IBM Institute for Business Value | Research Insights

# Quantum is coming

*5 realities shaping the race to advantage*

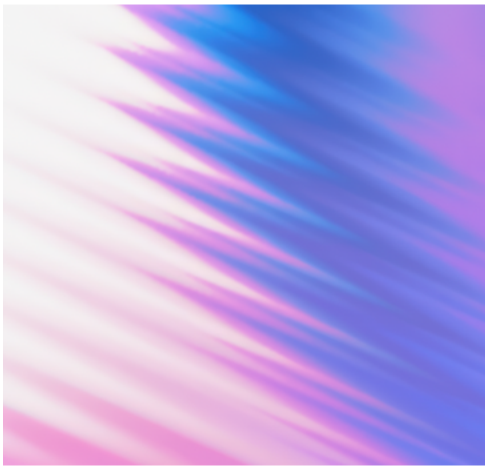
IBM

## Contents



## How IBM can help

IBM Quantum® is a full-stack quantum computing provider. Organizations can access the world's largest fleet of 100+ qubit quantum computers and performant Qiskit software tools with IBM Quantum Platform. For more information, please visit: ibm.com/quantum



# Key takeaways

"From exploration to exploitation, we want to show credible reasons for quantum technology to stay on the table."

Dr. Vanio Markov
Distinguished Engineer, Wells Fargo

- ## Quantum readiness is steadily gaining ground.

  The global Quantum Readiness Index rose six points since 2023, with leading organizations building organizational capabilities while technology matures.

- ## Five evidence-based realities are defining quantum leadership today.

  Success hinges on strategic readiness, diversified approaches, AI-quantum integration, continuous talent development, and embedded governance frameworks.

- ## The window for quantum readiness is narrowing fast.

  Organizations building capabilities now expect 53% higher ROI by 2030, while delayed action risks missing the quantum advantage wave entirely.

## Introduction

Quantum computing is on the cusp of advantage—the pivotal point at which quantum computers can run a computation more accurately, cheaply, or efficiently than any classical method. Recent research indicates quantum advantage is likely to emerge by the end of 2026.[1]

But quantum advantage won't arrive as a single "aha" moment. It'll come in waves, rippling across different industries and use cases, moving the technology forward until it achieves business value.[2] Even as enterprises race  to adapt to AI, quantum readiness has become an imperative. So which organizations will capture value from quantum capabilities—and which will get left behind?

The IBM Institute for Business Value (IBM IBV) developed its Quantum Readiness Index (QRI) in 2023 to identify where organizations fall on the readiness spectrum, the characteristics that define a quantum-ready organization today, and what actions can propel organizations on their their quantum journey (see Perspective, "The Quantum Readiness Index"). Leveraging proprietary data from an in-depth survey of C-suite executives representing 750 organizations across 28 countries and 14 industries, the 2025 index reveals both progress and persistent gaps. Quantum computing now captures 11% of R&D budgets on average—up from 7% in 2023—but commitment varies significantly by sector, suggesting uneven recognition of quantum's strategic impact (see Figure 1).

Among the organizations surveyed, we designated those with the highest QRI scores (the top 10%) as quantum-ready organizations (QROs). These organizations are differentiated as much by their attitude and approach as they are by their technology. Our survey results show that among QROs:

83%
are motivated by accelerating innovation.

83%
are aiming to solve intractable business problems.

88%
are looking to future-proof their computing strategy.

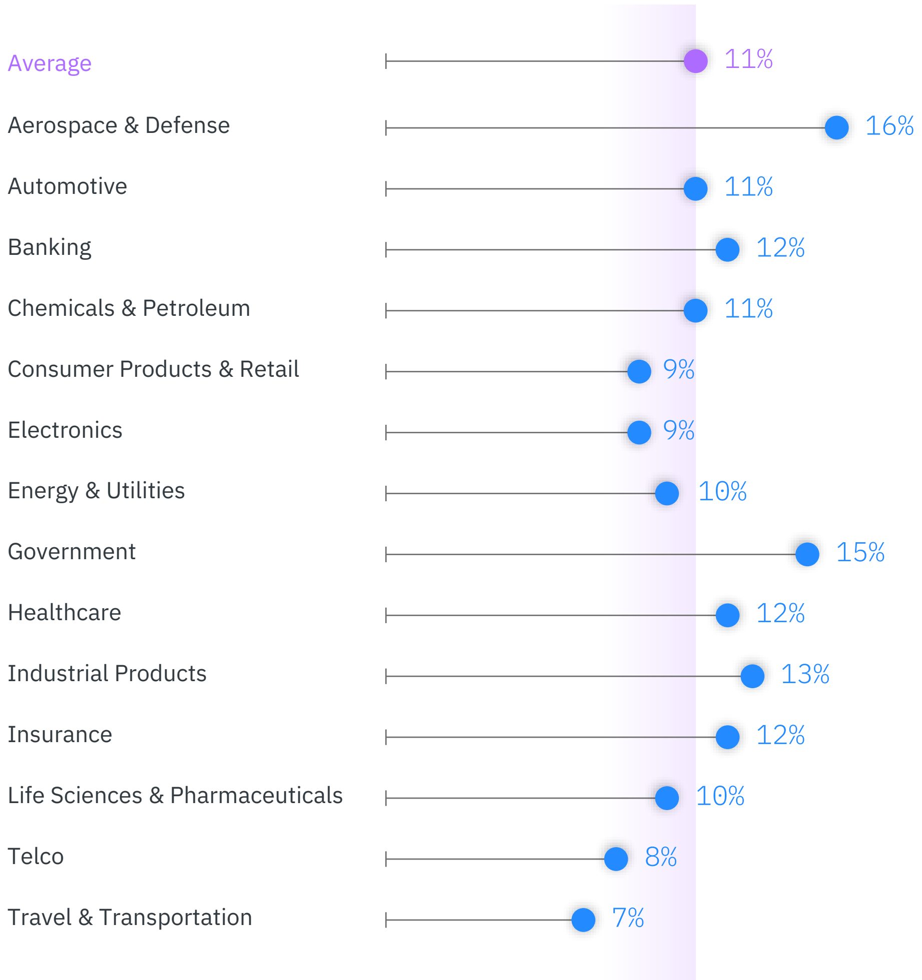
While organizational readiness has advanced since 2023, challenges remain. Across the board, organizations are dealing with inadequate quantum skills (61%), immature technology (56%), unclear use case timelines (46%), and expensive hardware (41%).

What separates the quantum-ready from the quantum-waiting is this: QROs have moved beyond acknowledging barriers to fundamentally dismantling them. In this report, we explore five critical realities enabling quantum leadership, as revealed by our data. These are not theoretical frameworks or wishful thinking. They're evidence-based principles derived from organizations already winning the quantum readiness race—concepts that challenge conventional wisdom and provide a roadmap toward quantum advantage.

FIGURE 1

**Commitment to quantum varies across industries**

Investment in quantum computing as a percentage of organizational R&D budget, by industry



**Perspective**

# The Quantum Readiness Index

The Quantum Readiness Index (QRI) is a weighted average index that monitors the global state of quantum readiness, evaluating indicators across three dimensions: strategy, technology, and operations. Scores for each indicator are weighted based on our experience with clients. The result of this data is a 100-point index designed to track changes in readiness over time for organizations, industries, and regions. The IBM IBV first introduced the QRI in 2023.

This year, the average global QRI score rose to 28—up six points from 2023—signaling gradual progress while still reflecting low overall readiness levels. However, the top 10% of organizations, which we've designated designated as QROs, demonstrate both robust operational models and emerging capabilities in strategy and technology. Their readiness scores are 35 or higher, with a maximum score of 47.

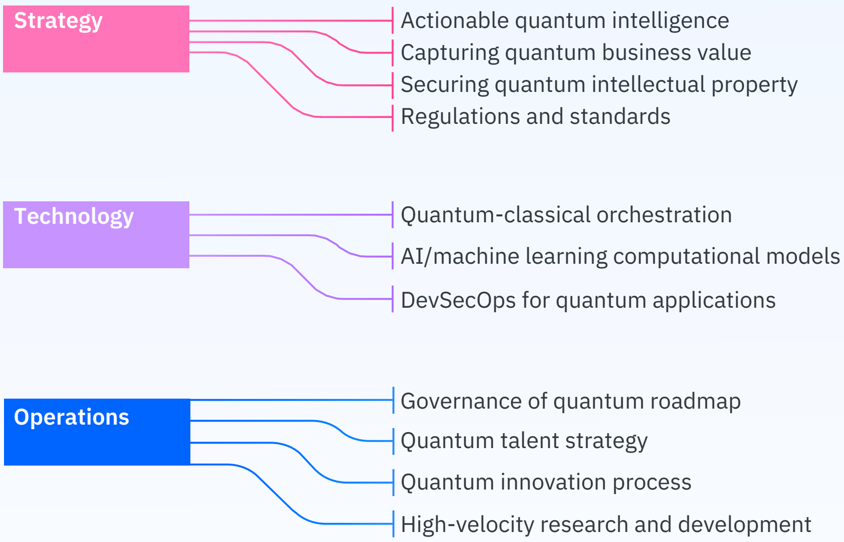
While operational maturity remains the dominant driver of readiness today, we anticipate that strategy and advanced technology capabilities will play a growing role as adoption increases. This evolution underscores the need for organizations to not only build technical competencies but also embed quantum innovation into their broader business vision, governance structures, and talent strategies.

For a complete description of the QRI methodology, see “Research methodology” on page 27.

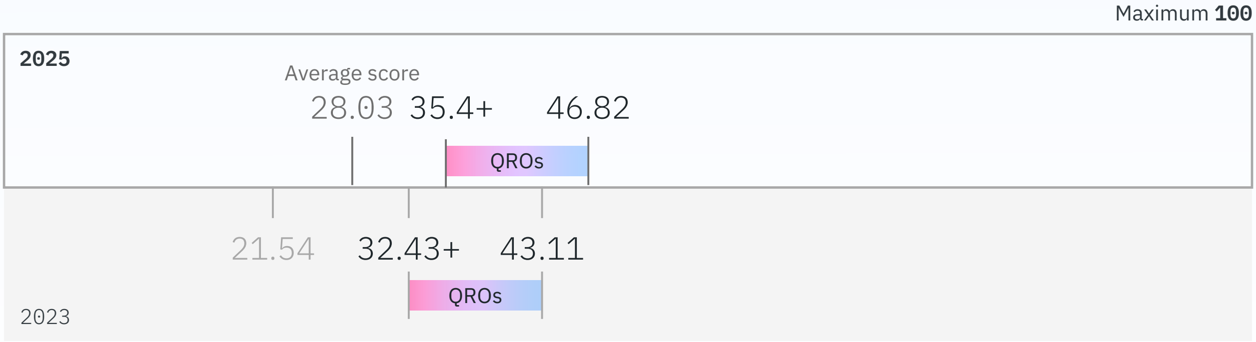
“Building the quantum market requires teamwork across the ecosystem: hardware providers, software startups, and research institutions must move together.”

Dr. Kevin Rhee
CEO, Qunova Computing

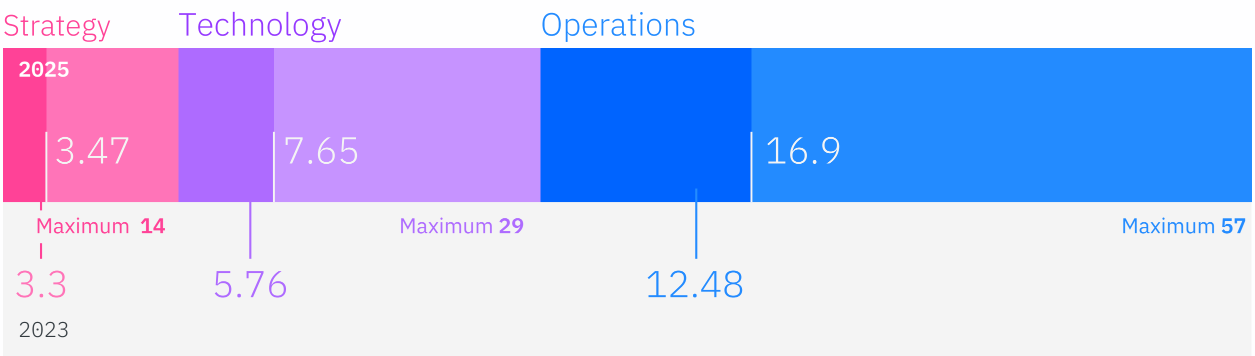
## The IBM Quantum Readiness Index




### Measuring progress toward quantum readiness




### Average scores by category



"Quantum computing is not something you simply buy and switch on. You must invest in talent, know where to apply it, and integrate it into a hybrid high-performance computing environment."

Dr. Nikolai Ardey
Executive Director, Volkswagen Group Innovation

Reality #1

# Organizational readiness is just as critical as tech maturity.

It's tempting to assume that once quantum systems reach specific performance thresholds, quantum computing will transform business.

But technology alone cannot deliver quantum advantage. True advantage arises from the complex interplay of hardware, algorithms, applications, and workflow integration—within hybrid classical-quantum environments and, increasingly, in quantum-centric supercomputing environments.[3] The real edge is sharpened by organizational readiness.

Our research shows that viewing immature technology as the biggest barrier to quantum adoption makes an organization four times more likely to expect delayed advantage—not in this decade, but the next. Meanwhile, those investing in readiness now see a compressed timeline, regardless of hardware evolution.

QROs exemplify how organizational perspective drives readiness. While 71% still cite immature technology as a barrier, QROs are actively mitigating constraints through ecosystem engagement, integrated roadmap development, and proactive intellectual property (IP) strategies. Half of QROs participate in one or more ecosystems—be it quantum collaboration networks, industry partnerships, or technical working groups. More than three-quarters prioritize alignment of their innovation roadmaps, and seven in 10 are developing the processes and infrastructure needed to address new quantum IP filings (see Figure 2).

FIGURE 2

**QROs are building readiness despite tech barriers**

Proportion of QROs pursuing organizational readiness strategies

Quantum readiness is a shared responsibility. Researchers, software developers, and ecosystem partners—alongside quantum system providers—all must play a role in validating when quantum computers deliver measurable gains. Development roadmaps show clear paths to performance milestones. But without organizational capability to integrate quantum into workflows and govern applications, potential advantage remains unrealized.

This all points to a clear reality: technology progress opens the door to quantum advantage, but readiness determines how quickly organizations can step through it. Integration capability, governance frameworks, IP strategy, and ecosystem engagement are all valuable levers that convert technical potential into strategic gains.

And the financial implications could be substantial. According to our research, organizations preparing for quantum advantage by 2027 expect 53% more ROI by 2030 than their peers.

Even the most advanced quantum computer won't reap rewards in unprepared hands. Quantum advantage belongs to those building organizational capabilities now—before the technology makes it obvious they should have started years ago.

"Even if the quantum computers of tomorrow appeared today, we're still not sure what to do with them. Mapping financial services problems to quantum frameworks is the real challenge."

Peter Tsahalis
Technology Senior Executive and CIO, Wells Fargo

## What to do today

**Develop integrated multitrack roadmaps.**
Create parallel timelines for quantum strategy, technology capability, and operational readiness that intersect at critical decision points. Map how quantum system development milestones align with your organization's integration capabilities, governance maturity, and talent development. This helps ensure you're building readiness in lockstep with technology evolution.

**Align leadership expectations to quantum's back-loaded ROI curve.**
Frame near-term quantum investments as strategic infrastructure rather than immediate revenue drivers. Justify current spending as the foundation for future competitive advantage. Establish measurement frameworks that track readiness progress, not just technology benchmarks.

**Engage overlooked drivers of quantum advantage.**
Join ecosystems—quantum collaboration networks and otherwise—to access complementary strengths and accelerate learning. Establish formal quantum governance structures now, before competitive pressures force decision-making. Develop a proactive quantum IP strategy aligned to your implementation timeline, protecting innovations while technology capabilities mature toward your target use cases.

**Case study**

# Vanguard explores quantum optimization for portfolio construction[4]

Vanguard, one of the world's largest investment management companies, tackled one of finance's most computationally demanding challenges: constructing optimized portfolios under real-world constraints. The company explored how quantum computing could enhance portfolio optimization beyond traditional methods, investigating variational quantum algorithms (VQAs) for complex financial optimization tasks.

Portfolio construction involves selecting a mix of financial assets that meet specific investment goals while balancing expected return against risk. Real-world portfolio management requires navigating complex constraints including transaction costs, liquidity limits, regulatory requirements, and nonlinear interactions between assets. As the number of candidate assets grows into the thousands, optimization problems become exponentially harder for classical solvers.

Vanguard's research team explored sampling-based VQAs that combine quantum sampling with classical optimization and post-processing. These hybrid quantum-classical workflows enable new heuristics that can explore complex solution landscapes more efficiently than traditional methods alone.

The team applied this approach to a simplified bond Exchange Traded Fund (ETF) portfolio construction problem, using 109 qubits and executing circuits with up to 4,200 gates. Quantum samples were then refined using classical local search algorithms to improve solution quality.

The results were benchmarked against CPLEX, a leading classical optimization solver. Key outcomes included:

- An optimization gap within accepted industry standards after quantum sampling and local search.
- Improved convergence at smaller problem scales when using more entangled quantum circuits.
- Robust performance even with hardware noise, with sample quality improving over iterations.
- A quantum-classical workflow that consistently outperformed purely classical local search approaches, especially as problem size increased.

Vanguard demonstrated that quantum hardware can already contribute to solving practical optimization tasks by combining quantum circuits that explore high-dimensional solution spaces with classical algorithms that refine results. This positions the company at the forefront of quantum-enhanced decision-making in asset management, with potential applications extending to trading algorithms and risk analysis as quantum technology continues advancing.

"Focusing on only one problem risks missing the full understanding of the field. A diversified portfolio of use cases builds resilience and deeper capability."

Dr. Jonatas Rossetti
R&D Specialist, Bradesco

Reality #2

# Portfolio approaches hedge against use case uncertainty.

Early exploration and conventional wisdom suggested quantum computing would have a breakout use case. Simulation of nature, search and optimization, and algebraic problems emerged as potential front-runners, and organizations placed their bets accordingly.

But this winner-take-all narrative is decidedly false. When asked which use case will be the first to deliver quantum advantage, 34% of organizations—including 10% of QROs—admit they're unsure. The largest group (47%) of QROs expects simulation to lead, but support remains scattered. This uncertainty isn't organizational indecision. It's strategic intelligence: our research reveals the most common organizational profile is experimenting across all major use case areas. And many are going all-in on two areas at once—a more common approach than being a beginner or a master in all three simultaneously.

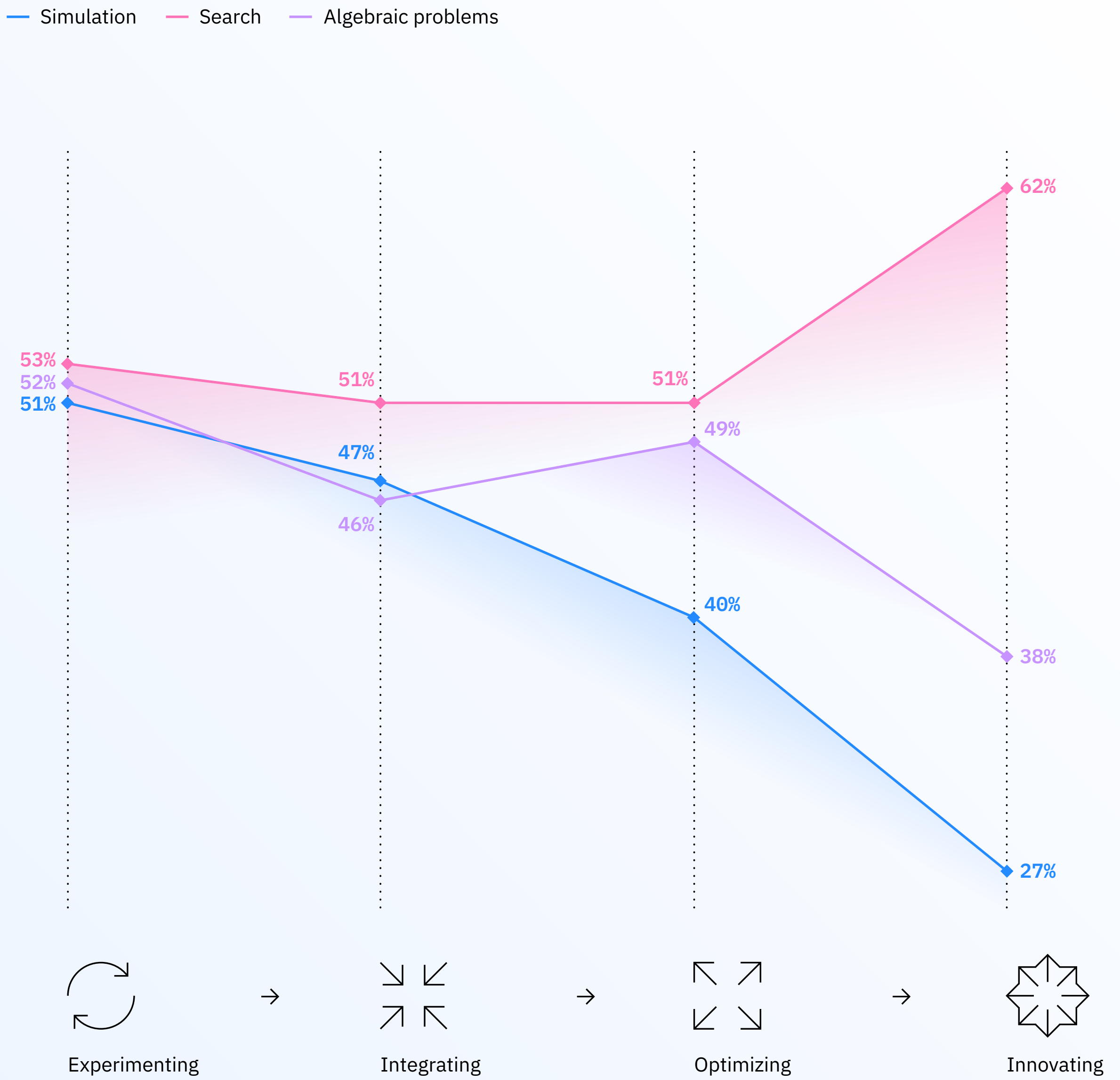
Yet quantum investment patterns reveal a troubling trend (see Figure 3). In the case of search and optimization, organizations increase budget allocation as projects mature. But across simulation and algebraic problems, they tend to front-load their budgets during early exploration, then cut spending as projects advance toward commercial deployment. This backwards investment trajectory could create a dangerous funding gap—precisely when use cases need the most resources to cross the finish line.

Within the QRO playbook, geographic and sector patterns tell a more nuanced story. Energy and utilities QROs focus heavily on simulation, targeting breakthroughs in materials science and battery chemistry that could transform energy storage and grid management. Banking and insurance QROs lean toward search and optimization, reflecting the need for complex risk modeling and fraud detection. Meanwhile, Japan's QROs emphasize algebraic problems in line with a national focus on mathematical sciences and algorithmic research.

FIGURE 3

**Investment drops as quantum use cases near commercial viability**

Quantum budget allocation across maturity stages, by use case area

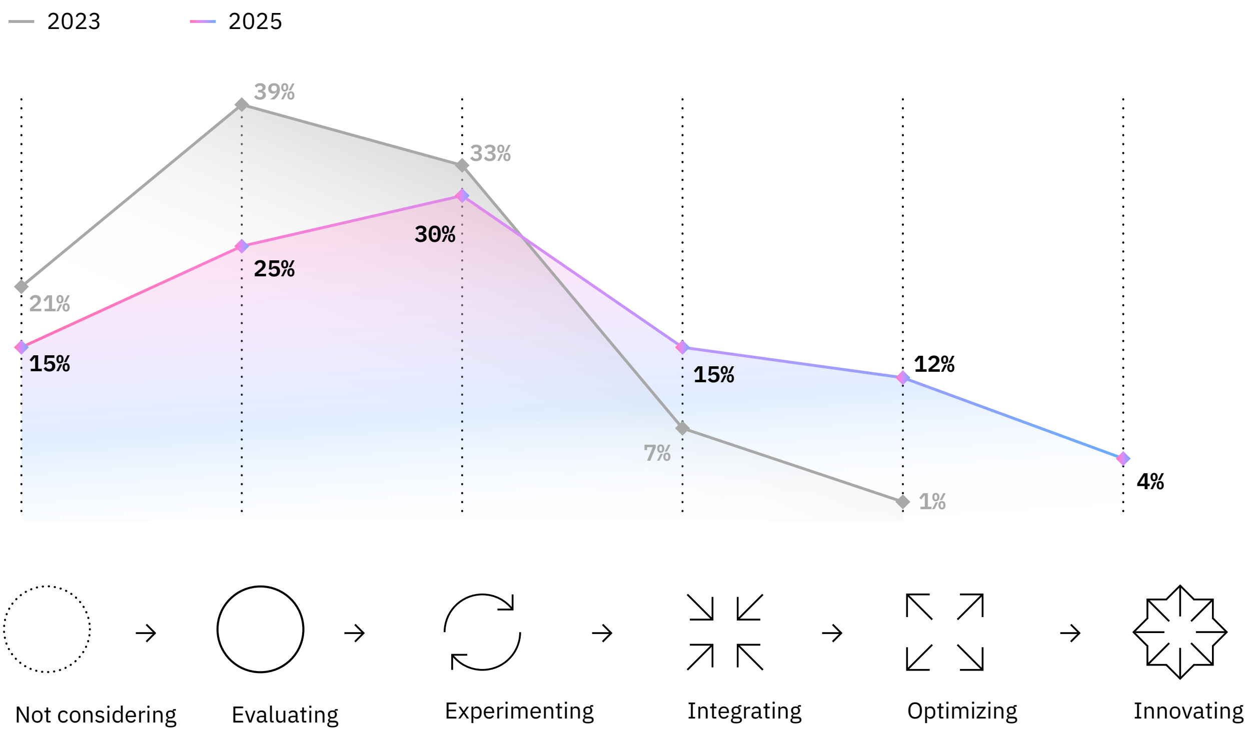


The smartest organizations are managing a savvy set of bets, not picking one victor. Since 2023, we've tracked incremental but steady progress integrating quantum use cases into enterprise workflows (see Figure 4). Across all areas, activity is shifting from exploration toward implementation—but no single domain has demonstrated scale yet.

FIGURE 4

**Organizations are advancing from quantum exploration to deployment**

Quantum use case progression, 2023 versus 2025



The myth of predetermined winners creates a slippery slope toward resource concentration, and organizations chasing a "sure thing" could very well miss out on breakthrough opportunities in adjacent areas.

"If I'm wed to a single use case, it becomes exceedingly risky, because it's difficult to predict the timeline or the success of that individual transition."

Dr. Jay Lowell
Principal Senior Technical Fellow, Boeing

## What to do today

- **Pursue a diversified quantum R&D portfolio.** Allocate resources across simulation, search and optimization, and algebraic problems based on your industry's needs. Test feasibility and organizational fit in each domain while building the capability to pivot quickly as technical progress accelerates.

- **Implement agile quantum investment strategies.** Establish budget review cycles at proof-of-concept and integration milestones to prevent an investment paradox in which funding peaks during exploration but drops just as use cases approach commercial viability. Create flexible funding mechanisms that can rapidly redirect resources toward breakthrough opportunities.

- **Align use case prioritization with specific goals.** Map your quantum readiness to natural application domains, such as simulation for materials-driven objectives, optimization for financial services, and algebraic problems for research. This targeted approach increases the likelihood of early impact while maintaining portfolio diversification across adjacent opportunities.

**Case study**

# RIKEN advances quantum chemistry simulations for complex molecular systems[5]

RIKEN, Japan's largest research institution, has explored a method for simulating chemistry with quantum-centric supercomputers called sample-based quantum diagonalization (SQD). SQD uses quantum to generate measurements corresponding to electronic configurations, then uses classical processing to produce results that withstand quantum computing noise.

This hybrid approach addresses significant computational challenges in molecular modeling. Take an iron-sulfur cluster, for instance. On today's pre-fault-tolerant quantum computers alone, it would take 3 million years to model. Even fault-tolerant quantum computing would require 13 days for such calculations.

RIKEN's SQD method dramatically transforms this timeline. Running on quantum-centric supercomputing infrastructure that combines quantum processors with classical supercomputers, the approach reduced iron-sulfur cluster simulation time to just 2 hours.

This technique demonstrates the potential to outperform what classical approximation methods could do alone, while offering a way to study complex compounds before the emergence of fault-tolerant quantum computing. It makes complex molecular simulations practically viable today, opening new possibilities for studying molecular systems critical to energy storage, catalysis, and biological processes.

Building on RIKEN's foundation, Cleveland Clinic is extending this work to run molecular simulations relevant for drug discovery. The new research combines quantum and classical computing using SQD to obtain information on molecular energies in a way that is robust to the noise inherent in quantum computation.

"AI and quantum computing approaches apply to different types of problems and are likely to ultimately complement each other through hybrid computing to address real-world use cases."

Choy Yong Cong
Director, International and Quantum Policy and Strategy, Singapore Ministry of Digital Development and Information and National Quantum Office

Reality #3

# Quantum and AI amplify each other's impact.

As quantum computing approaches advantage, many believe it will compete with AI for budget and strategic attention. With one finite resource pool, organizations may think they face a zero-sum choice between quantum investments and AI advancement.

That would be a mistake. According to our research, quantum and AI function as force multipliers, not competitors. When positioned as complementary, the two technologies can create exponential value—unlocking incremental budget and accelerating capabilities across both domains.

Today, AI budgets are holding steady at approximately 11% of total IT spend across organizations, regardless of their quantum readiness. This suggests AI investment has become an essential IT function, independent of quantum budgets. But perspective matters: when quantum is explicitly positioned as complementary to AI and high-performance computing, average quantum investment rises to 12% of R&D budgets. When quantum is framed as a competitor, it dips to 9% (see Figure 5).

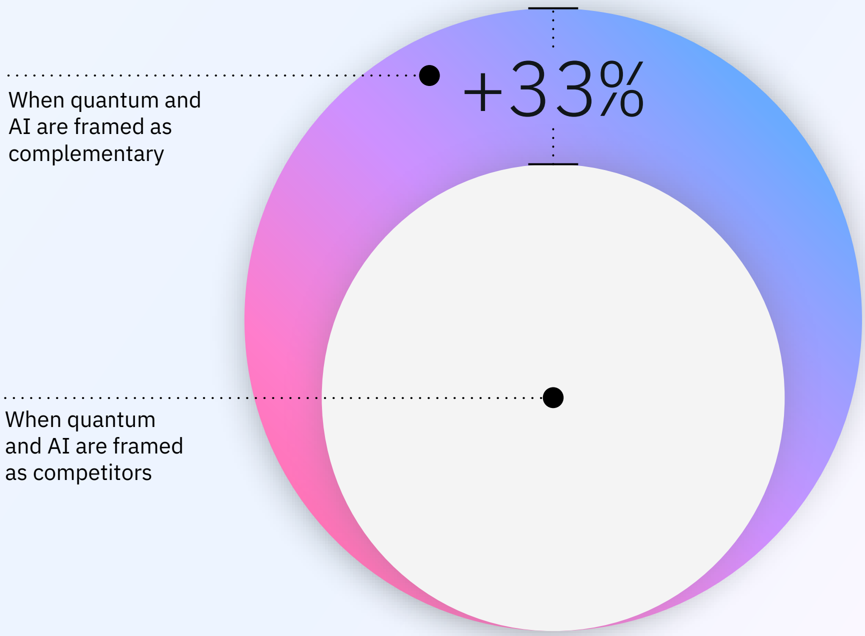
Among QROs, an overwhelming 86% see quantum as complementary, versus just 24% of the least-ready organizations. Organizations that establish quantum as part of a broader computational toolkit—rather than a separate silo—can gain access to joint funding streams, shared infrastructure investments, and cross-domain talent development.

Quantum also has the potential to accelerate AI model training through faster optimization, more efficient sampling, and improved simulation of complex systems. In turn, AI can optimize quantum workflows, guiding algorithm design, error correction strategies, and resource allocation across quantum-classical architectures. Among all our survey respondents, 73% agree that quantum can accelerate AI and high-performance computing capabilities. For QROs, this perception skyrockets to 98%. In fact, QROs are deliberately synthesizing their pursuits of AI and quantum with cross-functional teams that can identify opportunities where quantum enhances AI models or AI refines quantum processes.

FIGURE 5

**Quantum investment jumps when paired with AI and high-performance computing**

Average increase in quantum investment as a percentage of R&D spend



Without proper governance, on the other hand, the competition misconception could become self-fulfilling. Organizations lacking integration capabilities and cross-domain talent default to managing quantum and AI with separate budgets and disconnected teams. This separation only fuels the perception of rivalry.

The future belongs to organizations that recognize quantum and AI as partners, not as adversaries. Those clinging to competition narratives risk missing the exponential potential that emerges when these technologies work in concert.

"Quantum will never stand alone. Classical computing, AI, and quantum must work together in connected workflows."

Dr. Thomas Eckl
Chief Expert, Bosch

## What to do today

- **Reposition quantum as an AI force multiplier.**
  By framing quantum initiatives as complementary to AI, organizations can amplify existing investments and unlock incremental budget. Communicate a consistent, integrated vision to both technical teams and executive stakeholders.

- **Build cross-domain innovation teams with expertise in quantum and AI.**
  Establish integrated groups spanning quantum and AI capabilities to identify synergistic opportunities and prototype hybrid workflows. Consider exploring use cases where quantum accelerates AI model training or AI optimizes quantum error correction and resource allocation.

- **Integrate quantum capabilities into high-performance computing.**
  Identify AI algorithms and computing workloads likely to hit computational limits within 3–5 years—then begin prototyping quantum-enhanced approaches now. Proactive integration helps ensure quantum readiness aligns with AI scaling.

> "Quantum computing readiness is not just about hardware. It is about cultivating a pipeline of software talent that can work across hardware platforms."

Dr. Clifton Phua
Director of Labs, BizTech Group,
Infocomm Media Development Authority (IMDA) Singapore

Reality #4

# Talent gaps will expand with quantum sophistication.

Skills challenges don't diminish as quantum capabilities advance—they intensify. Among QROs, 90% cite inadequate skills as a barrier, compared to 60% of the least-ready organizations. The more ambitious organizations become about quantum computing, the steeper their talent deficiencies feel.

The reason is structural. Early-stage quantum efforts often rely on small, highly specialized teams working on contained experiments. As projects scale toward production deployment, talent footprints must expand across architecture, algorithm design, integration engineering, and domain-specific application development. Many of these roles will require interdisciplinary skills.

According to our research, talent development is the highest-leverage investment organizations can make—and developing internal skills is the most powerful predictor of quantum readiness. By incorporating academic partnerships and STEM field recruitment into their strategy, organizations can further maximize talent readiness. Among QROs, 74% rate internal skill development as highly effective, 79% are leveraging academic partnerships, and 67% are having success attracting STEM talent (see Figure 6). Overall, QROs average three times as many employees in quantum roles, compared to the least-ready organizations.

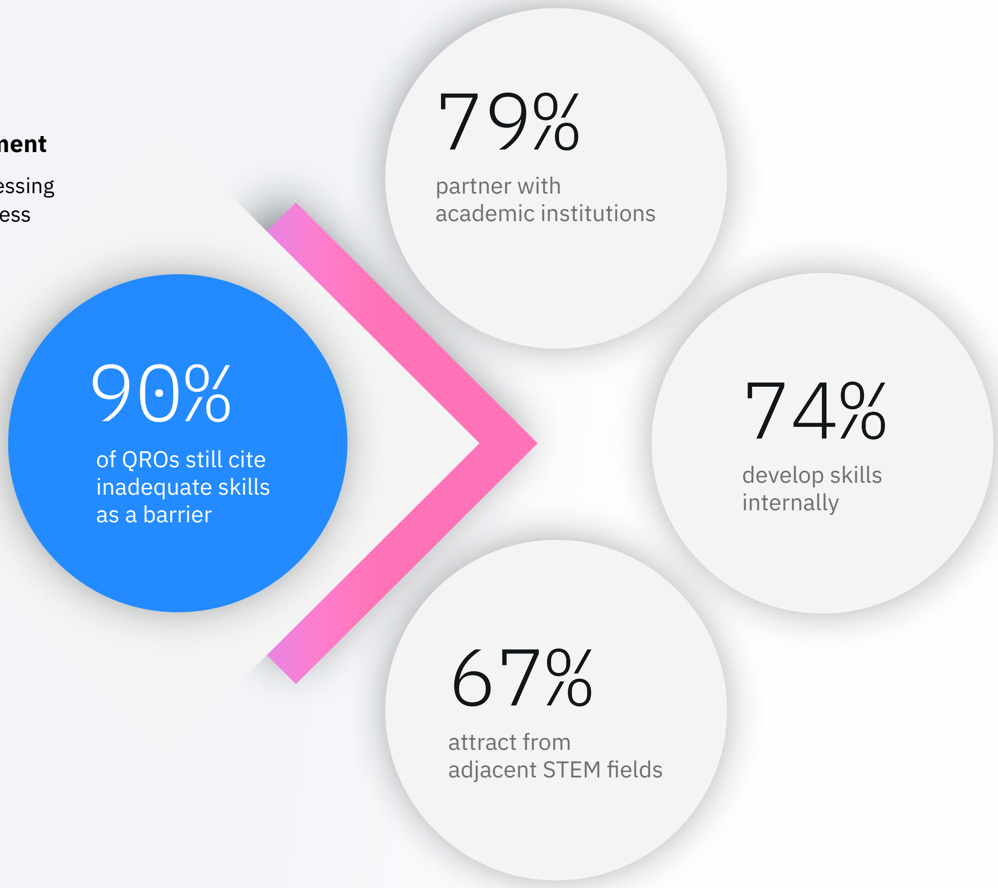
Quantum training approaches vary by region and by industry. US QROs augment internal teams by leveraging academic partnerships with universities and research labs, while QROs in Japan emphasize in-house skill building with an eye on long-term development. Both are sound strategies—so long as there's sustained commitment that scales with ambition. In a sector-specific example, insurance QROs project the highest reskilling needs in services, queuing up targeted training for actuaries, underwriters, and data scientists to work with quantum-enhanced models.

Our research did reveal one common mistake. Treating quantum talent development as a separate initiative, detached from broader workforce planning, creates gaps in succession planning, misalignment with enterprise skill frameworks, and missed opportunities for cross-training from adjacent disciplines. QROs avoid this trap by integrating quantum talent strategies into enterprise workforce planning. They identify roles where quantum literacy augments existing expertise, and they ensure talent investments align with business strategy, matching skills to high-priority use cases.

FIGURE 6

**Quantum talent development is a high-leverage investment**

Percentage of QROs addressing skills gaps with effectiveness




"Post advantage, talent shortages will intensify. It's vital to keep and grow the internal knowledge we've built."

Dr. Giorgio Cortiana
Head of Data & AI, Energy Intelligence, E.ON

Talent readiness is a continuous process. And it requires multichannel investment. As algorithms evolve, hardware architectures change, and integration approaches mature, skills that worked for early experimentation become inadequate for production deployment. Organizations that neglect to continuously refresh and expand talent bases risk falling behind—early movers included. Winning organizations will embrace a mindset of dynamic skill building.

> "We must democratize quantum knowledge the way we did with AI, simplifying concepts so people can understand and use quantum tools confidently."

George Loh
Associate Vice President (Strategic Partnership),
National University of Singapore

## What to do today

- **Conduct granular skills gap mapping across quantum capability areas.**
  Forget generic "quantum training." Instead, assess specific needs in application architecture, algorithm design, and domain-specific knowledge. Prioritize investment where gaps most critically impact your target use cases.

- **Integrate quantum talent development into enterprise workforce planning frameworks.**
  Embed quantum skill building into broader career development pathways and succession planning. Identify roles where quantum literacy will augment existing expertise, such as training data scientists in quantum optimization, or upskilling engineers in hybrid architectures.

- **Establish continuous learning programs that scale with quantum evolution.**
  Create ongoing training cycles to keep pace with rapidly changing algorithms, hardware architectures, and integration approaches. Build rotational opportunities across quantum projects to broaden experience and cross-pollinate skills.

**Case study**

# Moderna pioneers quantum computing in mRNA medicine development[6]

Moderna, a leading biotechnology company pioneering messenger RNA medicines and vaccines, faced a fundamental computational challenge that classical computers struggle to solve efficiently. For any given protein that could treat disease, there's an astronomically large number of possible mRNA sequences that could encode it—making optimization extraordinarily complex.

The challenge centered on developing mRNA technology instructions that accurately direct the body to produce therapeutic proteins. Researchers must identify nucleotide sequences that not only encode the right protein but remain stable in the body, can be manufactured at scale, and won't trigger unwanted immune responses. This requires sifting through millions of possible sequences to find optimal solutions.

"Our goal is to improve human health," said Alexey Galda, Associate Scientific Director, Quantum Algorithms and Applications at Moderna. "We believe it's critical to explore every available tool—including quantum computing—to scale our progress today, rather than wait for the technology to fully mature."

Moderna's breakthrough centered on predicting mRNA secondary structure—the complex folding patterns that determine how efficiently mRNA translates into proteins and interacts with cellular machinery. The company applied Conditional Value at Risk (CVaR), a financial risk-assessment technique, to improve variational quantum algorithms. CVaR focuses optimization on the most promising, lowest-energy solutions while reducing sensitivity to computational noise.

The results have been groundbreaking. Moderna recently achieved what appears to be the largest quantum secondary structure simulation to date—involving up to 80 qubits and mRNA sequences up to 60 nucleotides long. Previous quantum simulations had never tackled sequences beyond 42 nucleotides.

But the team pushed further, applying their methodology to problems involving up to 156 qubits and 950 non-local gates. Their quantum approach successfully matched results from commercial classical solvers for combinatorial optimization problems—demonstrating real quantum utility in pharmaceutical research.

Moderna's vision isn't quantum supremacy—it's quantum augmentation. The company is building toward a quantum-enabled biotechnology pipeline where quantum computing handles specific computational bottlenecks while classical methods manage the broader workflow, positioning itself to leverage quantum advantage as the technology scales.

> "Quantum brings both promise and risk. We need education, ethics, and governance frameworks to ensure the technology is used for good."

Dr. Akihisa Sekiguchi
Fellow, TEL

Reality #5

# Responsible computing must be built in, not bolted on.

Data privacy. Cybersecurity threats. Unintended societal impacts. As quantum computing rounds the corner on advantage, conversations about risk and responsibility will naturally intensify.

Many organizations fail to grasp the scope of that risk. More than half of our survey respondents (56%) see quantum-safe security as a technical issue, rather than a business threat. Yet as IBM IBV research on quantum safety has demonstrated, quantum-triggered risk is "a strategic concern for every organization that relies on digital trust to serve customers, protect intellectual property, and meet regulatory obligations."[7] To label it a mere technicality would be a severe—and costly—oversight.

What's more, expressing concern about quantum risks rarely equates to action. Our research shows no statistical link between worry over quantum's negative impacts and prioritizing responsible computing. When organizations treat responsible practices as a baseline requirement rather than a differentiator, they miss opportunities to embed governance as strategic advantage.

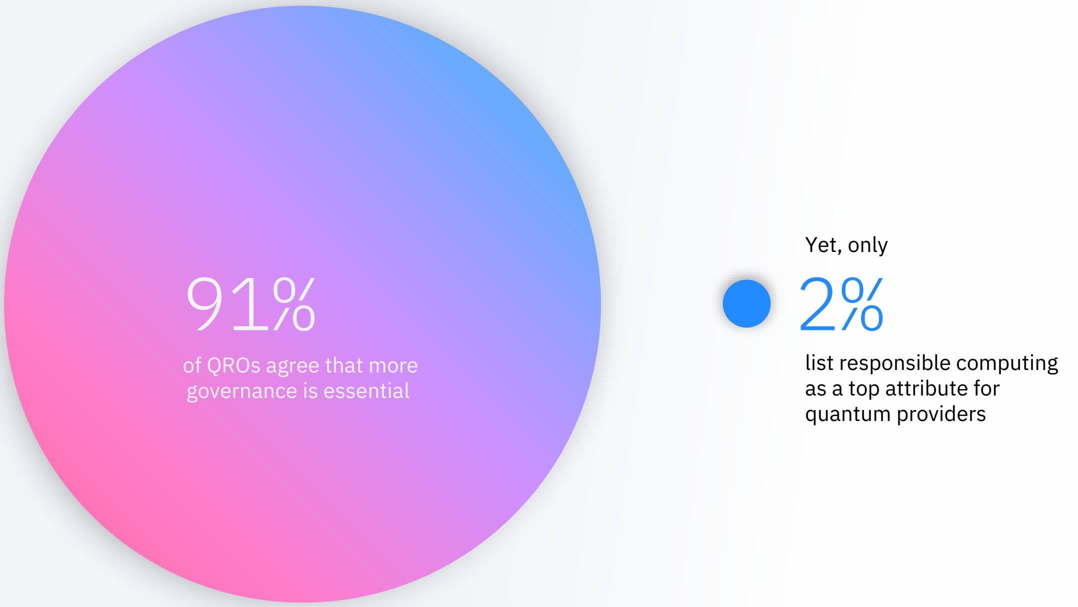
Gaps persist, even among QROs. Nearly half (49%) report misalignment between business and security teams, creating ownership ambiguities that slow responsiveness. Another 59% struggle to justify budgets for responsible quantum computing initiatives without clear ROI. And 54% cite insufficient industry collaboration, highlighting the difficulty of addressing systemic risks without coordinated effort. Despite 91% of QROs agreeing that more governance will be essential once quantum advantage arrives, only 2% list responsible computing practices as a top attribute when selecting quantum providers (see Figure 7).

Still, QROs lead in integrating governance into their operating models. To ensure risk considerations flow from ideation through deployment, 72% of QROs integrate quantum into R&D governance frameworks, and 78% share business-technology ownership of quantum initiatives—closing the gap between innovation teams and business leaders.

FIGURE 7

**QROs demand governance—but aren't prioritizing responsible computing**

Percentage of QROs agreeing with governance and responsibility sentiments



This embedded approach is critical. Why? Because responsible computing transcends policies or checklists. It's an operating principle that must be woven into how projects are conceived, funded, and executed—to avoid the pitfall of complacency.

Unlike classical technologies that scale gradually, quantum computing capabilities can exceed classical precedents in both scale and speed of impact. Organizations that acknowledge risk while forgoing responsible practices leave themselves exposed.

> "Don't treat quantum algorithms as black boxes. Without optimization and fine-tuning, they will rarely work in practice."

Dr. Sergii Strelchuk
Associate Professor, Department of Computer Science, University of Oxford

## What to do today

**Incorporate quantum into established governance frameworks.**
Ensure quantum is explicitly incorporated into policies and processes, rather than assuming it falls under broader technology ethics programs. Address governance, risk assessment, compliance, and stakeholder engagement early in your quantum journey—before competitive pressure forces reactive decisions.

**Include responsible computing criteria in quantum provider selection and procurement.**
Make quantum-safe capabilities and auditable governance practices explicit requirements, not optional considerations. This drives market accountability and helps ensure your quantum partnerships align with risk management objectives from the start.

**Align business and security leadership through shared accountability structures.**
Close the gap in business-security team alignment by establishing joint decision-making frameworks for responsible computing initiatives. Create shared metrics and reporting structures that accelerate collaborative action to avoid organizational finger-pointing.

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A growth-minded entrepreneur and inspirational executive at IBM, Heather leads a world-class team of global quantum industry and technical experts working with pioneering enterprises that are evaluating and adopting quantum technology for commercial impact. With 30 years at IBM, she has deep expertise at the intersection of business and emerging technology, combined with proven experience helping organizations harness technology to unlock value.

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Working closely with clients and partners to develop cutting-edge quantum projects, Petra is transforming research into business value and scaling quantum solutions across the world. She has delivered results in various roles in services, technology, and ecosystem development, including change management, global delivery, and business process improvement. Petra is a seasoned quantum computing leader driving digital transformationand growth acceleration across industries.

*Veena Pureswaran*

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Prior to her current role with the IBM IBV, Veena has held leadership positions in semiconductor product development, technology strategy, and management. Her research findings have influenced clients in industries ranging from electronics to government and financial services, and she is a frequent speaker at major conferences in Asia, Europe, and North America. Veena also serves as a Senior Quantum Ambassador for IBM.

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## Research methodology

**Survey scope and participant profile**

To assess global enterprise preparedness for quantum computing capabilities, the IBM IBV, in partnership with Phronesis Partners, conducted a comprehensive survey of 750 C-suite executives and senior business leaders. The cohort was designed to capture a balanced perspective from large enterprises across 14 major industries, including banking (10%), energy and utilities (9%), and industrial products (9%). Key roles included CIOs/Heads of IT (24%), COOs/Heads of Operations (13%), Business Unit Leaders (13%), and CTOs/Heads of Technology Strategy (10%). The surveyed organizations were predominantly publicly owned (86%), with a median annual revenue of $5.7 billion.

**Construction of the quantum readiness score**

To deliver a standardized benchmark of organizational maturity, a composite quantum readiness score was developed. This metric quantifies an organization's self-assessed advancement across 45 specific activities, which are categorized into three core pillars of quantum adoption. Each pillar is assigned a specific weight in the final score, reflecting its relative importance to overall readiness, as follows:

– Quantum operating model (57% weight): As the most critical component, this pillar evaluates the organizational and procedural infrastructure, including establishing governance roadmaps, talent initiatives, innovation processes, and high-velocity R&D practices.

– Quantum technology (29% weight): This pillar measures the maturity of the technical foundation, covering capabilities in quantum-classical workload orchestration, AI and computational model integration, and DevSecOps for quantum applications.

– Quantum strategy (14% weight): This pillar assesses the foundational strategic direction, including activities such as understanding quantum opportunities, analyzing business value, securing intellectual property, and engaging with regulatory standards.

**Methodological approach for quantum readiness score**

To quantify initiative progress, responses on the original five-point scale were recoded to a 0–2.5 scale using a nonlinear transformation (1 = 0, 2 = 1, 3 = 1.5, 4 = 2, 5 = 2.5). This was not a simple rescaling; rather, the increments between scale points were intentionally uneven to reflect the increasing marginal effort required as initiatives near completion. Early stages typically progress more rapidly, while final stages such as testing, validation, and optimization require substantial additional effort with comparatively smaller observable advances. Thus, the smaller numerical gain between "Mostly complete" and "Fully complete" acknowledges this disproportionate complexity and prevents overstating overall progress.

Following recoding, pillar scores were calculated as a percentage of the maximum possible score for their constituent activities. These percentage scores were then multiplied by their respective pillar weights (Strategy: 0.14, Operating Model: 0.57, Technology: 0.29) and summed. The final quantum readiness score is the sum of these three weighted pillar scores, multiplied by 100, providing a percentage-based measure of an organization's overall preparedness.

**Analytical framework: Uncovering drivers and trends**

Leveraging the quantum readiness score, the analysis employed a multipronged statistical framework to move beyond description and uncover the key drivers, barriers, and trends shaping enterprise quantum adoption. This approach was designed to answer critical business questions:

– Identifying performance drivers: Linear regression models were used to pinpoint the primary factors that most significantly influence an organization's quantum readiness score and perceived ROI. A subsequent stepwise regression specifically isolated the talent acquisition strategies with the greatest measurable impact on overall quantum readiness.

– Understanding barriers to adoption: Multinomial logistic regression quantified how specific organizational barriers—such as skill gaps or funding constraints—affect an executive's forecast of when quantum advantage will be achieved in their industry.

– Benchmarking across sectors and time: Analysis of Variance (ANOVA) identified statistically significant differences in skill gaps and reskilling priorities across industry sectors. Furthermore, longitudinal comparison against prior-year data was used to track the evolution of strategic outlooks and preparedness over time.

**The Quantum Readiness Index**

- **Strategy**
  - Actionable quantum intelligence
    - Understanding opportunities
    - Forecasting market scenarios
    - Monitoring market data
    - Business value of startups
    - Acquisition pipeline
  - Capturing quantum business value
    - Use case differentiation
    - Timing of value realization
    - Processes and governance
    - No-regret capabilities
    - Use case exploration
  - Securing quantum IP
    - Protection of IP
    - Decision models
    - Invention assessments
    - New filings
    - Licensing strategy
  - Regulations and standards
    - Engaging regulatory agencies
    - Understanding standards
    - Stakeholder collaboration
- **Technology**
  - Quantum classical orchestration
    - Containerized workloads
    - Quantum-classical orchestration
    - Optimized application times
    - Interoperating workloads
  - AI/ML computational models
    - AI/ML models
    - Advanced computational models
    - Data maturity
  - DevSecOps for quantum applications
    - Cloud-based tools
    - Continuous integration and delivery
    - Administration tools
- **Operations**
  - Governance of quantum roadmap
    - Alignment of innovation roadmaps
    - Integration with R&D
    - Shared business-tech exec responsibility
    - Centers of Excellence
  - Quantum talent strategy
    - Budgeting
    - Staffing
    - Community participation
    - Innovation culture
    - Risk tolerance
  - Quantum innovation process
    - Ideation to integration
    - Strategic planning models
    - Expected business value
    - Solution certificates
  - High velocity research and development
    - Agile methodology
    - Incremental deployment
    - Continuous workflow enhancements
    - DevSecOps

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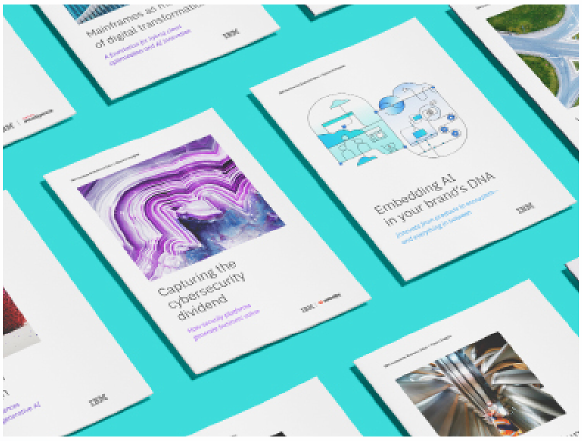


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