



McKinsey  
Technology

# Quantum Technology Monitor

April 2026

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# 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.

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Investment landscape

Quantum technology market development

Technological maturity and deep dives

Methodology and acknowledgments

# 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.

 Deep dive to follow



**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<sup>1</sup>–QC integration to industrialize quantum adoption



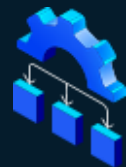
**Window of opportunity before clear winners emerge:** No dominant modality or player has been established yet



**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<sup>2</sup> development)



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



**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<sup>3</sup> 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

| Commercial stages | Build long-term customer relationships                                                     |                                                                           |                                                                                      |
|-------------------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|                   | 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**

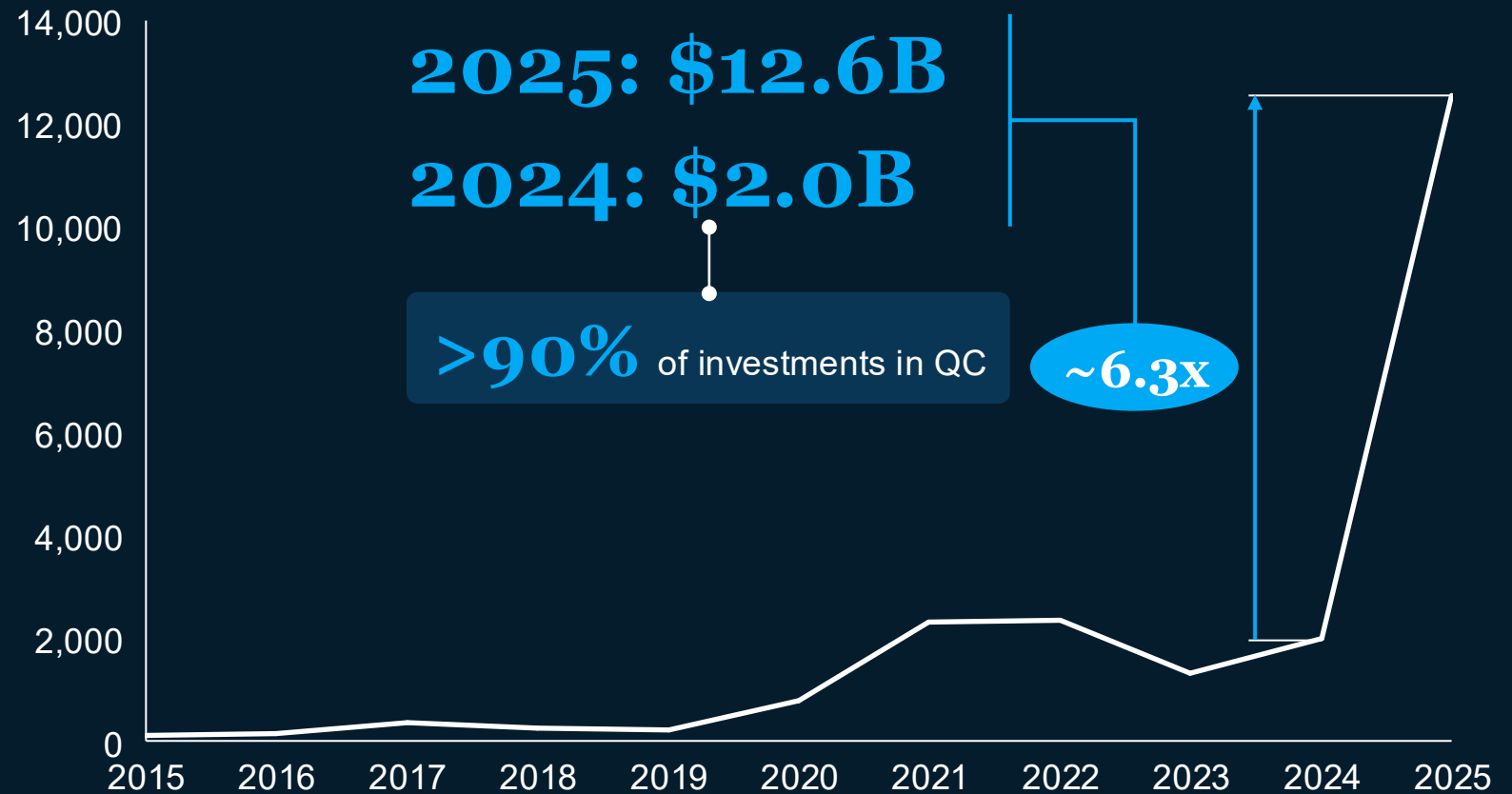
## 2. Investors: Quantum investment increased by 6.3x from 2024 to 2025.

### 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

Investment volume by year,<sup>1</sup> \$ million

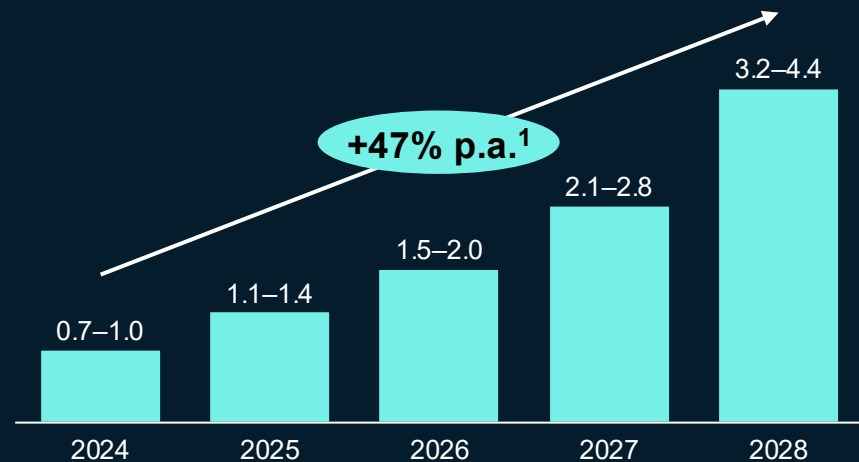


1. Based on investment data recorded in PitchBook, including investments via private markets (eg, venture capital [VC] funding and corporate investments), public markets (eg, IPOs, special-purpose acquisition companies [SPACs], secondary public offerings, and private investment in public equity [PIPEs]), 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.

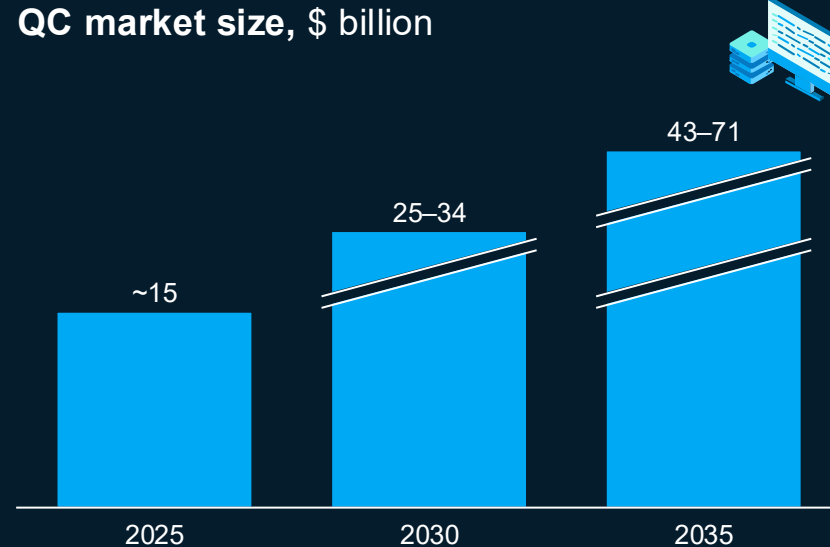
### 3. QT companies: Rising revenues signal accelerating commercialization.

■ Revenue ■ Market size  Quantum computing  Quantum communication  Quantum sensing

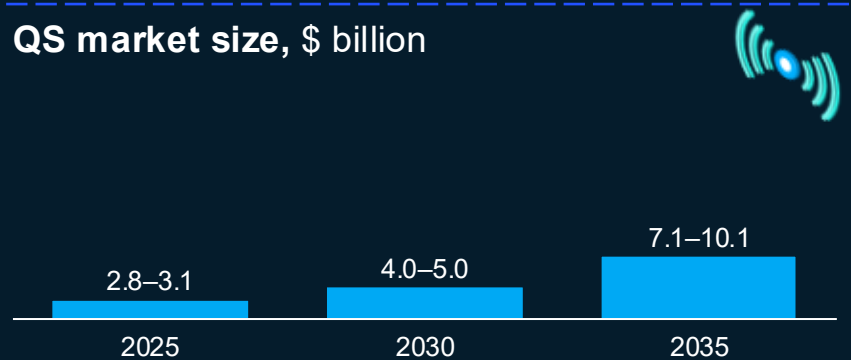
Revenue estimates of QC companies, \$ billion



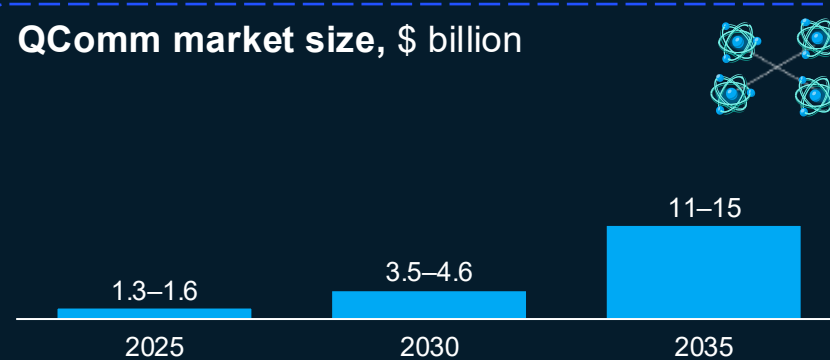
QC market size, \$ billion



QS market size, \$ billion



QComm market size, \$ billion



#### 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

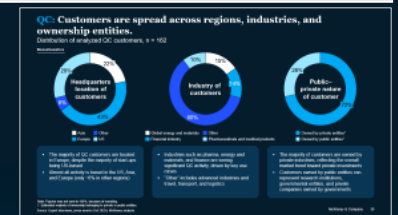
From ~2015 . . .



. . . to ~2025

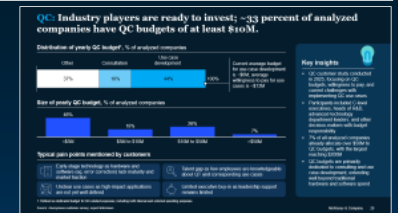
No meaningful commercial adoption

**300+**  
QT customers globally



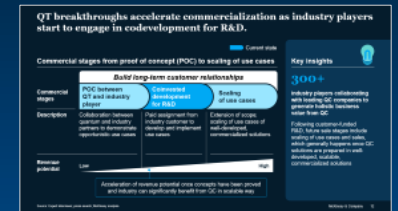
Minor dedicated QT budgets (\$1M–\$3M) for a few front-runners

**>\$5M**  
Budget for hundreds of industry players



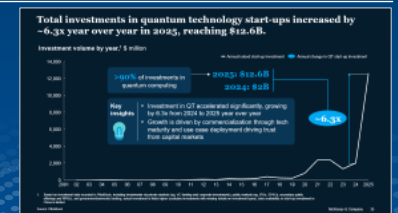
Few part-time quantum roles

**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)



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- Why consider quantum technology?
- Intersection of quantum with AI

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# 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



### 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



### 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<sup>1</sup>



### Quantum technologies: Product and service providers

Value generated from selling QT products and services

**\$60B–\$100B**

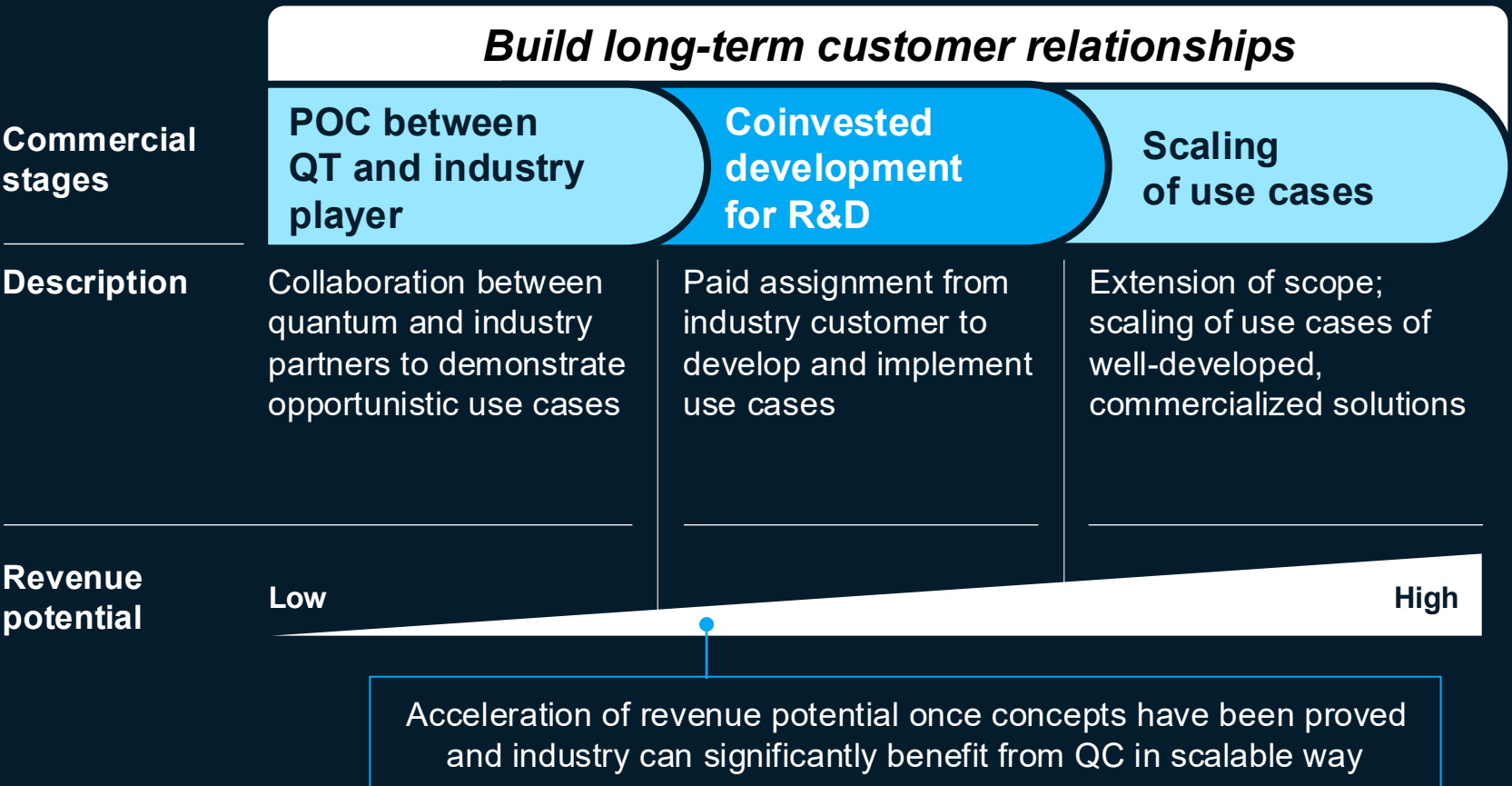
Market size for QT

1. Assuming valuation multiple of ~20x.

# 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



## 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

# Increased QT commercialization is supported by significant announcements.

Selected announcements for business impact and adoption of QT

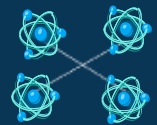
Nonexhaustive

## Signals of commercial progress



QC

QC players make **significant progress in fault-tolerant computation** and move estimates for Q-Day closer



QComm

**Commercialization of QComm accelerates** as QKD<sup>2</sup> integrates with existing telecom and satellite systems



QS

**Partnerships with government programs accelerate technology adoption**, including first moves for QS in the direction of production at scale

| Company                        | Content of announcement                                                                                                                                                                   | What it means                                                                                                                               | Announcement <sup>1</sup>                                                                                                       |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| <b>Quantinuum</b>              | 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 | <a href="#">“Introducing Helios: The Most Accurate Quantum Computer in the World” (2025)</a>                                    |
| <b>IonQ</b>                    | 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                                                       | <a href="#">“Introducing Helios: The Most Accurate Quantum Computer in the World” (2025)</a>                                    |
| <b>IBM</b>                     | 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                                                | <a href="#">“How IBM will build the world’s first large-scale, fault-tolerant quantum computer” (2025)</a>                      |
| <b>Quantum Computing Inc.</b>  | 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                  | <a href="#">“Quantum Computing Inc. Debuts Revolutionary Quantum Secure Solution at ECOC 2025” (2025)</a>                       |
| <b>IonQ incl Capella Space</b> | 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  | <a href="#">“IonQ Announces Plans for First Space-Based Quantum Key Distribution Network” (2025)</a>                            |
| <b>Honeywell</b>               | 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                          | <a href="#">“Honeywell awarded US government contracts to develop sensor-based navigation systems” (2025)</a>                   |
| <b>Quantum Diamonds</b>        | 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              | <a href="#">“QD Plans €152 Million Investment in Next-Gen Quantum-Based Chip Inspection Facility in Munich, Germany” (2025)</a> |

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 | North America | Asia | Other |
|--------------------------------------------------------------------------------------------------|--------|---------------|------|-------|
|  Automotive     | 3181   | 1133          | 2292 |       |
|  Energy         | 7271   | 2402          | 923  | 72    |
|  Finance        | 2382   | 7381          | 1083 |       |
|  Life sciences | 5601   | 3702          |      |       |
| 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)

# 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 <sup>1</sup>                                                                                                                                                                                                                                      |
|------------------|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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)<br>"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<sup>1</sup>

## 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.

# 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

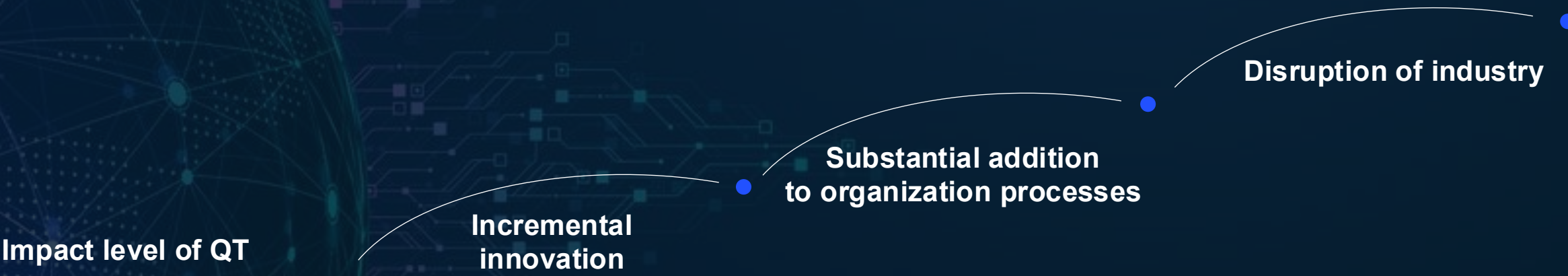
| Industry                                    | Key segment for QC               | Economic value of QC <sup>1</sup> |          | Value at stake for QC by 2035, <sup>2</sup><br>\$ billion |
|---------------------------------------------|----------------------------------|-----------------------------------|----------|---------------------------------------------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

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

 Details for selected industries to follow



## 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

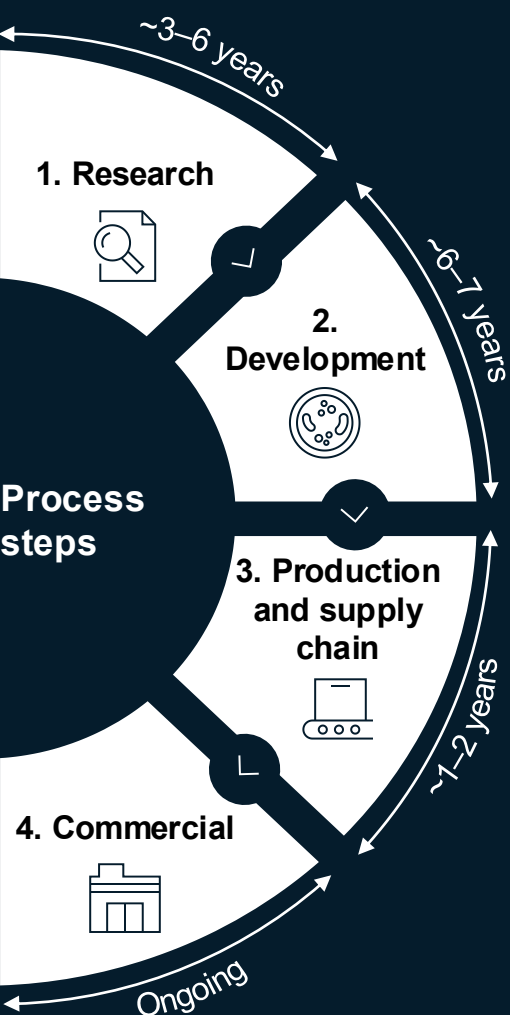
**Cost reduction**

**Acceleration potential (for existing business streams)**

**New business opportunity**

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

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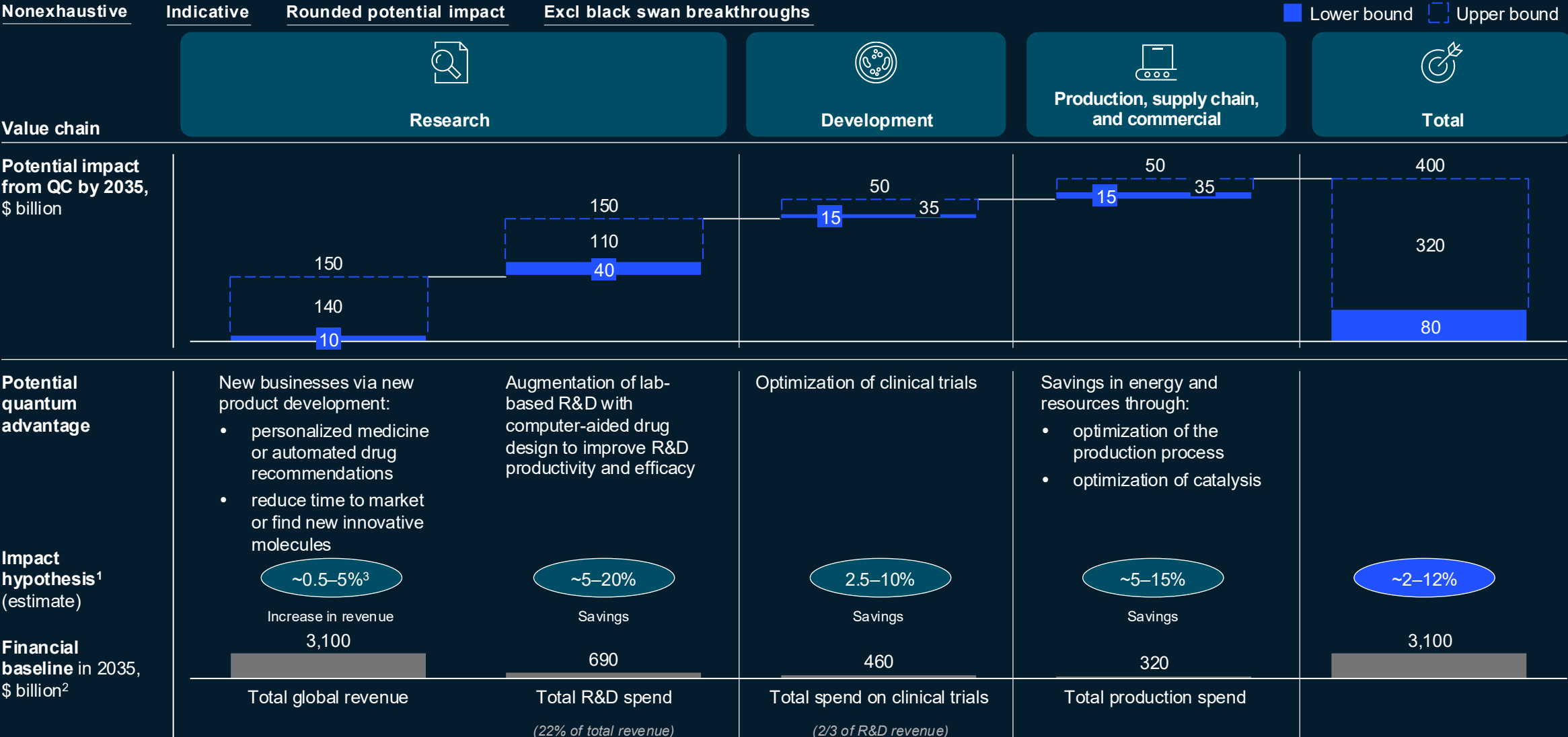
**Example impact:** AstraZeneca, IonQ, AWS, NVIDIA accelerating drug development through hybrid QC–classical computing<sup>1</sup> (2025)

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

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

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.



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.

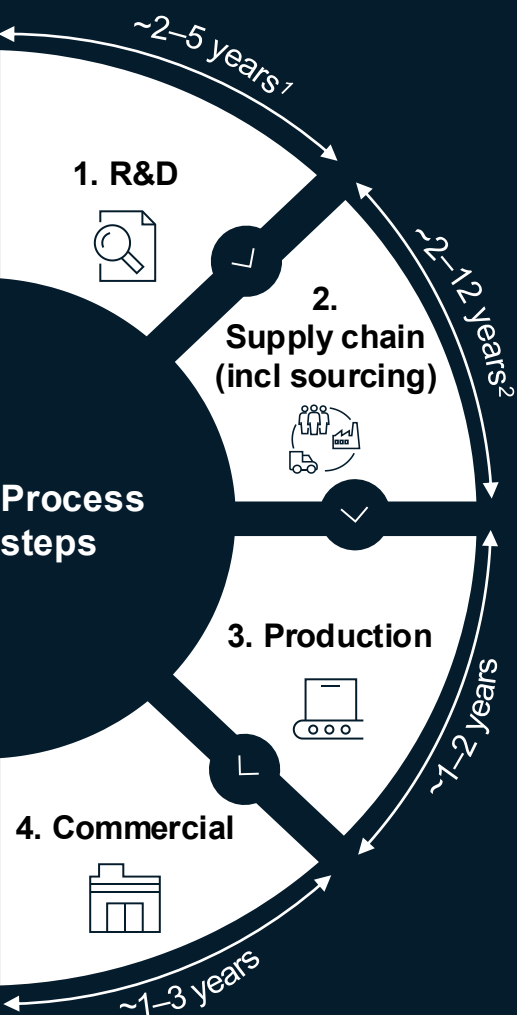
3. New businesses impacting entire value chain.

Source: Expert interviews; S&P Capital IQ; S&P Global Comparative Industry Service; web search

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

Nonexhaustive



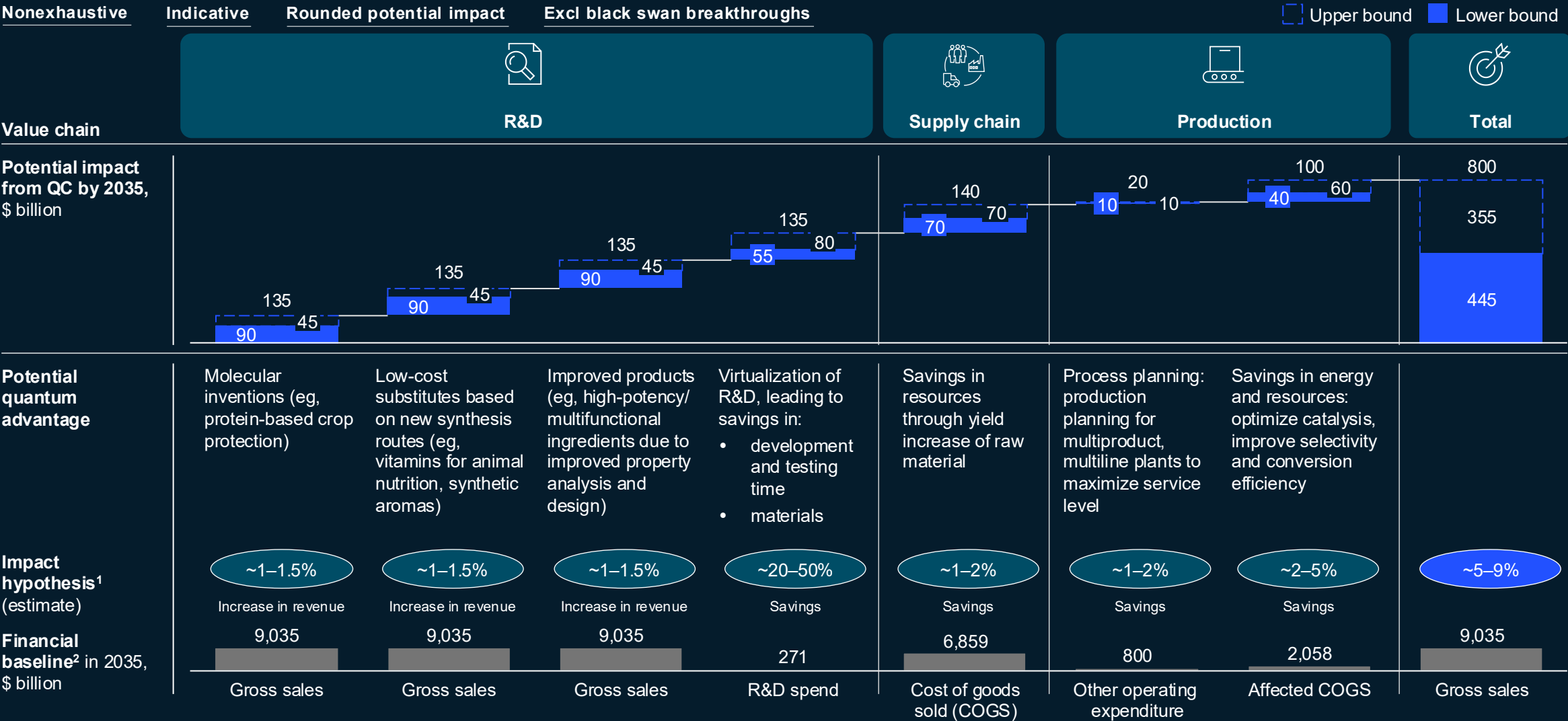
**Example impact:** BASF and D-Wave completing a proof-of-concept approach to improve manufacturing workflow efficiency<sup>3</sup> (2025)

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

| Description |                                                                                                                                            | Impact levers <sup>4</sup>                                                                                              |                                                    |                                                                                                                                          |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
|             |                                                                                                                                            | Cost reduction                                                                                                          | Acceleration potential (existing business streams) | New business opportunity                                                                                                                 |
|             | 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 |
|             | 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                                                   |
|             | 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                              |                                                                                                                                          |
|             | Launch the product into the market, manage customer relationships, and optimize product performance in real-world applications             | 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

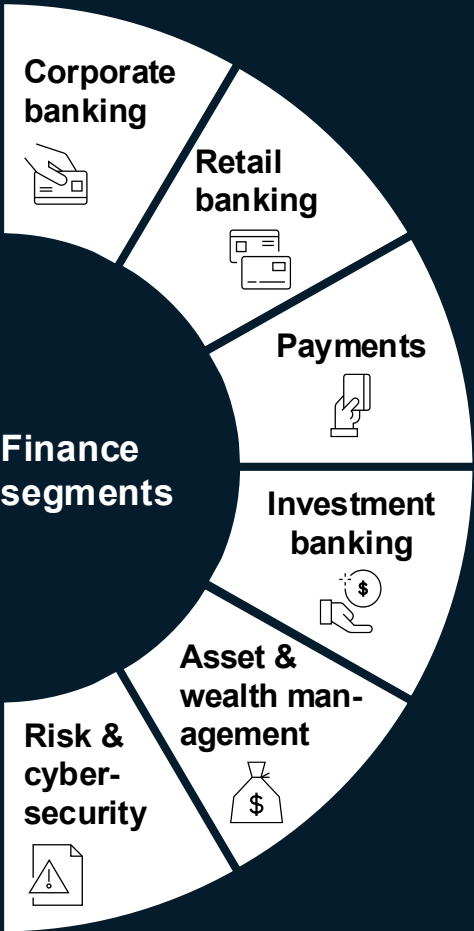
# QC in chemicals: By 2035, QC could unlock \$450B to \$800B in value, representing 5 to 9 percent of projected gross sales.



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.

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

Nonexhaustive



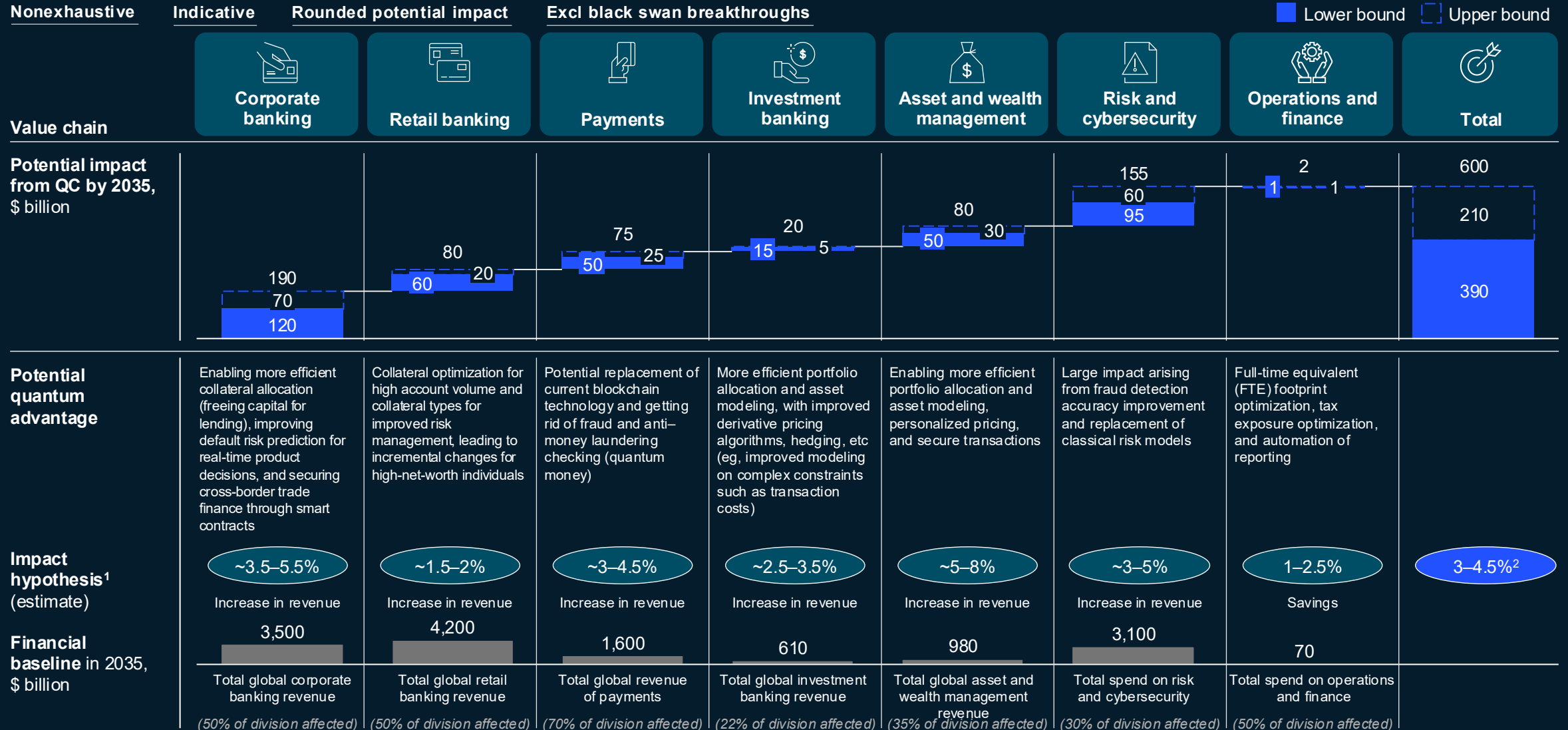
**Example impact:** HSBC and IBM demonstrating the world’s first-known quantum-enabled algorithmic trading<sup>1</sup> (2025)

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

| Description                                                                                                                                                                                                         | Impact levers <sup>2</sup>                                        |                                                                                     |                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------|
|                                                                                                                                                                                                                     | 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 <sup>3</sup> |

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.

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



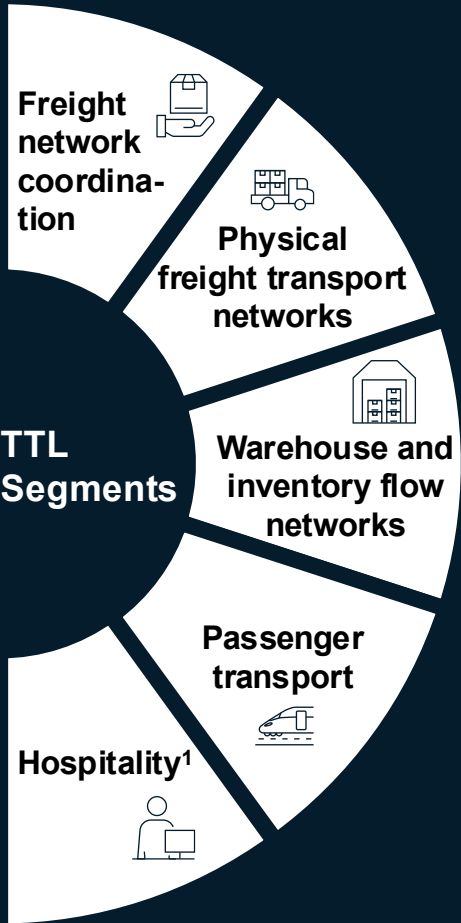
1. Savings are vs situation today, not vs future technology alternatives.

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<sup>2</sup> (2025)



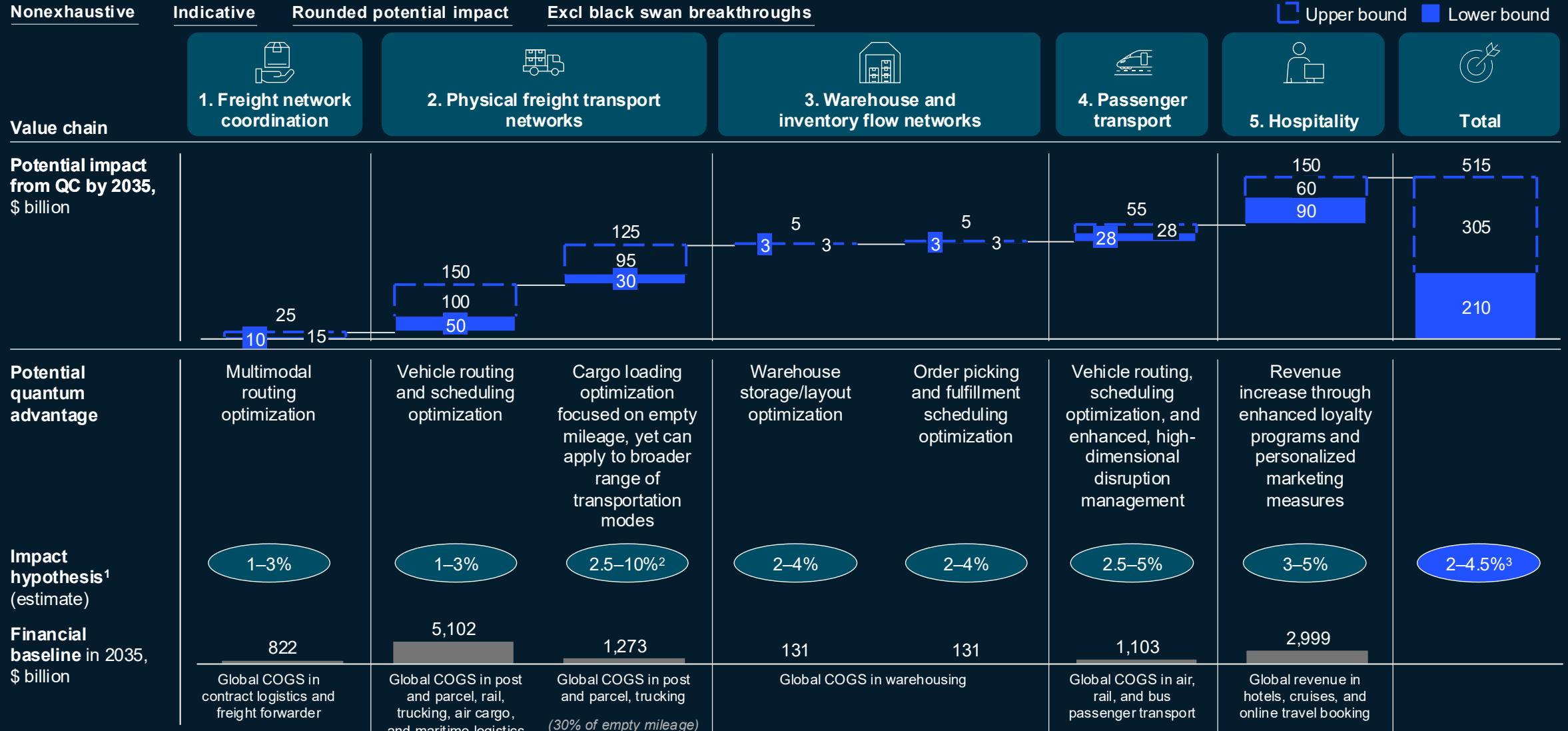
Individual use case implementation depends on multiple factors unique to each company

### Impact levers<sup>3</sup>

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

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



Note: Figures may not sum because of rounding.

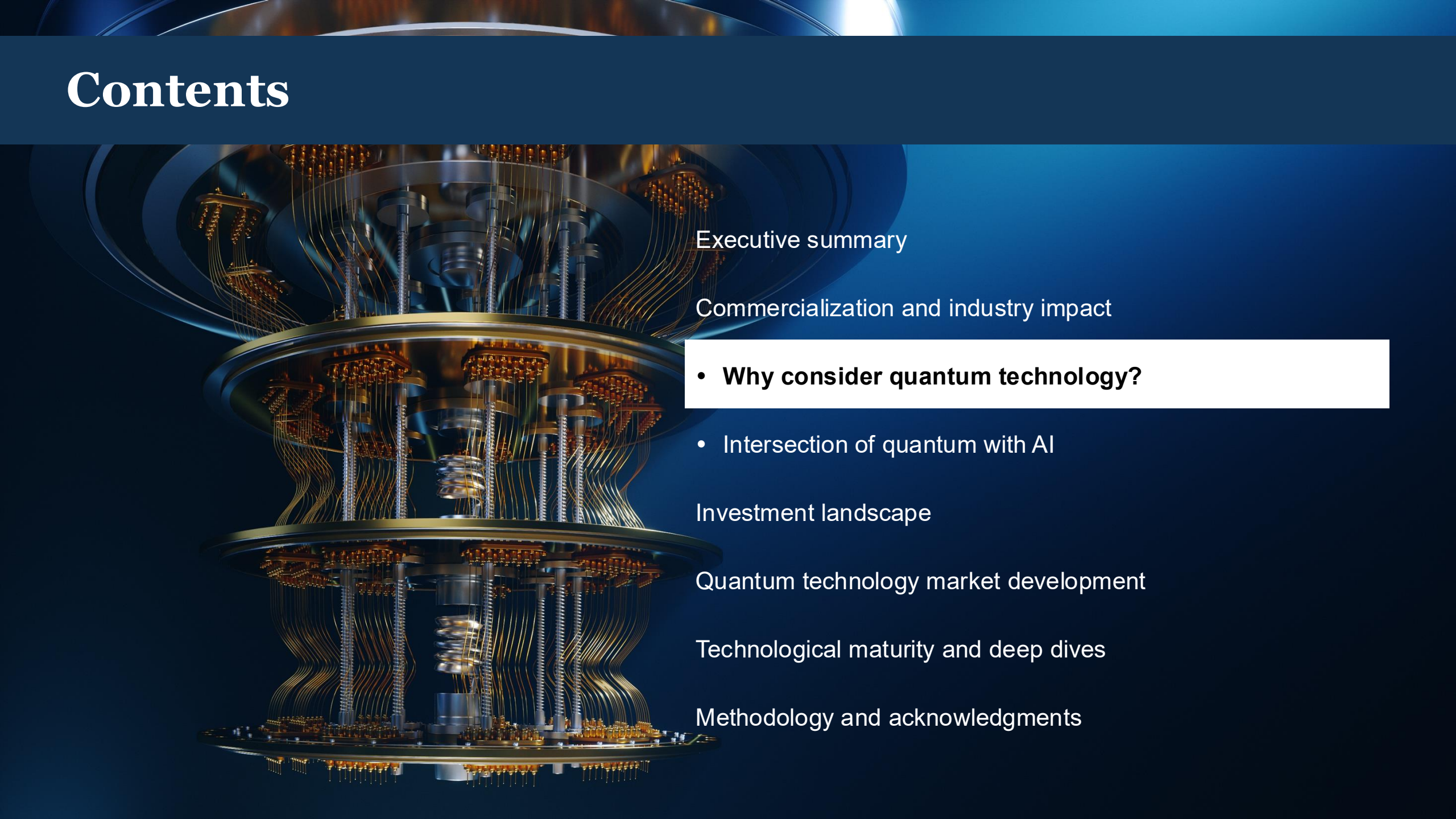
1. Savings are vs situation today, not vs future technology alternatives.

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

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- **Why consider quantum technology?**

- Intersection of quantum with AI

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# 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

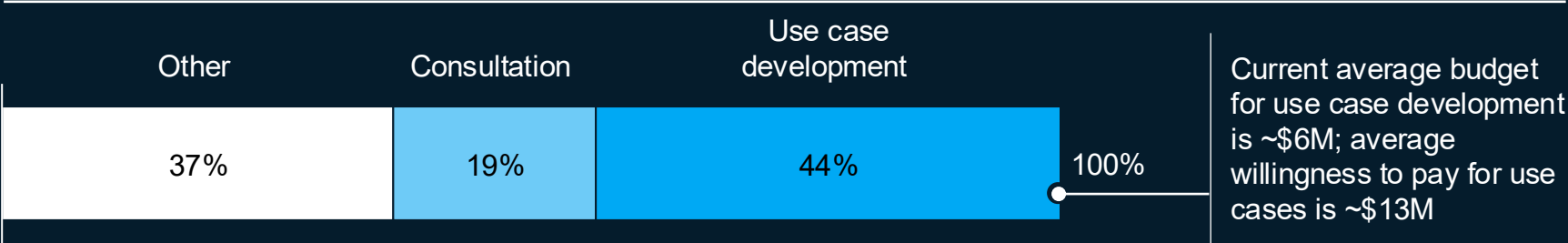


Late AI adopters paid a premium; QC could be at an inflection point

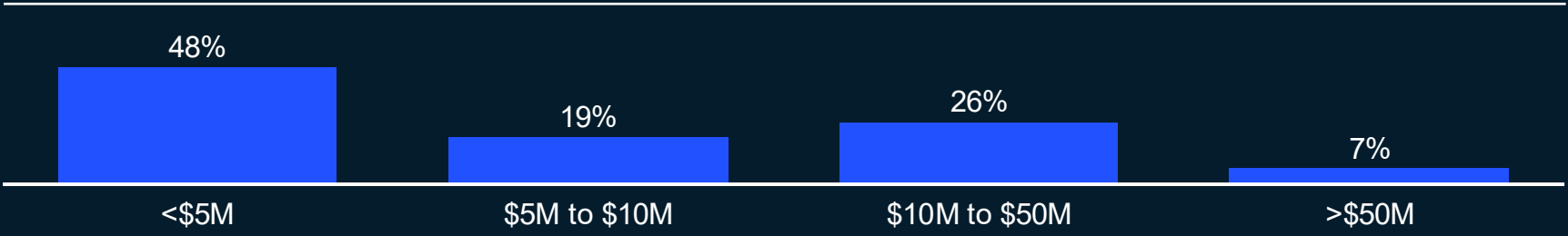
*As capital, talent, and access tighten, the cost of waiting is rising*

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

Distribution of yearly QC budget<sup>1</sup>, % 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

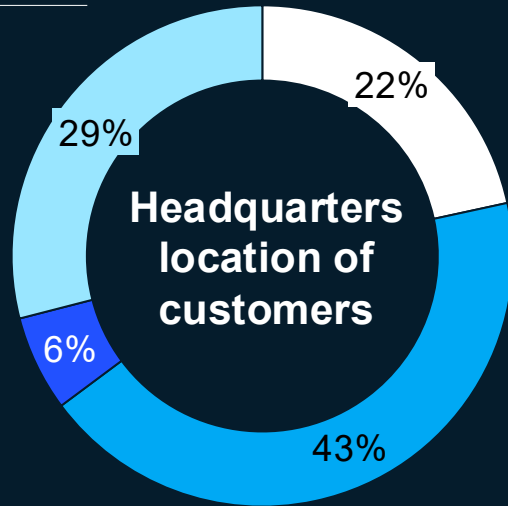
- QC customer study conducted in 2025, focusing on QC budgets, willingness to pay, and current challenges with implementing QC use cases
- Participants included C-level executives, heads of R&D, advanced-technology department leaders, and other decision-makers with budget responsibility
- 7% of all analyzed 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.

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

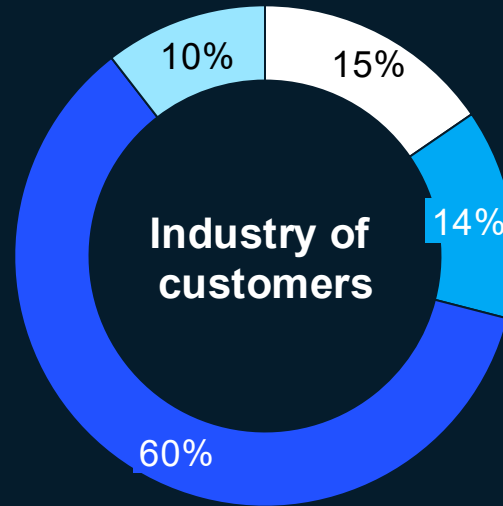
Distribution of analyzed QC customers, n = 162

Nonexhaustive



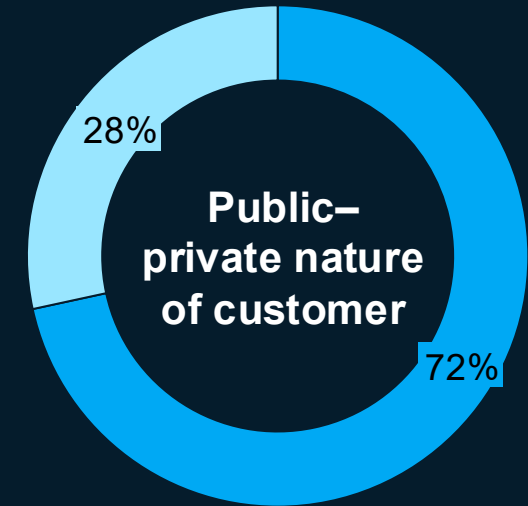
■ Asia ■ Other  
■ Europe ■ US

- 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)



■ Global energy and materials ■ Other  
■ Financial industry ■ Pharmaceuticals and medical products

- 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



■ Owned by private entities<sup>1</sup>  
■ Owned by public entities<sup>1</sup>

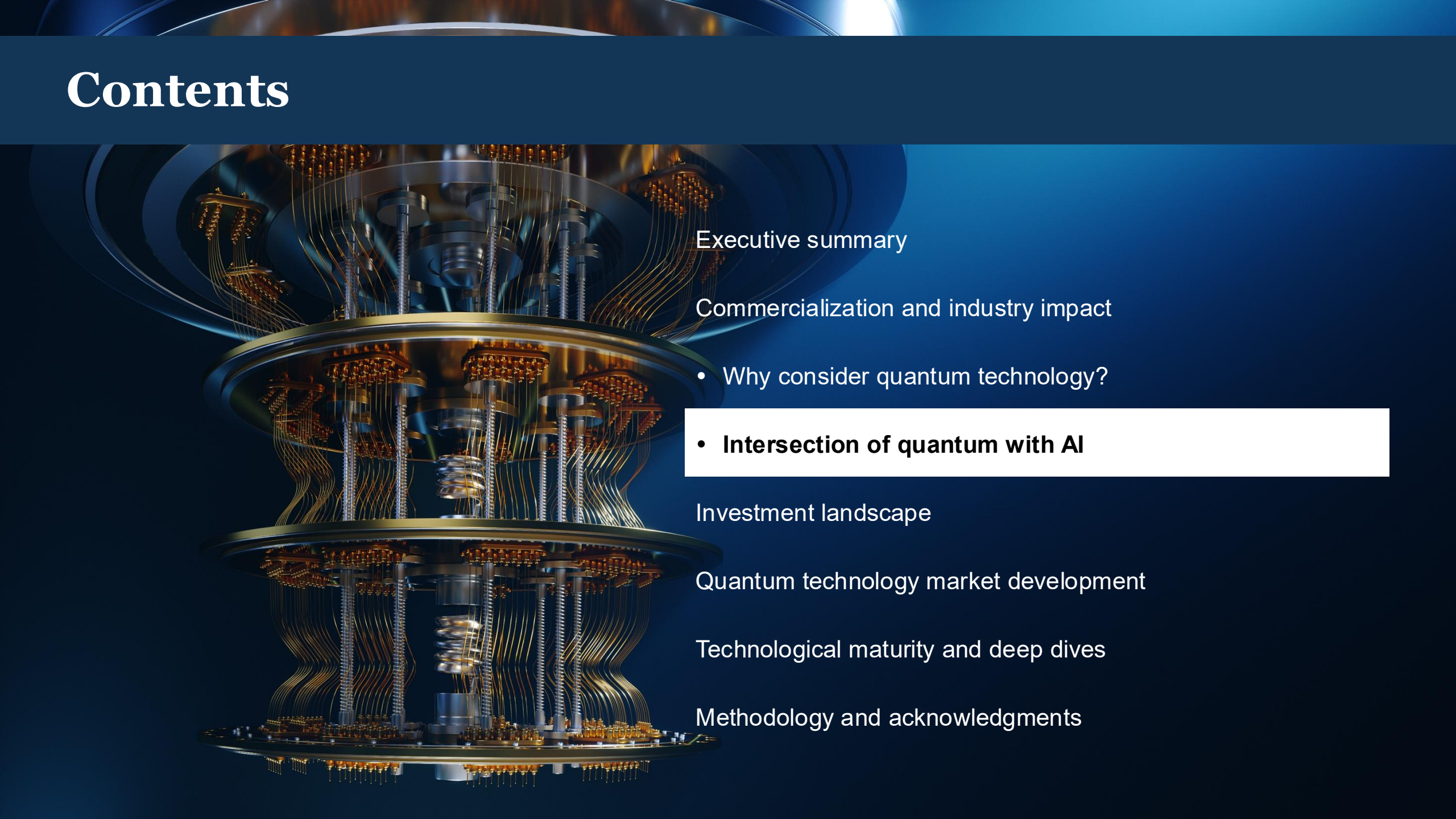
- The majority of customers are owned by private industries, reflecting the overall market trend toward private investments
- Customers owned by public entities can represent research institutions, governmental entities, and private companies owned by governments

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

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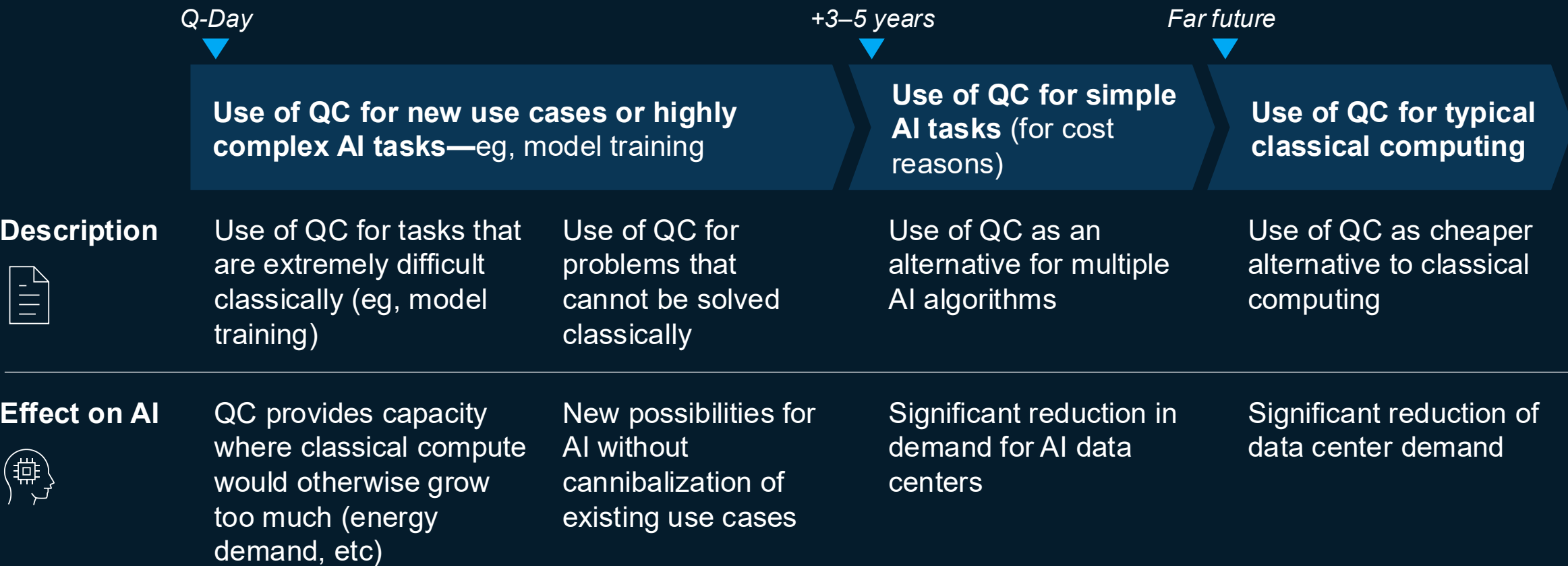
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# QC and AI can add value to each other in several areas.

Hypothetical   Indicative

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



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

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# 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



### 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



### 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<sup>1</sup>



### Quantum technologies: Product and service providers

Value generated from selling QT products and services

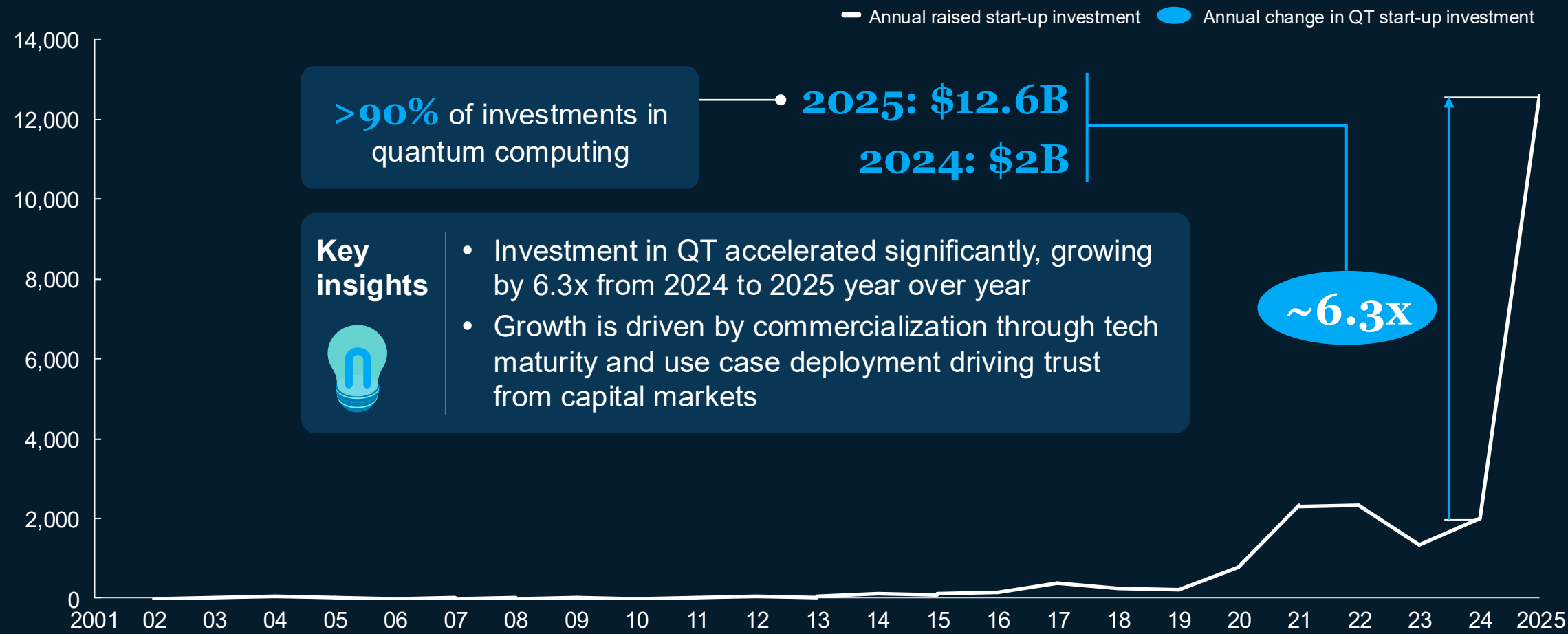
**\$60B–\$100B**

Market size for QT

1. Assuming valuation multiple of ~20x.

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

Investment volume by year,<sup>1</sup> \$ million

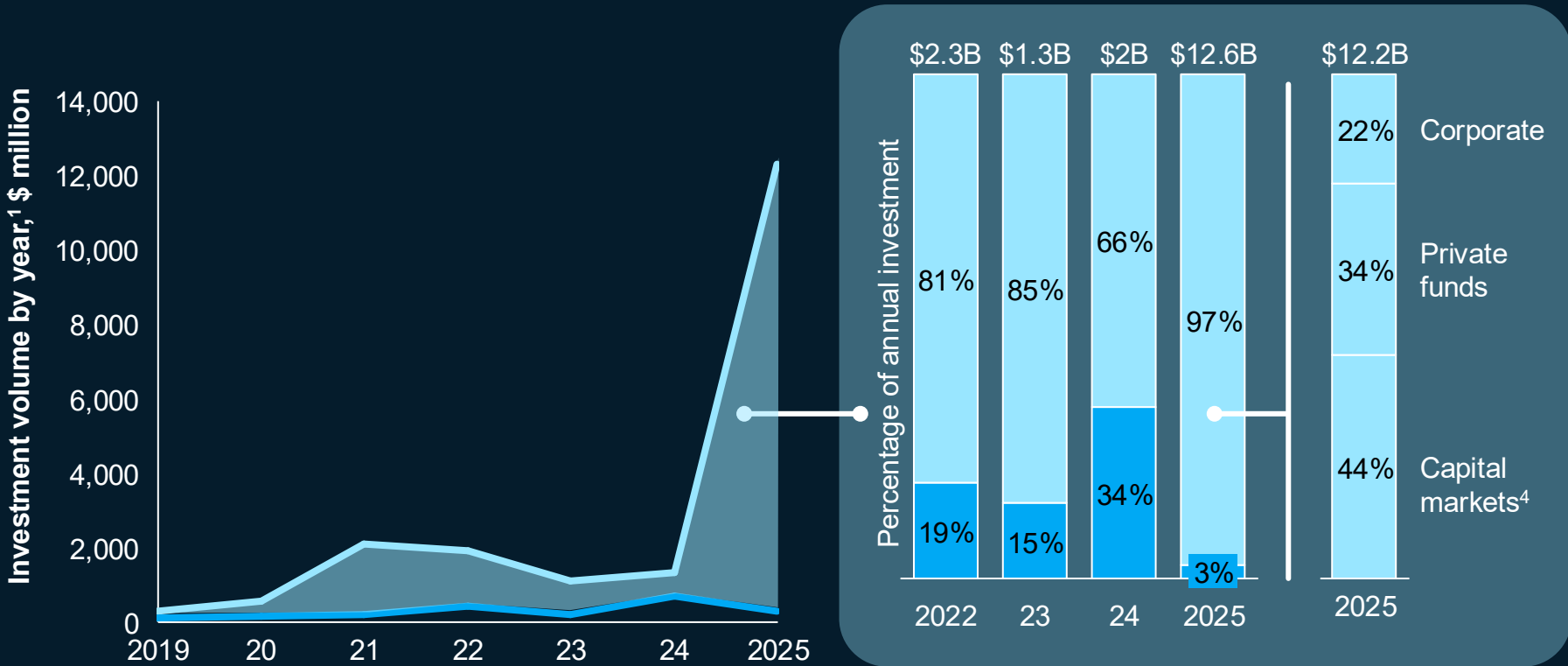


1. Based on investment data recorded in PitchBook, including investments via private markets (eg, VC funding and corporate investments), public markets (eg, IPOs, SPACs, secondary public offerings and PIPEs), and government/university funding; actual investment is likely higher (excludes investments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

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

Private<sup>2</sup> Government and institutional<sup>3</sup>

QT investments by funding type, 2019–25<sup>1</sup>



## 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.

# 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 <sup>1</sup>      | 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 |

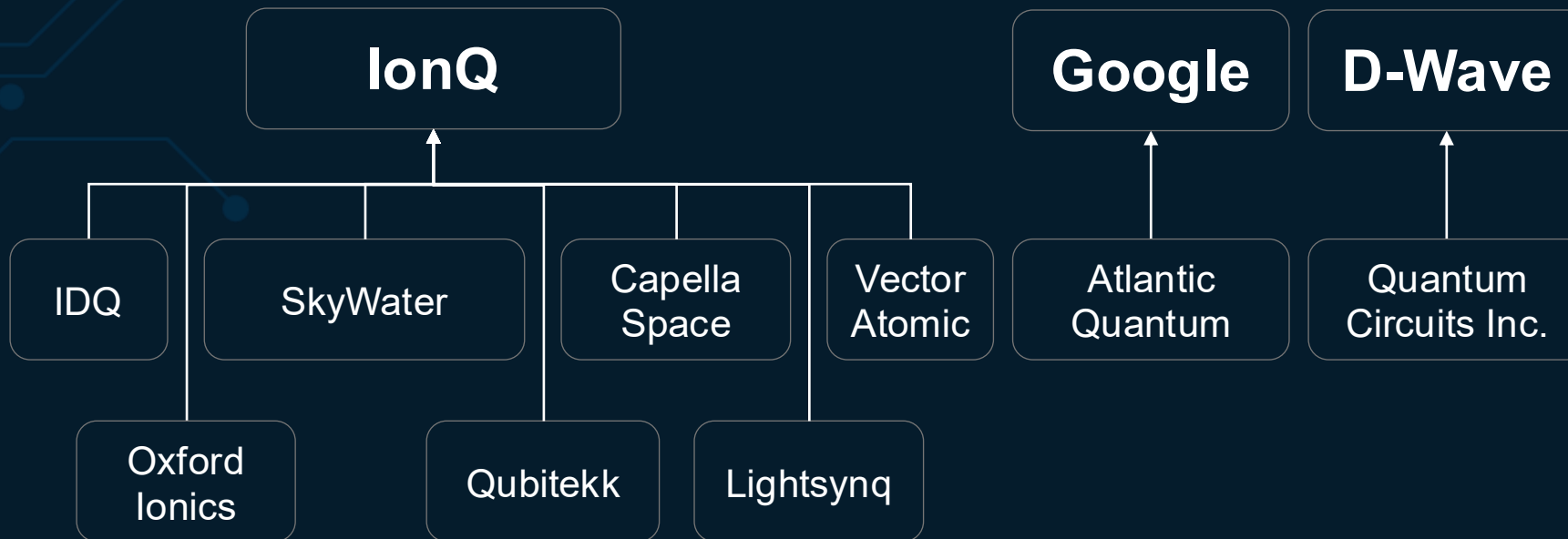
Total deal value includes IonQ shares

Total ~7,600 ~60% of total investments in 2025

# 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<sup>1</sup>



1. Includes some 2026 M&A activity.

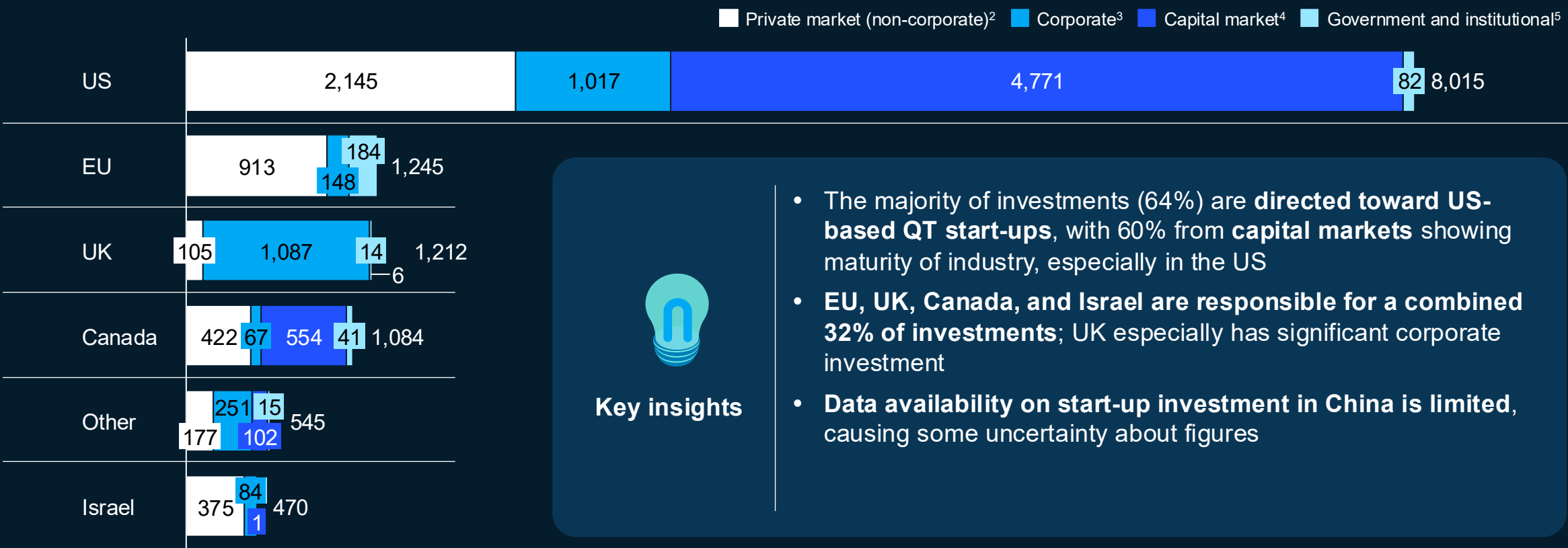
## Key insights



- 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

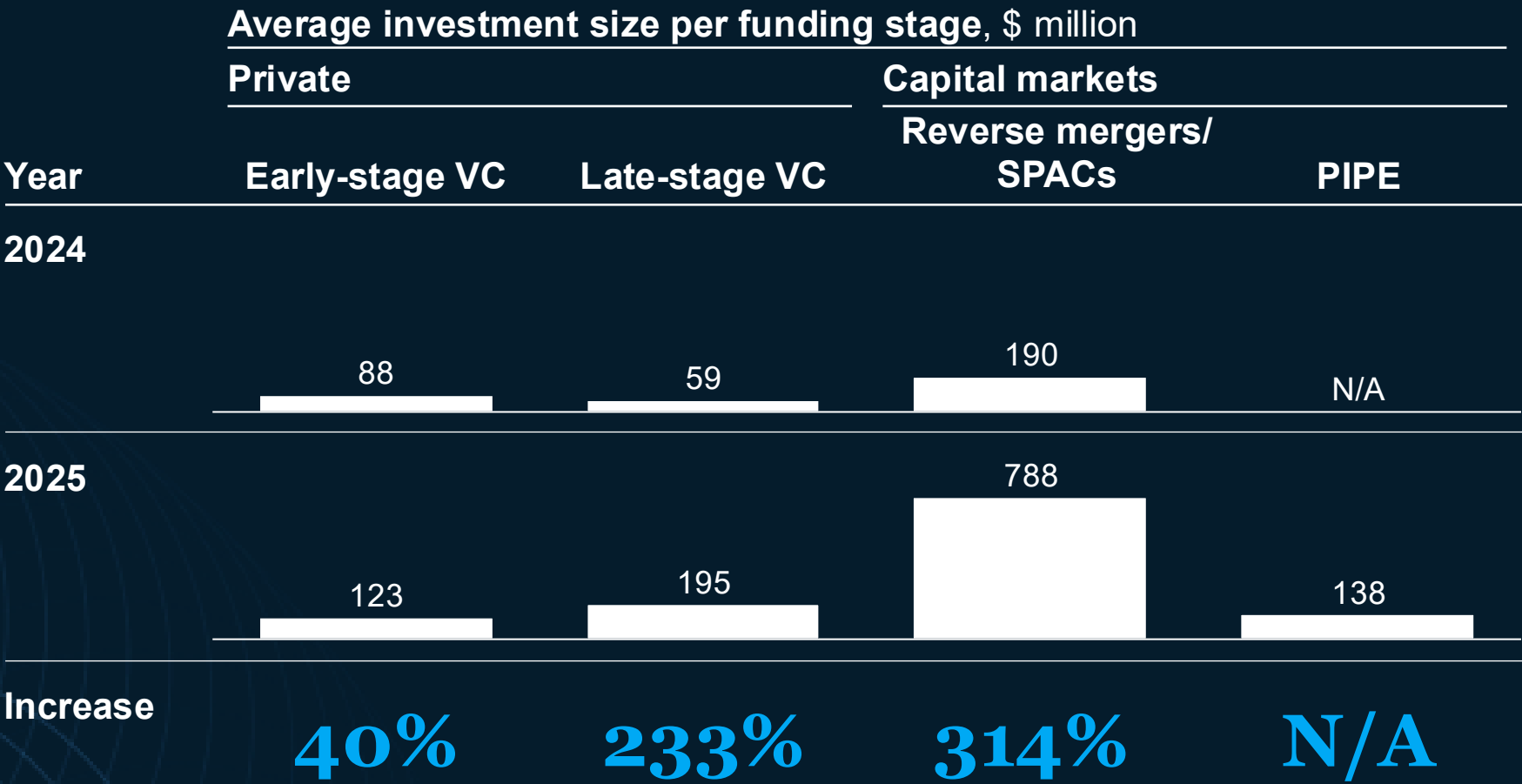
# In 2025, most QT start-up investment went to US-based companies, with capital markets providing the largest share of funding.

Total investment in QT by start-up location and primary investor type, 2025, \$ million<sup>1</sup>



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.

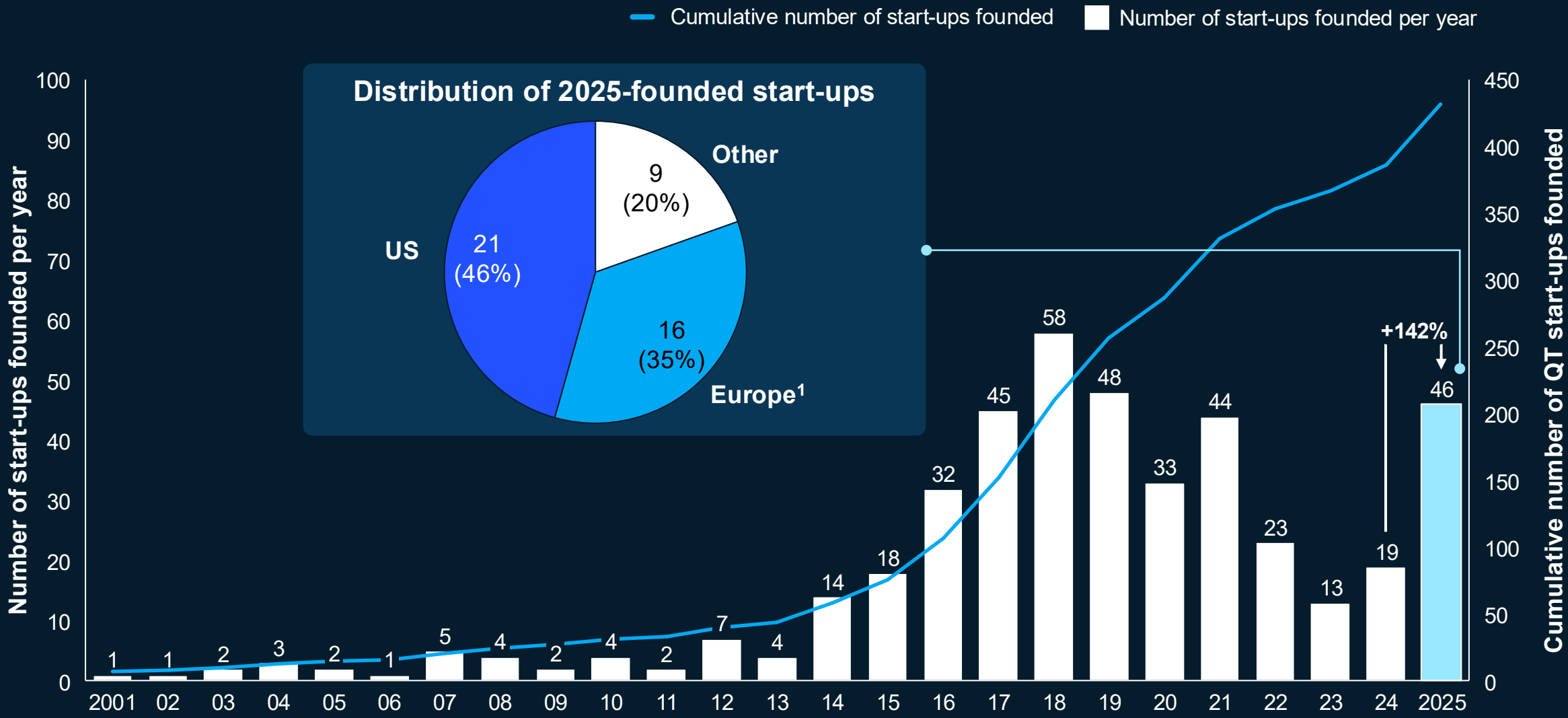
# Average round sizes increased significantly from 2024 to 2025, especially for QT companies going public.



## 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

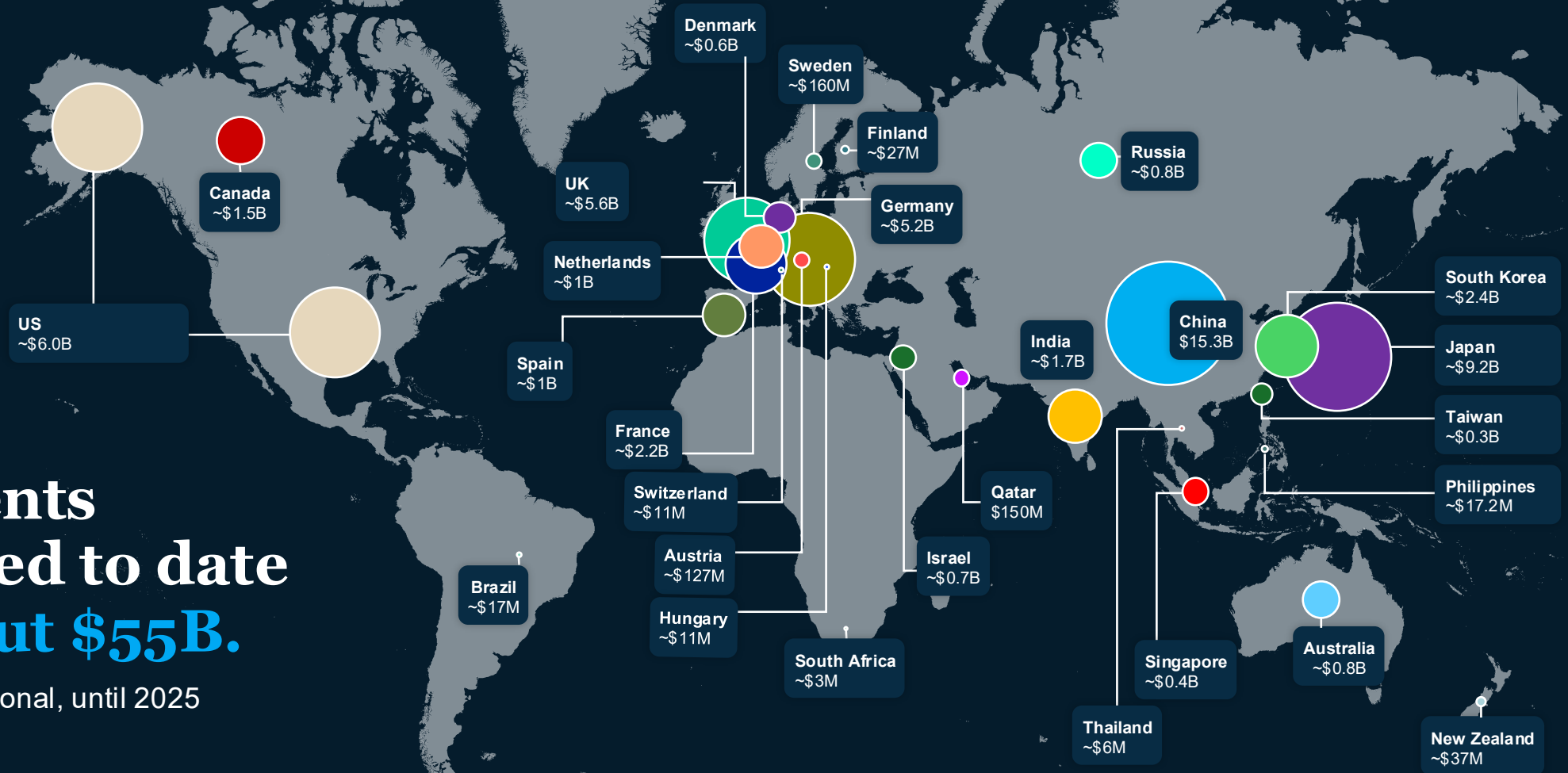
# QT start-up formation accelerated in 2025 amid rising investment volumes.



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

# National investments announced to date total about \$55B.

Estimated and directional, until 2025



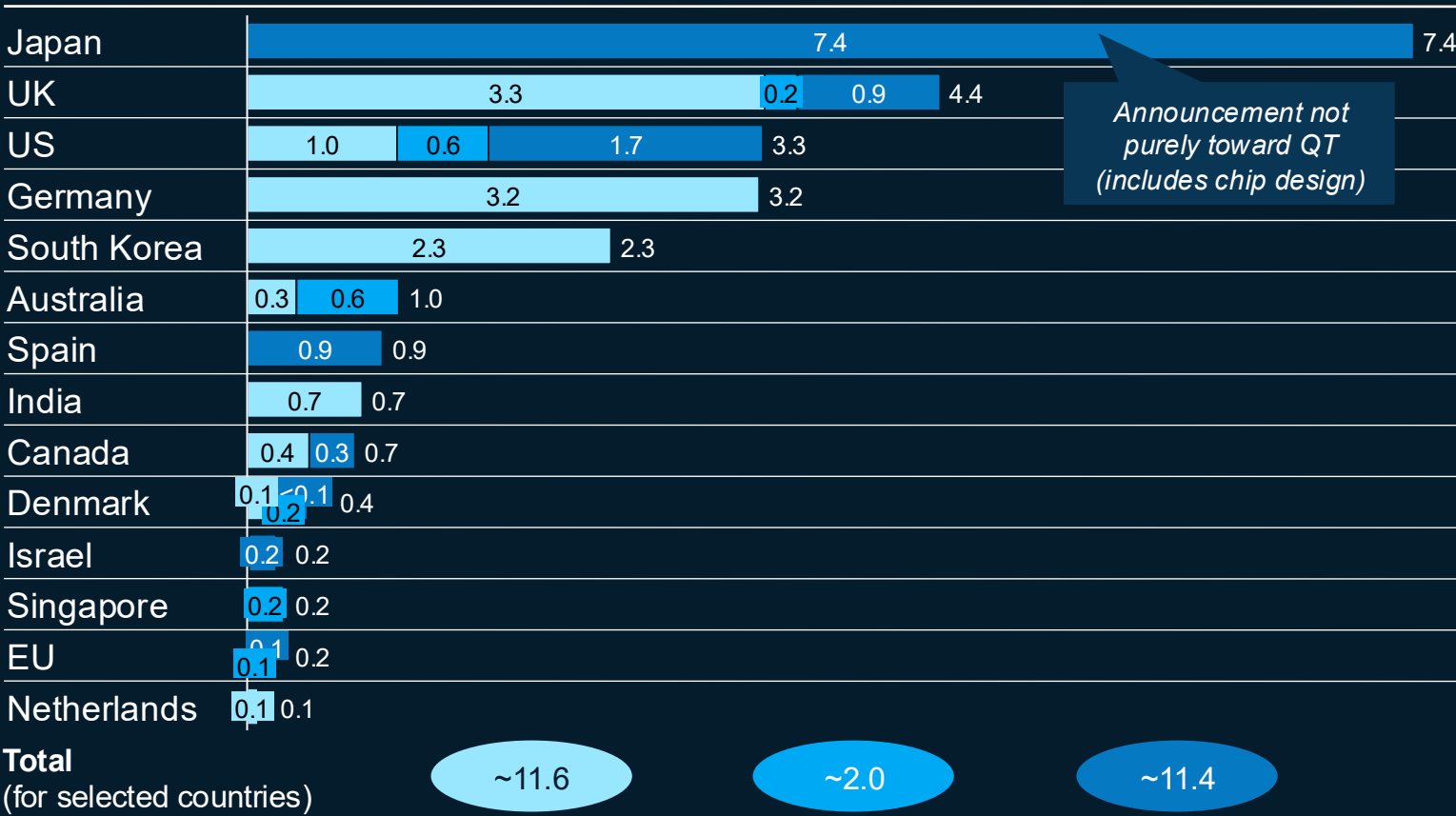
Note: Limited transparency on commercial activity in China; excludes the \$136B announced investment toward emerging technologies due to unclear relevance for QT. Excludes \$680M Swedish investment toward research and innovation, and US–Swedish investment of \$40M toward next-generation networks, AI, 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).

# 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



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).

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**\$1.3T–\$2.7T**

Value at stake from QC, excluding QS and QComm industry impact



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Value captured through increased valuation of QT companies and QT-exposed assets

**\$1.2T–\$2T**

Valuation of QT companies<sup>1</sup>



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Value generated from selling QT products and services

**\$60B–\$100B**

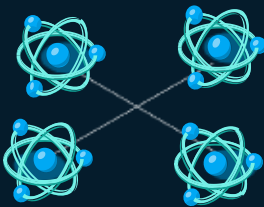
Market size for QT

1. Assuming valuation multiple of ~20x.

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

 Deep dive to follow     Conservative growth<sup>1</sup>     Optimistic growth

## QT market-size scenarios, 2035 and 2040

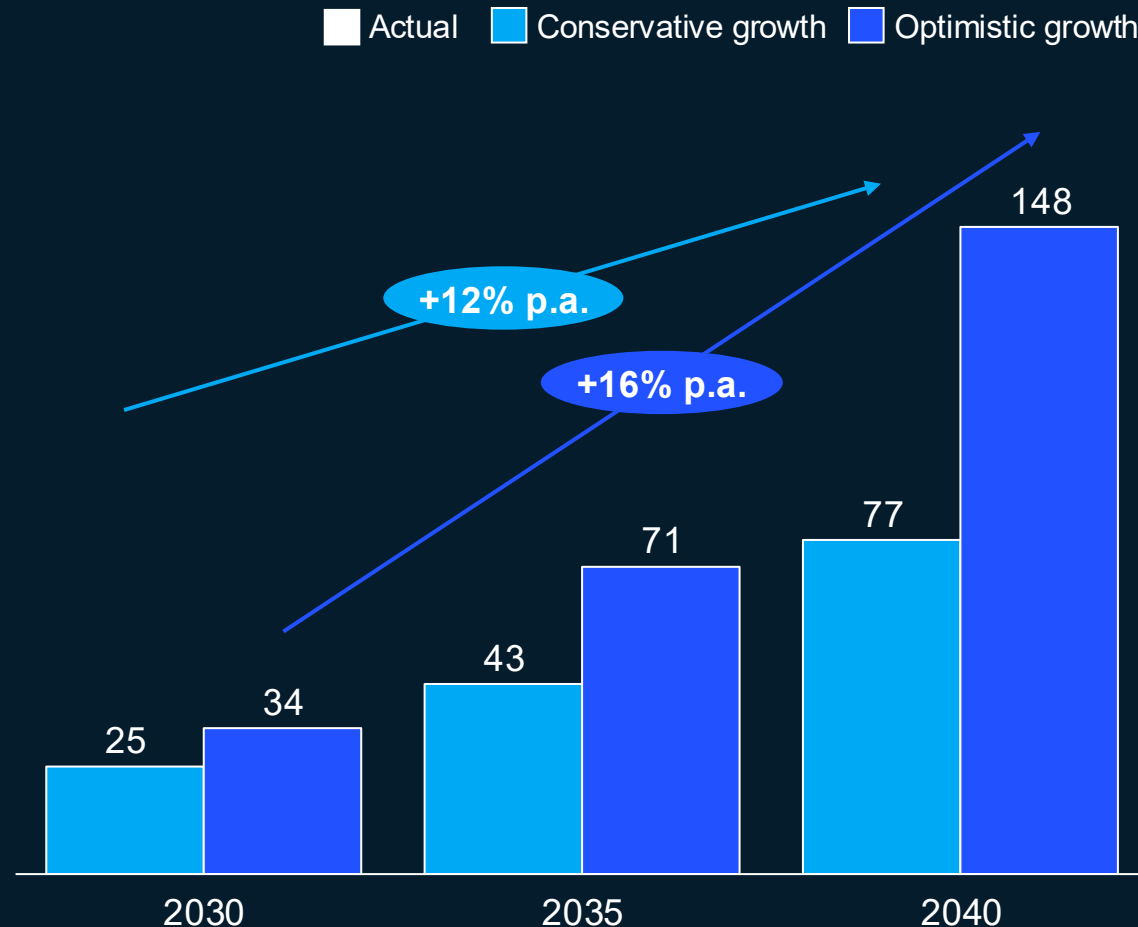
|      | <br>Quantum computing |        | <br>Quantum communication |       | <br>Quantum sensing <sup>2</sup> |       |
|------|--------------------------------------------------------------------------------------------------------|--------|--------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------|-------|
| 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.

# 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)



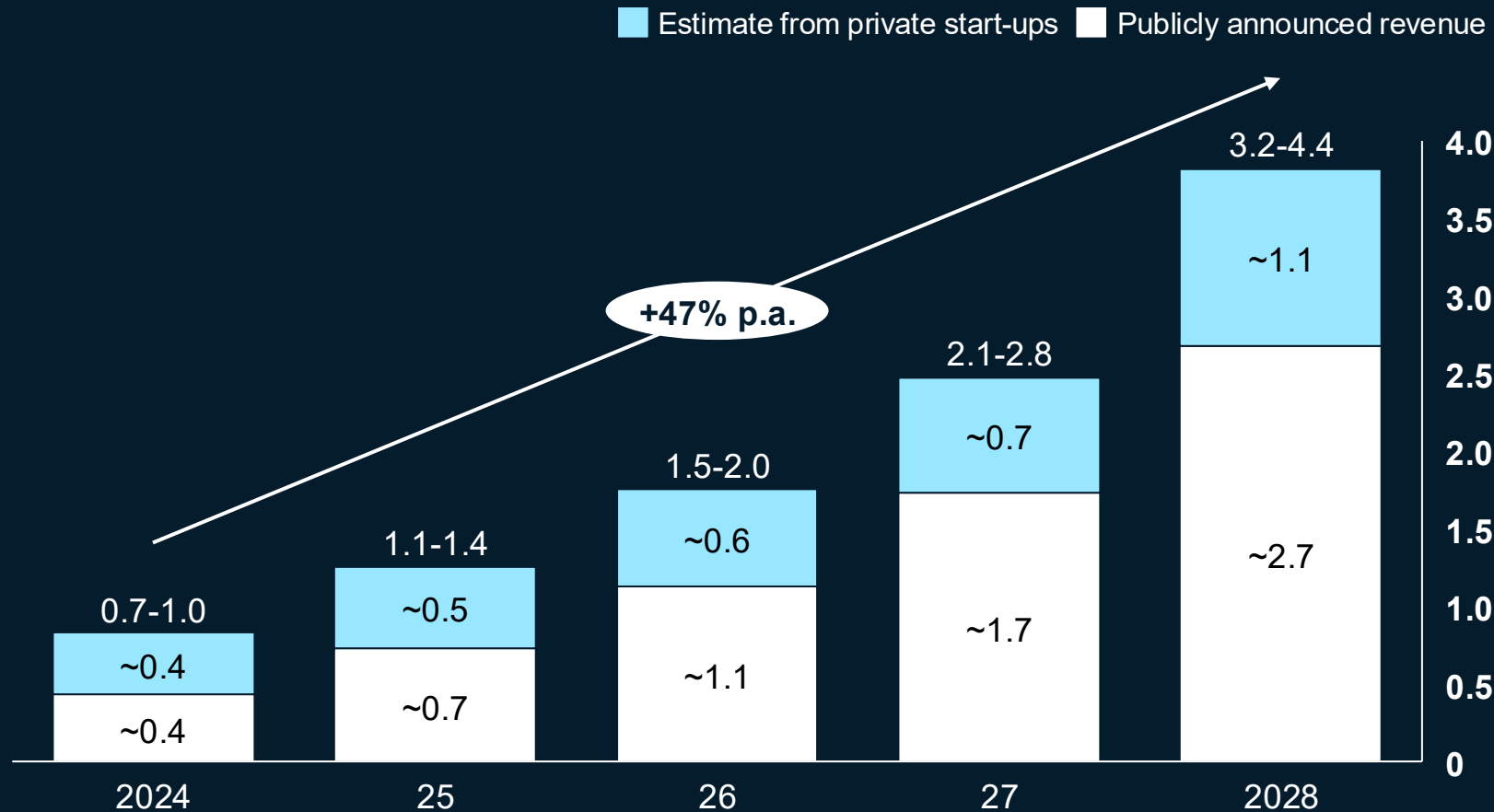
## Key insights



- **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

# 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



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

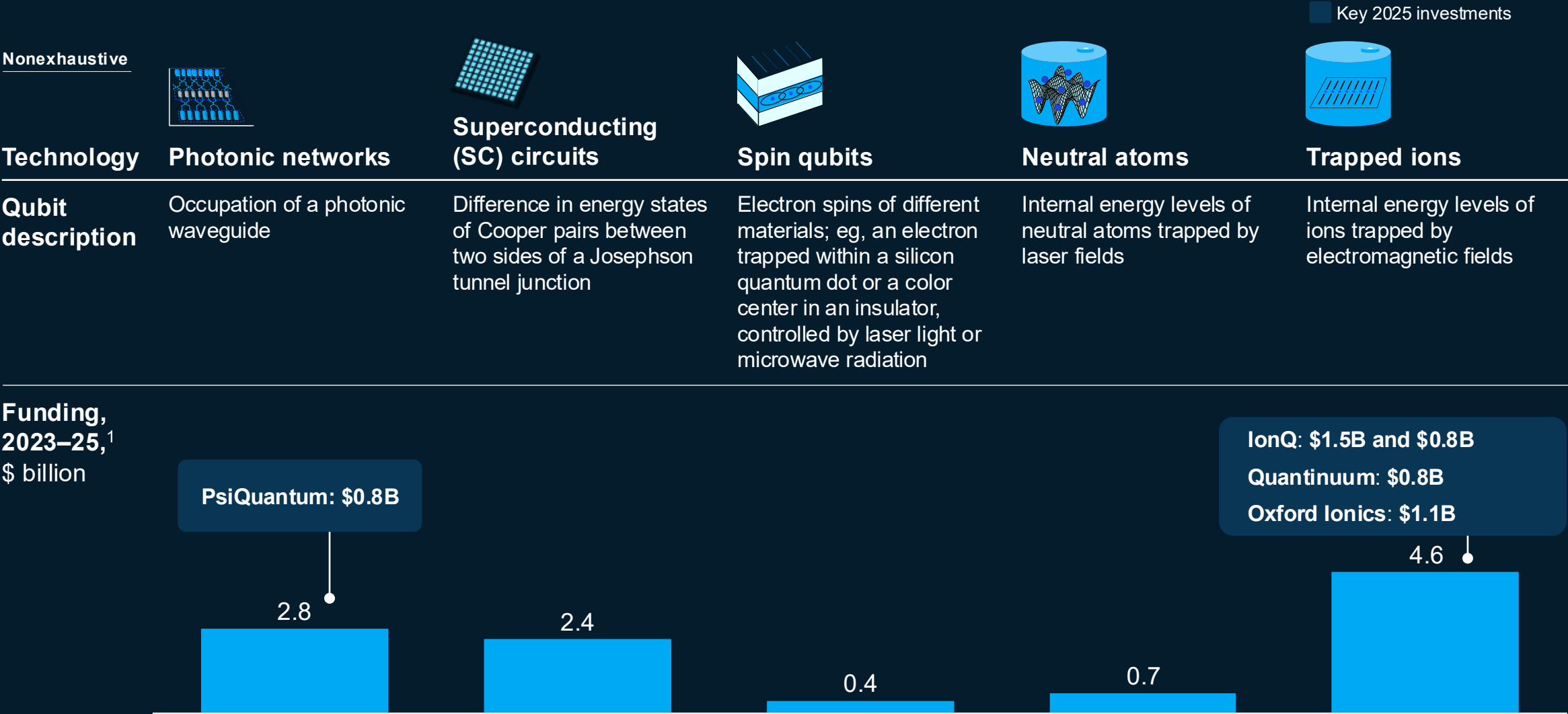
Source: Expert interviews; press search; McKinsey analysis

## 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

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



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).

# 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

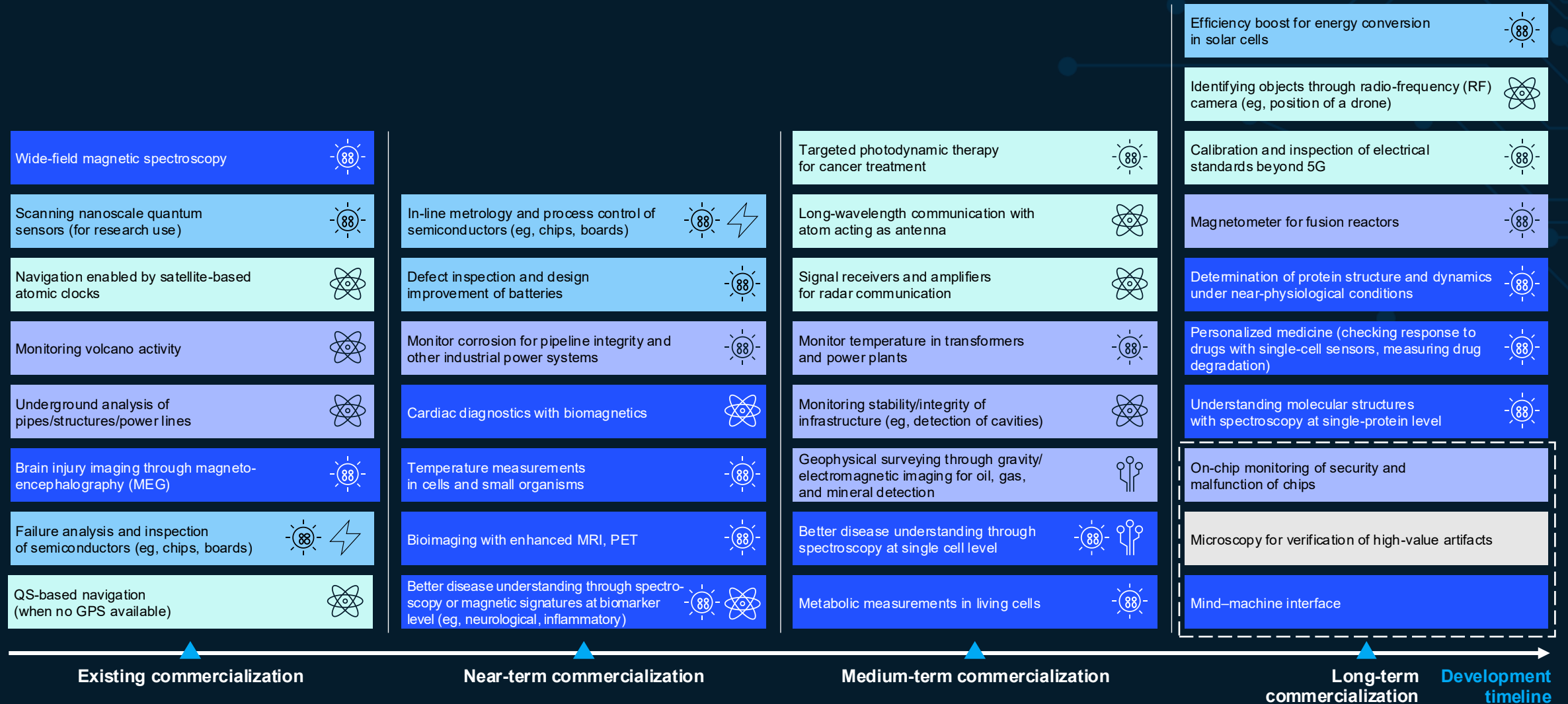
 Futuristic applications

## Industries

Life sciences  
Energy and materials  
Communication and logistics  
Microelectronics  
Others

## QS technologies

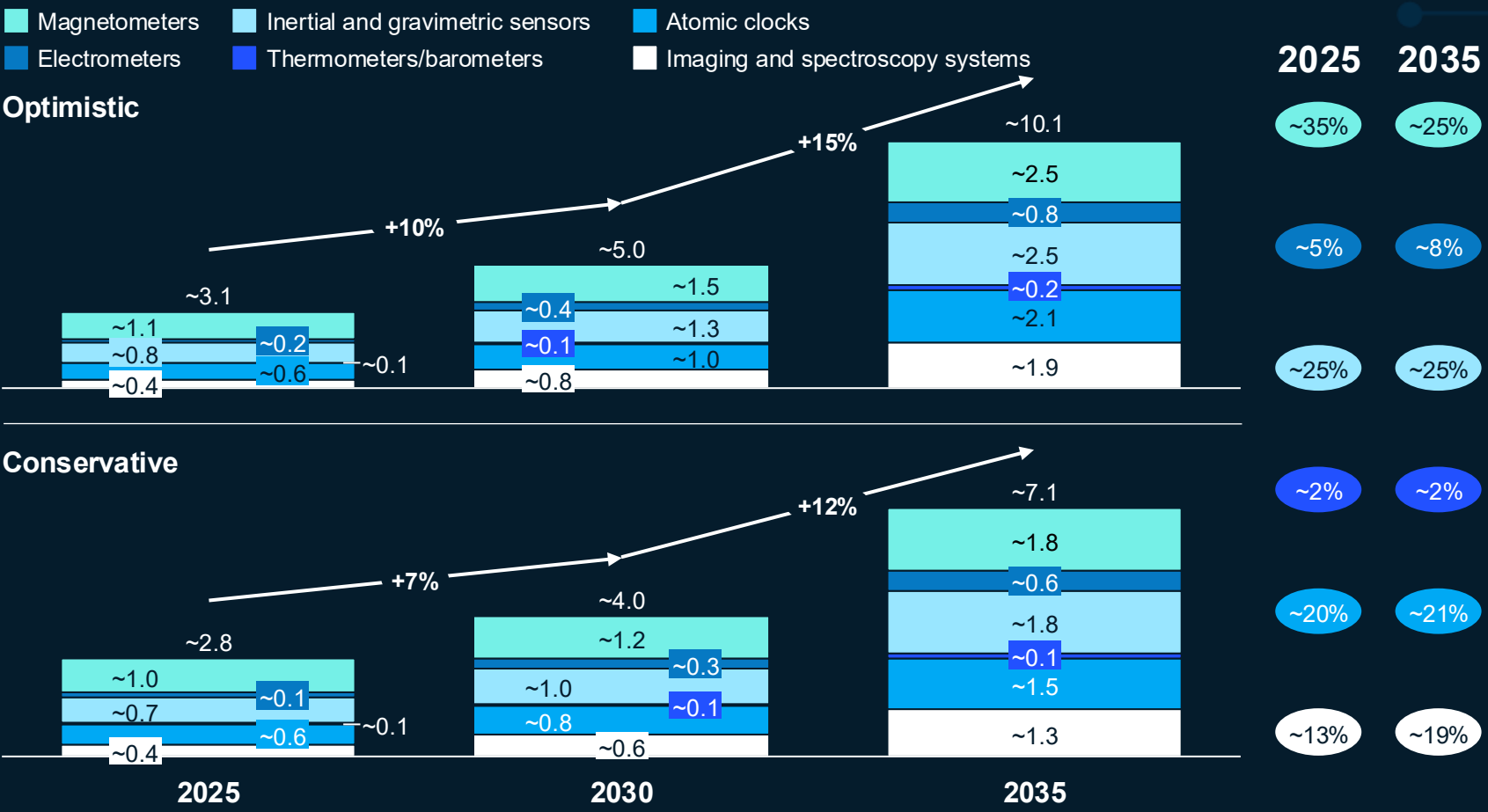
Solid state spins  
SC circuits  
Neutral atoms  
Photonics





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

QS market size, \$ billion



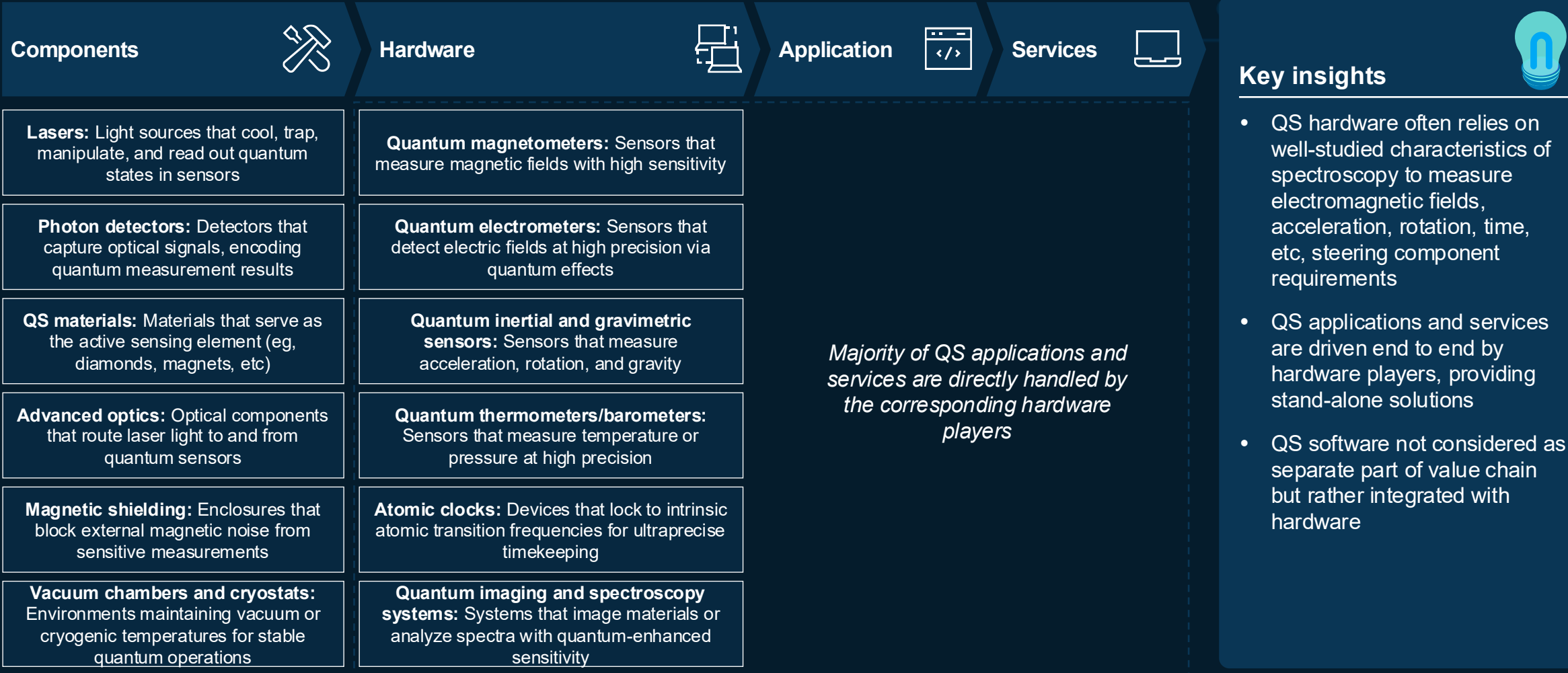
## Select growth rationales<sup>1</sup>

- 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.

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

Nonexhaustive



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

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

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- Hybrid computing and integration in data centers
- QT emerging ecosystems

Methodology and acknowledgments

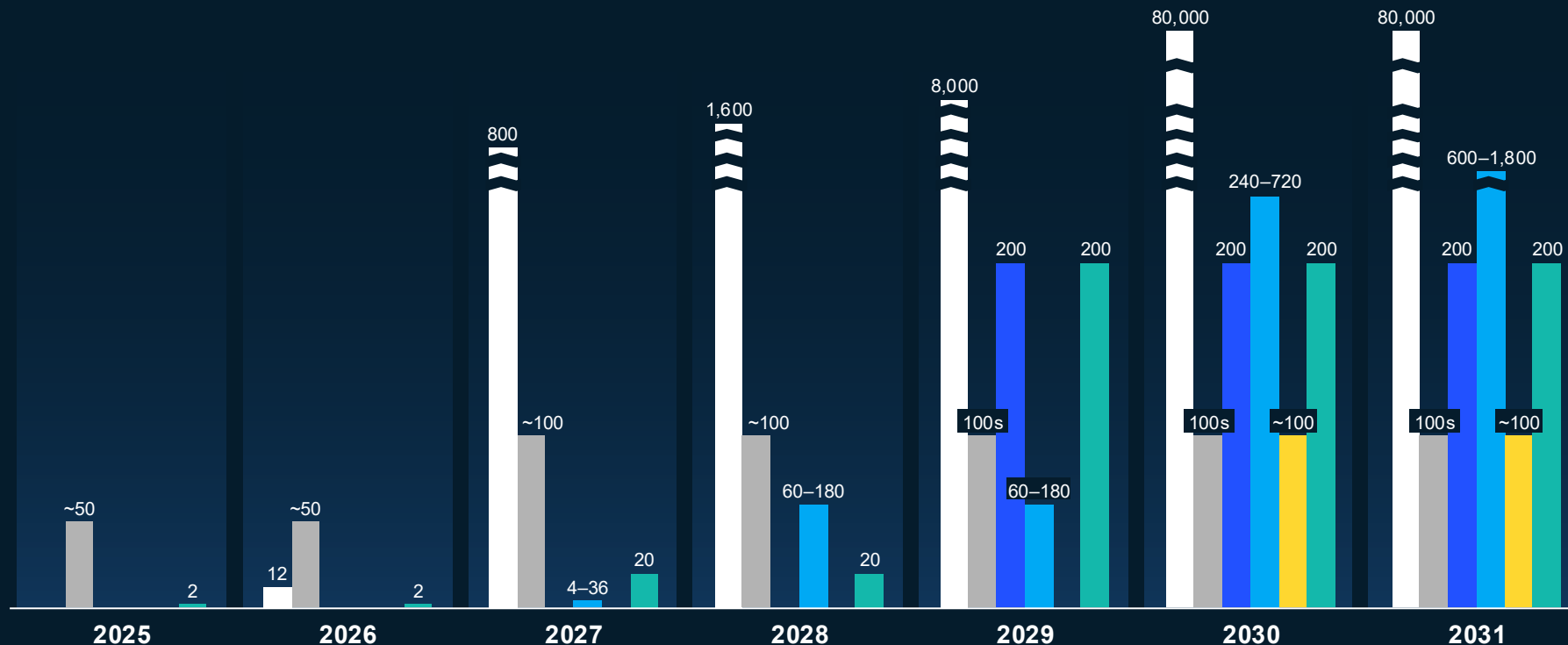
# Qubit road maps predict hundreds of logical qubits; qubit count alone does not fully describe computational capabilities.

Nonexhaustive

Trapped ions: IonQ Quantinuum | SC circuits: IBM<sup>2</sup> IQM | Cat qubits: Alice & Bob<sup>3</sup> | Neutral atoms: Pasqal

## Example logical qubit road maps<sup>1</sup>

(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.

# 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

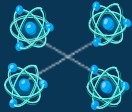
| Company    | Content of announcement                                                                                                                                                                                                     | What it means                                                                                                                                       | Announcement <sup>1</sup>                                                                                |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Google     | Deploying the “Quantum Echoes” algorithm on Willow chip to run molecular simulation tasks faster than classical supercomputers                                                                                              | Marks a practical demonstration of <b>verifiable quantum advantage</b> 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 <b>entry into quantum hardware</b> , expanding AWS from cloud access to full-stack quantum infrastructure                          | “AWS announces Ocelot, a new quantum computing chip” (2025)                                              |
| Microsoft  | Introducing the <b>Majorana 1</b> 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 <b>stable and scalable QC architecture</b> , 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 <b>scalable trapped-ion architecture</b> , control software, and cloud integration after acquisition of Oxford Ionics with its <b>record-setting ion-trap fidelity</b> and CMOS-compatible chip technology | <b>Shows prospect to unite</b> high-fidelity qubit technology with scalable, manufacturable hardware within <b>a single integrated stack</b>        | “IonQ Completes Acquisition of Oxford Ionics, Rapidly Accelerating Its Quantum Computing Roadmap” (2025) |
| Quantinuum | Launching Helios as the <b>most accurate commercial general-purpose QC</b> with industry-leading 99.921% 2-qubit gate fidelity for 98 physical qubits                                                                       | <b>Delivers a new performance benchmark</b> 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.

# 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)



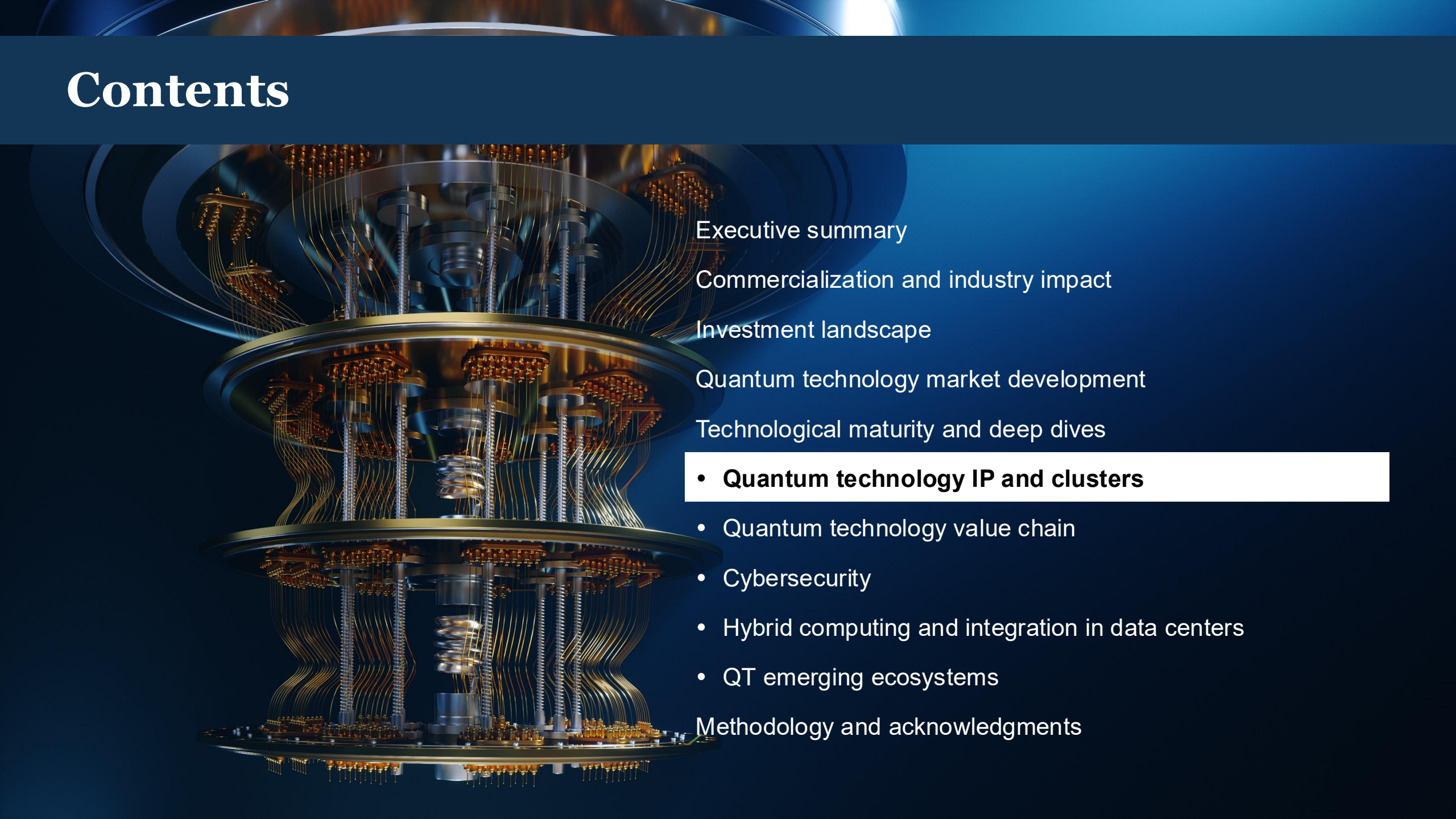
### QS

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

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

1. Based on publicly available data on company websites.

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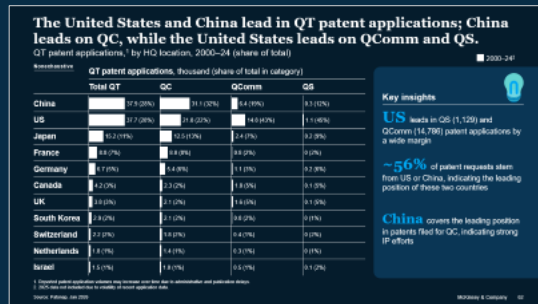
## Key insights

## Analyses

## Indicative

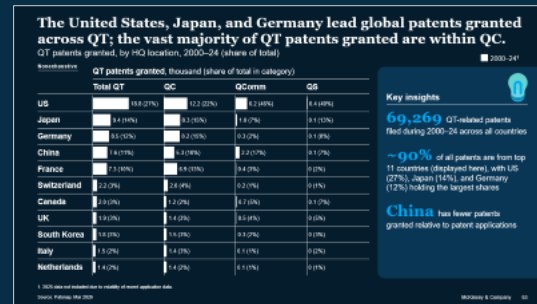
# Patent applications<sup>1</sup>

US and China lead in total QT patent applications; China leads on QC patent applications, while US leads on QComm and QS patent applications



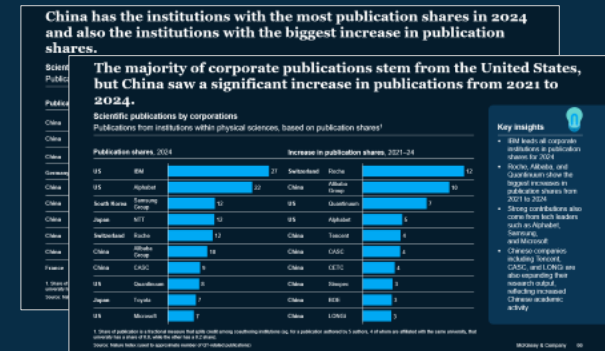
# Patents granted<sup>2</sup>

US, Japan, and Germany lead global patents granted across QT; vast majority of QT patents granted are within QC



## Publications

China has the institutions with the most publication shares in 2024, but the majority of corporate publications stem from the US



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.

# 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,<sup>1</sup> by HQ location, 2000–24 (share of total)

■ 2000–24<sup>2</sup>

Nonexhaustive

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

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

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.

## 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

# 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<sup>1</sup>

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

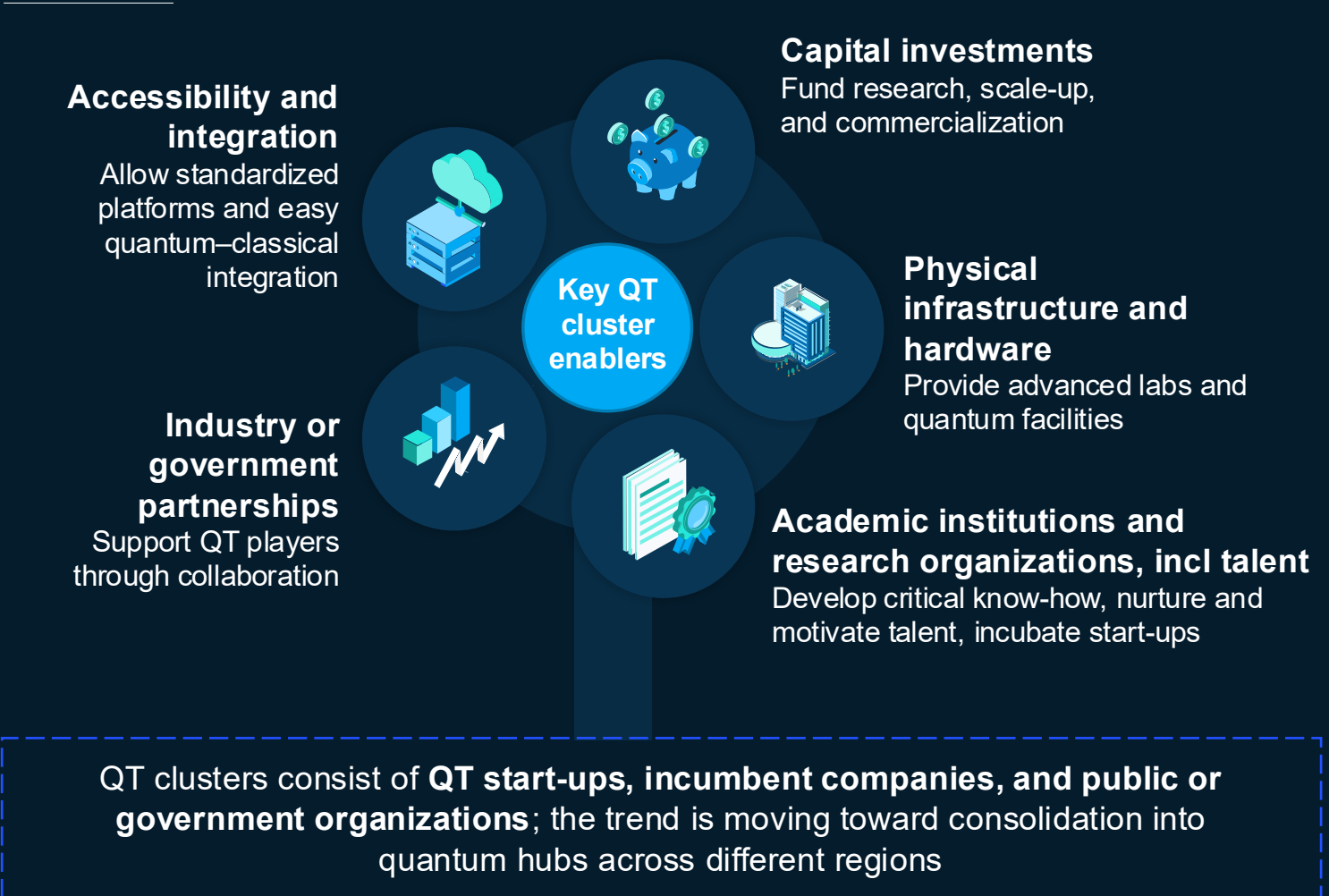
**China** has fewer patents granted relative to patent applications

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

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

Nonexhaustive

Existing clusters; example organizations   Emerging clusters; example organizations



## Examples of QT innovation clusters

|           |                                               |                                                             |                                 |          |        |
|-----------|-----------------------------------------------|-------------------------------------------------------------|---------------------------------|----------|--------|
| Boston    | Harvard University                            | MIT                                                         | QuEra Computing                 | AWS      | NVIDIA |
| Chicago   | University of Chicago                         | University of Illinois                                      | EeroQ                           | IBM      |        |
| Delft     | TU Delft                                      | Qbiox                                                       | 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 |        |

# 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<sup>1</sup>

| Publication shares, 2024 |                     | Increase in publication shares, 2021–24 |              | Increase in publication shares, 2021–24, non-Chinese |     |
|--------------------------|---------------------|-----------------------------------------|--------------|------------------------------------------------------|-----|
| China                    | CAS                 | 1,126                                   | China        | CAS                                                  | 498 |
| China                    | USTC                | 438                                     | China        | USTC                                                 | 212 |
| China                    | Tsinghua University | 409                                     | China        | Tsinghua University                                  | 197 |
| Germany                  | Max Planck Society  | 350                                     | China        | ZJU                                                  | 171 |
| China                    | UCAS                | 338                                     | China        | SJTU                                                 | 163 |
| China                    | ZJU                 | 336                                     | China        | NJU                                                  | 162 |
| China                    | NJU                 | 334                                     | China        | UCAS                                                 | 158 |
| China                    | PKU                 | 334                                     | China        | PKU                                                  | 150 |
| China                    | SJTU                | 311                                     | China        | JLU                                                  | 142 |
| France                   | CNRS                | 263                                     | China        | XJTU                                                 | 132 |
|                          |                     |                                         | 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  |

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)



### 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

# 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<sup>1</sup>

| Publication shares, 2024 |               |    | Increase in publication shares, 2021–24 |               |    |
|--------------------------|---------------|----|-----------------------------------------|---------------|----|
| US                       | IBM           | 27 | Switzerland                             | Roche         | 12 |
| US                       | Alphabet      | 22 | China                                   | Alibaba Group | 10 |
| South Korea              | Samsung Group | 12 | US                                      | Quantinuum    | 7  |
| Japan                    | NTT           | 12 | US                                      | Alphabet      | 5  |
| Switzerland              | Roche         | 12 | China                                   | Tencent       | 4  |
| China                    | Alibaba Group | 10 | China                                   | CASC          | 4  |
| China                    | CASC          | 9  | China                                   | CETC          | 4  |
| US                       | Quantinuum    | 8  | China                                   | Sinopec       | 3  |
| Japan                    | Toyota        | 7  | China                                   | BOE           | 3  |
| US                       | Microsoft     | 7  | China                                   | LONGi         | 3  |

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)



### 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

# 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

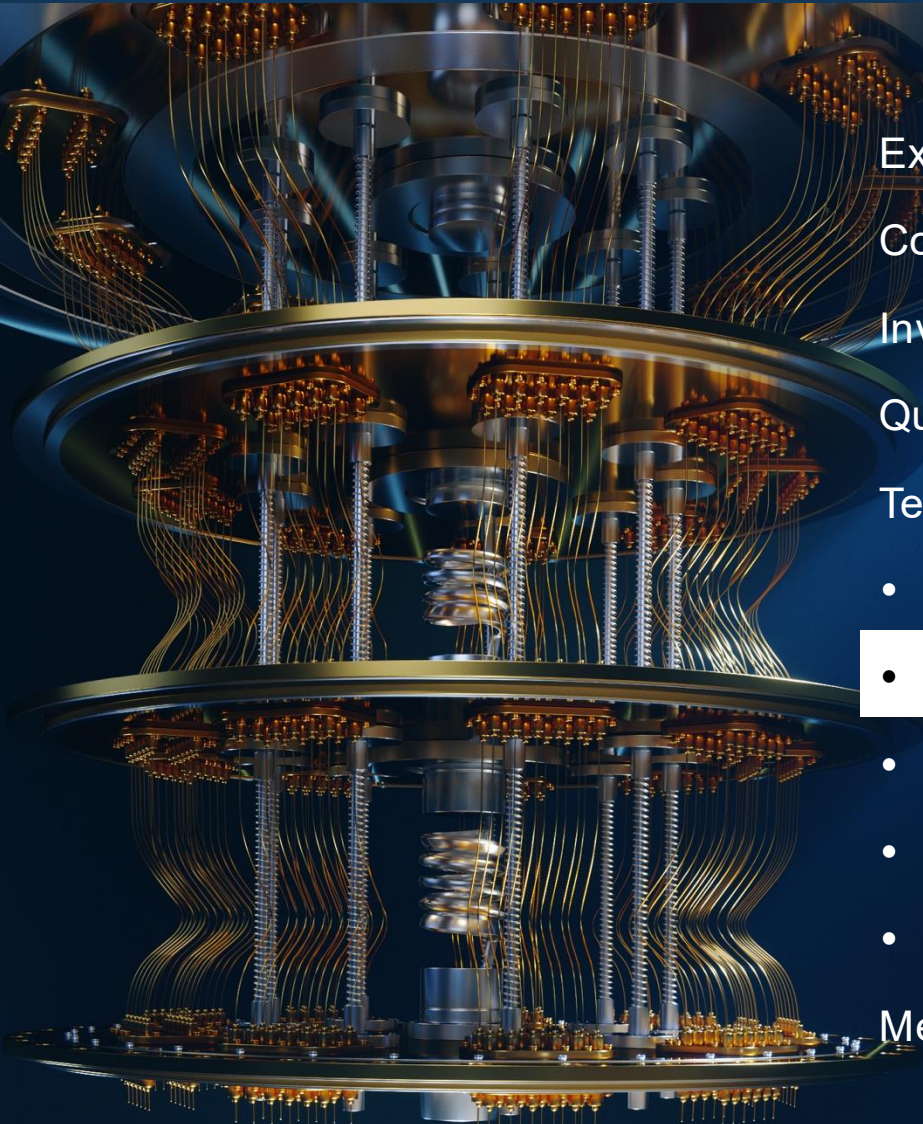
**Zapata  
Quantum**



## 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

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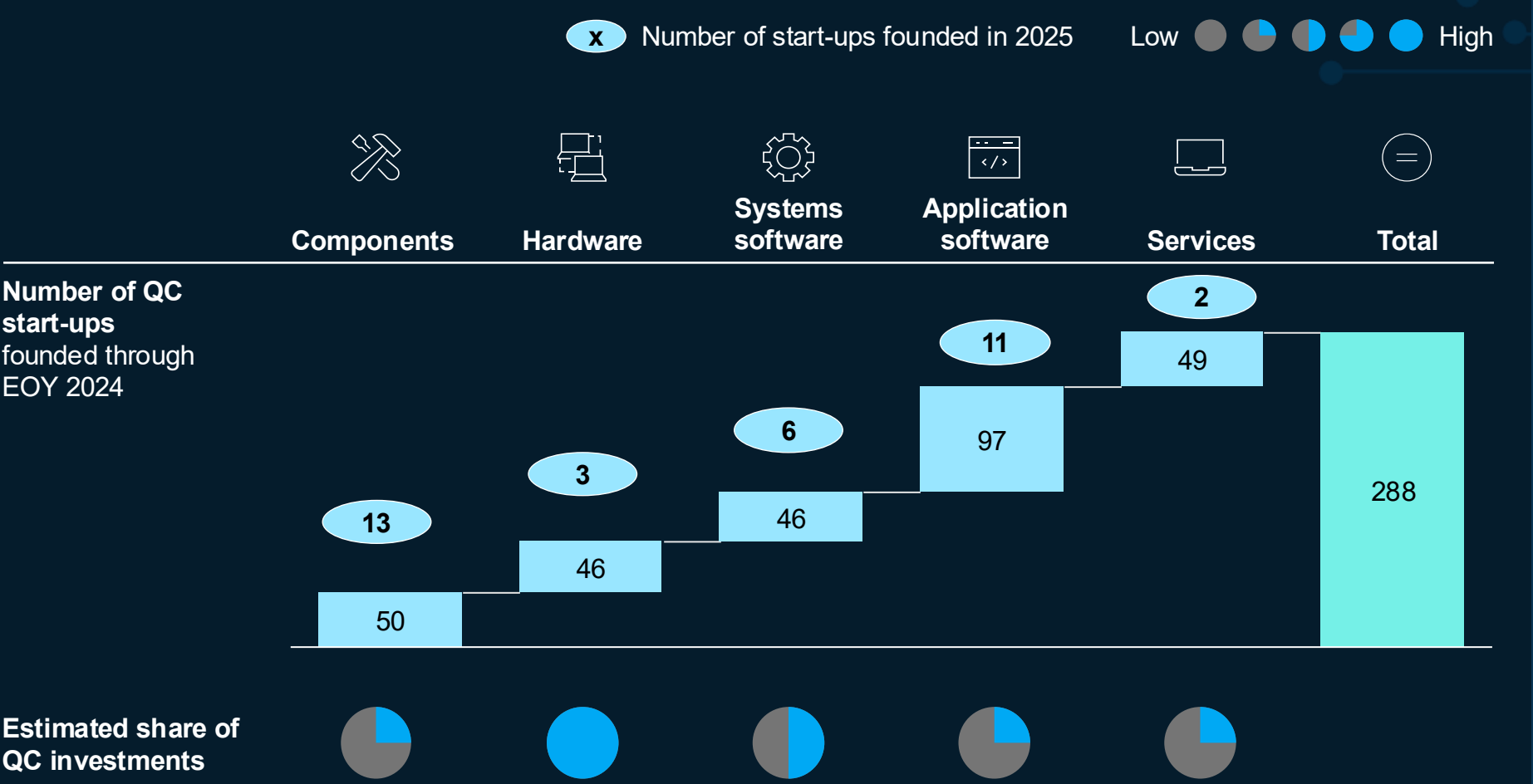
Technological maturity and deep dives

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- **Quantum technology value chain**
- Cybersecurity
- Hybrid computing and integration in data centers
- QT emerging ecosystems

Methodology and acknowledgments

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

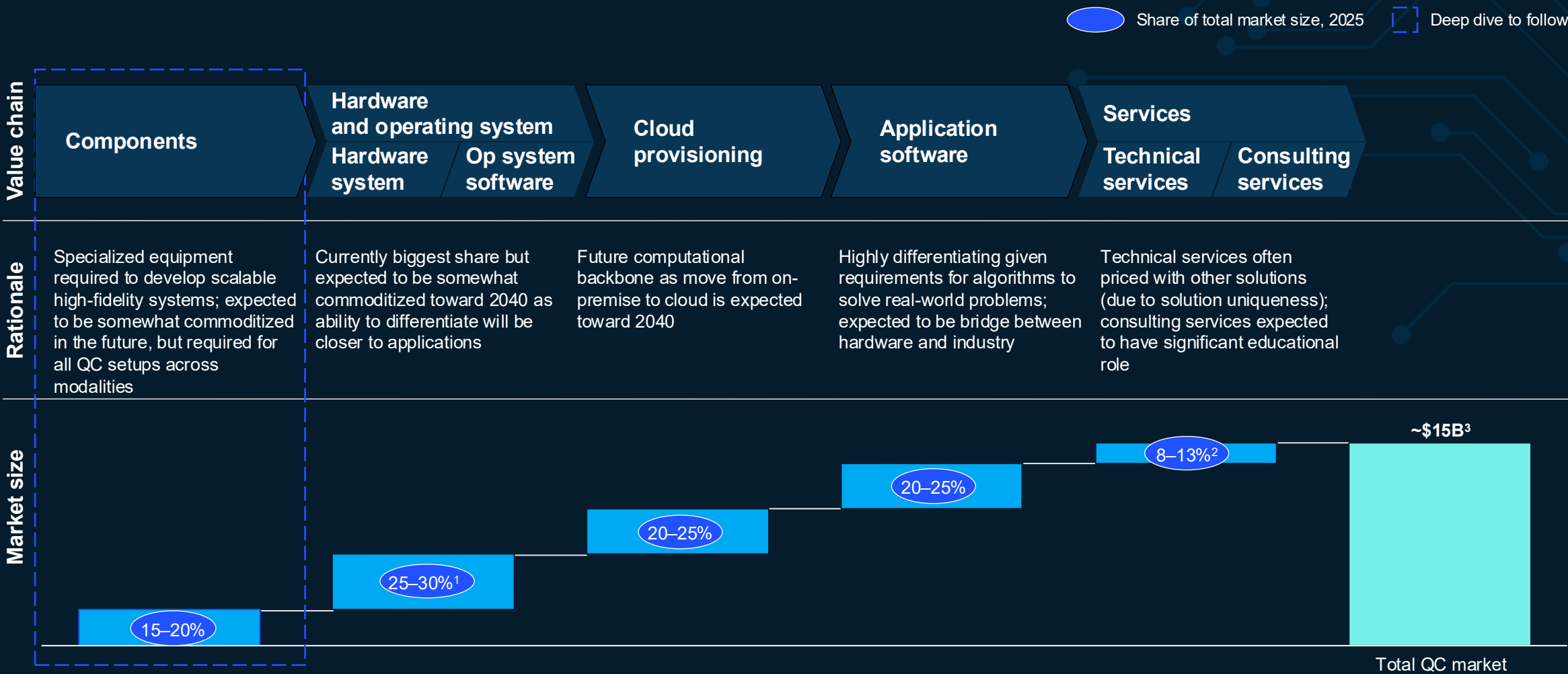
Number of QC start-ups, by value chain segment



### 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

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



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).

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

Nonexhaustive

Selected areas  
of supply chain

Role for QC

Challenges and  
potential  
bottlenecks

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

## Microwave or radio frequency control

Control and measure microwave or radio frequency–based qubit setups (eg, SC and spin; trapped ions can be either optical or microwave-based)

- 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)

## Specialized lasers and optical systems

Control and measure optical qubit setups (can have relevance for all modalities but SC); reliable high-precision lasers required for high-fidelity qubit manipulation

- 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

## Cryogenics and vacuum chambers

Control qubit environments through ultracold cryostats or vacuum chambers (depending on modality); required to minimize noise in qubits

- 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

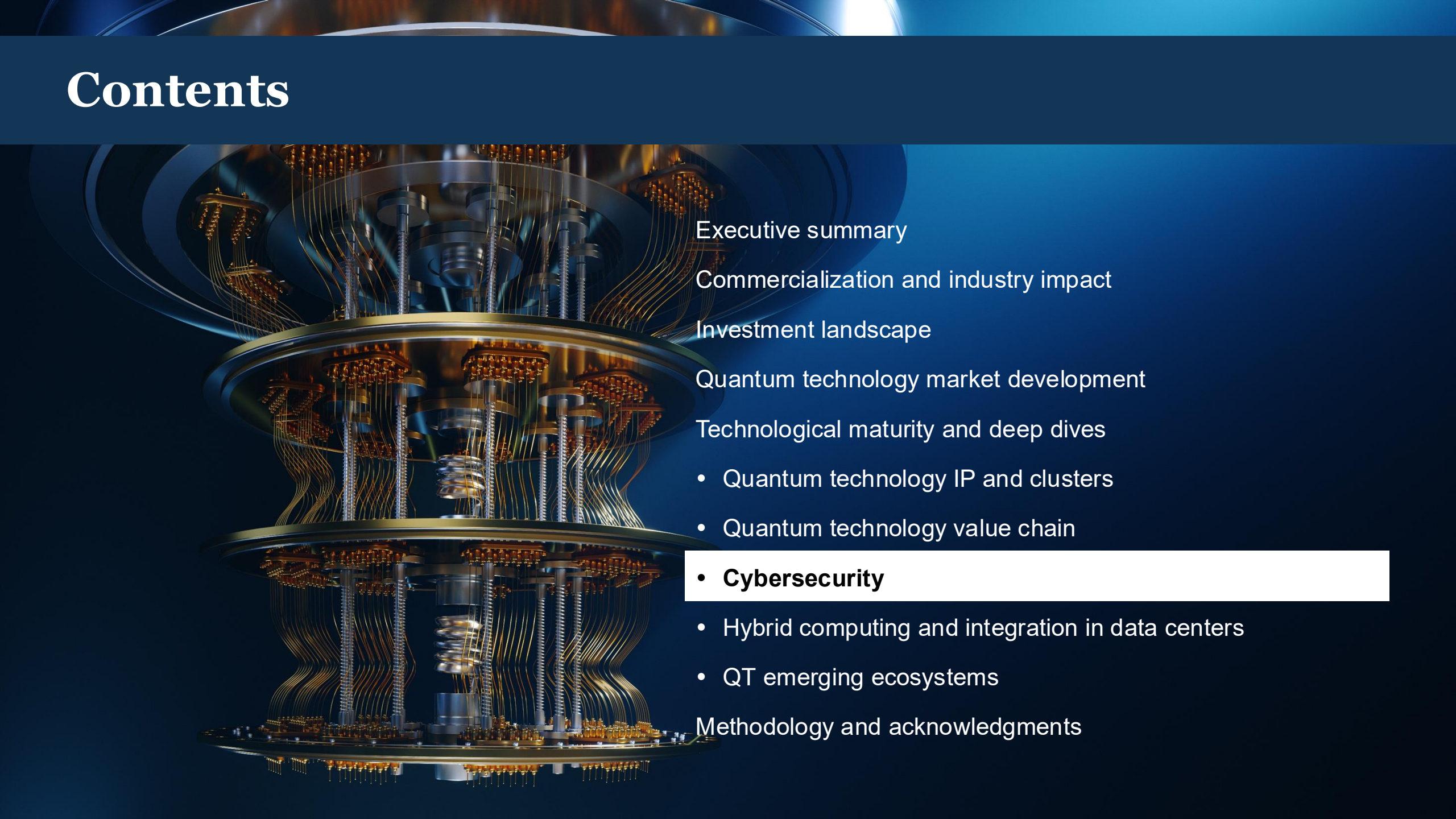
Rare earths

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

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## • **Cybersecurity**

- Hybrid computing and integration in data centers
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Methodology and acknowledgments

# 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<sup>1</sup> and standardization efforts,<sup>2</sup> 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<sup>3</sup> 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,<sup>4</sup> 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<sup>5</sup>; 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.

# 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) | <b>US:</b> Driving PQC adoption through federal mandates and procurement guidance, targeting full transition of quantum-resistant protocols by 2030                                                                                                          | <b>US:</b> Partnering with industry (eg, Chattanooga and Qubitekk) to launch first commercially available quantum networks; Cisco launched quantum testbed in LA  |
|                                | <b>China:</b> Advancing centrally driven, sovereign PQC path, aligning national standards and quantum-secure communications outside the US-led track                                                                                                         | <b>China:</b> Building early advantage in satellite-based QC and quantum networks; built system spanning thousands of kilometers                                  |
|                                | <b>Europe:</b> Reinforcing cybersecurity with PQC; transition by 2030 but mainly at high level, with detailed implementation guidance still emerging                                                                                                         | <b>Europe:</b> Investing in QKD through coordinated infrastructure projects (eg, EuroQCI and OPENQKD) and testbeds                                                |
|                                | <b>Japan:</b> 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 |                                                                                                                                                                   |
|                                | <b>South Korea:</b> Aiming to transition federal and critical infrastructure to PQC by 2035; runs own national PQC standardization initiative (KPQC)                                                                                                         | <b>South Korea:</b> Driving progress with breakthroughs in quantum repeaters; announced plans to develop a 100-km regional quantum network                        |

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

## Nonexhaustive

### Governments

#### US

Federal agencies<sup>1</sup> 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<sup>2</sup> 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<sup>3</sup>) 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.

# 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/<br>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<sup>1</sup>**; QKD is a physics-based secure alternative solution

1. Fault-tolerant quantum computing.

# 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

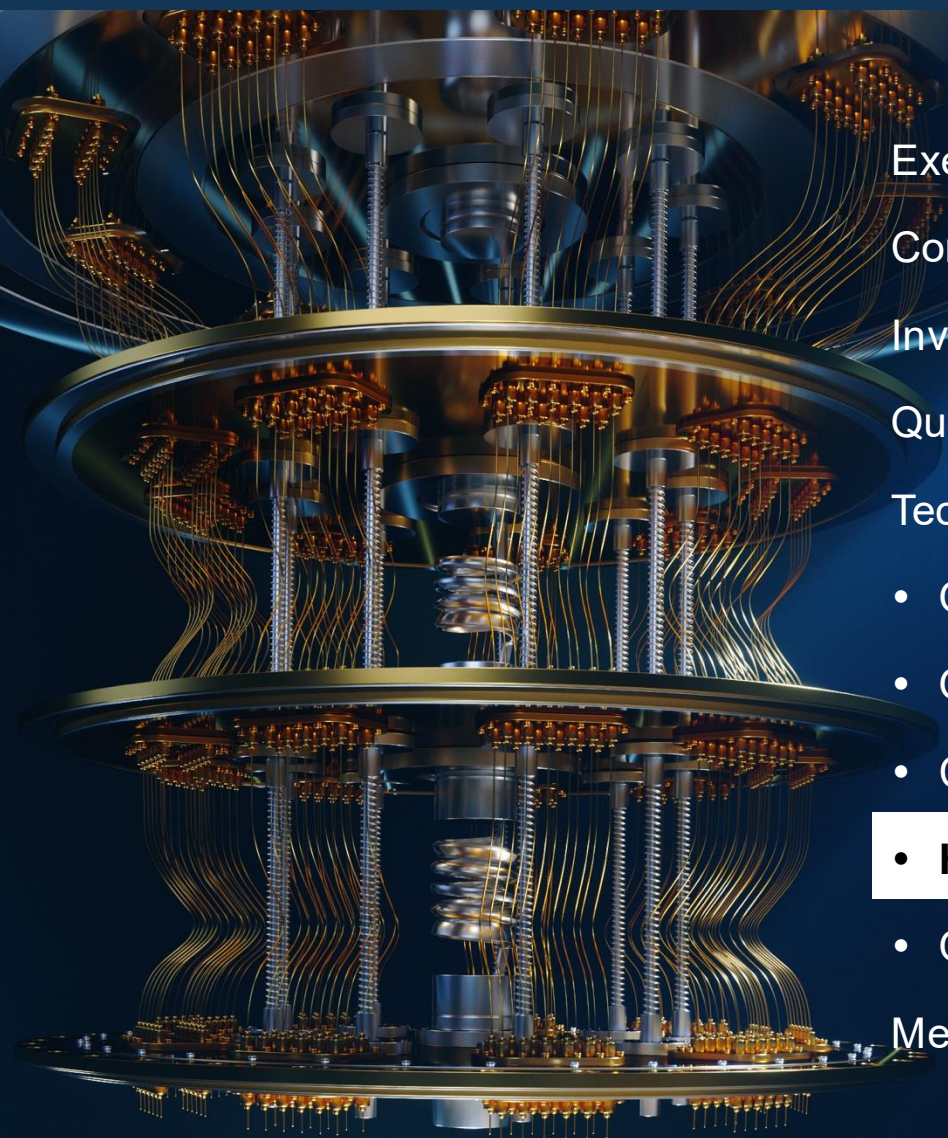
|                                                                                                                               |                               |                                    |                          |                                  |
|------------------------------------------------------------------------------------------------------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

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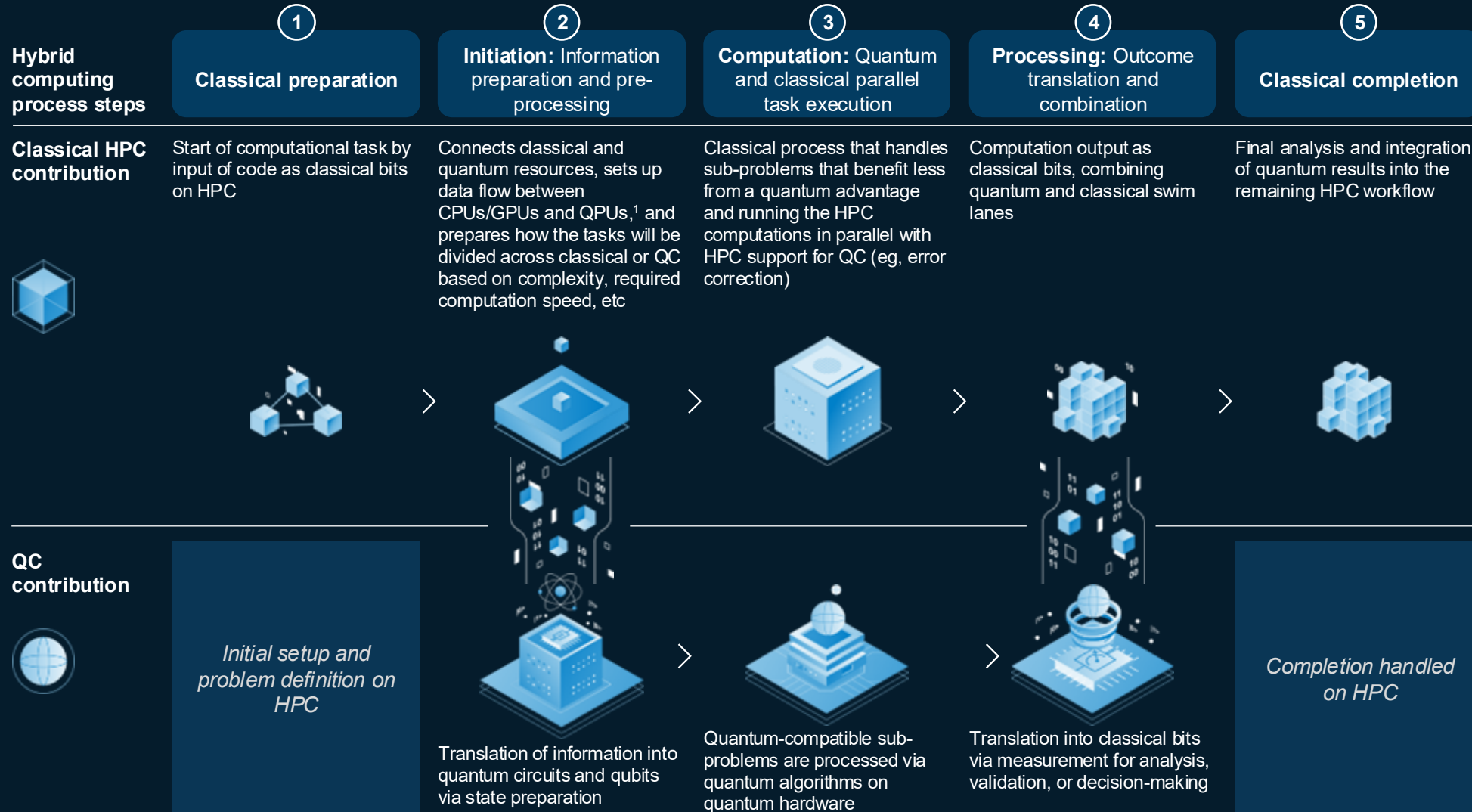
- Quantum technology IP and clusters
- Quantum technology value chain
- Cybersecurity

- **Hybrid computing and integration in data centers**

- QT emerging ecosystems

Methodology and acknowledgments

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



## 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.

# 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

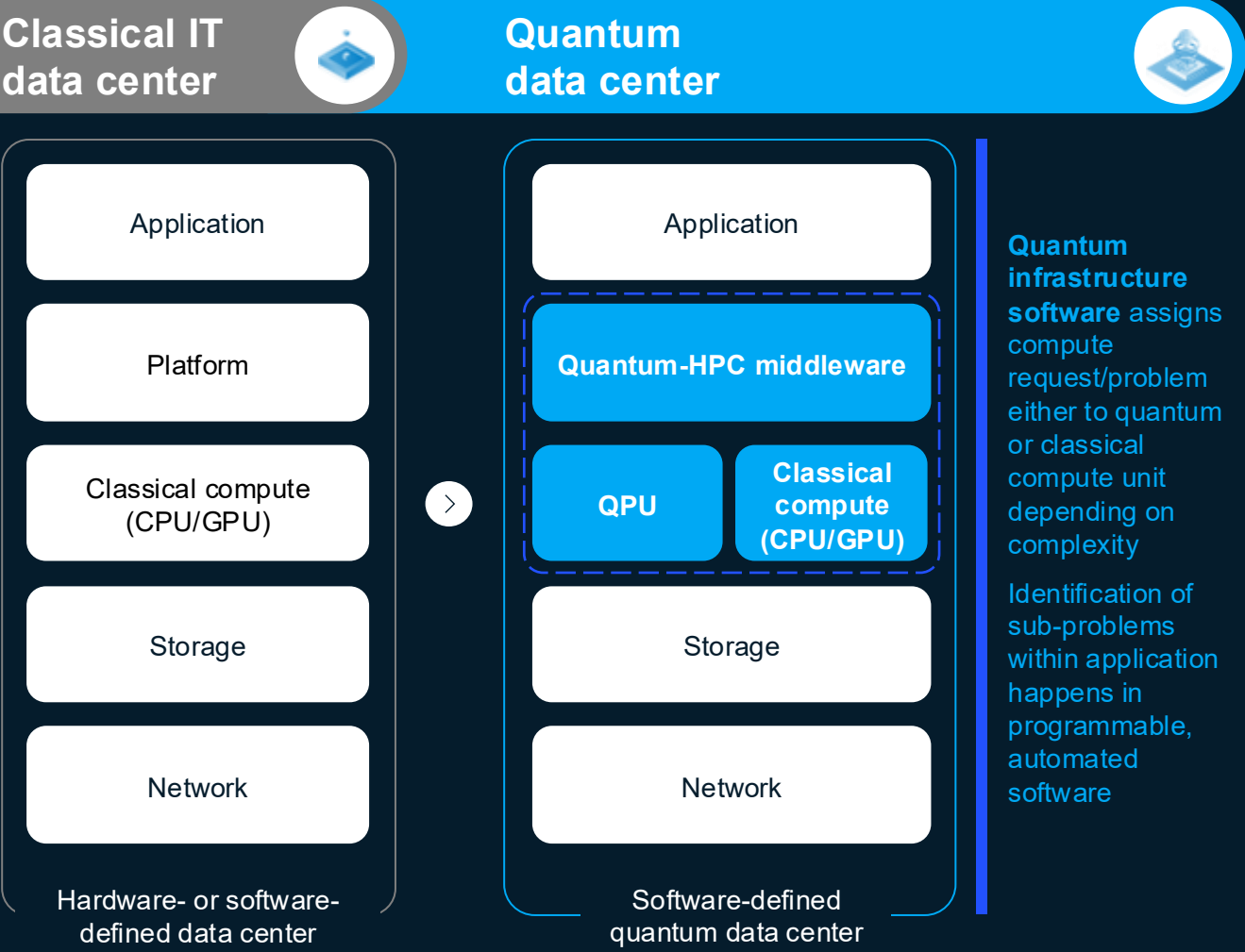


## Key insights

- 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

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

 Key differentiating unit for hybrid computation



## 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

# 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 <sup>1</sup>                                                                                                                  |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <b>NVIDIA</b>                   | <b>Launching the NVQLink platform</b> 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 | <a href="#">“NVIDIA Introduces NVQLink — Connecting Quantum and GPU Computing for 17 Quantum Builders and Nine Scientific Labs” (2025)</a> |
| <b>Alice &amp; Bob</b>          | <b>Advancing fault-tolerant hardware</b> 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          | <a href="#">“Alice &amp; Bob share results on integration error-corrected architectures into HPC workflows” (2025)</a>                     |
| <b>Microsoft and Quantinuum</b> | <b>Expanding hybrid execution via Azure with Quantinuum</b> through cloud workflows coordinating classical CPUs and QPUs                                                                                              | Reduces barriers to experimentation by embedding hybrid tooling directly into cloud developer workflows                   | <a href="#">“Microsoft Quantum unlocks the next generation of Hybrid Quantum Computing” (2025)</a>                                         |
| <b>IBM</b>                      | <b>Demonstrating a quantum algorithm</b> 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       | <a href="#">“IBM says conventional AMD chips can run quantum computing error correction algorithm” (2025)</a>                              |

## 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).

# 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 <sup>1</sup>                                                                                                                                                                                                                                                                                             |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Japanese programs (eg, Q-Leap)</b> | <b>National effort in integrating quantum processors</b> 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                                             | <a href="#">“Fujitsu and RIKEN develop world-leading 256-qubit superconducting quantum computer” (2025)</a><br><br><a href="#">“Quantinuum’s ‘Reimei’ Quantum Computer Now Fully Operational at RIKEN” (2025)</a><br><br><a href="#">“IBM and RIKEN Unveil First IBM Quantum System Two Outside of the US” (2025)</a> |
| <b>EuroHPC and HPCQS project</b>      | <b>Supporting deployment of hybrid quantum-HPC platforms</b> 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 | <a href="#">“One step closer to European quantum computing: The EuroHPC JU signs hosting agreements for six quantum computers” (2023)</a>                                                                                                                                                                             |

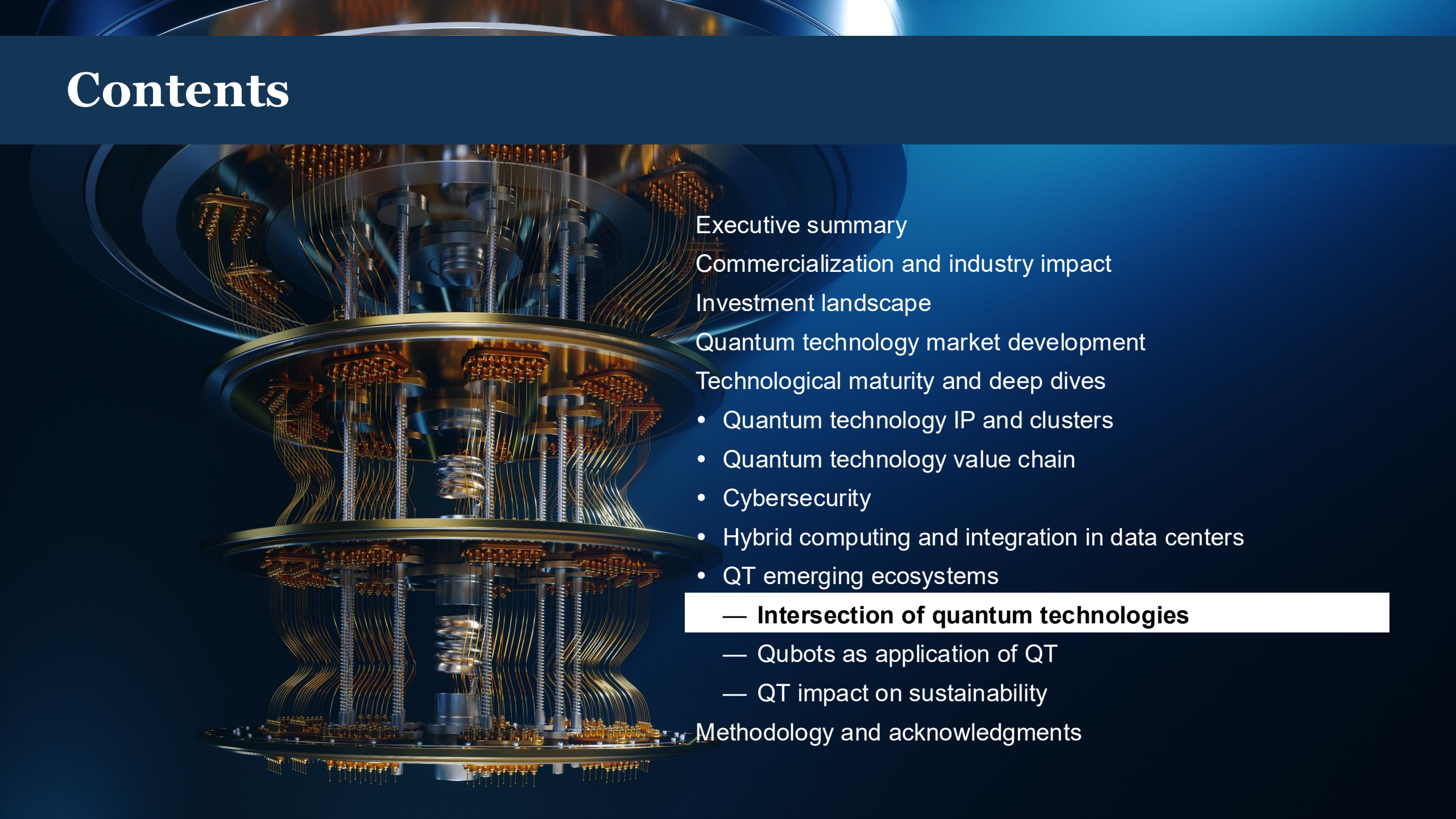
### Key insights



- 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.

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- QT emerging ecosystems

— **Intersection of quantum technologies**

— Qubots as application of QT

— QT impact on sustainability

Methodology and acknowledgments

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

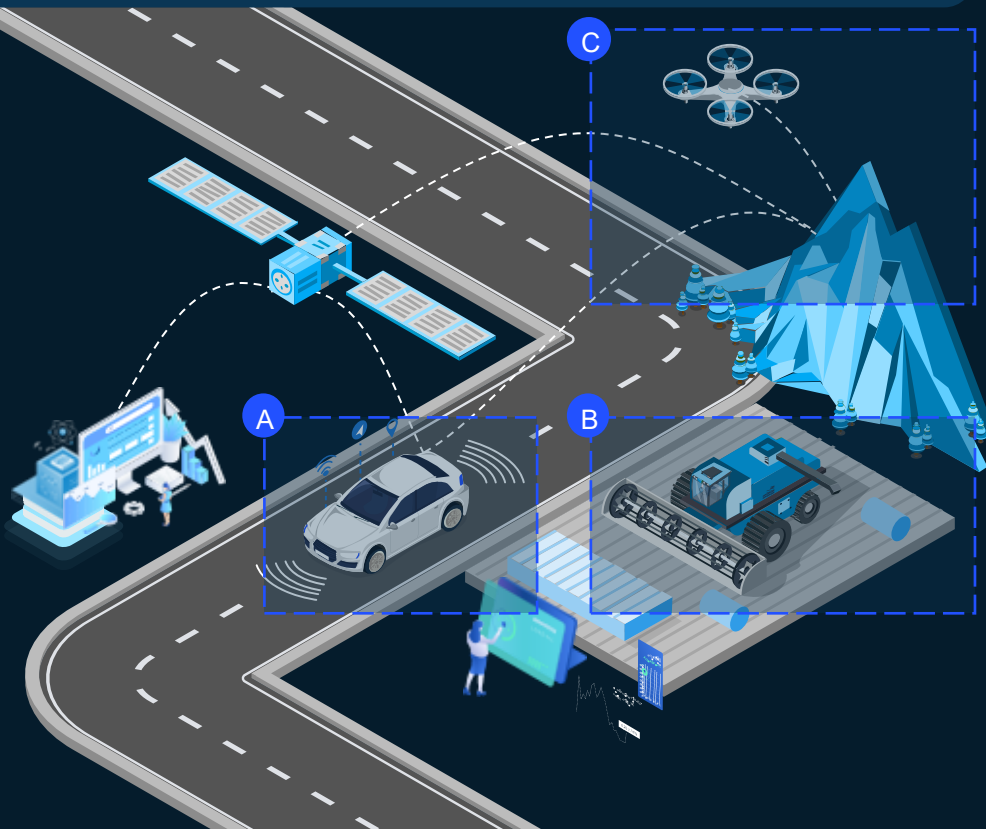
Illustrative

**Quantum computing** can unlock computations that are impossible today and improve accuracy and pace of existing computations

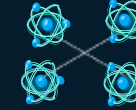
**Quantum networking** can provide secure and authenticated communication

**Quantum sensing** can increase the measurement resolution of fundamental properties across domains

# 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<sup>1</sup> 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 ...

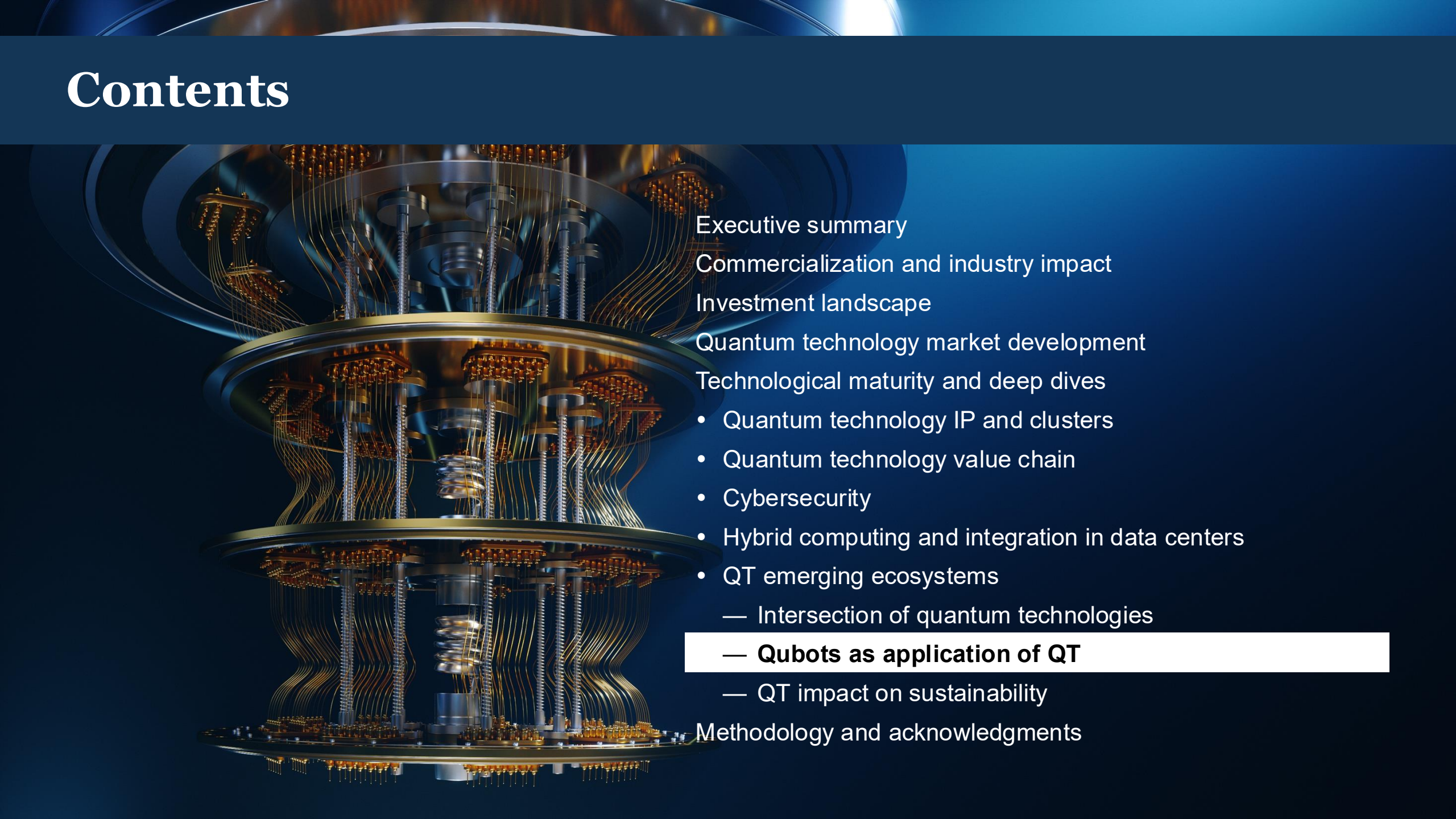
... enhancing accuracy by enabling distributed sensing and securely sharing quantum sensor data ...

... 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

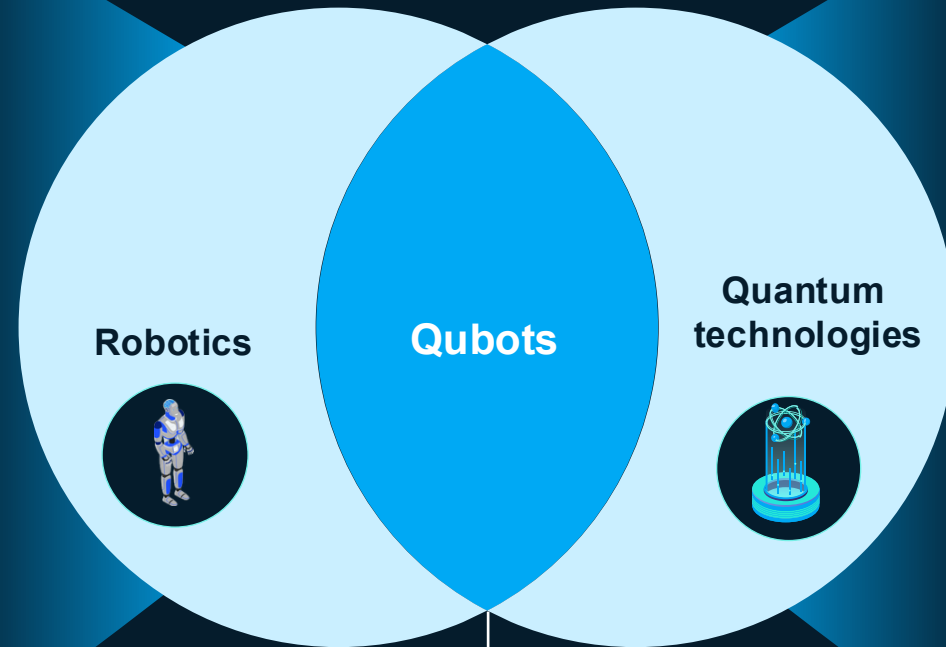
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# Quantum-enabled robots (qubots) shape the far future of robotics.

**Humanoid robotics is a fast-growing market** (+70% p.a., 2025–40) with projected TAM<sup>1</sup> 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)



**All 3 quantum technologies continue to mature rapidly:**

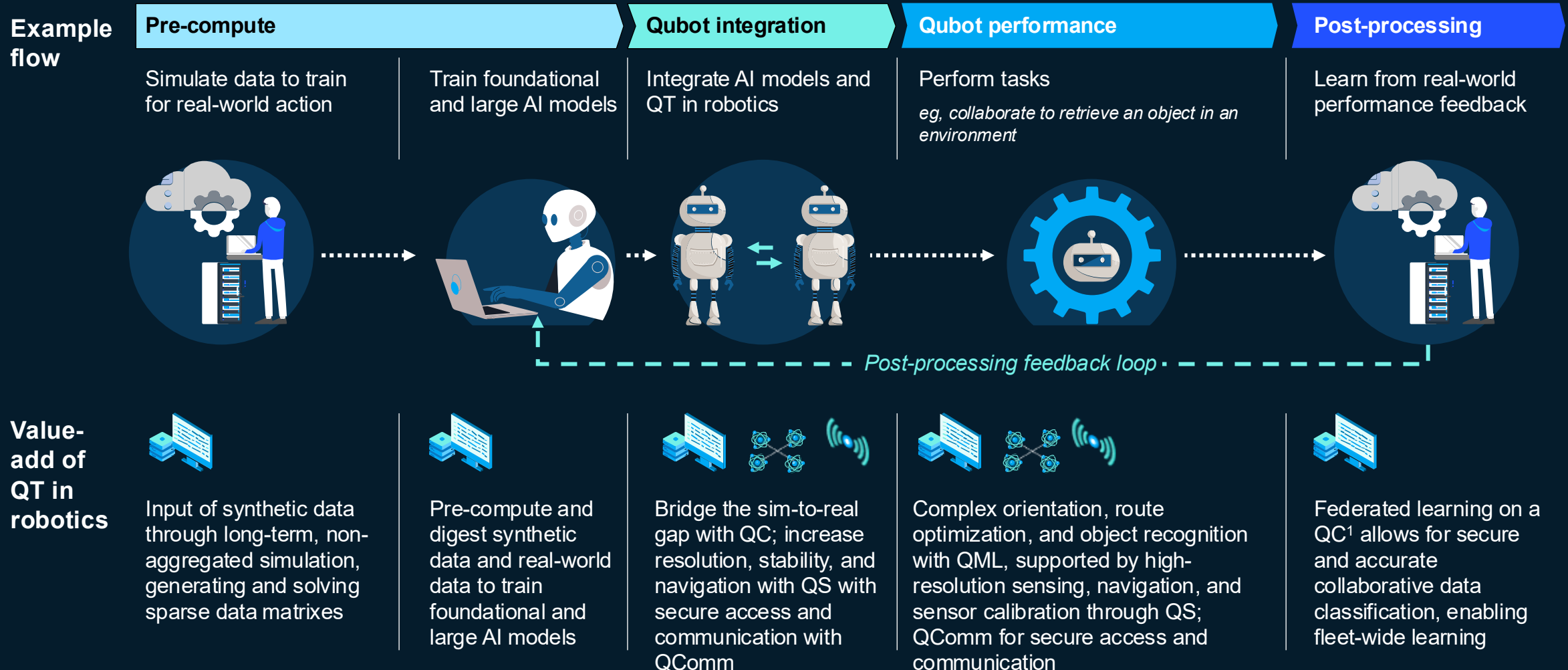
- **QC** supercharges compute capacities
- **QS** enhances high-resolution measurements
- **QComm** unlocks ultrasecure, low-latency coordination

**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

1. Total addressable market.

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

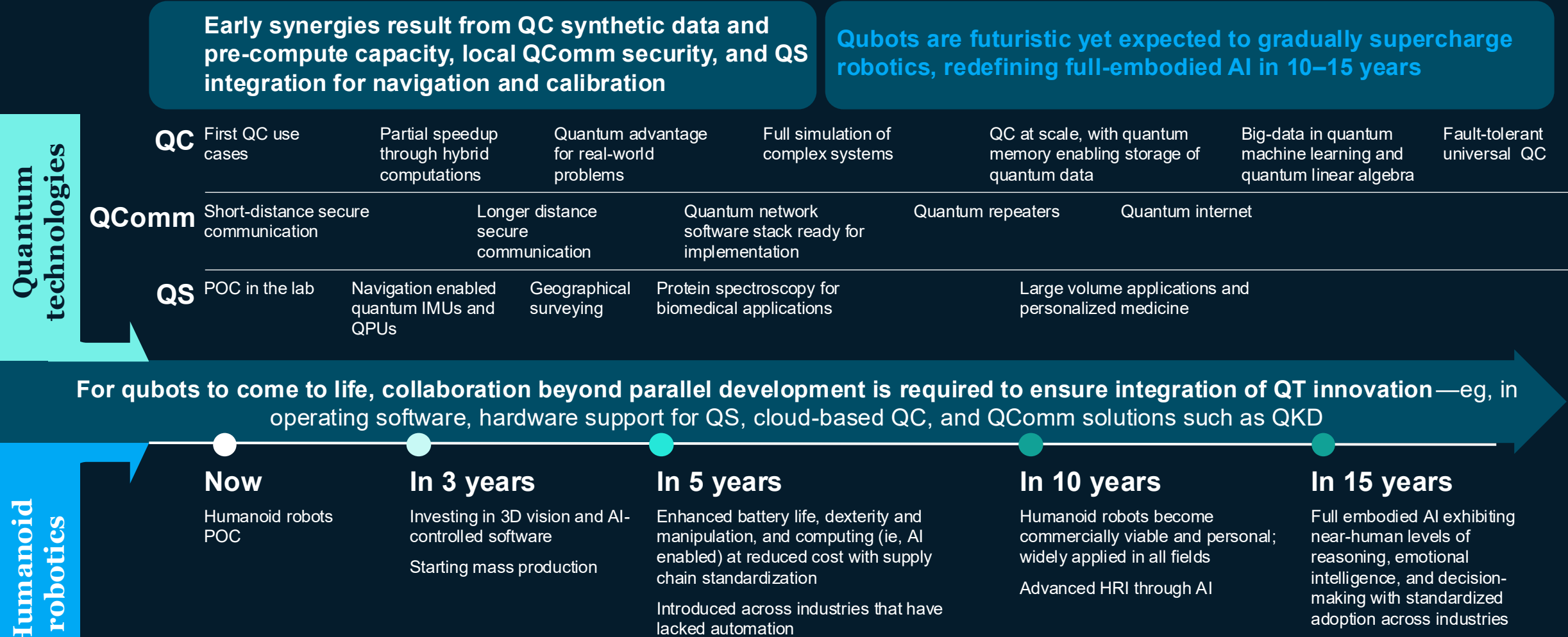
 Quantum computing
  Quantum communication
  Quantum sensing



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

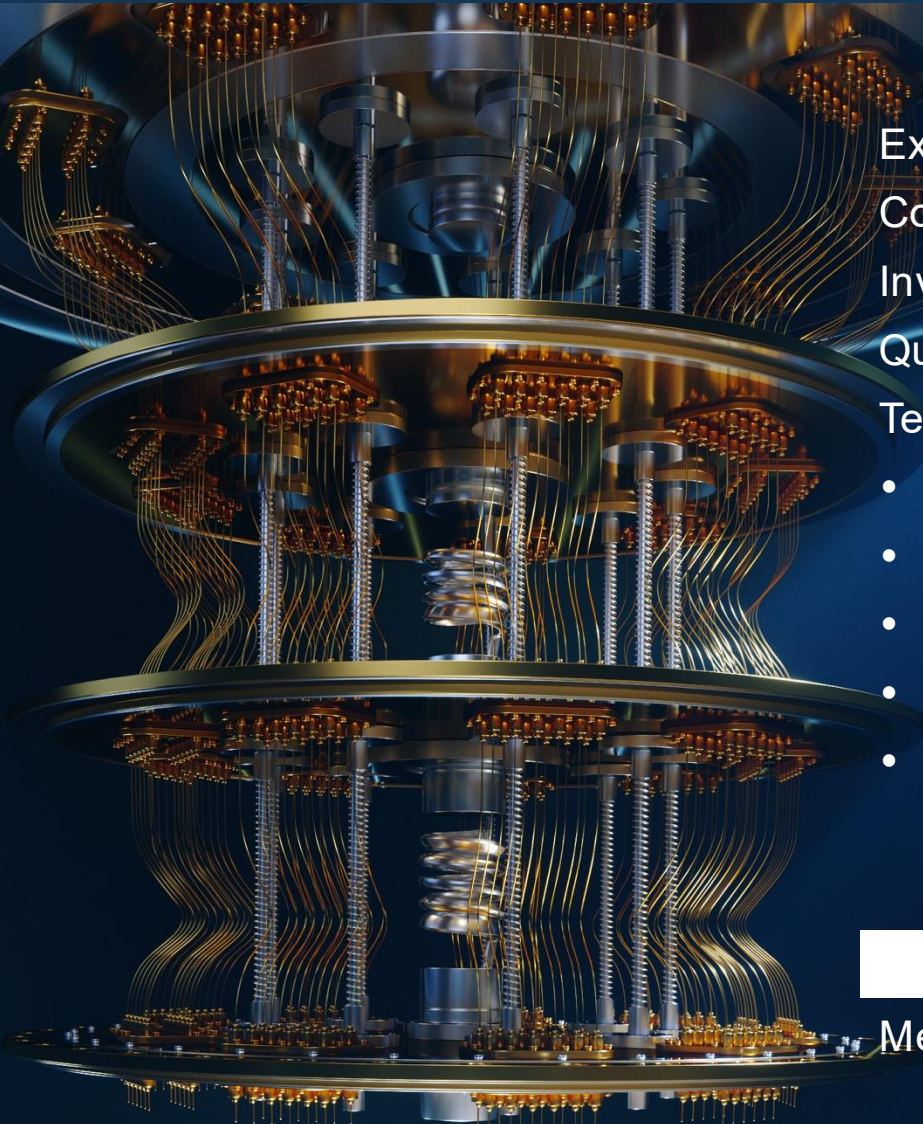
# Qubots define a high-value future white space that will be accessed through collaboration beyond parallel development.

Highly indicative



Source: Expert interviews; press search; McKinsey analysis

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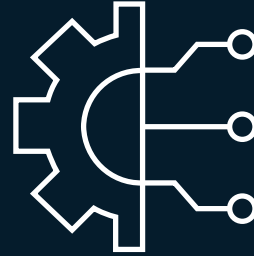
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# QC could help combat the rising energy demand from AI through more efficient scaling compared to classical GPUs.



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

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



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

QC is scaling more efficiently than classical GPUs



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

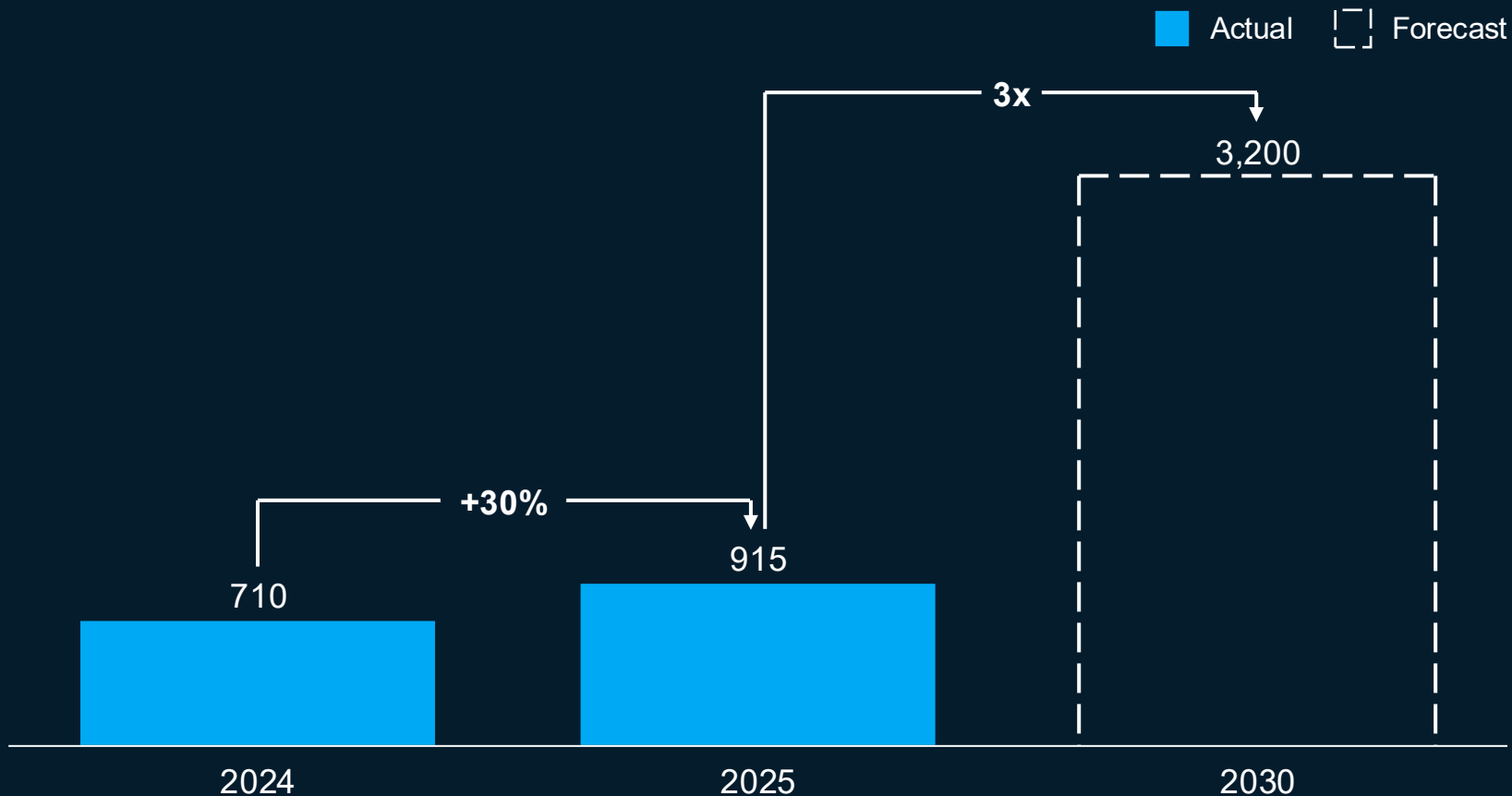
This could enable AI to scale without a proportional rise in energy consumption

1. Information and communications technology.

# 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

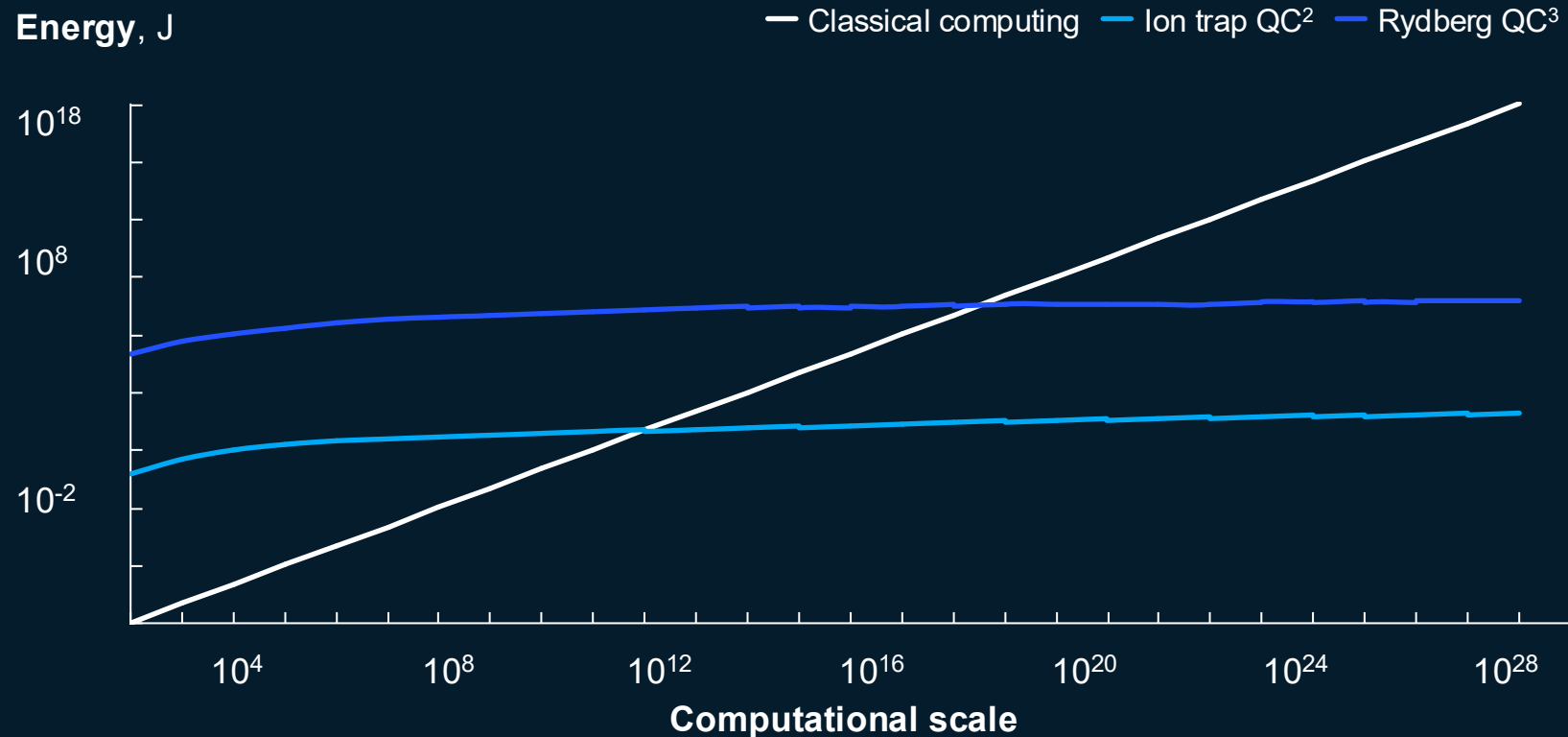


### Key insights

- 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

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

## Energy required for classical vs QC at large workloads<sup>1</sup>



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 cooling technologies 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

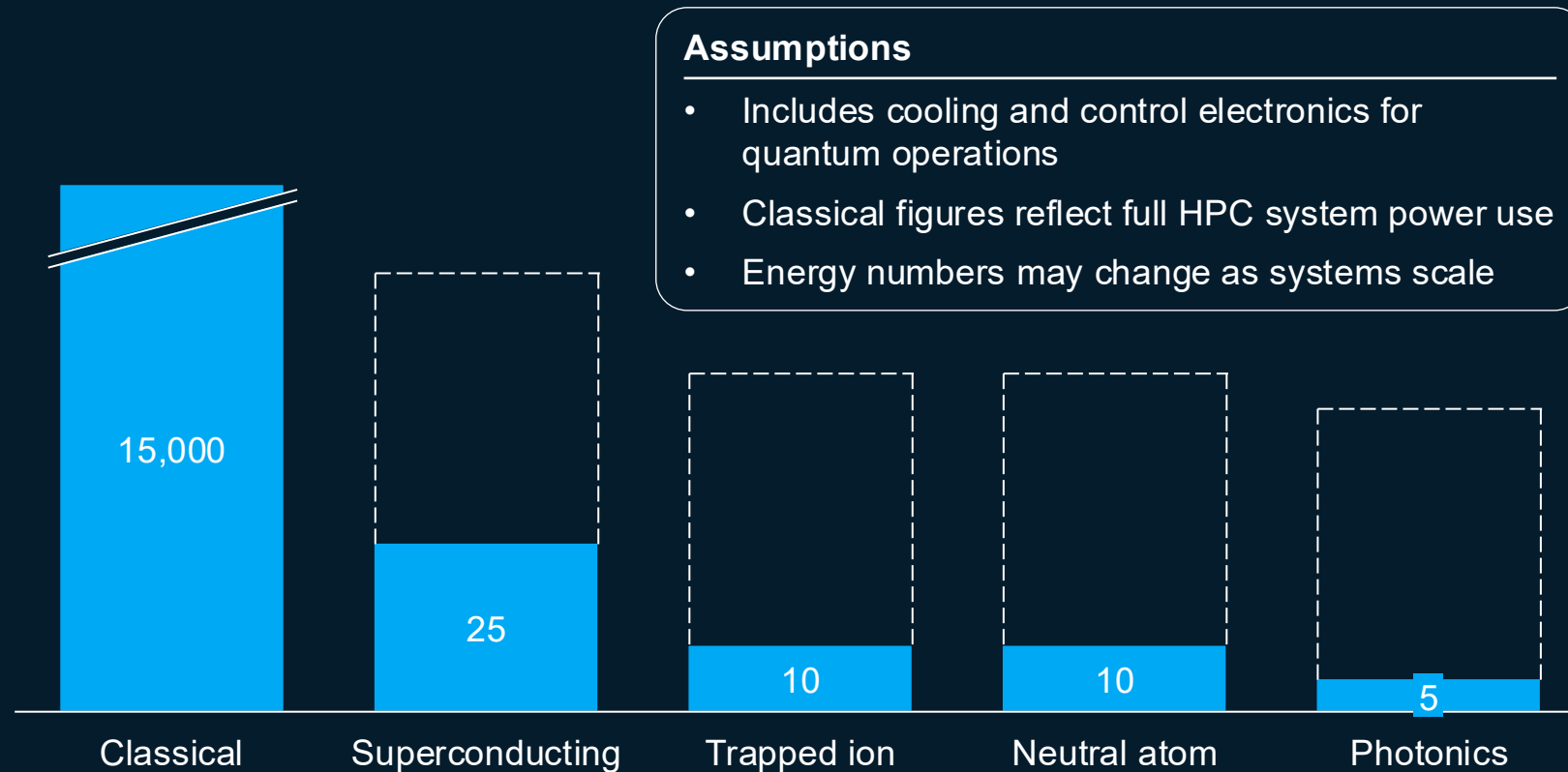
## Key insights



- 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



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*

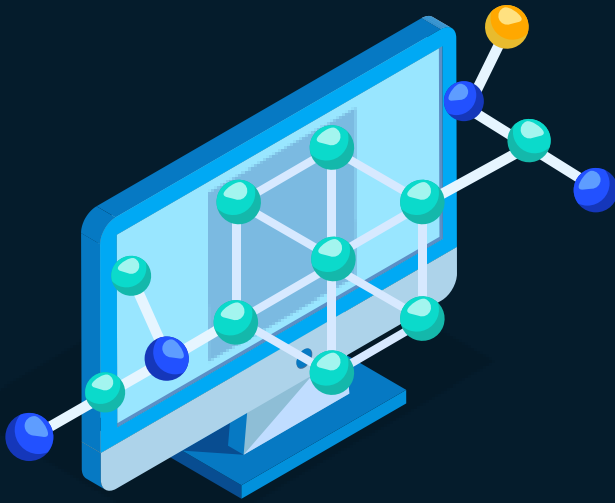


## Key insights

- 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

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# 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

# 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

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# Appendix

# QT player ecosystem

Selection of QT players across QC, QS, and QComm

Nonexhaustive

## QC



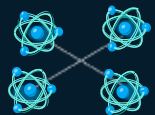
|                |                      |                  |                |           |              |             |                 |                 |          |           |         |       |            |
|----------------|----------------------|------------------|----------------|-----------|--------------|-------------|-----------------|-----------------|----------|-----------|---------|-------|------------|
| 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