The Quantum Leap: Navigating the Future of Computing

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If recent advances are any indicator, **the future of quantum computing may be closer than anticipated**, raising obsolescence risks for businesses that are unprepared to capitalize on a technology that will mature rapidly

Over the last few decades, technological breakthroughs such as the Internet, Wireless Broadband, and AI have redefined the rules of engagement, compelling businesses to rethink and recalibrate their strategies for the future. Quantum computing is poised to emerge as one of the most promising – and perplexing – transformative innovations of our time. While still nascent, it will revolutionize industries by solving problems currently intractable to classical computers. From optimizing supply chains and enhancing drug discovery to fortifying cybersecurity, its potential is as boundless as the quantum states themselves.

Through this article, we share a BCG framework to help readers evaluate the transformative impact of quantum technology on their organization and assess their readiness to embrace it, using a dedicated questionnaire. First, let's explore how quantum technology positions itself within the business landscape.

Separating Fact from Fiction

Quantum computing represents a fundamental shift in computational capabilities. Its ability to address complex problems through optimization and simulation positions it as uniquely suited to challenges that classical systems and even supercomputers cannot handle. While quantum computing is not positioned to replace traditional computing, it complements classical systems by addressing challenges that are beyond their capabilities.

Contrary to perceptions that quantum computing is decades away, early applications are already appearing. For example, Microsoft's Azure platform incorporates hybrid-quantum capabilities, enabling businesses to secure data against future threats. Organizations can access advanced quantum capabilities without owning quantum hardware, making the technology increasingly practical and accessible.

From a business perspective, understanding that quantum technology does not require billion-dollar investments is crucial. Businesses can explore quantum solutions with minimal resources, paving the way for innovation while avoiding excessive costs.This accessibility positions quantum computing as a practical and immediate enabler across industries, particularly for niche applications where its unique advantages can be fully leveraged.

It is equally important to acknowledge the current limitations of quantum computing. Today's quantum systems are highly specialized and suited to solving very specific problems using tailored algorithms. Unlike a general-purpose computer, a quantum computer functions more like a dedicated machine optimized for particular tasks. We are still far from achieving a generic quantum computer akin to a personal computer that can handle a wide range of tasks.

Unlocking Unprecedented Business Value

Because of its unique advantage in solving complex problems that are impractical or would require vast amounts of time for classical technologies to address, quantum computing offers transformative benefits across multiple areas such as simulation, optimization, machine learning, and cryptography. Its core value propositions lie in:

1 **Solving the Unsolvable :** By processing vast datasets in near real-time, quantum computing can uncover insights that classical systems may miss or handle too slowly, optimizing operations and delivering solutions faster. For example, high-frequency simulations can model complex systems with unprecedented detail, providing richer predictive insights and enabling strategic decisionmaking. In simulation scenarios, industries like pharmaceutical companies can benefit from accelerated drug discovery, and the aerospace sector can optimize designs through computational fluid dynamics (CFD).

2 **Delivering Immediate Value :** Accelerating simulations and reducing R&D cycles can enable businesses to achieve faster market time while improving product quality by enhancing designs and reducing errors. The technology can also reduce costs by optimizing processes and cutting operational inefficiencies. For example, logistics can benefit from route optimization; finance professionals can use portfolio optimization to improve performance and reduce risks.

3 **Securing Data :** Quantum technology offers significant potential in cryptography. Quantum enhanced encryption addresses future threats posed by quantum-enabled decryption methods, safeguarding sensitive communications and critical data. This innovation aims to establish ultrasecure encryption standards for data-reliant industries, including finance, healthcare, and government.

Quantum computing's potential can drive innovation and improve our ability to identify and address complex risks. Advanced simulations could have helped prevent disasters like the Challenger explosion or provided earlier warnings for tsunamis. By enhancing risk identification capabilities, quantum computing enables smarter decisions, giving organizations a valuable edge.
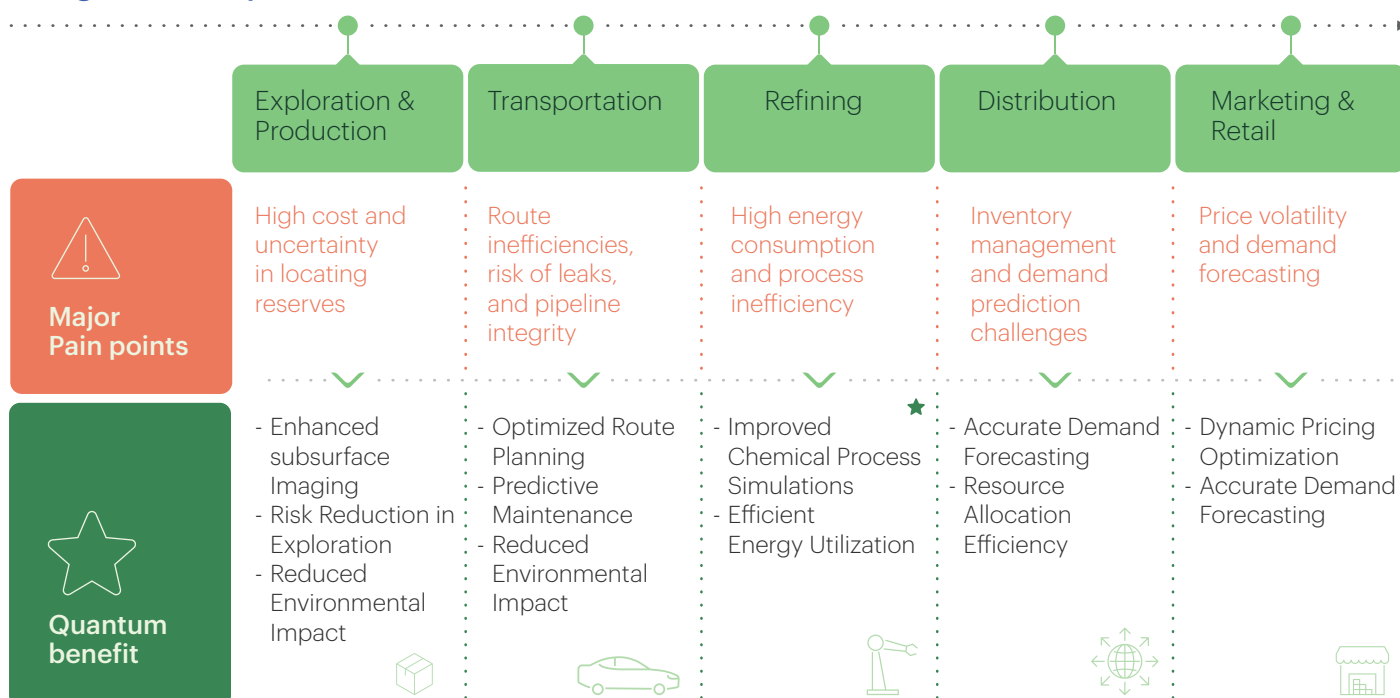
Industry Snapshot 1: Oil and Gas

WHY IT MATTERS

The oil and gas industry is the cornerstone of global energy supply, supporting economies and industries worldwide. Yet, it faces growing challenges, including rising costs, operational inefficiencies and mounting environmental concerns. Quantum technology offers transformative solutions to address these pain points, driving efficiency, sustainability and profitability across the value chain.

Quantum computing will bring numerous **impactful advancements to every stage of the oil and gas industry's** value chain

	Exploration & Production	Transportation	Refining	Distribution	Marketing & Retail
Major Pain points	High cost and uncertainty in locating reserves	Route inefficiencies, risk of leaks, and pipeline integrity	High energy consumption and process inefficiency	Inventory management and demand prediction challenges	Price volatility and demand forecasting
Quantum benefit	- Enhanced subsurface Imaging - Risk Reduction in Exploration - Reduced Environmental Impact	- Optimized Route Planning - Predictive Maintenance - Reduced Environmental Impact	- Improved Chemical Process Simulations - Efficient Energy Utilization	- Accurate Demand Forecasting - Resource Allocation Efficiency	- Dynamic Pricing Optimization - Accurate Demand Forecasting

★ Most Significant Impact

Five core Sources of value

- Efficiency in Routing Optimization
- Reduced Refining Energy Consumption
- Improved Crude-to-Product Pathway Predictions
- Predictive Maintenance for Distribution Pipelines
- Minimized Environmental Impact in drilling

From a quantitative perspective, the Oil & Gas industry sees the greatest added value in two key areas of the value chain: "exploration and production" and "refining." For context, the International Energy Forum projects upstream Oil & Gas Capex to exceed $600 billion[1] in 2024, for the first time in a decade. Conservative projections suggest that the introduction of quantum capabilities could improve exploration and production processes by 1–5%, representing potential cost savings of $6–30 billion[2]. Similarly, in the refining segment, where average capital expenditures in 2023 were $71[3] billion, quantum capabilities could enhance processes by 3–10%, translating to estimated savings of $2.13–7.10 billion[4].

1. Upstream Oil and Gas Investment Outlook - A report by the International Energy Forum and S&P Global Commodity Insights
2. BCG Analysis based on experts interviews
3. U.S. Energy Information Administration
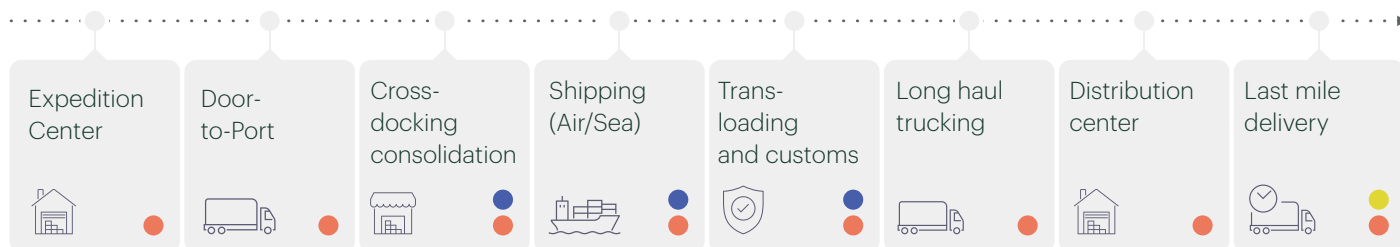4. BCG Analysis based on experts interviews
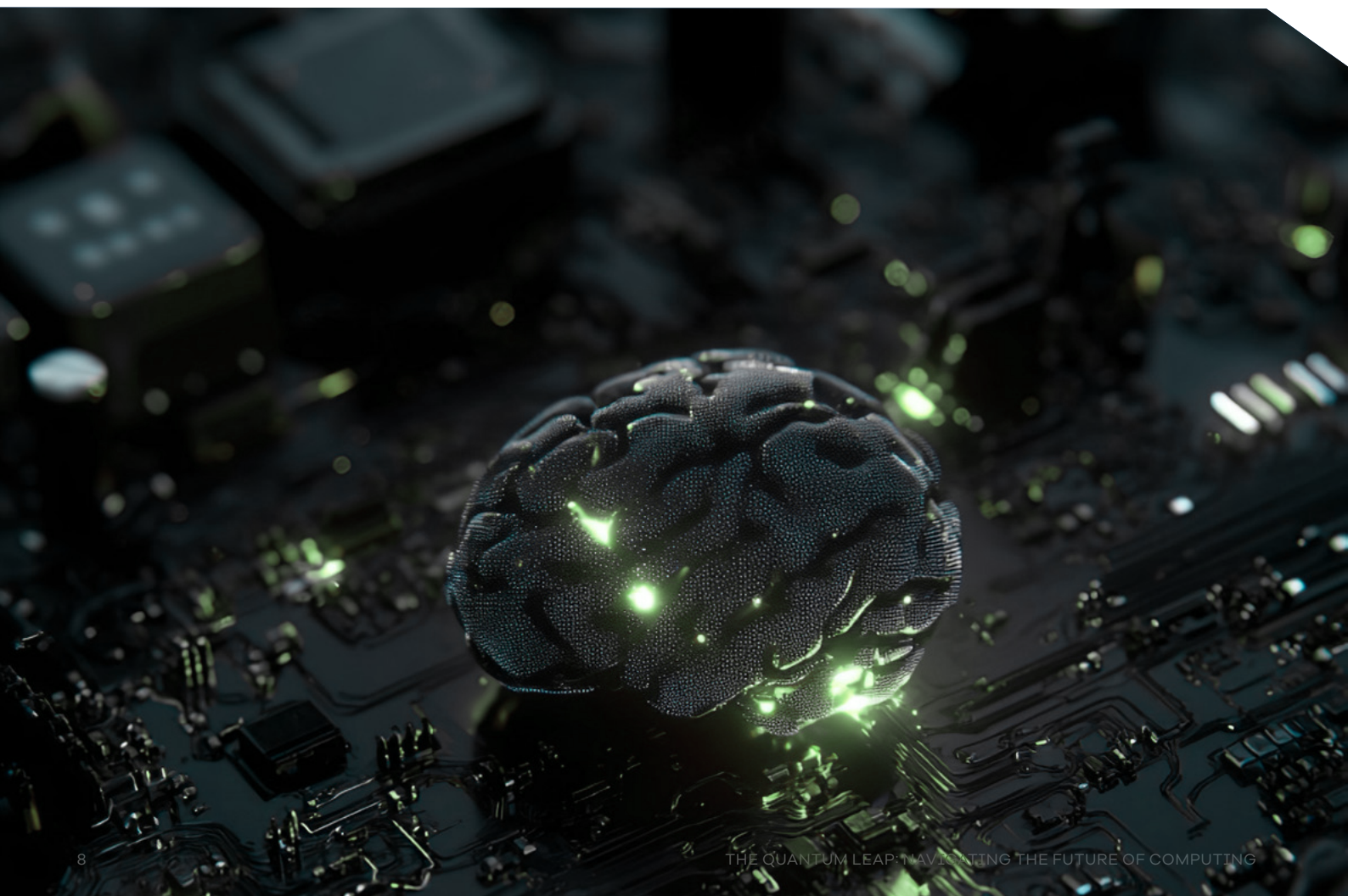
Industry Snapshot 2: Logistics

WHY IT MATTERS

The logistics sector faces growing pressures to improve efficiency, reduce costs, and meet sustainability targets while at the same time meeting customer expectations for faster and more reliable deliveries. Quantum computing promises to revolutionize logistics by optimizing operations, improving route efficiency, and enhancing resilience to supply chain disruptions.

Quantum can transform **logistics by optimizing complex operations** and enhancing resilience

Expedition Center	Door-to-Port	Cross-docking consolidation	Shipping (Air/Sea)	Trans-loading and customs	Long haul trucking	Distribution center	Last mile delivery

Sustainable maritime routing	Last mile delivery	Distribution management
Eco-friendly optimization of maritime routes and resources	Final delivery step from hub to customer	Response and recovery processes for supply chain disruptions
Routing complexities increase costs, delays, and emissions —	Delivery planning challenges raise costs and affect agility —	Limited foresight increases costs and recovery time —
Increased computational capacity enables optimal container routing, reducing costs, delays, and emissions +	Enhanced processing capabilities reduce costs, enable real-time routing, and improve demand adjustments +	Improved simulation capabilities enhance planning and accelerate recovery strategies +

| Five core Sources of value	Efficiency in Routing Optimization	Reduced Time to Adapt to Disruptions	Cost Savings from Resource Optimization	Improved Predictive Accuracy	Sustainability in Operations

— Pain points   + Value unlocked[2]

1. Global Last mile delivery market for 2022 2. Value unlocked through the quantum computer's ability to simulate and optimize complex, multifactorial models
Source: IBM Study, IBM Institute for Business Value, Exploring quantum computing use cases for logistics – BCG analysis

Drawing on expert interviews and insights from the IBM study Exploring Quantum Computing Use Cases for Logistics, we've quantified the transformative potential of quantum capabilities across three key logistics areas: "last mile delivery," "disruption management," and "sustainable maritime routing." For last mile delivery, a market projected to grow from $40.7B in 2022 to $86.2B by 2032, quantum-enabled process improvements of 1–3% could unlock $400M–1.2B in value.[5] In disruption management, where annual losses amount to $184M, improvements of 1–5% could save $1.8–10M. In sustainable maritime routing, optimizing a $150B container shipping market could reduce empty shipping by 1–5%, unlocking $1.5–7.5B.[6] These figures, combined with gains in efficiency, recovery time, and sustainability, highlight the game-changing potential of quantum technologies.

5.   IBM Study, IBM Institute for Business Value, Exploring quantum computing use cases for logistics
6.   BCG Analysis based on experts interviews
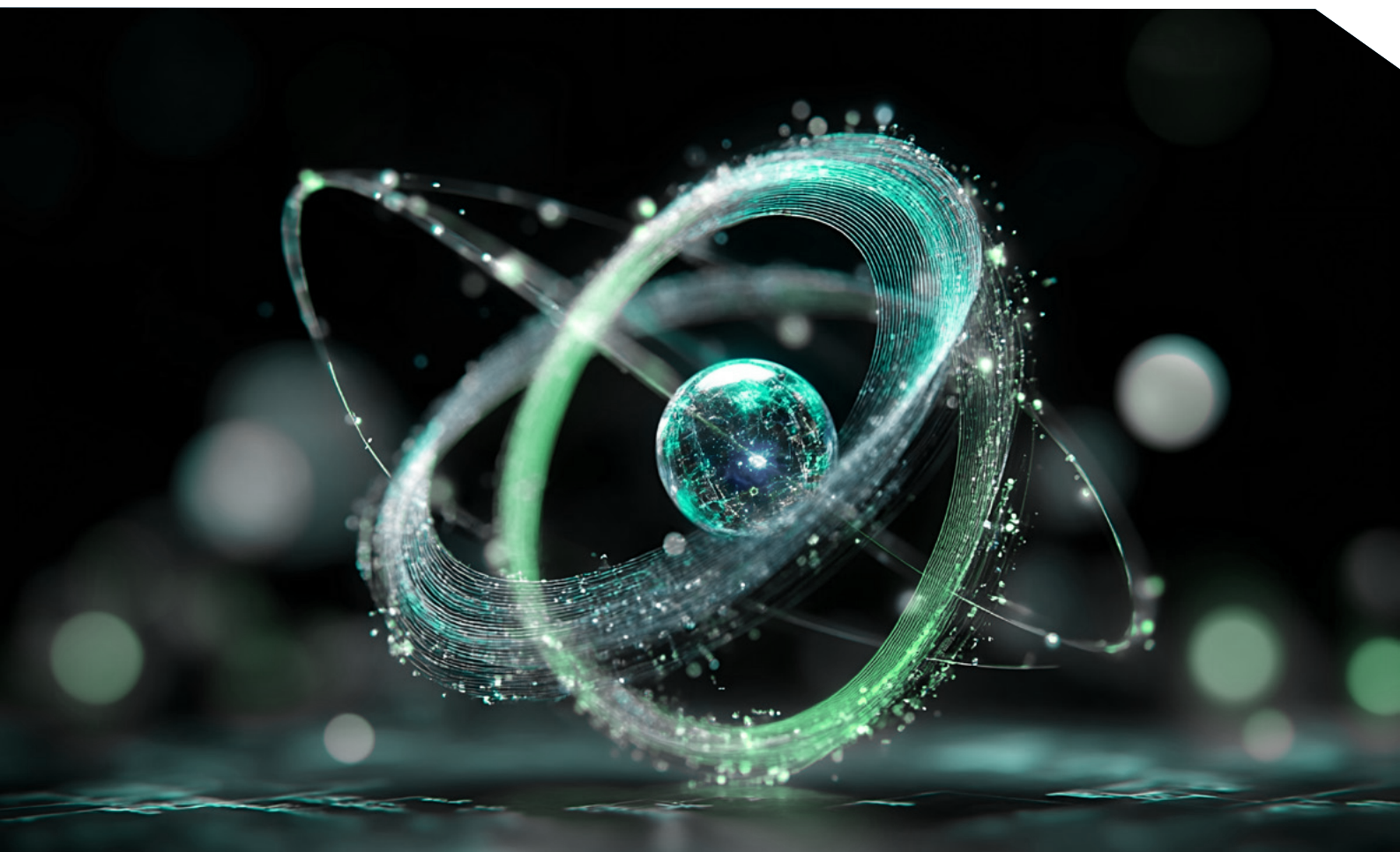
Quantum Computing's Impact on Cryptography

Quantum computing poses significant risks to modern cryptographic systems. Asymmetric encryption is particularly vulnerable, as quantum algorithms enable decryption at unprecedented speeds, rendering many traditional methods obsolete. While symmetric encryption is generally considered safe, it remains potentially at risk with further advancements in quantum technologies. The "harvest now, decrypt later" approach also represents an immediate risk, where encrypted data intercepted today can be stored and decrypted once quantum capabilities advance. These threats could lead to breaches, data manipulation, compromised decision accuracy, and erosion of market trust.

Long-lifecycle data is especially exposed, as future quantum capabilities may retroactively compromise today's encrypted communications and archives—threatening data integrity, decision-making, and market confidence.

MITIGATING CRYPTOGRAPHY RISKS

While the full implementation of quantum-resistant solutions is still in its early stages, organizations can begin by addressing quantum-induced cryptography risks through two complementary approaches:

1. **Post-Quantum Cryptography (PQC):** Employs advanced algorithms resistant to quantum decryption while remaining compatible with existing infrastructure. PQC enhances encryption without requiring quantum hardware

2. **Quantum Key Distribution (QKD):** Secures encryption key exchanges by leveraging quantum mechanics. Interception attempts are immediately detectable, ensuring unmatched security for critical keys in transit

By combining PQC and QKD, organizations can establish a layered security model that addresses both immediate and long-term risks to sensitive data. This approach provides comprehensive protection against quantum threats, including the current challenge posed by "store now, decrypt later" attacks.

Building resilience must begin without delay to counteract threats that are already present. A proactive approach ensures businesses can adapt to the evolving security landscape with minimal disruption. Key steps include:

1. **Collaborate with Vendors:** Partner with cryptography specialists to procure and integrate PQ Cenabled products, addressing present vulnerabilities.

2. **Understand Regulatory Requirements:** Align with emerging regulations to ensure compliance and build stakeholder confidence in current security measures.

3. **Identify Data at Risk:** Audit and classify data, prioritizing sensitive datasets that may already be targeted for future decryption.

4. **Adopt a Hybrid Approach:** Combine classical and quantum-resistant methods to create defense in depth while quantum-resistant solutions continue to mature.

By acting now, organizations can effectively mitigate quantum threats and safeguard their data against both current and evolving risks.

Projecting the Evolution of Quantum Computing

The evolution of quantum computing will significantly reshape industries over the next two decades. Businesses that align their strategies with quantum's development timeline can unlock immense value.

1 **Short-term (2026-2027): Foundational Exploration** PoC development within industries like logistics, finance, and healthcare will enable applications in route optimization, fraud detection, and molecular simulations. Early adopters will leverage these initiatives to lay the groundwork for broader deployment.

2 **Medium-term (2027-2030): Scalable Solutions** Error-corrected quantum systems will enable scalable solutions in areas including energy grid optimization, pharmaceutical drug development, and quantum sensing for defense. Industries will transition from experimentation to operational integration, driving transformative impact.

3 **Long-term (Post-2030): Widespread Transformation** Quantum computing will fully mature, enabling applications like advanced chemical simulations and resilient encryption. Early adopters will dominate markets, while laggards risk falling behind as industries redefine value creation.

Minimal Investments Today can Yield Outsized Returns Tomorrow

A BCG survey on the adoption of quantum technology by businesses gathered insights from C-level executives across various industries and regions spanning mostly Europe and North America. The findings revealed several interesting trends.

Roughly 34% of businesses surveyed by BCG reported investing between $1-5 million in exploring quantum computing applications annually, while 17% were committing upwards of $5 million. With annual global quantum computing investments projected to reach nearly $13bn by 2025, early investments in quantum computing are projected to provide[7] more than just technological readiness – they are laying the foundation for sustained competitive advantages.

The survey underscores almost no companies regret their quantum investments, and early adopters report higher confidence in their strategic positioning; with a steep majority planning to significantly increase their spending on their quantum journey.

Quantum's potential as a 'winner-takes-most' technology means early adopters might capture a disproportionate share of value. Indeed, early adopters making minimal investments now are positioning themselves to shape industry standards and regulatory frameworks and establish dominant positions in high-value quantum applications, such as supply chain optimization and drug discovery.

7.   BCG Corporate survey

Early Adopters Will Lead Tomorrow's Industries

Organizations integrating quantum computing early are positioned to define their industries' future. Evidence suggests that early adopters will capture an outsized share of the technology's value, using quantum to innovate, optimize, and secure a competitive edge. As quantum computing begins to transition from experimental to operational, the advantages of adoption are increasingly tangible.

The survey mentioned earlier highlights a threefold increase in active proof of concepts (PoCs) since 2022, underlining the growing recognition of quantum potential across sectors. This rapid expansion indicates that businesses are not merely exploring quantum for theoretical gains but are aligning it with practical use cases designed to create value.

ADVANTAGES FOR EARLY ADOPTERS

Any transformative technology is characterized by a 'winner-takes-most' dynamic, where rapid evolution leaves late adopters grappling with significant investments in time and costs to grasp its potential, while early adopters capitalize on their head start to secure a disproportionate share of value. In the case of quantum technology, its adoption lifecycle is driven by the potential for breakthroughs cross-industries, suggesting an even more pronounced future, where early adopters are poised to capture the majority of benefits. This disparity underscores the urgency for businesses to position themselves ahead of the curve.

1. **Economic Benefits:** Early movers can monopolize economic gains, from reduced operational costs to enhanced product quality. For example, a pharmaceutical firm leveraging quantum could drastically cut development times, beating competitors to market with breakthrough drugs.

2. **Market Leadership:** Companies that lead quantum adoption are poised to set standards, define best practices, and create barriers to entry. This solidifies their dominance while forcing competitors to follow their lead.

3. **Talent and Ecosystems:** Early adopters attract top talent and form partnerships within emerging quantum ecosystems, further amplifying their advantage. These collaborations enable them to stay ahead of technological advancements.

4. **Long-Term Expertise:** As early movers refine their quantum capabilities, they develop proprietary knowledge and infrastructure that competitors cannot easily replicate.

WHY TIMING IS CRITICAL

Businesses that delay adoption face significant challenges in competing with established quantum players. Late adopters may struggle to secure talent in a competitive hiring environment, develop partnerships or access resources already claimed by early movers, or achieve ROI as market dynamics shift to favor companies already proficient in quantum applications.

Understanding the potential impact of quantum on their industry and organization should be companies' first priority:

1. **Where do we stand on the quantum adoption curve?** Evaluating their position relative to competitors is critical.

2. **What value-driven use cases can we pilot today?** Identifying and acting on key PoCs ensures early entry into the quantum space.

3. **Are we aligning quantum initiatives with strategic goals?** Ensuring that quantum efforts integrate with broader business priorities enhances their relevance and impact.

By acting decisively, organizations can transition from exploratory efforts to measurable impact, ensuring they remain part of the 10% of businesses poised to capture the majority of quantum computing's value

Evaluating Impact and Readiness

BCG-SITE's Impact and Readiness Framework is designed to help organizations evaluate two key factors: the extent to which quantum computing could influence their operations and strategy (Impact) and their preparedness for its transformative potential (Readiness).

The framework achieves this by mapping organizations on the Quantum Adoption Curve, a matrix that positions them across readiness and impact dimensions.

This mapping informs tailored recommendations, enabling businesses to align quantum initiatives with their strategic goals and progress effectively along the adoption curve.

Impact examines the potential of quantum technologies to influence an organization's operations, processes, and competitive positioning. A structured scoring system assesses the impact across three key enablers:

IMPACT

1 **External Landscape:** Examines how quantum technologies are transforming the industry, creating new revenue opportunities, and altering competitive dynamics, providing a lens to evaluate their potential impact on the organization.

2 **Operational Impact:** Analyzes the organization's internal environment, including its processes, business model, and operational bottlenecks, to assess how quantum technologies could address existing challenges and create value.

3 **Data and Compliance:** Evaluates the organization's data landscape and compliance requirements to determine how quantum technologies might influence data management, mitigate risks, or introduce new regulatory challenges.

Readiness toward the technology adoption is measured through a structured survey that scores an organization's profile across three key enablers:

READINESS

1 **Infrastructure Readiness:** The ability of IT systems to support seamless quantum integration alongside classical technologies.

2 **Talent and Expertise:** The presence of a workforce skilled in quantum technologies, supported by training and retention strategies.

3 **Governance and Processes:** The incorporation of quantum initiatives into governance frameworks with clear accountability and risk management.

Understand Your Quantum Readiness

Organizations looking to navigate the opportunities and challenges of quantum computing can benefit from a detailed assessment of their readiness and potential impact. BCG's 20-question web survey provides a structured evaluation, helping businesses position themselves on the Quantum Adoption Curve and identify where they stand relative to peers.

By answering the questions at the link [https://www.bequantumready.com/] decision-makers can access survey results as well as:

1. **Impact and Readiness score:** A clear assessment of your organization's current capabilities and preparedness.

2. **Position on the Readiness-Impact Matrix:** Visualizing where your organization stands relative to peers and benchmarks.

3. **Prioritized sequence of action steps:** A tailored roadmap to guide initiatives and align them with your strategic goals.

Positioning on the Quantum Adoption Curve highlights whether your organization is leading as an innovator, actively piloting as an early adopter, or beginning to explore as part of the early majority. This perspective will enable businesses to better understand their trajectories as quantum technology matures.

Next Steps: Building a Quantum Roadmap for Success

Quantum investments are not just about innovation – they're about navigating an inevitable shift. As quantum computing advances toward practical application, businesses must shift from exploration to strategic execution, laying the groundwork for success by identifying risks, exploring use cases, and preparing teams and systems for quantum integration.

Assessment	Target	Roadmap
Evaluate Quantum Risks Identify vulnerabilities and outline mitigation plans	**Define Strategies Goals** Set measurable quantum adoption objectives	**Launch PoCs** Validate quantum solutions for specific challenges
Analyze Use Cases Pinpoint high-impact applications for PoCs	**Prioritize Use cases** Focus on scalable, high-value applications	**Allocate Resources** Invest in talent, training, and R&D initiatives
Audit Current Capabilities Assess skills gaps and system readiness	**Build Partnerships** Collaborate with providers for innovation access	**Define Milestones** Use metrics to measure progress and refine plans
Gauge Ecosystem Maturity Review quantum technology trends and providers	**Develop Talent** Upskill teams and onboard quantum specialists	**Enhance Cybersecurity** Implement Quantum-safe solutions for future-proof protection

By embracing these strategies, businesses can establish themselves as leaders in the quantum revolution, unlocking benefits that extend well beyond technological advancements. Taking early action will not only ensure readiness but also sustained relevance, long term impact, and a lasting competitive edge in a rapidly evolving future.