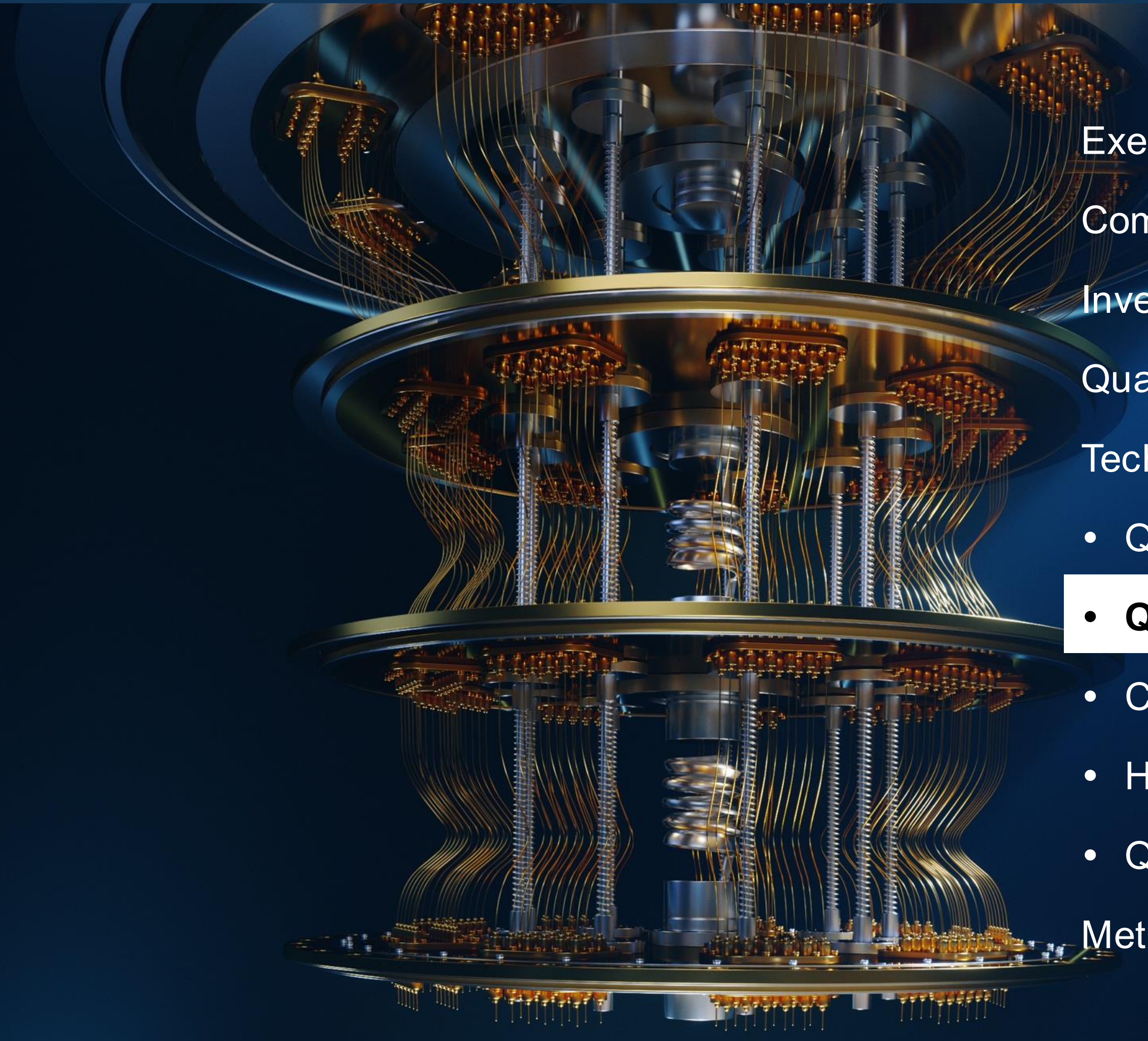
Atlantic Quantum acquired by Google, providing access to essential IP (especially on modular chip stack integrating qubits and control electronics) that would otherwise be legally inaccessible	**Google** **Atlantic Quantum**
IonQ acquiring SkyWater, securing access to US-based specialty semiconductor manufacturing (incl know-how and IP), strengthening potential hardware integration	**IonQ** **SkyWater**
Zapata's proposed sale of IP when facing bankruptcy, specifically algorithms for uploading software to quantum computers	**Zapata Quantum**

Key insights

- **IP is increasingly a strategic pillar** that can be used both offensively (to advance development and keep competitors from access) and defensively (to ring-fence development from competitors)
- **Geopolitics can potentially become a key factor** for IP in case a key player is excluded from certain geographies (eg, Bluefors, a key manufacturer of cryogenics, being able to only operate in certain geographies)
- **Commercialization of QT drives importance of ensuring IP**—to avoid bottlenecking development

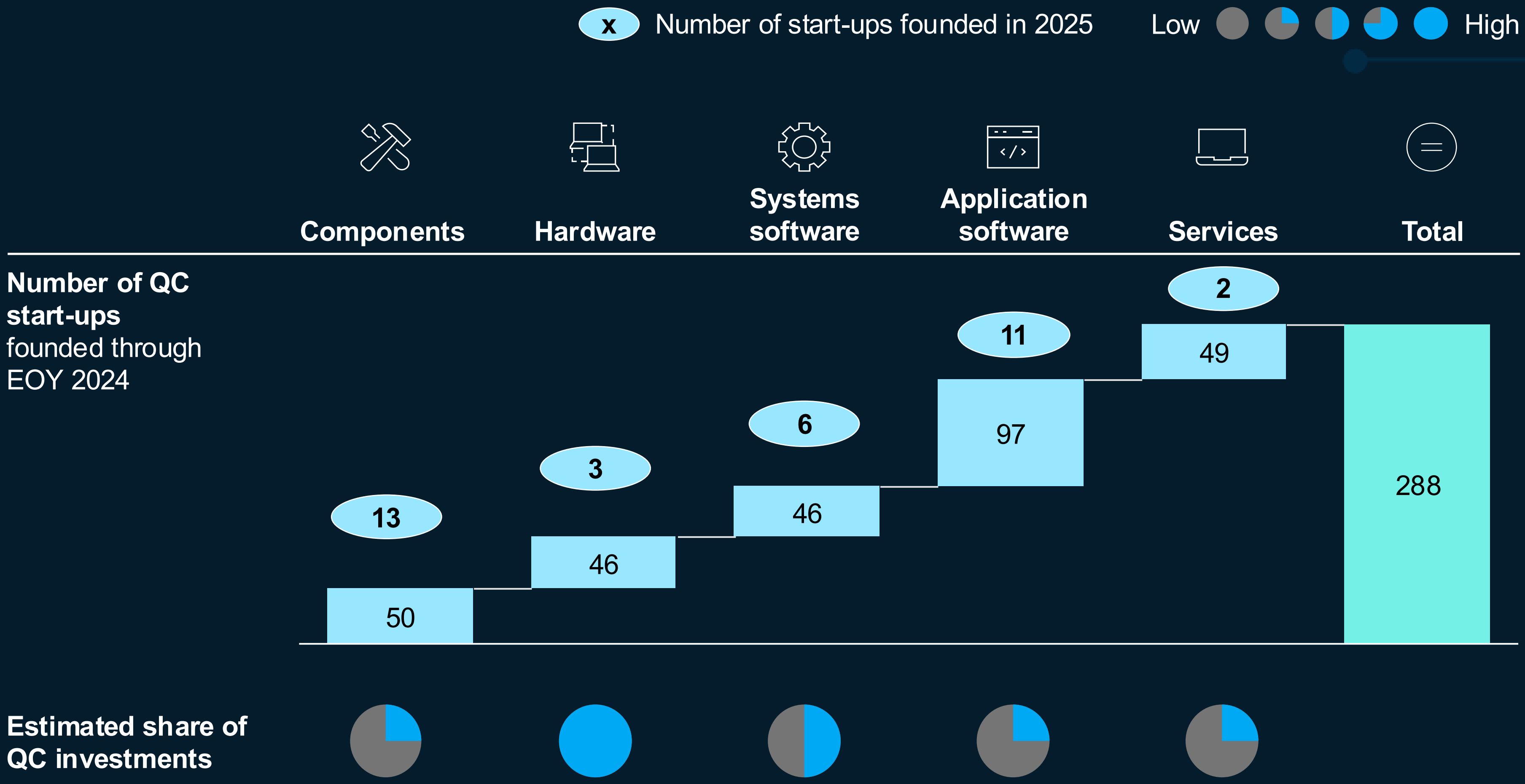
Source: Expert interviews; press search; McKinsey analysis

Contents



Most new QC start-ups are emerging in components and application software.

Number of QC start-ups, by value chain segment



Key insights

- Components and application software segments are especially attractive for new start-ups (accounting for 24 of 35 new QC start-ups)
- Components segment attracts investment attention due to lower-risk opportunities, caused by the hardware player–agnostic nature of the segment
- Relatively few new players emerge within hardware, but the segment receives the most investments, showcasing the general consolidation of start-ups within the segment

Source: Capital IQ; Crunchbase; expert interviews; PitchBook; *Quantum Computing Report*

The QC market is estimated at about $15B, led by hardware and operating systems.

Share of total market size, 2025 | Deep dive to follow

Value chain	Components	Hardware and operating system: Hardware system	Hardware and operating system: Op system software	Cloud provisioning	Application software	Services: Technical services	Services: Consulting services
Rationale	Specialized equipment required to develop scalable high-fidelity systems; expected to be somewhat commoditized in the future, but required for all QC setups across modalities	Currently biggest share but expected to be somewhat commoditized toward 2040 as ability to differentiate will be closer to applications		Future computational backbone as move from on-premise to cloud is expected toward 2040	Highly differentiating given requirements for algorithms to solve real-world problems; expected to be bridge between hardware and industry	Technical services often priced with other solutions (due to solution uniqueness); consulting services expected to have significant educational role	

Market size

1. Full-stack hardware players (eg, IBM, IonQ, and Quantinuum) have sales across value chain; only HW sales are counted here.
2. Services are considered an approach to sell other parts of value chain and are thus often pursued by full-stack providers.
3. Market size is estimated by adding investments, estimated revenue, and estimated internal funding from big tech players (ie, Alibaba, AWS, Google, IBM, Intel).

Source: Expert interviews; press search; McKinsey analysis

Among selected areas of the supply chain, specialized lasers and optical systems are most at risk of limiting development.

Nonexhaustive

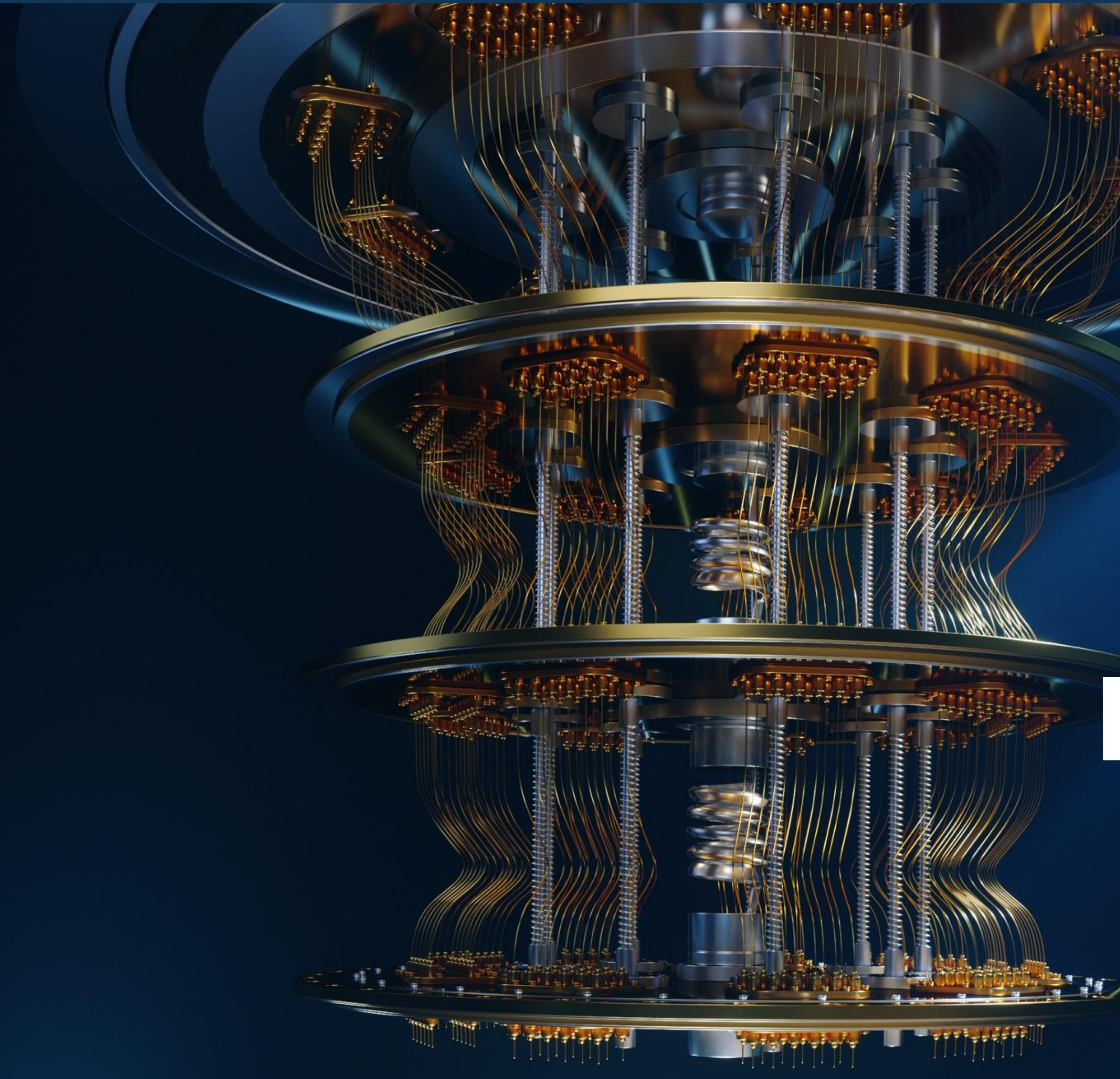
Specialized lasers and optical systems create the largest risk of bottlenecking QC development

Selected areas of supply chain	Microwave or radio frequency control	Specialized lasers and optical systems	Cryogenics and vacuum chambers
Role for QC	Control and measure microwave or radio frequency–based qubit setups (eg, SC and spin; trapped ions can be either optical or microwave-based)	Control and measure optical qubit setups (can have relevance for all modalities but SC); reliable high-precision lasers required for high-fidelity qubit manipulation	Control qubit environments through ultracold cryostats or vacuum chambers (depending on modality); required to minimize noise in qubits
Challenges and potential bottlenecks	• Requirements for high-precision control equipment increase as QC systems scale (especially with high-fidelity requirements) • Relatively few specialized players (eg, Quantum Machines and Qblox) and some larger players are pursuing wider approaches across industries (eg, Keysight and Rohde & Schwarz through Zurich Instruments)	• Requirements for reliable high-power, low-noise lasers increase as QC systems scale (especially with high-fidelity requirements) • Limited number of specialized suppliers may cause challenges for rapidly upscaling production needs in case of rapid QC growth (eg, in case of early Q-Day) • Manufacturing is highly specialized, creating challenging barrier to entry for new start-ups	• Requirements for sizable and reliable cryogenics and vacuum chambers increase, especially as physical QC systems scale with number of qubits • High-performance cryogenic and vacuum technologies rely on relatively small pool of specialized suppliers, limiting scalability • Extended lead and deployment times further constrain supply chain responsiveness and project timelines

Rare earths | Act as a fundamental resource, enabling development of components and hardware (especially high-quality lasers)

Note: Allocation based on primary positioning from publicly available information; example players, such as Keysight, can operate across multiple segments.
Source: Expert interviews; press search; McKinsey analysis

Contents



Why companies are acting now—and why waiting is risky.

Why companies are acting now

External momentum

Acceleration in investment: Global quantum investment increased by 6.3x year over year, largely driven by advances in QC, compressing timelines toward Q-Day

Global activity: Europe is investing in QKD infrastructure, while the US is leading PQC adoption, driven by federal mandates[1] and standardization efforts,[2] while China is actively advancing QKD and creating its own Quantum-Resistant Encryption Standards

Regulatory momentum: Governments and public institutions are beginning to mandate or incentivize quantum-safe communication over the next 5 years (eg, US federal agencies must adopt PQC, EU reinforcing its cybersecurity with PQC, NATO or G7 CEG[3] guidance and initiative to transition to PQC/QKD)

Technology maturity

Breakthroughs: Fiber and satellite QKD breakthroughs signal accelerating industry deployment and commercialization of quantum-secure networking

Quantum-safe communication options across maturity horizons: PQC shows the highest maturity and deployment among quantum-safe options,[4] but QKD represents the only natively quantum-secure option in the long run

Innovation indicators: Increase in publication or patent granted, providing insights into maturity of emerging technologies

Commercial adoption

Early production deployment underway: PQC, QKD, and QComm services are already in (partial) production; eg, Apple introduced PQC protocols (PQ3) for enhanced security in iMessage

Enterprise-ready tooling emerging: Ease of deployment (incl integration with existing infrastructure), support services, and tools

What this means

Near-term security exposure

"Harvest now, decrypt later" attacks: Vulnerability extends to years preceding Q-Day on data lifetime; given accelerating advances in QC, relevant security impacts are expected within next 5 years

Q-Day as an inflection point

Q-Day can be an inflection point with RSA-2048[5]; classical public-key cryptography starts being susceptible to quantum attack as powerful quantum computers emerge and disrupt PQC algorithms or render them obsolete

Strategic risk of inaction

As with AI, early movers in quantum-safe cybersecurity are setting standards and architectures, making inaction a conscious—and risky—decision, increasing future transition cost, reducing optionality, and forcing reactive implementation

1. Department of Homeland Security's Cybersecurity and Infrastructure Security Agency (CISA) 2. NIST's efforts on post-quantum encryption standards 3. Cyber Expert Group. 4. QKD solutions, PQC, regional quantum networks, global quantum internet. 5. Craig Gidney and Martin Ekerå, "How to factor 2048-bit RSA integers in 8 hours using 20 million noisy qubits," *Quantum*, April 2021.

Source: Expert interviews; press search; McKinsey analysis

Current state of PQC and QKD: Increasing cyberthreats and data breaches are driving demand for ultrasecure communication.

Deep dive to follow

	Post-quantum cryptography (PQC)	Quantum key distribution (QKD)
Description	Classical algorithms (eg, hash-based, lattice-based, etc) designed to be secure against potential threats posed by QC	Leverages principles of quantum mechanics to generate encryption keys that are provably secure, alerting communicating parties to the presence of an eavesdropper
Advantages	High ease of deployment without major changes to current infrastructure	Enables the highest degree of security
Drawbacks	Lack of certainty over future protection due to emerging innovations in QC (eg, quantum cryptography)	Currently not favored because of regulation, high costs, deployment complexity with change of underlying infrastructure, and incumbent IP protection
Global approach (illustrative)	**US:** Driving PQC adoption through federal mandates and procurement guidance, targeting full transition of quantum-resistant protocols by 2030	**US:** Partnering with industry (eg, Chattanooga and Qubitekk) to launch first commercially available quantum networks; Cisco launched quantum testbed in LA
	China: Advancing centrally driven, sovereign PQC path, aligning national standards and quantum-secure communications outside the US-led track	**China:** Building early advantage in satellite-based QC and quantum networks; built system spanning thousands of kilometers
	Europe: Reinforcing cybersecurity with PQC; transition by 2030 but mainly at high level, with detailed implementation guidance still emerging	**Europe:** Investing in QKD through coordinated infrastructure projects (eg, EuroQCI and OPENQKD) and testbeds
	Japan: Employing hybrid approach, integrating PQC by 2035 and QKD for highly secure, point-to-point hardware communications (eg, Japan to link major cities with 600-km quantum encryption network); SoftBank and Toshiba successfully integrated QKD	
	South Korea: Aiming to transition federal and critical infrastructure to PQC by 2035; runs own national PQC standardization initiative (KPQC)	**South Korea:** Driving progress with breakthroughs in quantum repeaters; announced plans to develop a 100-km regional quantum network

Source: Expert interviews; press search; McKinsey analysis

PQC is becoming a geopolitical cybersecurity priority, with governments aligning on 2030–35 migration horizons.

Nonexhaustive

Governments

US
Federal agencies[1] are directed to adopt PQC for secure communications and data protection with goal of full adoption of quantum-resistant protocols by 2030. CISA, in coordination with the National Security Agency (NSA), will maintain a list of product categories where PQC is widely available to guide procurement, while NIST will issue updated secure-software guidance to embed these requirements into development practices

EU
ENISA[2] reinforces its cybersecurity with PQC; coordinated transition with national road maps for each member state and migration of high-risk use cases: critical infrastructure (eg, water, energy, healthcare, finance ,and transportation) by 2030 and full migration (medium- and low-risk use cases) by 2035

China
China's quantum-safe policy is centrally driven, emphasizing national QKD infrastructure for government communications and sovereign PQC standards. Its own Quantum-Resistant Encryption Standards bypasses US efforts, positioning it outside the US-led NIST standardization track

Japan
Japan's National Cyber Command Office (NCO) concluded that government systems should complete the transition to PQC by 2035, mirroring US and EU goals; detailed road map expected in 2026

South Korea
South Korea aims to transition federal and critical infrastructure to PQC by 2035, with phased pilot deployment through 2028 across sectors; also runs its own national PQC standardization initiative (KPQC), complementing international (eg, NIST[3]) PQC standards

UK
UK government's National Cyber Security Centre (NCSC) has published official guidance setting a national PQC migration road map with clear indicative milestones: execute early, high-risk use case migration by 2031 and complete migration to PQC by 2035

Others

NATO
NATO's first quantum strategy urges member states to prepare for quantum threats through coordinated adoption of PQC (as the essential near term) and exploration of QKD

G7 recommendations
The G7 Cyber Expert Group (CEG) calls for early, internationally coordinated PQC migration, with critical systems addressed by 2030–32 and 2035 as the outer planning horizon for the financial sector

Key insights

- **Risk-based prioritization is consistent:** Across regions, critical systems and long-lived data are being prioritized for earlier migration (often 2030–32), reflecting shared concern over "harvest now, decrypt later" risk
- **PQC is the near-term foundation:** PQC is universally positioned as the primary near-term defense
- **QKD is recognized as a valuable longer-term and high-assurance complement**; however, it is not presently mandated or explicitly scheduled

1. Department of Homeland Security's CISA, etc
2. European Union Agency for Cybersecurity.
3. National Institute of Standards and Technology.

Source: Expert interviews; press search; McKinsey analysis

PQC companies have multiple products in production—and a track record of solving real-world problems.

Selection; nonexhaustive

Company	Type	Core tech	Security infrastructure	Deployment and migration
IBM	Tech incumbent	✓	✓	✓
Thales	Cybersecurity incumbent		✓	✓
Entrust	Security infrastructure provider		✓	✓
Palo Alto Networks	Cybersecurity platform incumbent		✓	✓
Cisco	Networking incumbent		✓	✓
Cloudflare	Internet infrastructure		✓	✓
PQShield	PQC pure play	✓		
Isara	PQC pure play			✓
QuSecure	PQC pure play			✓
CryptoNext	PQC pure play	✓		✓
SandboxAQ	Quantum/ AI security firm			✓
Quantinuum	Quantum tech firm	✓		

Key insights

- PQC landscape consists of **incumbents** (eg, IBM, Thales, Cisco) and **pure-play players** (eg, PQShield, ISARA, CryptoNext Security)
- Pure-play PQC vendors accelerate adoption by providing **integration-ready components** and **migration tooling** (libraries, tool kits, etc)
- Majority of pure-play players do not report revenue but have a **significant number of customers and partners**
- PQC is an algorithmic solution that could **potentially *not* be fully secure against FTQC**[1]; QKD is a physics-based secure alternative solution

1. Fault-tolerant quantum computing.

Source: Company websites; expert interviews; press search; roundtable discussions

Preparing for quantum-safe communication: Holistic assessment is required to create transparency and understand readiness.

Nonexhaustive

A comprehensive assessment across all relevant dimensions is required to determine where the organization stands—and thereafter provide the basis for a structured PQC or QKD implementation

Quantum resilience assessment dimensions

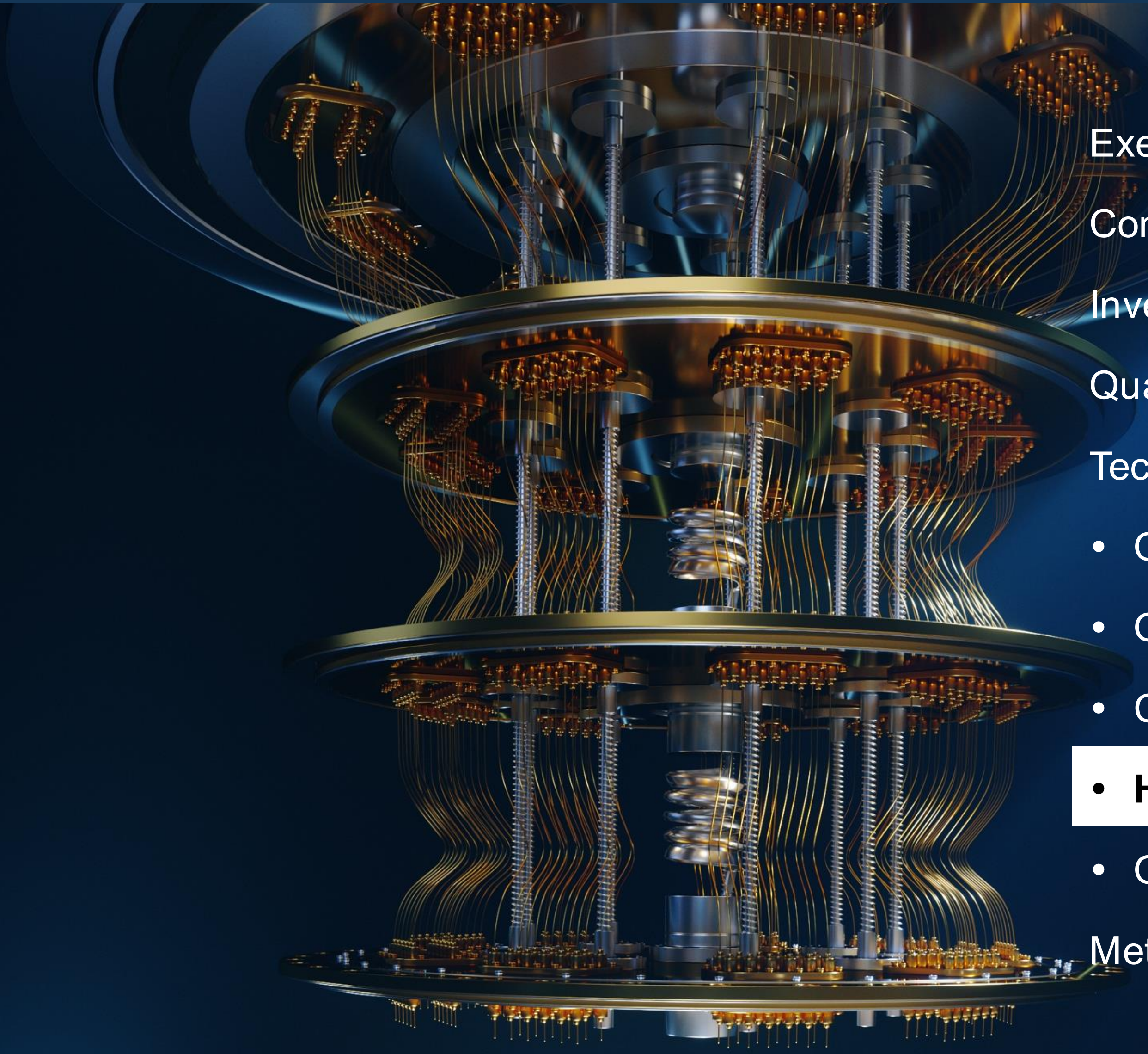
Dimension				
Technical assessment	Infrastructure readiness	Vulnerability scanning and testing	Data encryption	Network security
	Product security	Cloud and edge security		
Risk scenarios	Threat modeling	Scenario planning	Risk mitigation	Residual risk management
	Customer impact	Data breach scenarios	Operational disruption	Reputation risk
Cyber processes	Cryptographic inventory	Transition planning	Incident response	Vendor and supply chain security
	Data protection	Cryptographic agility	Third-party dependencies	
Governance	Policy and strategy alignment	Leadership and oversight	Regulatory compliance	Stakeholder engagement
Org capabilities, including talent	Skill development	Expertise availability	Collaboration	Resource allocation

Key questions to be addressed

- Where is **long-lived sensitive data** created, processed, or stored?
- Where are the **key vulnerabilities—within the network** or access points where internal or external actors could gain entry?
- How prepared are we for a **"harvest now, decrypt later" scenario**? Do we have a war room setup, incident response processes, and a clear communication strategy in place?

Source: Expert interviews; press search; McKinsey analysis

Contents



Hybrid computing combines QC with HPC capabilities to access early use cases with quantum advantage.

Hybrid computing process steps	1 **Classical preparation**	2 **Initiation:** Information preparation and pre-processing	3 **Computation:** Quantum and classical parallel task execution	4 **Processing:** Outcome translation and combination	5 **Classical completion**
Classical HPC contribution	Start of computational task by input of code as classical bits on HPC	Connects classical and quantum resources, sets up data flow between CPUs/GPUs and QPUs,[1] and prepares how the tasks will be divided across classical or QC based on complexity, required computation speed, etc	Classical process that handles sub-problems that benefit less from a quantum advantage and running the HPC computations in parallel with HPC support for QC (eg, error correction)	Computation output as classical bits, combining quantum and classical swim lanes	Final analysis and integration of quantum results into the remaining HPC workflow
QC contribution	*Initial setup and problem definition on HPC*	Translation of information into quantum circuits and qubits via state preparation	Quantum-compatible sub-problems are processed via quantum algorithms on quantum hardware	Translation into classical bits via measurement for analysis, validation, or decision-making	*Completion handled on HPC*

Key insights

- Hybrid computing can run through one software layer that manages both classical and quantum steps
- Most workloads will stay hybrid, with classical systems doing most tasks and quantum used where it adds value
- Defined workflow can become a general platform of computation, not just for specific use cases

1. Quantum processing unit.

Source: Publicly available hybrid computing descriptions from Alice & Bob, Amazon Bracket, IBM Quantum, Microsoft Azure Quantum, NVIDIA CUDA-Q, QuEra, and Xanadu

Integration of quantum systems directly into data center workflows accelerates overall hybrid performance.

Nonexhaustive

Why integration matters	• Embedding quantum systems into standard data center operations uses existing networking, reliability, and monitoring practices • As quantum capacity expands over the next decade, integrated environments help organizations use capacity more effectively • Some hybrid workflows can benefit from reduced latency between classical and quantum systems, especially when iterative exchanges are required (this applies only to specific cases)
Shift toward on-premise integration	• Vendors are moving quantum hardware closer to HPC clusters to shorten hybrid cycles and stabilize performance • Examples include IBM Quantum System Two, Riken-Fujitsu collaboration, and IQM deployments within EuroHPC sites • On-premise setups reduce long physical paths and create more consistent operating conditions
Cloud platforms enabling unified hybrid execution	• Cloud providers offer managed workflows that coordinate classical and quantum tasks • AWS Braket Hybrid Jobs and Microsoft Azure Quantum provide unified orchestration and scalable access to capacity • These platforms simplify execution and reduce the need for dedicated on-site infrastructure
Operational upgrades required	• Low-latency, high-stability networking is essential for efficient hybrid execution • Stable environmental conditions support predictable quantum performance uptime • Data center practices such as automated calibration, monitoring, and structured intermediate data handling remain critical

Key insights

- Integrated environments improve reliability and consistency for hybrid workloads
- Closer placement of quantum and classical systems simplifies coordination
- Unified orchestration tools make hybrid operations easier to manage and scale
- Stable operating conditions support consistent performance and higher uptime

Source: Company websites; expert interviews; press search; McKinsey analysis

QC integration is less about replacing infrastructure than about enhancing the HPC stack to solve specific compute challenges.

Key differentiating unit for hybrid computation

Classical IT data center

- Application
- Platform
- Classical compute (CPU/GPU)
- Storage
- Network

Hardware- or software-defined data center

Quantum data center

- Application
- Quantum-HPC middleware
- QPU | Classical compute (CPU/GPU)
- Storage
- Network

Software-defined quantum data center

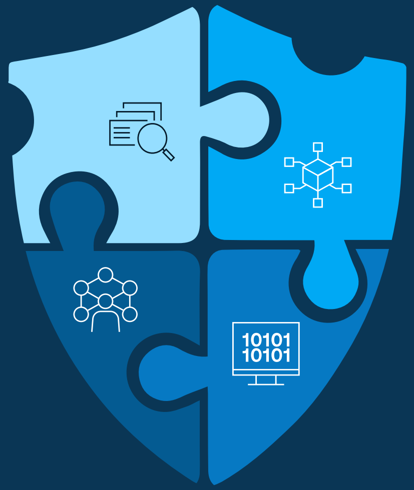
Quantum infrastructure software assigns compute request/problem either to quantum or classical compute unit depending on complexity

Identification of sub-problems within application happens in programmable, automated software

Key insights

- **Quantum is an accelerator, not a stand-alone system, in HPC centers** with specific subtasks (eg, optimization) running on QPUs
- **Successful integration requires software-defined quantum layers** (to route workloads dynamically to CPU, GPU, or QPU)

Quantum readiness: What this means for transitioning data center provider-customers



Workloads: Identify quantum-suitable sub-problems in existing HPC workloads

Architecture: Plan for hybrid workflows, not "pure quantum" stacks

Software: Invest in right middleware, orchestration, and runtime software, not only QC hardware

People: Train HPC teams to work with quantum accelerators

Source: Expert interviews; "Integrating quantum computing into your HPC infrastructure," QuEra, Oct 2024; *Seizing quantum's edge*, Alice & Bob, Aug 2025; "Three steps to integrate quantum computing into your data center or HPC facility," Q-CTRL, May 2025; McKinsey analysis

Integration of hybrid computing in data centers gains momentum. (1/2)

Select HPC announcements: Private contributors

Nonexhaustive

Company	Content of announcement	What it means	Announcement[1]
NVIDIA	**Launching the NVQLink platform** connecting quantum processors with classical GPUs, enabling high-speed data exchange between quantum processors and NVIDIA GPUs through a new interconnect for hybrid workloads	Shows continued development of integrated quantum-GPU stacks that strengthen hybrid computing in data center environments	"NVIDIA Introduces NVQLink — Connecting Quantum and GPU Computing for 17 Quantum Builders and Nine Scientific Labs" (2025)
Alice & Bob	**Advancing fault-tolerant hardware** with software integration of future QPUs with HPC environments via Slurm using a cat-qubit-based architecture	Highlights progress toward more stable hybrid configurations that may ease integration into existing HPC systems	"Alice & Bob share results on integration error-corrected architectures into HPC workflows" (2025)
Microsoft and Quantinuum	**Expanding hybrid execution via Azure with Quantinuum** through cloud workflows coordinating classical CPUs and QPUs	Reduces barriers to experimentation by embedding hybrid tooling directly into cloud developer workflows	"Microsoft Quantum unlocks the next generation of Hybrid Quantum Computing" (2025)
IBM	**Demonstrating a quantum algorithm** running effectively on AMD chips, enabling quantum-inspired approaches without dedicated quantum machines	Suggests that hybrid compute strategies can deliver performance benefits while quantum hardware continues to mature	"IBM says conventional AMD chips can run quantum computing error correction algorithm" (2025)

Key insights

- US hybrid computing development is private-driven, with public focus on funding FTQC R&D
- Focus of hybrid computing development is currently on optimally integrating QC and HPC hardware (eg, NVIDIA) that allows co-defining hybrid workflows to address HPC bottlenecks
- Codevelopment of software stack building on existing HPC capabilities for seamless integration will be key for early adoption and use cases (eg, Alice & Bob adopting Slurm)
- Cloud hybrid computing remains a popular solution for easing integration (Microsoft and AWS); integration of QC into a data center becomes relevant when timeliness is required (eg, financial trading, real-time coordination)

1. Based on publicly available data on company websites (including Reuters).

Source: Company websites; expert interviews; press search; McKinsey analysis

Integration of hybrid computing in data centers gains momentum. (2/2)

Select HPC announcements: Private–public partnerships

Nonexhaustive

Project	Content of announcement	What it means	Announcement[1]
Japanese programs (eg, Q-Leap)	**National effort in integrating quantum processors** into HPC centers; systems are provided in collaboration with Fujitsu (4x increase in qubits on Fujitsu and RIKEN's hybrid quantum computing platform to expand computational capabilities), Quantinuum (Reimei), and IBM	Government investment accelerates hybrid infrastructure adoption and builds local ecosystem capabilities, concentrating capabilities of HPC and QC integration across modalities investigating integration of superconducting and trapped ion modalities	"Fujitsu and RIKEN develop world-leading 256-qubit superconducting quantum computer" (2025) "Quantinuum's 'Reimei' Quantum Computer Now Fully Operational at RIKEN" (2025) "IBM and RIKEN Unveil First IBM Quantum System Two Outside of the US" (2025)
EuroHPC and HPCQS project	**Supporting deployment of hybrid quantum-HPC platforms** across Europe with HPCQS aiming to integrate two quantum simulators into existing HPC; EuroHPC joint undertaking (JU) has procured six quantum computers and co-funded two more through the HPCQS project, enabling quantum processors to be installed within European supercomputing centers; aims to integrate two quantum simulators in GENCI's Joliot-Curie in France and in the Jülich supercomputing center in Germany, partnering with Pasqal, IQM, AQT, Quandela, and Qilimanjaro	Signals coordinated public-sector momentum to adopt hybrid computing infrastructure with European support for public–private partnerships for pan-European development of local capabilities in QC across modalities, supercomputing capabilities, and integration between two strategic innovations	"One step closer to European quantum computing: The EuroHPC JU signs hosting agreements for six quantum computers" (2023)

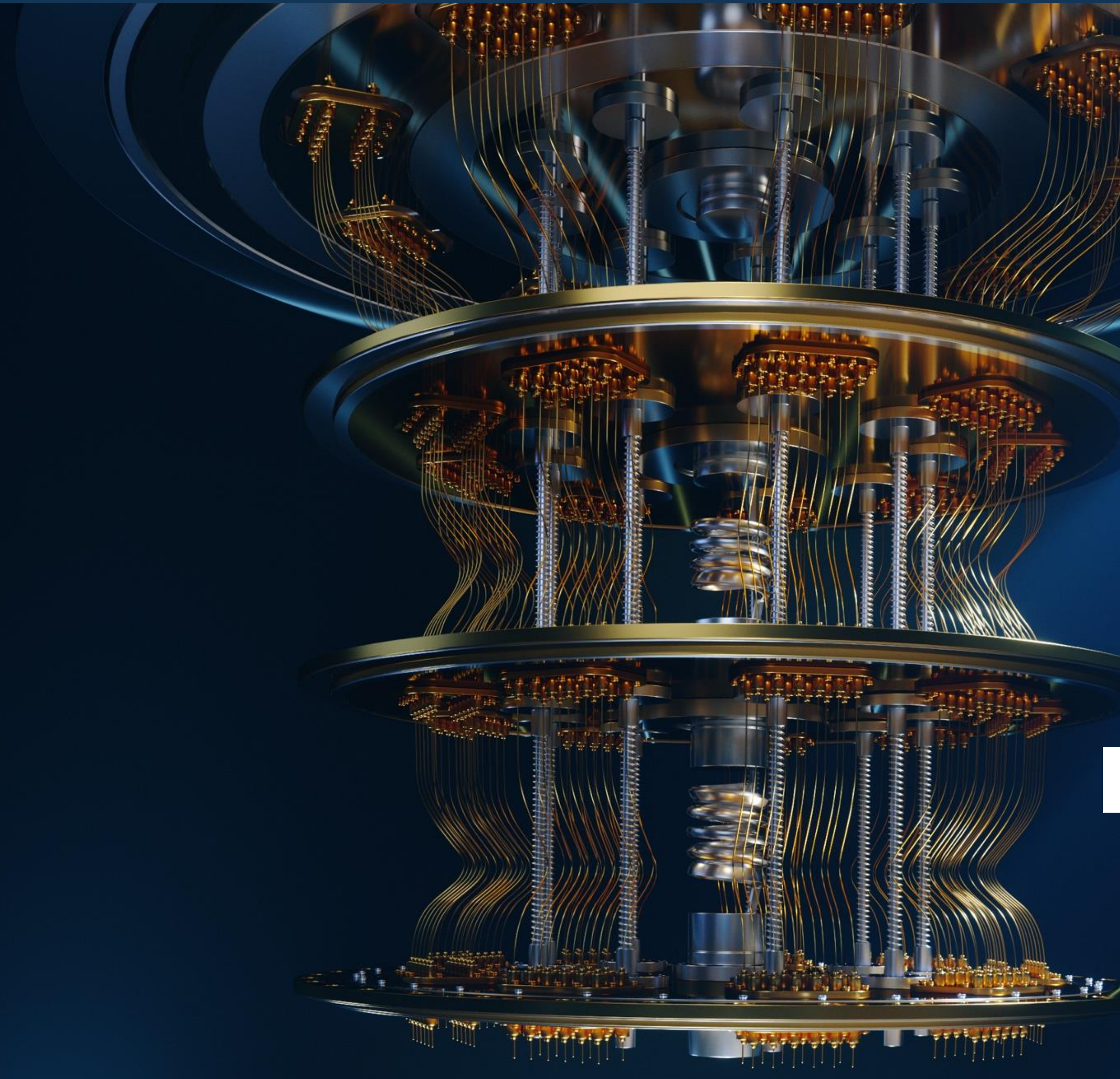
Key insights

- European public partnerships for hybrid computing are publicized to connect and (financially) encourage domestic quantum players to develop hybrid-computing integration
- Long-term success of private–public partnerships have two main success factors: involvement of major IT players that can take over long-term maintenance, and involvement of QC players to provide quantum expertise as seen in Japan; European endeavors seem more research center–led
- Focusing too much on hybrid computing at the cost of not committing to FTQC development can be a risk long term but can help access early use cases

1. Based on publicly available data on company websites.

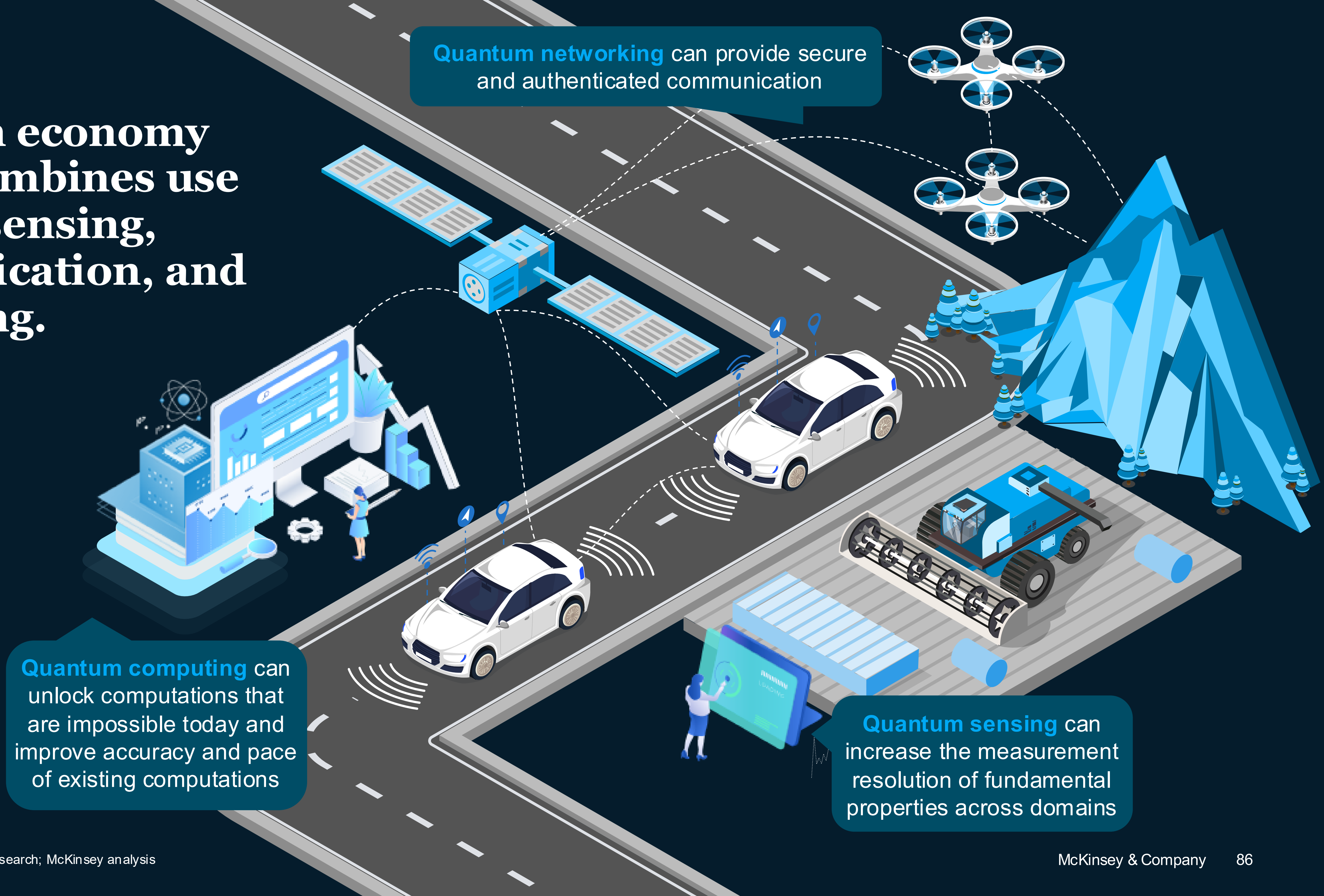
Source: Company websites; expert interviews; press search; McKinsey analysis

Contents



Quantum economy access combines use cases of sensing, communication, and computing.

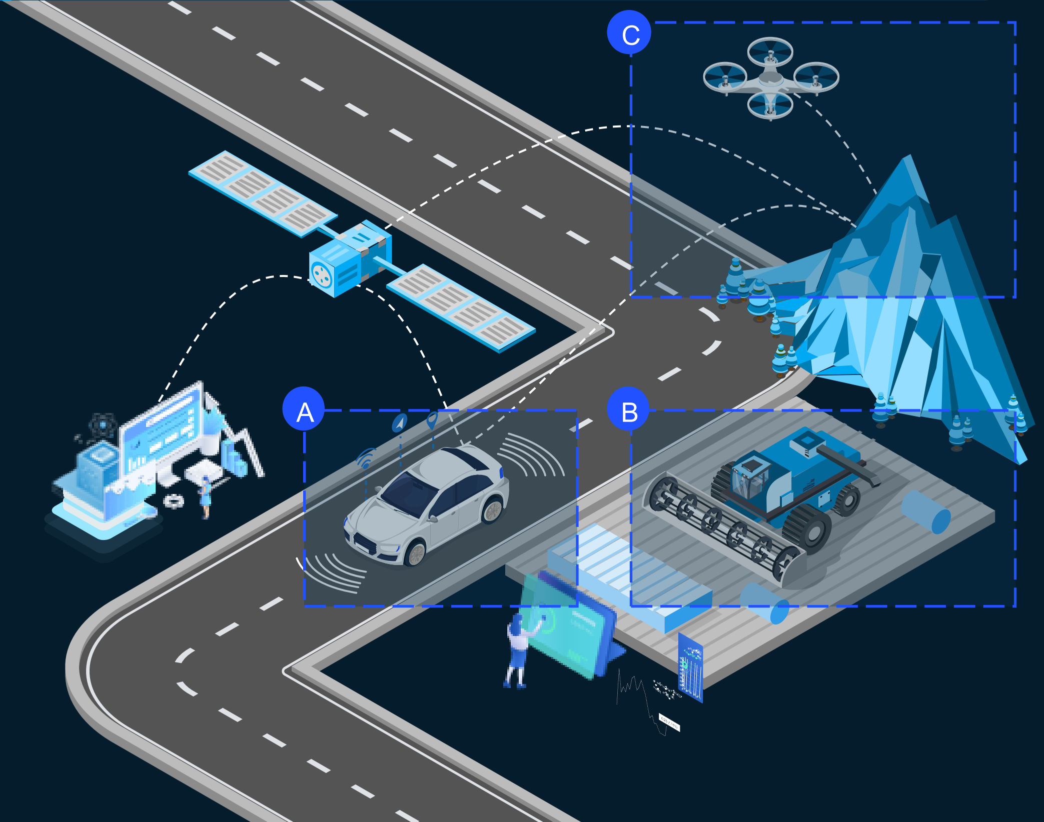
Illustrative



Source: Expert interviews; press search; McKinsey analysis

Selected examples; nonexhaustive

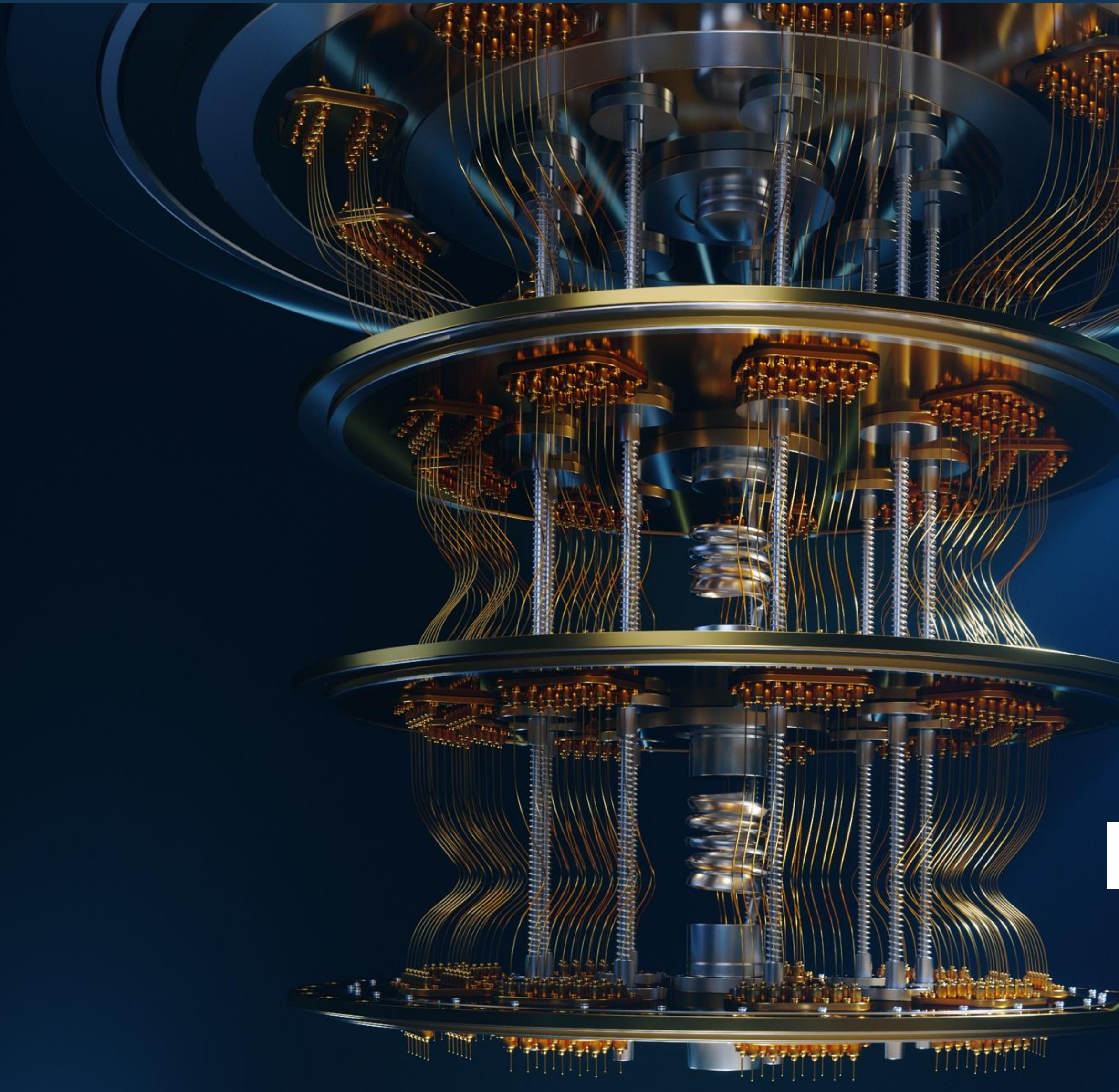
Illustrative examples show how quantum technologies can be combined to enable use cases supporting the quantum economy.



	Quantum sensing	Quantum communication	Quantum computing
A **Autonomous vehicles can change mobility …**	… through photon-efficient vision, imaging using single-photon detectors, and quantum IMUs[1] for GPS-independent and drift-free navigation …	... synchronizing unit clocks with authenticated access and secure communication between servers and other vehicles …	... that can optimally and safely navigate the real world by leveraging distributed sensor data and using kernels trajectory reconstruction
B **Precision agriculture can increase crop yield …**	… through precision access to soil moisture, nutrient levels, and noninvasive tracking of farmlands …	... enhancing accuracy by enabling distributed sensing …	... enriched by new molecular inventions accessed by quantum simulation and with optimized yield
C **Global mineral mapping supports innovation …**	… through magnetometry and gravimetry at the quantum limit using quantum sensors …	... enhancing accuracy by enabling distributed sensing and securely sharing quantum sensor data …	... that is analyzed using quantum linear algebra and quantum kernel methods to build a quantum-enhanced Earth model

1. Inertial measurement units.
Source: Expert interviews; press search; McKinsey analysis

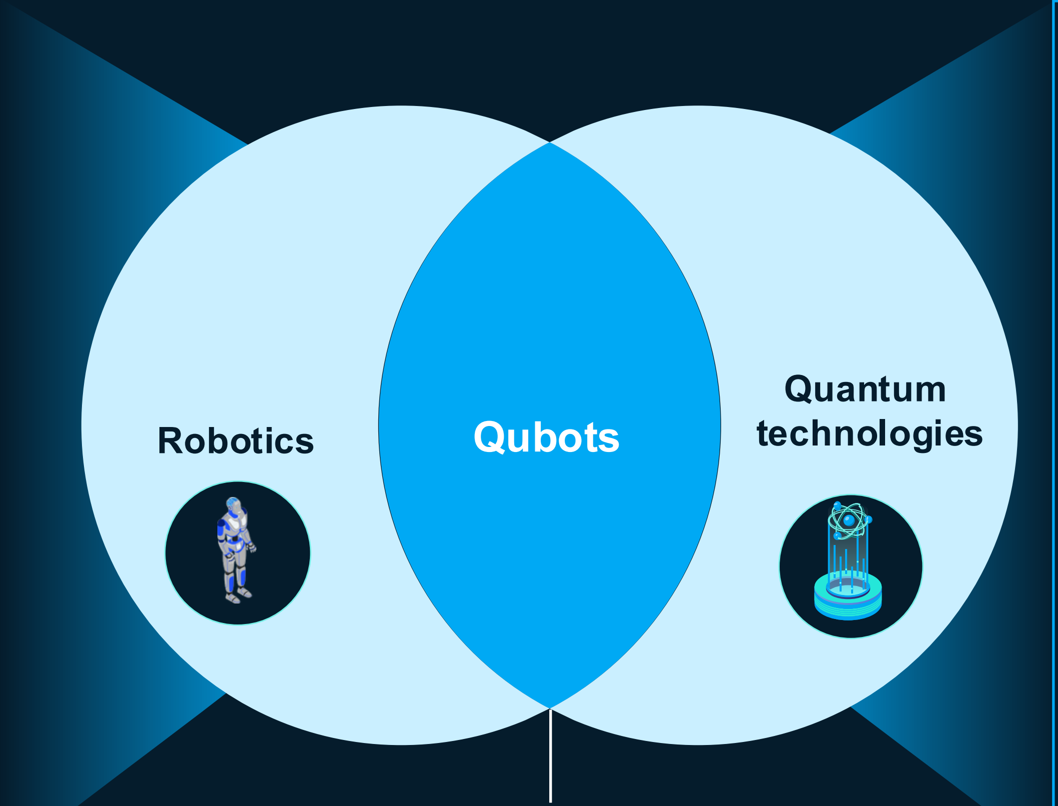
Contents



Quantum-enabled robots (qubots) shape the far future of robotics.

Humanoid robotics is a fast-growing market (+70% p.a., 2025–40) with projected TAM[1] of ~$350B–$400B by 2040 driven by:

- increased performance (AI enabled, solving the sim-to-real gap)
- lower cost (unlocking sub-$50k price)
- battery endurance (>8 hours of battery life)



Qubots are robots enhanced by quantum technologies—computing, sensing, and communication—building on the fundamental properties and leveraging the power of quantum mechanics that will emerge in 10–15 years

All 3 quantum technologies continue to mature rapidly:

- **QC** supercharges compute capacities
- **QS** enhances high-resolution measurements
- **QComm** unlocks ultrasecure, low-latency coordination

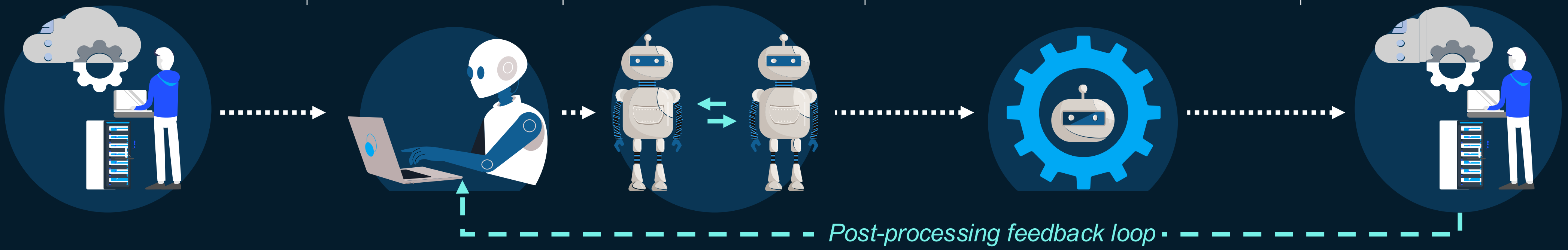
1. Total addressable market.

Source: Expert interviews; press search; McKinsey analysis

Intelligent task performance follows a loop of pre-computation, qubot integration, qubot performance, and post-processing.

Quantum computing | Quantum communication | Quantum sensing

	Pre-compute		Qubot integration	Qubot performance	Post-processing
Example flow	Simulate data to train for real-world action	Train foundational and large AI models	Integrate AI models and QT in robotics	Perform tasks *eg, collaborate to retrieve an object in an environment*	Learn from real-world performance feedback



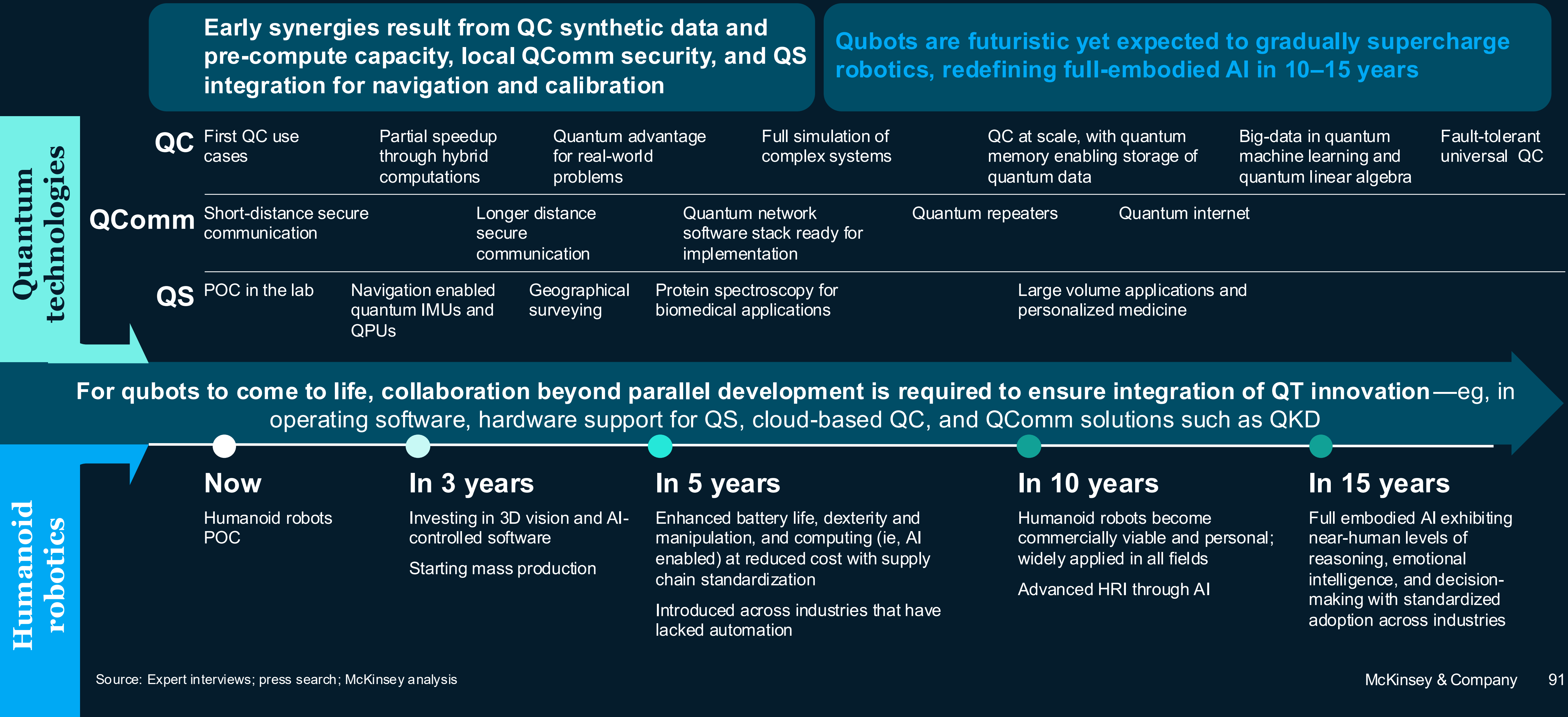
	Pre-compute		Qubot integration	Qubot performance	Post-processing
Value-add of QT in robotics	Input of synthetic data through long-term, non-aggregated simulation, generating and solving sparse data matrixes	Pre-compute and digest synthetic data and real-world data to train foundational and large AI models	Bridge the sim-to-real gap with QC; increase resolution, stability, and navigation with QS with secure access and communication with QComm	Complex orientation, route optimization, and object recognition with QML, supported by high-resolution sensing, navigation, and sensor calibration through QS; QComm for secure access and communication	Federated learning on a QC[1] allows for secure and accurate collaborative data classification, enabling fleet-wide learning

1. Quantum Federated Learning (QFL) could be considered as well when processing quantum states instead of classical training of neural network.

Source: Expert interviews; press search; McKinsey analysis

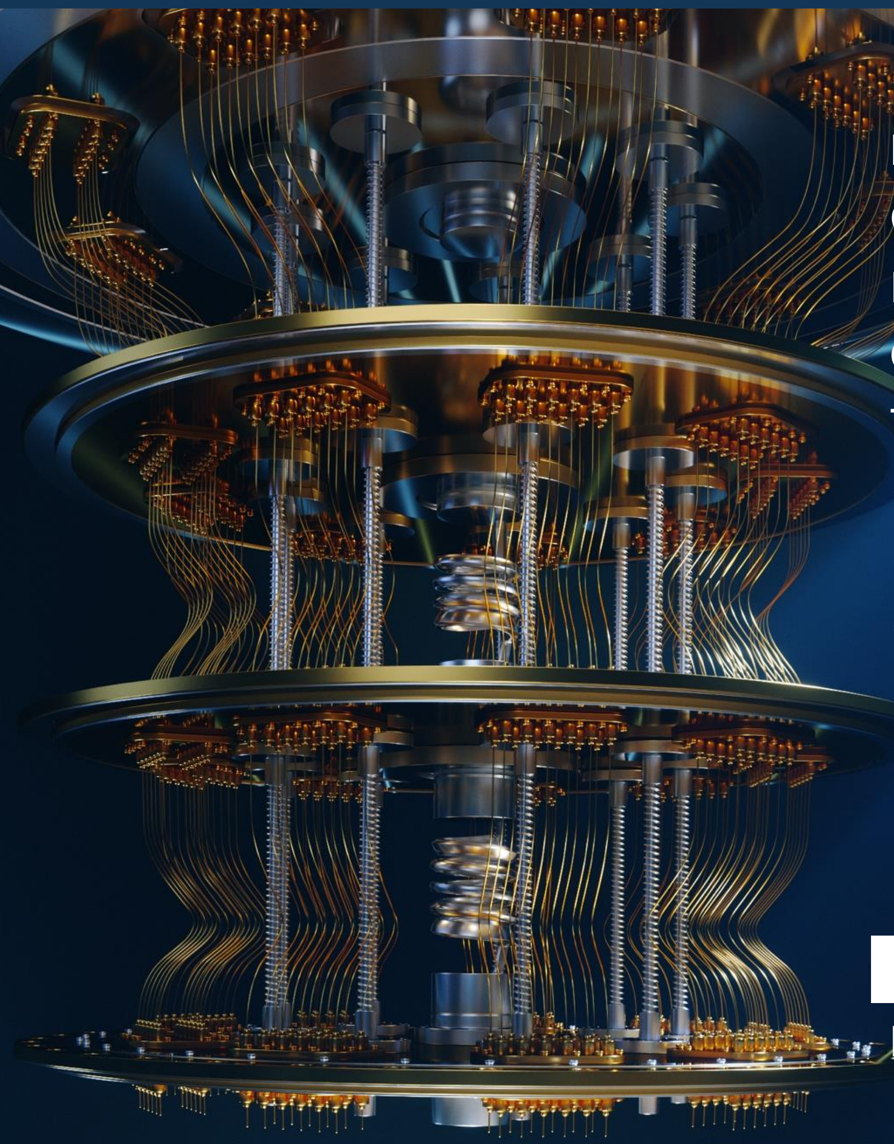
Qubots define a high-value future white space that will be accessed through collaboration beyond parallel development.

Highly indicative



Source: Expert interviews; press search; McKinsey analysis

Contents



QC could help combat the rising energy demand from AI through more efficient scaling compared to classical GPUs.

AI is rapidly increasing energy demand, with the ICT[1] sector power consumption expected to triple by 2030, putting pressure on electricity grids and sustainability targets

Quantum systems, even with high-point energy needs, can reduce overall computing energy through efficient scaling by completing certain tasks with far fewer total steps and maintaining nearly flat energy use

Quantum can make AI model training more energy efficient by handling the most intensive steps and limiting dependence on large GPU workloads

Advanced AI model training is becoming a major driver of energy use

QC is scaling more efficiently than classical GPUs

This could enable AI to scale without a proportional rise in energy consumption

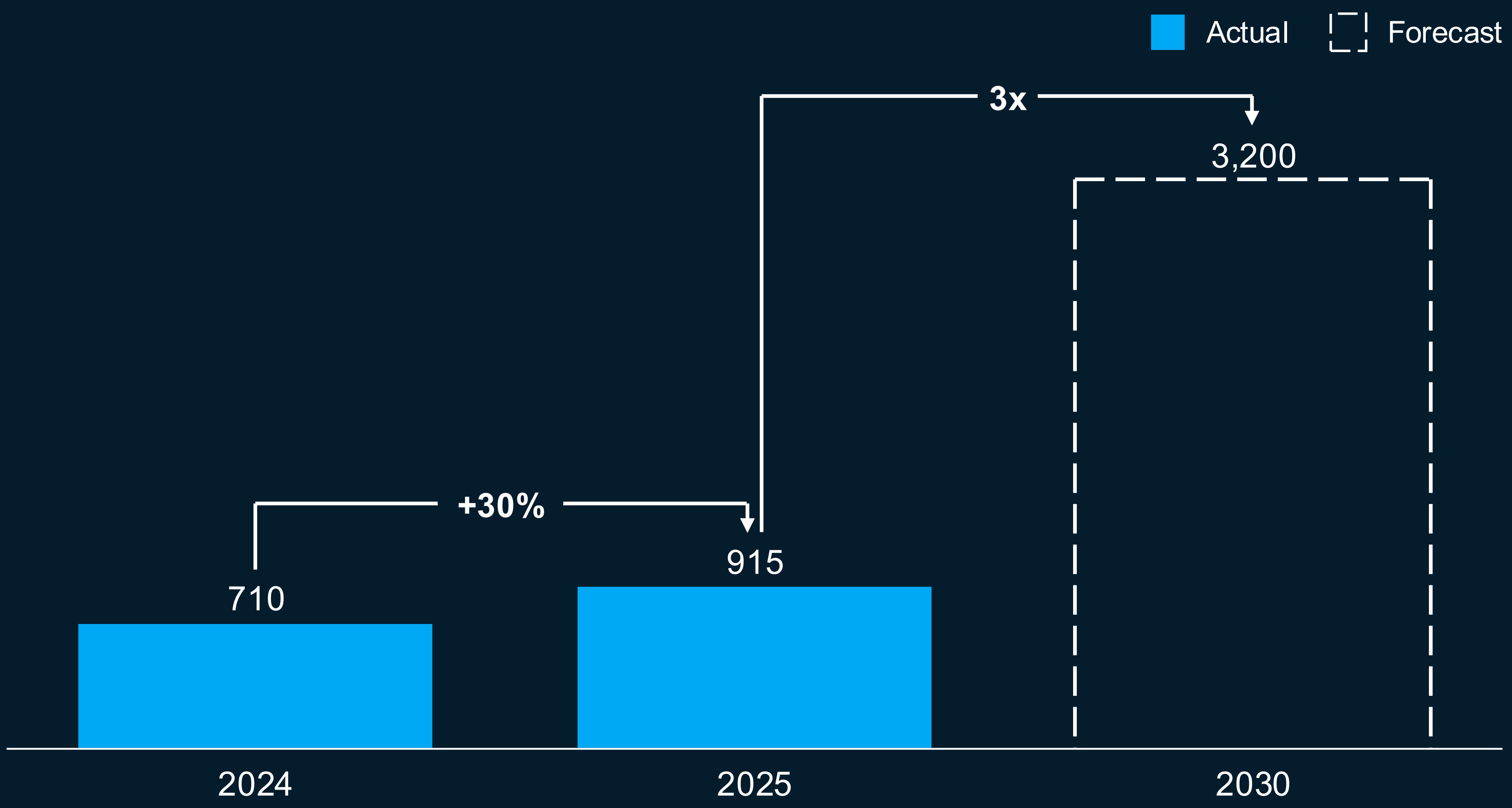
1. Information and communications technology.

Source: Expert interviews; press search; McKinsey analysis

Global ICT energy consumption is expected to increase threefold by 2030, driven by accelerated data center build-out for AI applications.

Illustrative

ICT sector energy consumption, TWh



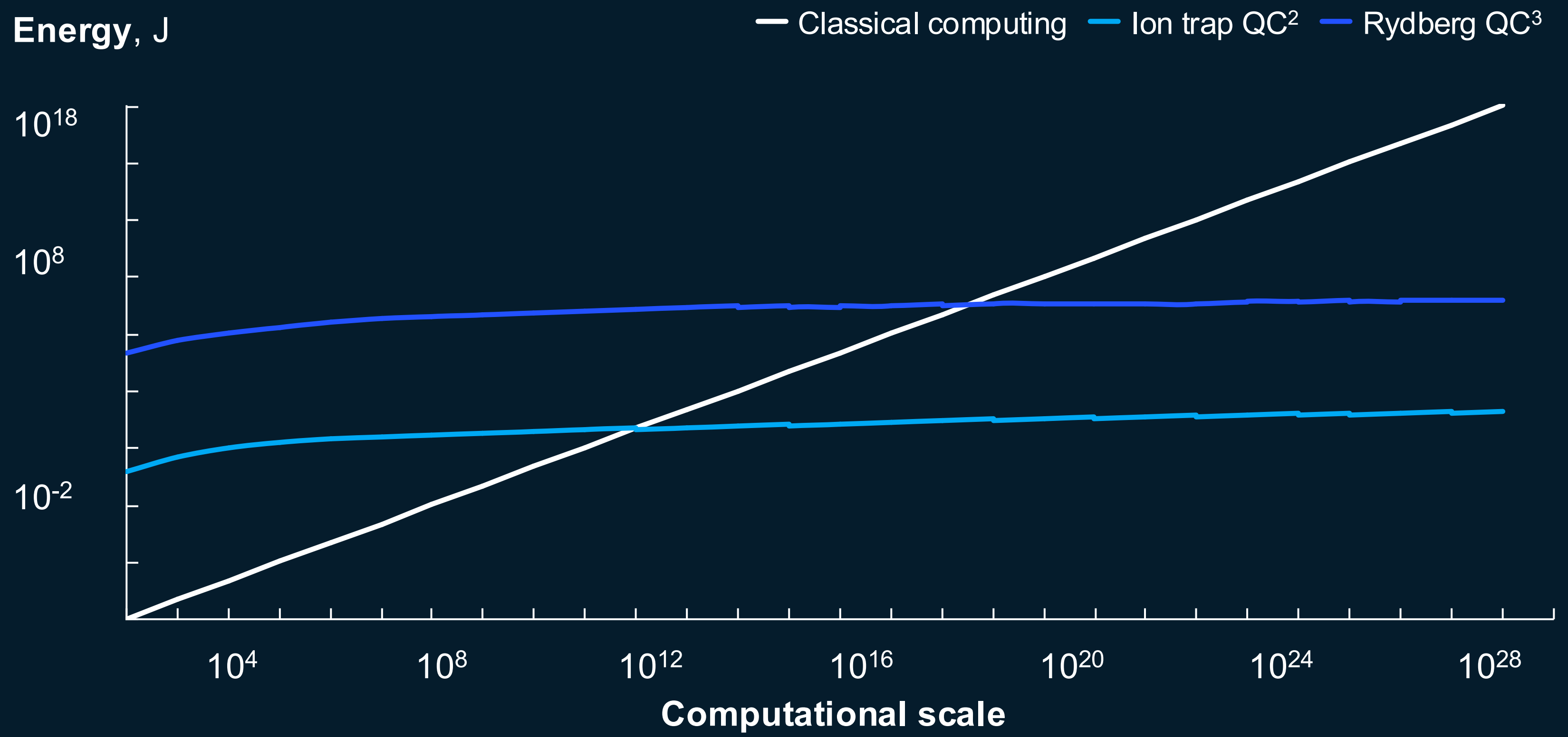
Key insights

- ICT energy use grew ~30% between 2007 and 2020
- Energy demand is expected to triple by 2030, driven by heavy data center build-out, largely due to AI
- AI workloads increase strain on global power availability and put pressure on sustainability targets where energy demand cannot be met through renewable energies

Source: Jens Malmodin et al., “ICT sector electricity consumption and greenhouse gas emissions – 2020 outcome,” *Telecommunications Policy*, April 2024, Volume 48, Number 3.

QC can significantly reduce total energy use for large-scale workloads through more efficient scaling.

Energy required for classical vs QC at large workloads[1]



1. The energy requirements of classical computers, neutral atom QCs, and ion trap QCs have been calculated as a function of a modeling parameter representative of computational scale. There is uncertainty regarding the exact energy requirements due to the significant control and coolingtechnologies associated with QC and potential for further breakthroughs reducing energy needs.
2. Ion trap QC uses ions in electromagnetic fields to store and process quantum information with high stability; added for comparison, this does not suggest trapped ions as a winning modality.
3. Rydberg QC uses highly excited atoms with strong interactions that enable fast multi-qubit operations; added for comparison, this does not suggest trapped ions as a winning modality.

Source: Junyu Liu, Hansheng Jiang, and Zuo-Jun Max Shen, "Potential energy advantage of quantum economy," arXiv:2308.08025, Aug 2023

Key insights

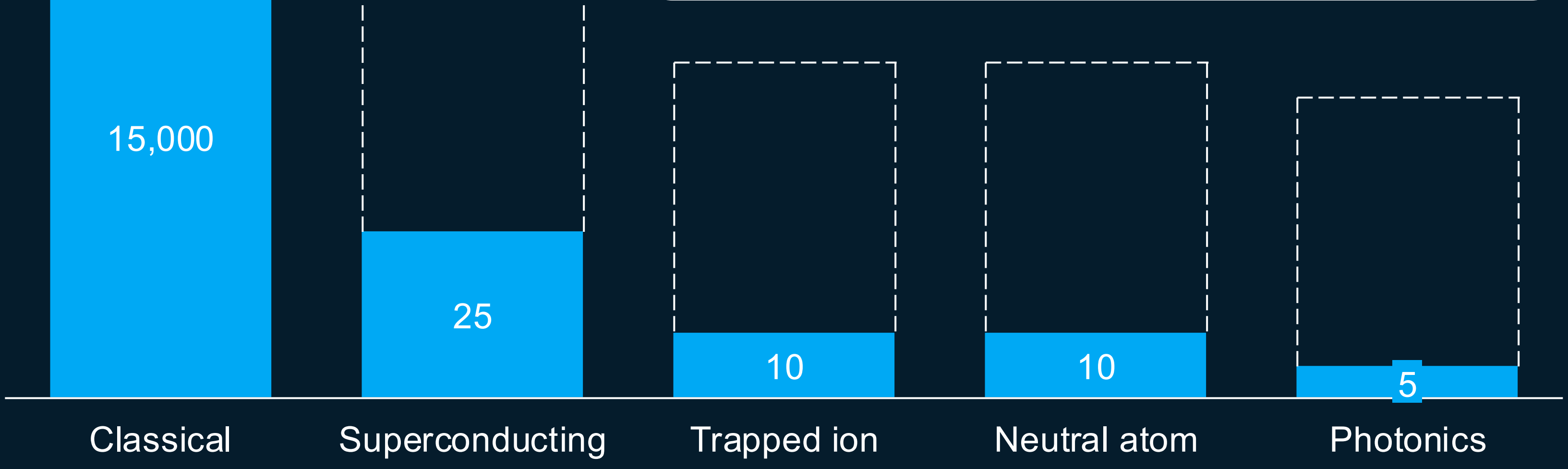
- Energy use from **classical systems increases linearly** as workloads grow
- **QC energy use stays nearly flat across the scale**, becoming more energy-efficient for large tasks compared with classical computing
- **Sustainability benefits appear at scale**, after initial higher energy demand due to control electronics and cooling is offset

QC uses significantly less energy than classical supercomputers across different qubit modalities.

Power consumption estimates for different computing platforms integrated with HPC centers, kW

Assumptions

- Includes cooling and control electronics for quantum operations
- Classical figures reflect full HPC system power use
- Energy numbers may change as systems scale



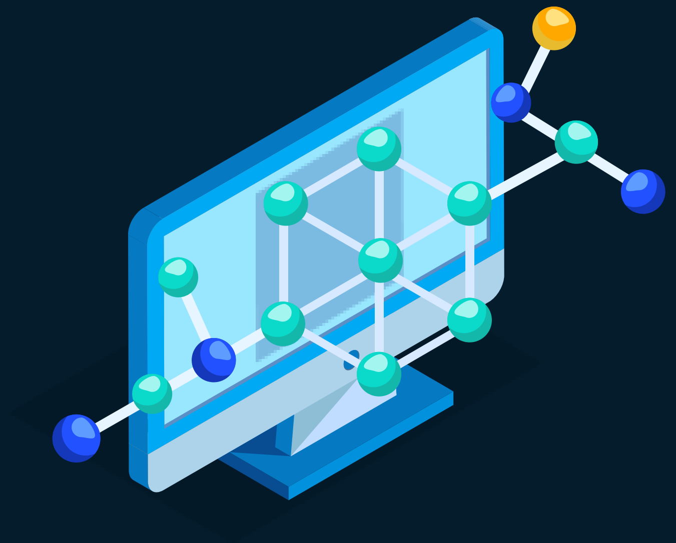
Source: Xiaolong Deng, Martin Schulz, and Laura Schulz, "Power consumption and energy efficiency of quantum computing platforms in high performance computing integration," *Parallel Processing and Applied Mathematics: 15th International Conference, PPAM 2024, Ostrava, Czech Republic, September 8–11, 2024, Revised Selected Papers, Part II*

Key insights

- Classical supercomputers require significantly higher power and cooling infrastructure
- Current quantum systems consume far less energy, even when including cooling and control electronics
- Energy efficiency offers a potential cost advantage as systems scale and mature

QC use cases could unlock strategies to combat climate change that were previously out of reach.

Example use cases; nonexhaustive



1

Carbon capture materials

Enhanced and broader scope of modeling of chemical reactions to discover and optimize new materials for carbon capture

2

Electric grid load balancing

Finding the optimal solution for load balancing in electrical grids to enable efficient integration of renewable energy sources

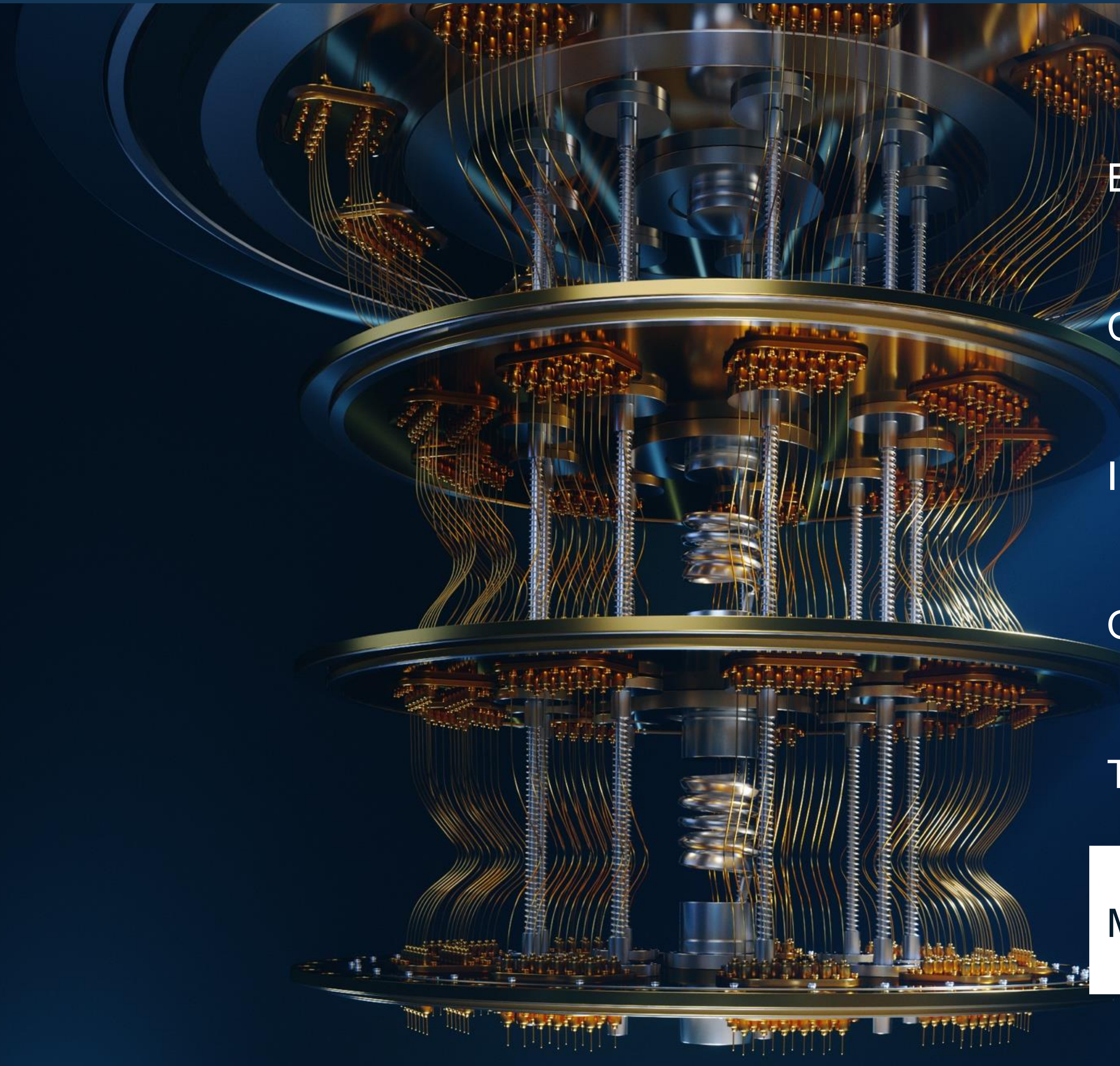
3

Green ammonia

More accurate modeling of nitrogenase enzyme structure and activity to develop a green scalable alternative for ammonia production

Source: Expert interviews; press search; McKinsey analysis

Contents



Methodology

QT investments, patents, publications, revenue, market sizing, and player landscape

Investment analysis
Start-up investment data (and founding year of start-ups) was sourced from PitchBook and subsequently analyzed by McKinsey. This analysis includes deal size, stage, HQ location, and investor type to provide insight into capital flows within the QT landscape

Public funding assessment
Public funding data was compiled through comprehensive press research and supplemented by PitchBook records, capturing government and institutional investments into quantum technologies

Value at stake
Economic impact from QT was assessed based on use case analysis across key segments for QC, with two different scenarios representing conservative and optimistic growth

Patent landscape evaluation
Patent data was extracted from Patsnap filtered by quantum technology and analyzed by McKinsey to assess the innovation pipeline across QC, QComm, and QS

Scientific publications
Publication data was extracted from Nature Index, filtering for publications in physical sciences. Share per country is based on share of publications (ie, fractional measure that splits credit among coauthoring institutions)

Revenue
Revenues are estimated based on publicly announced revenues of QC start-ups

Market sizing approach
Market sizes were estimated across two scenarios based on growth rates, each reflecting different adoption trajectories of QC, QComm, and QS. These scenarios account for varying assumptions about both the pace of technological breakthroughs and the rate of commercial uptake

QT player landscape
To map the QT ecosystem, we applied the following definitions:

- **Start-ups**: companies founded within the past 25 years with estimated revenues below $200M
- **Incumbents**: established companies generating revenues exceeding $200M
- **Component manufacturers**: included only if they produce components specifically designed for QT applications; suppliers of general-purpose components were excluded
- **Hardware developers**: included if they have either demonstrated a quantum computer or publicly committed to building one
- **Telecommunication providers**: included if they are actively investing in QComm with the ambition to serve as quantum network operators

To quantify the impact of QT, we considered internal market size and value at stake.

Internal market size

Market size of QT infrastructure, hardware, software, and services (ie, entire tech stack for quantum technologies)

QT tech stacks include the following:

- physical components
- assembled hardware
- embedded and application software
- networking (eg, cloud infrastructure)

Value at stake

Economic value from impact of quantum technologies on (non-QT) industries along respective value chains

Example industries:

- finance
- pharmaceuticals
- energy and materials

Example value chain components:

- R&D
- logistics and distribution

Source: Expert interviews; press search; McKinsey analysis

Meet the team behind the Quantum Technology Monitor

This research was conducted in collaboration with the McKinsey Global Institute (MGI), whose mission is to provide a fact base to aid decision-making on the economic and business issues most critical to the world’s companies and policy leaders

Key contacts

Henning Soller
Partner
Frankfurt

Martina Gschwendtner
Engagement manager
Munich

Waldemar Svejstrup
Associate
Copenhagen

Victor Kermans
Associate
Brussels

Waris Ziarkash
Senior associate
Vienna

Duc Nam Nguyen
Fellow senior associate
Berlin

Kimberly Beals
Communications manager
Chicago

Philipp Hühne
Communications expert
Düsseldorf

Senior sponsors

Holger Harreis
Senior partner
Düsseldorf

Steve Suarez
Guest lecturer, MIT
Dubai

Additional team members

Jessica Cerdas
Senior capabilities and insights analyst
San Jose

Jess Fleming
Data scientist II
London

Mara Brinkmann
Fellow
Hamburg

Additional contributors

Erik Doersching, Evgeni Kochmann, Hannes Schmidt, Hussein Hijazi, Jonas Koehne, Ken Somers, Michael Chui, Ming Xu, Nicole Morgan, and Sven Smit

Appendix

QT player ecosystem

Selection of QT players across QC, QS, and QComm

Nonexhaustive

QC

- IBM
- Google
- Microsoft
- AWS
- NVIDIA
- Quantinuum
- IonQ
- D-Wave
- PsiQuantum
- Rigetti
- Pasqal
- IQM
- QuEra
- Infleqtion
- Xanadu
- Atom Computing
- Quantum Machines
- Origin Quantum
- eleQtron
- Fujitsu
- Intel
- NEC
- Kvantify
- NTT
- Classiq
- ORCA Computing
- Quantum Brilliance
- SpinQ
- Qubitcore
- SandboxAQ
- Hitachi
- Alice & Bob
- OQC
- Diraq
- SEEQC
- Riverlane
- Q-CTRL
- Multiverse Computing
- Algorithmiq
- Kipu Quantum
- QuantWare
- Strangeworks
- Phasecraft
- Horizon Quantum
- Sparrow Quantum
- QC Ware
- Qblox
- Entropica Labs
- Zapata Quantum
- 1QBit
- QunaSys
- Planqc
- Quobly
- Photonic Inc.
- Quandela
- QBoson
- TuringQ

QS

- Bosch
- Honeywell
- Lockheed Martin
- Northrop Grumman
- Muquans
- RTX
- Exail
- Infleqtion
- Vector Atomic
- Q.ANT
- Teledyne
- AOSense
- IonQ
- TOPTICA
- CIQTEK
- Sony
- Atomionics
- Nomad Atomics
- Qnami
- QuSpin
- Cerca
- Quantum Diamonds
- SBQuantum
- NVision
- QLM
- QuantX
- Aquark Technologies
- Chilas
- QuPrayog
- EuQlid
- IRsweep
- Photek
- Rydberg Technologies
- DIASENSE
- QZabre
- TeraView
- M Squared
- Q-CTRL
- QDTI

QComm

- ID Quantique (IDQ)
- Toshiba
- China Telecom
- QuantumCTek
- Thales
- Cisco
- Nokia
- BT
- Deutsche Telekom
- SK Telecom
- KT Corp
- Quantum Dice
- Arqit
- PQShield
- QNu
- Quantum XChange
- IonQ
- Nu Quantum
- QuSecure
- Qasky
- Qubitekk
- KETS
- Crypto Quantique
- evolutionQ
- Post-Quantum
- Crypto4A
- Xiphera
- SpeQtral
- Qunnect
- LuxQuanta
- Quan2D Technologies
- Qrypt

Note: Slide with logos can be shared on request.

Source: Expert interviews; press search; McKinsey analysis