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Embracing the Quantum Economy:
A Pathway for Business Leaders

INSIGHT REPORT

JANUARY 2025

Images: Getty Images

Contents

Foreword

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In an era marked by rapid technological advancements, the quantum economy stands at a transformative milestone. Through discussions and work with our partners and experts across industries and stakeholder groups, we recognize the profound impact that quantum technologies will have on industries worldwide. This document serves as a comprehensive guide for navigating this new frontier.

It provides valuable insights into the practical applications of quantum technologies throughout various sectors, from finance and healthcare to energy and transportation. By embracing these advancements and implementing quantum-safe cryptography, business leaders can not only enhance their competitive edge but also protect their systems against the cybersecurity threats posed by quantum technology. It is crucial to start preparing today to build trust and ensure a secure, sustainable and resilient global economy.

Accenture has always been at the forefront of technological innovation, helping businesses harness the power of emerging technologies to drive growth and efficiency. Quantum computing, sensing, and communication and security represent the next wave of disruption, offering unprecedented capabilities that can solve complex problems and unlock new opportunities. However, as highlighted at the Quantum World Congress 2024, the gap between quantum potential and quantum security is dangerously wide. Most organizations are woefully unprepared for the quantum-powered future, particularly in terms of cybersecurity.

The World Economic Forum is committed to advancing responsible innovation and commercialization in quantum technologies for industry and society. Through its Quantum Economy Network,[1] part of the Centre for the Fourth Industrial Revolution, the Forum provides a global platform for various stakeholders to understand the potential of quantum technologies, shape their development and prepare for their introduction into the economy. Our joint efforts through the Forum's Quantum Application Hub[2] initiative, aim to foster innovation and drive the adoption of quantum technologies in various sectors. The insights and strategies presented in this report are designed to help leaders navigate the complexities of the quantum economy and drive meaningful change in their organizations and beyond.

The importance of this paper is further underscored by the proclamation of 2025 as the International Year of Quantum Science and Technology by the United Nations.[3] This year-long initiative aims to increase public awareness of the significance of quantum science and its applications, enhancing international cooperation and focusing on sustainable development. As we celebrate 100 years of the development of quantum mechanics, this milestone provides a unique opportunity to engage with quantum science and technology, inspiring the next generation of quantum pioneers.

We invite you to explore the transformative potential of quantum technologies and join us in shaping a future where innovation and collaboration pave the way for sustainable growth and prosperity.

Executive summary

The quantum economy presents an unprecedented opportunity to reshape industries and redefine economic landscapes globally. Both public and private sectors need to explore and adopt emerging quantum technologies. This report offers a comprehensive guide that equips leaders with the knowledge and strategies necessary to leverage the transformative power of quantum technologies in a rapidly evolving economic landscape.

Quantum technologies include:

- **Quantum computing**, which is expected to accelerate scientific discovery and potential to solve complex problems in various fields through optimization, machine learning and simulation.

- **Quantum sensing**, which offers advancements in precision and autonomous measurement, impacting many sectors, and is at various stages of adoption maturity from proofs of concept to production systems.

- **Quantum communication and security**, which ensure secure data transmission through theoretically unbreakable encryption, crucial for future-proofing cybersecurity and creating new products and services.

Economic impacts and opportunities:

Quantum technologies have the potential to drive economic growth and diversification throughout various industries. Early adoption can provide competitive advantages, but also comes with challenges such as high research and development (R&D) costs and the need for skilled workforce development.

Risks and mitigation strategies:

Addressing technological readiness, intellectual property management and equitable distribution of quantum advancements is crucial. Strategic measures include fostering public-private partnerships, investing in education and training, and developing robust regulatory frameworks.

Industry-specific applications where quantum technologies are poised to transform various industries by offering innovative solutions in key sectors:

- **Financial services** (banking and capital markets, institutional investors, insurance, asset management and private investors): Quantum computing has the potential to optimize portfolios, accelerate risk analysis and refine models for pricing and insurance.

- **Pharmaceuticals and healthcare:** Quantum sensing technologies can revolutionize diagnostics and treatment, particularly in cardiology and neurology, and have applications even in early clinical studies.

- **Energy and utilities** (mining and metals, oil and gas, and energy technology and utilities): Quantum solutions can enhance energy storage and grid optimization, contributing to more sustainable energy systems.

- **Technology and telecommunications:** Quantum communication can provide enhanced security through quantum key distribution and encryption methods.

- **Chemicals and advanced materials:** Quantum solutions could be used to predict molecular behaviours to discover stronger, lighter and more sustainable materials in the future.

- **Automotives, aerospace and transportation:** Quantum solutions could optimize processes, enhance navigation and solve complex routing problems, leading to a more efficient and sustainable transportation network.

Strategic pathways for businesses:

- **Explorative initiatives:** Engage with the quantum ecosystem through partnerships and pilot programmes to test and understand the potential impacts of the technology.

- **Building dedicated teams:** Develop in-house expertise and capabilities to drive quantum strategies forward.

- **Strategic investments:** Allocate resources to quantum initiatives, considering market potential, risk management and regulatory environment.

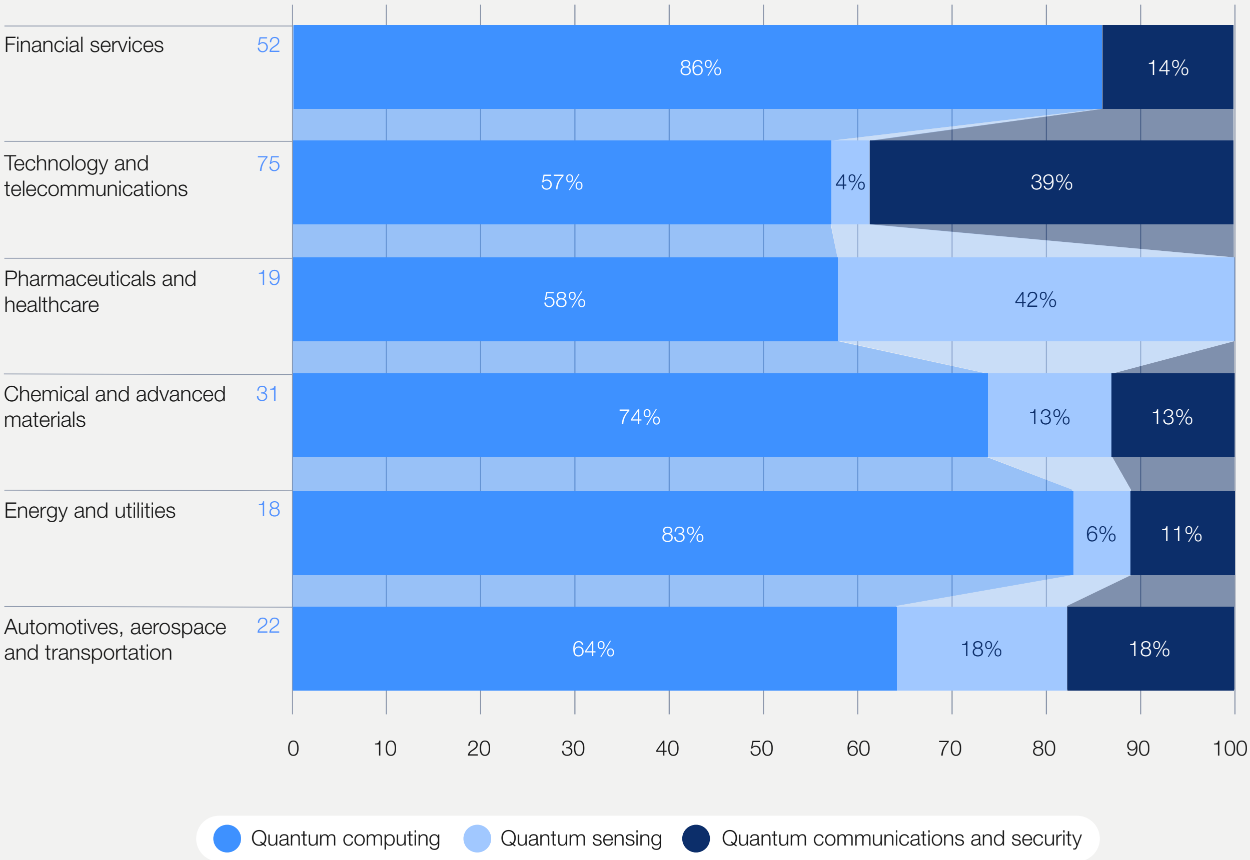
Businesses and policy-makers must conduct risk assessments, engage with quantum ecosystems, initiate pilot programmes, build dedicated teams, invest strategically and continuously monitor and adapt their approaches. By following these steps, leaders can effectively navigate the complexities of the quantum economy and harness its potential for growth, value creation and innovation.

Introduction

As significant advancements are made in quantum technologies, it brings forth the potential to fundamentally reshape and redefine the global economic landscape. Quantum technologies, defined in this report as quantum computing, quantum sensing, and quantum communications and security, are poised to permeate and transform every major industry of the global economy. This evolution will collectively drive significant economic impact and give rise to a distinctive ecosystem, commonly referred to as the quantum economy.[4]

Quantum technologies promise substantial economic impact in every single sector (see Figure 1). Some industries, such as finance, technology and telecommunications, pharmaceuticals and healthcare, chemicals and advanced materials, energy and utilities, and automotives, aerospace and transportation, are poised to be early adopters. This is because quantum technologies promise to redefine their businesses and truly impact their competitive edge.

FIGURE 1 **Early adopters in different industry sectors (by number of companies)**



Source: The Quantum Insider app and Accenture

To grow and thrive, the quantum economy will require strategic investments from the public and private sectors, a skilled workforce and an ever-growing ecosystem that expands beyond the dominant countries and largest players, thus avoiding the consequences of a quantum divide. It is estimated that the potential economic value for the trio of quantum computing, quantum sensing, and quantum communication and security in the leading industries could reach between $900 million and $2 trillion by 2035.[5]

This potential to propel economic growth, however, requires strategic measures to mitigate the challenges this novel technology brings. To maximize the advantages of early adoption, business leaders should not only examine the transformative capabilities of quantum technologies but also address the accompanying challenges such as intellectual property issues, resource constraints, and the risk of widening the digital divide: a quantum divide.[6]

It is for this reason that visionary leaders should start investing and building their quantum strategy now. Despite technical hurdles and the lack of a clear return on investment (ROI), the sooner businesses assimilate the innovation and start experimenting, the faster they will find opportunities for new business value and growth providing a competitive edge.

This report offers actionable pathways for business leaders to integrate quantum technologies, emphasizing the importance of dedicated quantum teams and strategic investments. By leveraging real-world examples and insights from industry leaders, it provides practical guidance for adopting quantum technologies to foster economic diversification and innovation.

This report consists of four sections exploring the potential of the quantum economy, providing business leaders with the necessary steps to develop informed quantum strategies.

1. **Section 1. Advancements and impact in the quantum economy** introduces the current quantum landscape, sharing details of the risks and opportunities of the quantum age, and exploring specifics on the interplay between quantum technologies and artificial intelligence (AI). This section sets the stage for understanding the broader context and implications of quantum advancements.

2. **Section 2. The quantum economy: Building new growth areas** discusses how quantum technologies can drive economic diversification in various industry sectors. Each subsection highlights the specific impacts on finance, healthcare, materials, energy and transportation and telecommunications, providing detailed insights into sector-specific innovations.

3. **Section 3. The quantum leap: Navigating the new frontier of use cases** provides insights into practical applications and industry engagement, highlighting real-world use cases to explore how different sectors can leverage quantum technologies, while emphasizing their transformative potential across industries.

4. **Section 4. The business of quantum: How to get started** provides actionable steps for businesses and policy-makers to embark on their quantum journey. Examples include exploratory initiatives, capacity building and strategic investments, providing a roadmap for integrating quantum technologies into organizational strategies.

1 Advancements and impact in the quantum economy

Pitfalls and opportunities abound in the evolving quantum landscape. Quantum technologies' interaction with AI will drive unparalleled innovation and efficiency.

1.1 The rapid advancement and evolution of quantum technologies

Continued and rapid growth of quantum technologies is heralding a new era in computing, communication and sensing.

Quantum computing, with its potential to vastly outperform classical computers in solving certain complex problems, is at the forefront of this technological revolution. This acceleration is predicated on the construction of machines that can run the theoretically proven algorithms. The motivation to build these computers is incredibly strong because the potential economic impact of quantum technologies is profound. By unlocking new levels of computational efficiency and security, they promise to revolutionize industries including finance, healthcare, logistics and energy.

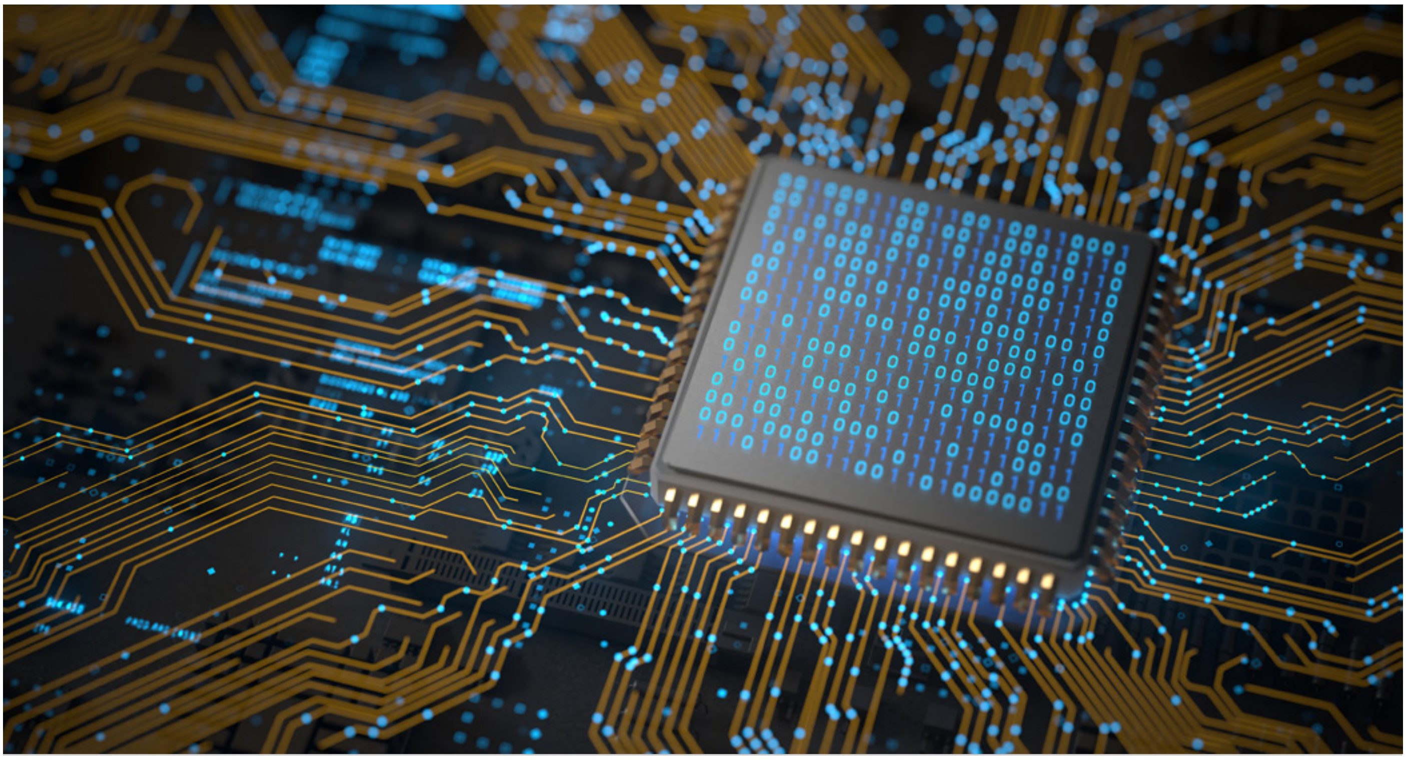
Quantum communication, which leverages the principles of quantum entanglement and superposition, offers a new way to secure data transmission. This technology ensures theoretically unbreakable encryption, making it a cornerstone for future-proof cybersecurity infrastructures.[7] It can enable detection of eavesdroppers on communication channels and, when used properly in conjunction with current communication security technologies, can offer increased cyber defence. This is intriguing because current cybersecurity methods depend on mathematical problems that are difficult for computers to solve. In contrast, a communication system based on physics has unique features that offer greater potential.

Meanwhile, quantum sensing is pushing the limit of precision measurement capabilities, enabling breakthroughs in fields ranging from medical imaging to environmental monitoring.[8] The most fascinating is the global dependence on quantum clocks, which deploy quantum sensing for timing. To make quantum sensing devices more widely usable and accessible, the next crucial step is to make them smaller, lighter, more energy-efficient and cost-effective.

The current state of quantum technologies is marked by exponential advancements. Quantum computers, once confined to academic laboratories, are now being developed by major corporations and start-ups with investments in billions, all around the world.[9] These devices have begun to scale enough to run small variants of problems that classical computers currently find insurmountable, such as optimizing complex systems, simulating molecular structures for drug discovery, and solving large-scale linear equations.

Central to this transformation are the ongoing R&D efforts that continuously push the boundaries of what quantum technologies can achieve. Governments, academic institutions and private enterprises are investing heavily in quantum research, fostering an ecosystem that encourages innovation and collaboration.[10] Currently, public-sector investments worldwide exceed $40 billion.[11]

These rapid advancements in quantum technologies are set to redefine capabilities in various sectors. Delving deeper, it becomes evident that their potential to solve currently intractable problems will catalyse significant economic transformations, driving a wave of innovation and efficiency that will shape the future.[12]



1.2 The main challenges for unlocking the potential of quantum technologies

Quantum technologies have the potential to significantly benefit industry and society. However, they also bring several challenges to successful and equitable adoption, pertaining to technological readiness, intellectual property management and the equitable distribution of quantum advancements.

TABLE 1 **Foundational challenges by technology type**

Quantum computing	
Error rates and stability	Quantum bits (qubits) are fragile, and prone to errors from environmental interference and decoherence. Developing robust error correction methods and achieving stable qubit operation are critical challenges. Although there are devices with different means to address this fragility, they still face some challenges with respect to stability.
Scalability	Building a quantum computer with many qubits that can perform meaningful computations is still work in progress. Current systems are limited in size and scope, and scaling up without exponentially increasing the error rates and resource requirements is a significant technical challenge.
Interoperability and integration	Integrating quantum computers alongside existing classical systems is essential for practical applications. This requires the development of hybrid computing models and new software paradigms to leverage the strengths of both quantum and classical computing.
Quantum sensing	
Sensitivity and precision	Quantum sensors, which have been in use for decades, offer unprecedented sensitivity and precision. These sensors, including atomic clocks, magnetometers, gravimeters and accelerometers, are used in various applications such as navigation, medical imaging and geophysics. However, achieving consistent performance in real-world environments remains challenging. Factors such as temperature fluctuations and electromagnetic interference can affect sensor accuracy. To address these issues, the convergence of technologies, including the integration of current methods with machine learning (classical AI) techniques, is being used to de-noise and enhance sensor performance.
Miniaturization and practicality	Developing compact and practical quantum sensors that can be easily deployed in various applications, such as medical diagnostics and environmental monitoring, poses a significant hurdle. It is critical to balance sensitivity with size and power consumption to ensure these sensors can effectively function in diverse fields – in applications such as detecting diseases at an early stage or monitoring air and water quality in real time.
Standardization and calibration	Ensuring that quantum sensors are standardized and can be calibrated accurately is essential for widespread adoption. This involves developing robust manufacturing processes and calibration techniques that can be replicated across different devices and applications.
Quantum communication and security	
Security and reliability	Quantum communication promises theoretically unbreakable encryption, but ensuring the security and reliability of quantum communication networks over long distances is challenging. Factors such as signal loss and noise can compromise the integrity of keys generated using such protocols.
Scalability	Building the necessary infrastructure for quantum communication, such as quantum repeaters and satellite-based systems, requires substantial investment and technological breakthroughs. Integrating quantum communication networks with existing classical networks is also a complex task.
Interoperability and integration	Developing and standardizing quantum communication protocols is crucial for interoperability and widespread adoption. This includes establishing international standards and ensuring compatibility across different quantum communication systems.

Source: Accenture

The rapid pace of innovation in quantum technologies presents unique opportunities for safeguarding intellectual property (IP). The field's competitive nature and the significant advantages conferred to early movers add complexity to IP management and IP law. The risks and value to be mindful of in terms of IP management are as follows:

TABLE 2 **Complexities of intellectual property management**

Patent race and first-mover advantage	Presently, the race to secure patents is intense, with companies and research institutions vying for the first-mover advantage. However, IP law is still evolving, making it challenging to sustain these advantages, as new discoveries could render existing patents obsolete. IP law covers various types of patents, including utility patents, design patents and plant patents. However, the evolution and enforcement of IP law vary significantly across different jurisdictions, adding complexity to global IP management.[13]
Cross-border collaboration and IP protection	Given that both talent and technologies reside globally, research and business often require international collaboration, raising concerns about IP protection in different legal jurisdictions. Ensuring that IP rights are respected and enforced globally is a complex challenge that requires robust international agreements and cooperation.[14]
Open science versus proprietary research	Balancing open scientific research with the need to protect proprietary technologies is a delicate act. While open research fosters collaboration and accelerates innovation, it also poses risks to IP security. Companies and researchers must navigate this landscape carefully to protect their investments while contributing to the broader scientific community.[15]

Source: Accenture

Ensuring the equitable distribution of quantum advancements is crucial for fostering global development and avoiding exacerbating existing inequalities. According to the World Economic Forum's Quantum Economy Blueprint report,[16] three potential approaches ensure that the benefits of quantum technologies are equitability distributed, and that existing inequalities are not worsened:

TABLE 3 **Equitable distribution of quantum advancements**

Access to quantum technologies	Not all quantum technologies are accessible across regions and economic sectors. Initiatives like cloud-based quantum computing services and international collaborations attempt to bridge the gap, but this is not always the case.[17]
Inclusive quantum ecosystems	Lack of unified strategies among industry, academia and government can hinder innovation and support for start-ups. Without strong public-private partnerships and adequate preparation of future quantum experts by educational institutions, the potential of quantum technology may not be fully realized.[18]
Use of responsible and sustainable development	Development of quantum technologies must prioritize sustainability and social responsibility. Ethical implications, such as impacts on privacy, security and employment, need careful consideration. Both public and private sectors must engage in proactive dialogue to create frameworks ensuring these technologies benefit society and the planet.[19]

Source: Accenture

The journey towards the widespread adoption of quantum technologies is undoubtedly challenging, with numerous risks that must be managed through strategic planning and cautious optimism. While the potential rewards are immense, so too are the complexities and uncertainties inherent in this rapidly evolving field. Addressing technological readiness, safeguarding intellectual property and ensuring equitable distribution can pave the way for a quantum future that benefits all of humanity.

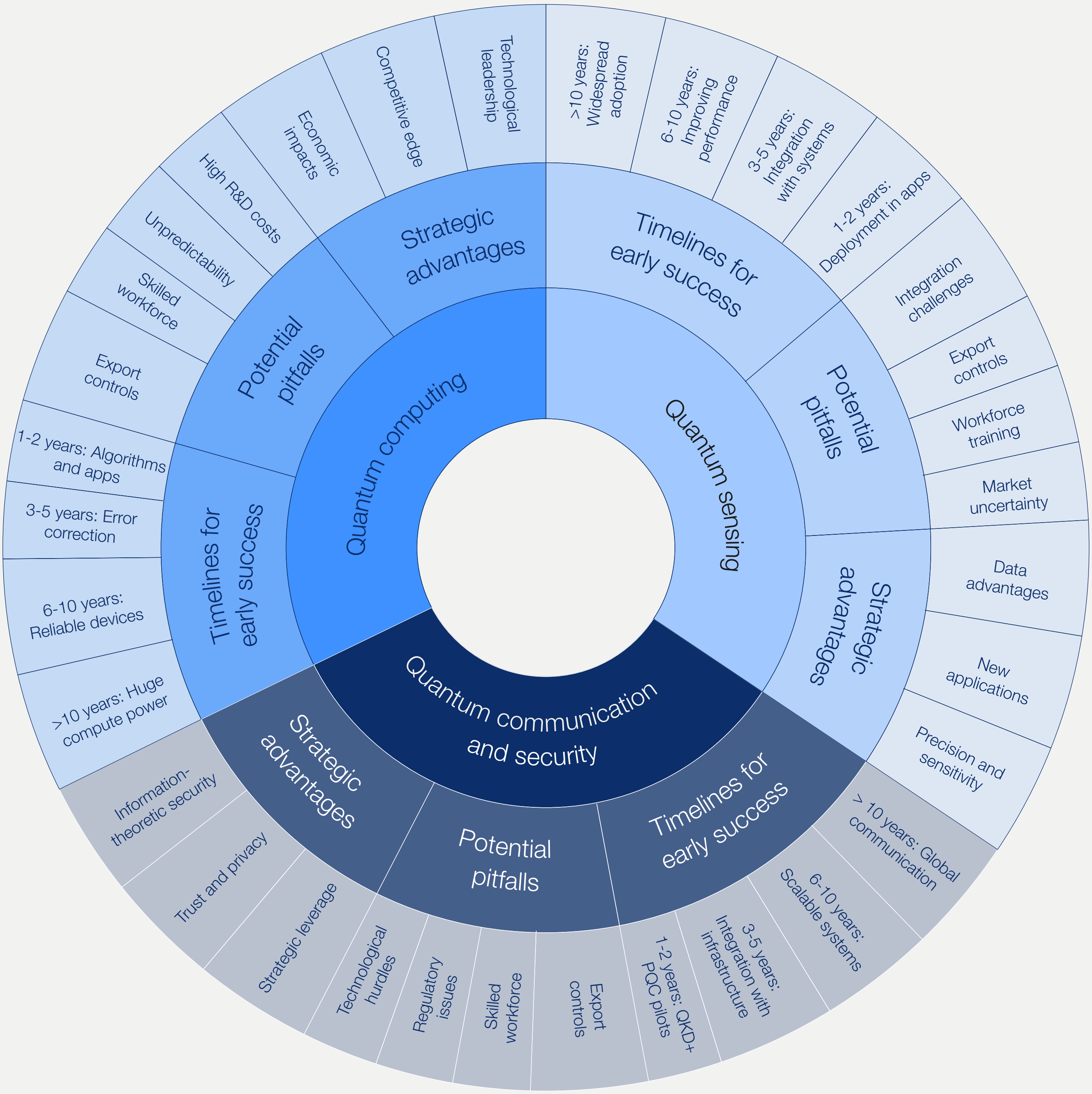
1.3 First-mover advantages and challenges

“

If you can tie quantum to real business outcomes, you'll get the buy-in you need to start preparing for quantum now,"
said Adam Burden at Quantum World Congress,
"The question is: are you ready?"[20]

Organizations that invest early in quantum technologies may position themselves at the forefront of this transformation. However, the path of a first mover is fraught with challenges, including high R&D costs, insufficient technology maturity, unpredictability and the shortage of a skilled workforce. This section delves into the strategic advantages, potential pitfalls and competitive dynamics shaped by early investment in quantum technologies, offering insights into the timelines of early success for each domain.

FIGURE 2 **First-mover advantages and challenges**



Source: Accenture

TABLE 4 **First-mover advantages and challenges**

Technology	Strategic advantages	Timelines of early success	Potential pitfalls
Quantum computing[21]	**Technological leadership:** Early adopters can establish themselves as leaders, setting standards and influencing the development of the ecosystem. **Competitive edge:** Access to advanced systems early on provides capabilities to solve complex problems faster and more efficiently – a significant competitive advantage. **Economic impacts:** Quantum computing has the potential to revolutionize industries such as finance, pharmaceuticals and healthcare to drive economic growth and job creation.	**Commercial (1-2 years):** Hybrid quantum-classical algorithms and initial commercial quantum computing applications are developed. **Prototype (3-5 years):** Quantum error correction and scaling improve significantly, leading to broader adoption in various industries. **Experimental (6-10 years):** Enhanced error correction and optimization techniques make quantum computing more reliable and accessible. **Theoretical (10+ years):** Fully fault-tolerant quantum computers are available, unlocking unprecedented computational power.	**High R&D costs:** Significant investment in research and development is required, with no guaranteed returns. **Unpredictability:** The maturation of quantum computing technology is uncertain, and breakthroughs may take longer than anticipated. **Skilled workforce:** Building and retaining a workforce capable of developing and utilizing quantum computing technology is a major challenge. **Export controls:** These could restrict the transfer of quantum algorithms, software and hardware that may be deemed a national security risk for the country.
Quantum sensing[22]	**Precision and sensitivity:** Quantum sensing offers unparalleled precision and sensitivity, which is set to revolutionize the healthcare industry and is on its way to aid defence and environmental monitoring. **New applications:** With early investments, it is possible to discover novel applications and markets for quantum sensors, positioning companies as industry pioneers. **Data advantages:** New data insights can be seen improving decision-making processes and operational efficiencies; however, capitalizing on this still far away.	**Commercial (1-2 years):** Prototype quantum sensors are in the marketplace and initially deployed in niche applications. **Prototype (3-5 years):** Quantum sensors are integrated into existing systems and expanded into broader markets. **Experimental (6-10 years):** Quantum sensor technologies are refined and optimized, improving reliability and performance. **Theoretical (10+ years):** Quantum sensing achieves widespread adoption and standardization.	**Market uncertainty:** The demand for sensors is still evolving, so early adopters may face uncertain returns. **Integration challenges:** Integrating with existing systems and infrastructure can be costly (e.g. data adoption for decision-making is uncertain). **Workforce training:** Developing expertise in quantum sensing technologies and their applications requires investment in workforce training and education (e.g. upskilling of healthcare workers) and creation of intuitive interfaces. **Export controls:** Sensors that have potential military applications (e.g. quantum navigation) may face strict export limitations.
Quantum communication and security[23]	**Information-theoretic security:** Theoretical unbreakable encryption can provide a significant advantage in cybersecurity. **Trust and privacy:** Early adopters can position themselves as leaders to foster trust and protect sensitive information. **Strategic leverage:** Countries and companies that lead in quantum communications (networks) can gain strategic advantages in intelligence and secure data transmission.	**Commercial (1-2 years):** Demonstration of practical quantum key distribution (QKD) systems and deployment of quantum random number generators (QRNGs) into cybersecurity systems and critical infrastructure, followed by pilot projects that combine post quantum cryptography (PQC). **Prototype (3-5 years):** Quantum communication networks expand and are integrated with classical infrastructure. **Experimental (6-10 years):** More advanced QKD protocols and scalable quantum communication systems are developed. **Theoretical (10+ years):** Global quantum communication networks are established, enabling secure international data transmission.	**Technological hurdles:** Developing reliable and scalable quantum communication systems presents significant technical challenges such as geostationary equatorial orbit (GEO) and low earth orbit (LEO) satellite [24] communications for QKD. **Regulatory issues:** Regulation is still developing, potentially leading to legal and compliance challenges. **Skilled workforce:** Building a skilled workforce capable of developing and maintaining quantum communication systems is crucial and challenging. **Export controls:** Restrictions could apply to quantum encryption of physical devices that are deemed critical infrastructure.

As noted in Table 4, being a first mover in the quantum technology space offers significant strategic advantages, including technological leadership, competitive edge and economic impact. However, these benefits come with risks, such as high R&D costs, technology unpredictability and the challenge of building a skilled workforce. Decision-makers must carefully weigh these factors, considering the timelines of early success and the evolving competitive dynamics. By balancing the benefits and risks, companies and economies can effectively navigate the path to leadership in the quantum technology revolution.

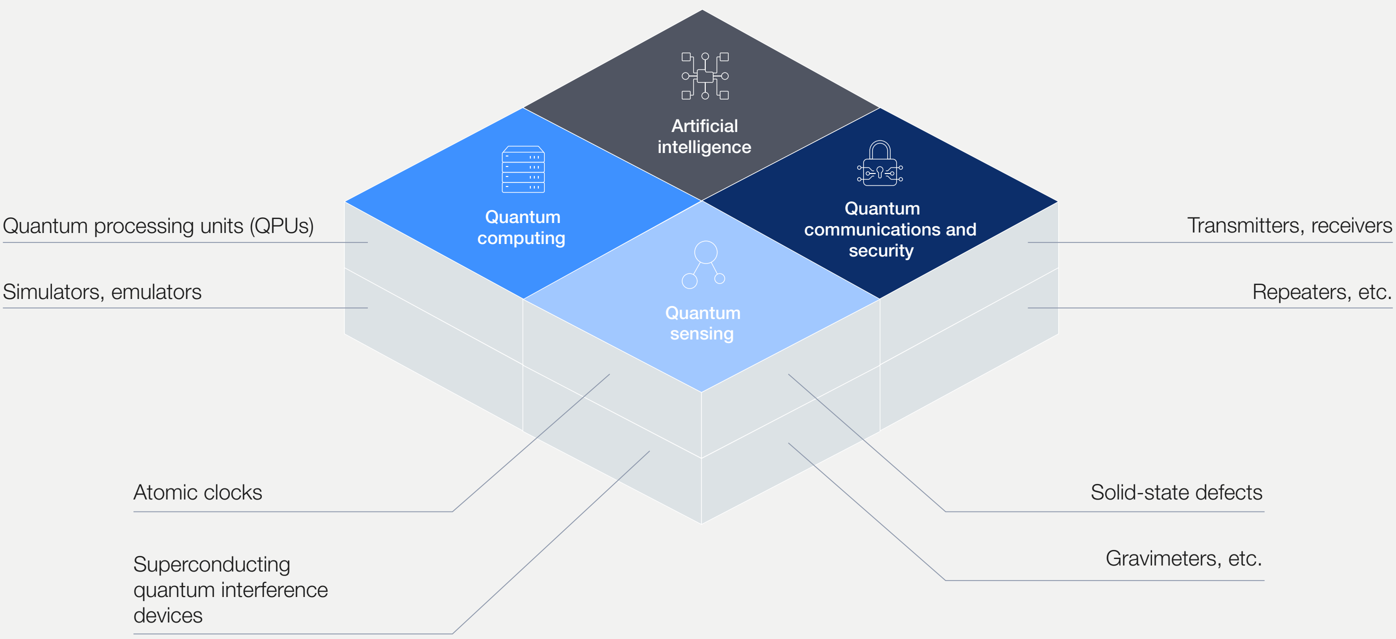
1.4 The next wave of disruption: Quantum and AI

The intersection of quantum technologies and artificial intelligence (AI) marks a pivotal advancement in technology, creating a symbiotic relationship where both fields propel each other forward. This relationship promises to unlock new possibilities, driving innovation and efficiency across various domains.

AI is already enhancing quantum advancements by optimizing quantum algorithms, refining data from quantum sensors and improving the efficiency of quantum communication systems. This relationship will not only accelerate the development and practical application of quantum technologies but will also reveal new avenues for innovation and problem-solving that classical systems cannot achieve. By leveraging AI, quantum technologies can address complex challenges in various industries more effectively, driving significant economic and technological progress.

Rajeeb Hazra, President and CEO of Quantinuum, is focused on accelerating fault-tolerant quantum computing at scale. This advancement will enable the combination of AI, classical high-performance computing (HPC) and quantum computing to become a revolutionary tool for the next phase of human discovery and creation. “Our goal is to accelerate fully fault-tolerant, universal quantum computing by delivering a full-stack solution with unmatched hardware capabilities and software that harnesses the combined power of HPC, AI and quantum computing to create a new era of insight and achievements,” he says.

FIGURE 3 **A medley of quantum information and AI systems**



Source: Accenture

AI advancing quantum technologies

AI's role in advancing quantum computing is multifaceted, offering significant enhancements in programming, system design and algorithm development. Prominent examples include machine learning (ML) algorithms that aid the calibration of configurable components of quantum hardware, reinforcement learning algorithms to improve the efficiency of quantum algorithms, and decoders based on neural networks that make quantum error correction more efficient, enhancing the reliability of quantum computers.

- Microsoft's Copilot in Azure Quantum, trained on extensive data from over 300,000 open-source documents, publications, textbooks and manuals focused on chemistry and materials science, aids researchers and developers in writing quantum code more efficiently. By providing intelligent code suggestions and optimizations, it significantly accelerates the development process, reducing the time and effort required to create complex quantum algorithms.[25]
- IBM's Qiskit Transpiler Service exemplifies how AI can work alongside quantum hardware to enhance the productivity of quantum R&D. The Qiskit Transpiler Service is a cloud-based resource that translates Qiskit code into machine language. It uses AI to reduce the number of gates to perform computations faster and with fewer errors. Improving transpiling – the automatic translation of source code from one programming language to another – could lead to better outputs from the quantum computer and accelerate the R&D process.[26]

Quantum sensors offer unprecedented accuracy in biotech applications, advancing medical insights by enhancing detection capabilities. These sensors, combined with AI, refine the collected data into actionable intelligence. For instance, in medical imaging, quantum sensors can detect subtle changes, while AI removes environmental interference and improves image analysis and classification. This integration delivers high-resolution, detailed data to healthcare professionals, enabling faster and more accurate diagnoses, potentially improving patient outcomes.

Quantum technologies propelling AI

Conversely, quantum computing has the potential to revolutionize AI by overcoming the computational limitations of classical systems. Quantum computers could increase the speed of training AI models, for instance in deep learning, where quantum sampling (Quantum Monte Carlo) techniques may significantly speed up the training process. (This speed-up is quadratic, meaning that the improvement in training time scales with the square of the problem size, leading to faster and more accurate model development.)

Quantum mechanics also inspires new types of ML algorithms, such as quantum reservoir computing.[27] These algorithms leverage the unique properties of quantum systems that enable them to perform computations that are infeasible for classical computers. For instance, quantum classification algorithms can enable more efficient data segmentation, enhancing the performance of recommendation engines. Researchers are exploring the results of implementing classically intractable ML algorithms on quantum computers to potentially provide more accurate and personalized recommendations. [28]

Moreover, quantum computing has the potential to improve image recognition. This is because quantum algorithms may be able to handle the high-dimensional data involved in image recognition tasks more effectively than classical algorithms, leading to more accurate and reliable recognition systems. This advancement has significant implications for fields such as medical imaging, autonomous vehicles and security.

Quantum machine learning (QML): The future of AI algorithms

This is one of the most promising areas where AI and quantum computing reinforce each other. In this longer-term vision, highly trained AI platforms could have access to additional inferential power (thus enhancing their performance) by leveraging quantum computers as problem- or data-specific accelerators. Quantum computers' ability to process and evaluate data in ways that are intractable on classical computers opens new frontiers for ML. Complex tasks such as pattern recognition, optimization problems and data analysis could be aided by future quantum machines when QML proves scalable. This paradigm shift promises to enhance the capabilities of AI, enabling breakthroughs in fields ranging from natural language processing to drug discovery.

AI-enhanced quantum technologies: Current practical applications

Another critical area of synergy is the enhancement of today's quantum technologies through AI. For example, reducing the size of quantum sensors – by eliminating the need for bulky Faraday cages or cryogenic cooling – requires sophisticated ML algorithms for signal processing. AI plays a crucial role in making quantum sensors more practical and efficient by processing the raw data they collect into usable results. This integration is already being applied in quantum navigation systems and quantum medical devices, where the powerful ML layer ensures accurate and reliable performance in real-world applications.

AI's broader ML capabilities, beyond just generative AI or large language models (LLMs), are essential in this context. Techniques such as neural networks, reinforcement learning and unsupervised learning are crucial for developing and refining quantum technologies. These advancements make quantum sensors more accessible and versatile, paving the way for their use in various industries, from healthcare to aerospace.

The future of AI and quantum computing

Despite the promising advancements, there are still challenges (Section 1.2) to overcome. Currently, generative AI (GenAI) struggles with complex mathematical tasks, particularly in converting classical algorithms to quantum algorithms. However, as AI continues to develop and improve its understanding of mathematical libraries and solvers, it holds the potential to bridge this gap.

Business leaders preparing for this future of AI and quantum computing should consider the strategic value of large quantitative models (LQMs), which use advanced algorithms to analyse and simulate complex systems, providing deep insights in various industries. These models, which run on classical not quantum computers, can simulate quantum mechanical behaviours and other quantitative factors that traditional methods struggle to address.

SandboxAQ CEO Jack Hidary emphasizes the importance of this convergence: "Advanced quantum technologies paired with powerful Large Quantitative Models – or LQMs – are already delivering significant value across industries such as aerospace, biopharma, healthcare, chemicals, manufacturing, defence, finance and other sectors years before quantum computers become mainstream."

As AI and quantum computing technologies continue to evolve, their convergence is set to create new fields of research and application, enabling quantum-enhanced AI systems to solve problems currently beyond reach, such as optimizing complex logistics networks and discovering new materials and drugs. This symbiotic relationship holds immense potential, promising to revolutionize industries, drive innovation and address some of humanity's most complex challenges.

2

The quantum economy: Building new growth areas

Quantum technologies are driving economic diversification in various sectors, and each industry stands to gain unique benefits from its leaders.

2.1 Quantum-driven economic diversification

As quantum technologies begin to yield economic advantages, industries and markets will grow, adapt or be replaced. According to McKinsey, the potential economic value of quantum technologies is substantial, with quantum computing alone expected to generate between $450 billion and $850 billion annually by 2035. Quantum sensing and quantum communication are projected to contribute economic impacts of $100-200 billion and $50-100 billion annually, respectively.[29]

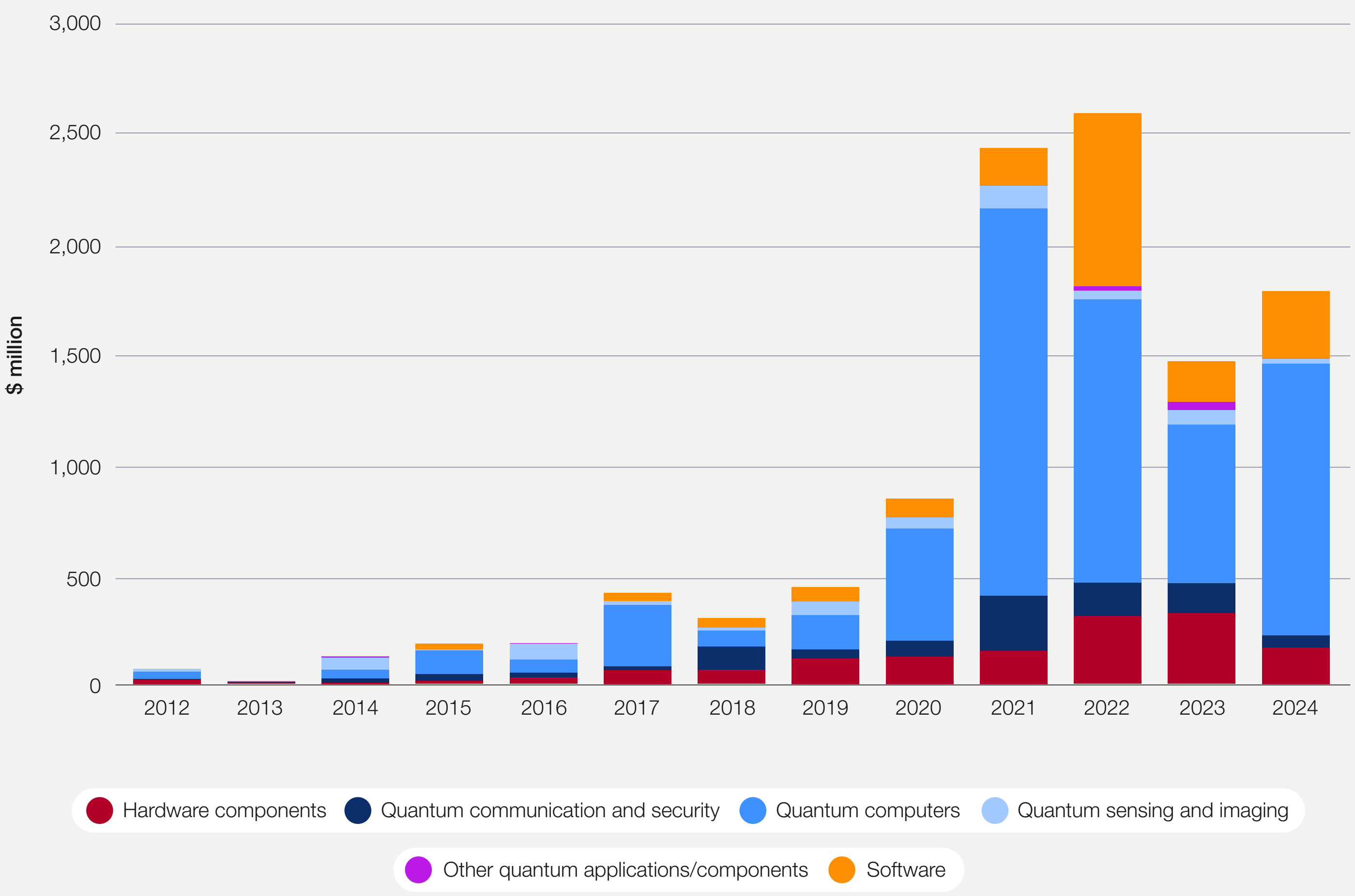
These technologies are poised to revolutionize various industries, driving economic growth and diversification. Understanding how quantum technologies can spur economic growth as they evolve is key for business leaders to unlock their potential. Global impacts will vary according to local priorities and investments. The opportunities to drive economic impact and gain competitive advantage are vast, as noted in Section 2.2.

To realize these benefits, businesses need to develop a strategic vision that outlines their long-term goals and the role quantum technologies will play in achieving them.

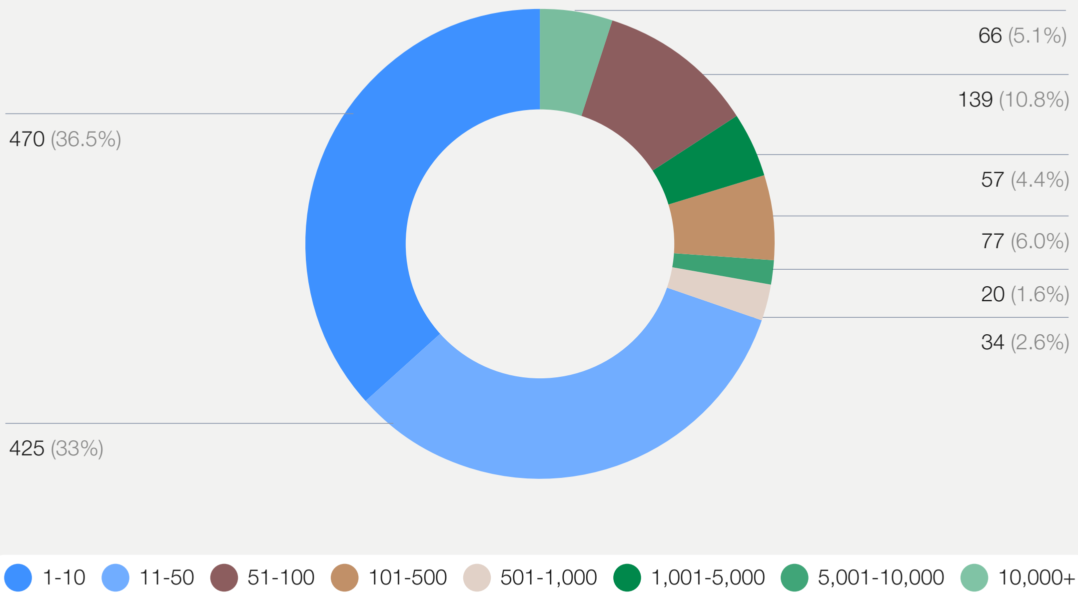
This vision should be supported by substantial investments in R&D to foster innovation and advance the technology. Additionally, businesses must gain practical experience by implementing more mature quantum technologies in real-world applications. This combination of strategic planning, R&D investment and hands-on implementation will enable businesses to harness the full potential of quantum technologies and secure a competitive edge in the evolving market.

FIGURE 4 | **Investment trends and companies working in quantum technologies**

Investment in quantum technology companies



Number of companies in quantum technology (by employee count)



Source: The Quantum Insider App[30] and Accenture

Figure 4 illustrates the dynamic growth in quantum technology funding, alongside the challenges of scaling companies and commercializing emerging technologies.

– Despite the challenges of scaling the headcount, **investment growth** in quantum technology has been **rapid**, particularly after 2020. Most of the funding is directed towards quantum computing, with other areas like software, sensing and communications also receiving increased funding. This trend highlights the growing interest in quantum technologies, signalling opportunities for businesses to leverage these advancements for competitive advantage and for quantum providers to continue innovating to meet market demands.

– **Size distribution** in the quantum sector reveals that a large proportion of companies are small-sized. Specifically, 470 companies have 1-10 employees and 425 companies have 11-50 employees. This suggests that most of the quantum industry is composed of start-ups and small firms, which are still in the early stages of development. For businesses, this indicates opportunities for partnerships and investments, while for quantum providers, it highlights the importance of agility and the need for support in scaling operations.

– Investment data highlights the **concentration of funding in quantum computing**, which attracts the largest share. This could be due to its wide range of potential applications and significant transformative impact on industries like finance, logistics and healthcare. However, the smaller number of companies in the mid- to large-sized range (51-plus employees) implies that even with increased investment, few firms have scaled up significantly. This may indicate challenges in commercializing quantum computing solutions or a need for further technological maturity before larger companies invest more heavily.

– Although investment in areas like quantum communications and sensing is smaller, the steady increase suggests **potential growth in these fields**. Applications in cybersecurity, environmental monitoring and defence may see expanded investment in the coming years as these technologies mature. Supporting the growth of mid-sized firms in these areas could help diversify the quantum ecosystem and foster broader adoption.

– The predominance of smaller companies indicates **barriers to scaling companies** in the quantum business, such as the need for specialized talent, high R&D costs and technological (e.g. infrastructure) barriers. The relatively small number of companies in larger employment ranges (500-plus employees) suggests that even with substantial investments, companies face obstacles in transitioning from research to commercialization. These implications underscore the quantum industry's rapid development, driven by significant investments in various sectors but constrained by scalability and supply-chain challenges. To increase adoption and facilitate growth, strategic actions are needed to overcome these barriers and accelerate commercialization.

2.1.1 Economic implications of quantum computing

Quantum computing represents a paradigm shift from computing in the past century by leveraging principles of quantum mechanics to potentially perform certain calculations at speeds and efficiencies previously not possible. The increase in investment (Figure 4) indicates that industries expect quantum computing to significantly impact various sectors (see Section 3.2).

Today, innovative enterprises are investing heavily in institutionalizing quantum computing expertise, both pioneering new applications and maximizing their competitive advantage. Financial firms such as HSBC and JPMorganChase are investing, partnering with hardware vendors and contributing research publications back to the quantum ecosystem.

"Financial services has been identified as one of the first industries that will benefit from quantum technologies. As such, we have been investing in quantum research and our team of experts – led by Marco Pistoia – have made groundbreaking discoveries, partnering with quantum computing leaders like Quantinuum. We look forward to continuing to work together to positively impact our businesses, customers and the industry at large," said Lori Beer, Global Chief Information Officer, JPMorganChase

2.1.2 Opportunities enabled by quantum sensing

Quantum sensing offers new levels of precision in measurement, impacting fields such as healthcare, environmental monitoring and navigation. Detection of changes in magnetic and gravitational fields using quantum sensors can provide early diagnosis of diseases, more accurate climate models and improved navigation systems.[31] Early adopters are leveraging quantum gravitational sensors that have the potential to far exceed the capabilities of traditional hardware to explore deep underground, providing a better understanding of the geological makeup of the earth.[32]

Quantum sensing attracts a smaller but consistent share of investments (Figure 4), indicating a steady growth potential. This steady investment might suggest niche applications in fields such as quantum navigation, health and defence, which could gradually lead to economic diversification into specialized areas.

John Lowell, Principal Senior Tech Fellow for Boeing Research and Technology, emphasizes the significant potential of quantum sensing in navigation: "Our business fundamentally is about building platforms that connect people across the world. We cannot succeed in that without the ability for those platforms to navigate from point A to point B with great precision and accuracy. Therefore, it is inherent on us as a business to understand how best to implement quantum technology and integrate it into those platforms so that they'll be successful. This is why we are committed to investing in quantum navigation technologies and in developing them and integrating them into our future platforms."[33]

2.1.3 Economic implications of quantum communication and security

Four opportunities are evident: QRNGs can provide a stronger foundation for cryptography; QKD can provide an alternative for security methods as mentioned in Section 1.1; quantum communications can be used to connect quantum computers, increasing their overall processing power; and finally, quantum networks could connect quantum sensors or function as quantum sensors themselves, enabling a better understanding of science and the world.

However, quantum security is the primary focus of most businesses in the quantum communication industry today. According to the "Quantum Economy Blueprint" report by the World Economic Forum,[34] quantum communication could protect up to $1 trillion in digital assets annually. With these advancements, new markets could be created and existing ones transformed.

Quantum communication and security is attracting increasing investment (Figure 4), reflecting the reaction to the risk to secure communication that quantum computing creates, and the consequent concerns for critical digital-enabled infrastructure. This rising trend implies that quantum communication is becoming more relevant for industries focused on data privacy and cybersecurity, potentially transforming information and communication technology (ICT) and finance.

Quantum networking test beds are being deployed and scaled across the globe including in London and New York. In the latter, GothamQ is creating a local network by connecting hubs in Manhattan and Brooklyn.[35] Research institutions and universities such as Delft University of Technology (TU Delft) are exploring the future of a worldwide, secure quantum internet.

2.1.4 Overcoming barriers to quantum economic growth

While the potential for quantum technologies to drive economic growth is immense, several barriers must be addressed to fully unlock this potential. These barriers span technical, financial, regulatory and societal (workforce) domains. Overcoming these challenges will require coordinated efforts from leaders within both public and private domains.

One of the primary barriers to the widespread adoption of quantum technologies is the **technical complexity** involved. Quantum computing systems are highly sensitive to environmental disturbances (as noted in Section 1.2), which can lead to errors in computations. Recent breakthroughs in Quantum Error Correction, demonstrated by the Google Willow chip and the continued innovative research from IBM, Quantinuum, IonQ, Atom Computing and Rigetti, are bringing us closer to harnessing the full potential of quantum computers to tackle complex challenges. Developing such robust technical solutions for improving the stability of quantum systems is a critical area of ongoing research, requiring a combination of business adoption leading to financial investments. Another such example is to create a technical solution that scales quantum systems in a distributed manner, as seen in the strategies of companies such as IBM and Photonic in building quantum computers.[36]

Developing a robust, industry-driven business case to prioritize **financial investment** in quantum technologies ensures that stakeholders including the business leadership and quantum specialists can identify the correct strategic outcomes. Organizations can begin to distil business value by developing information about use cases, relying on tools such as Metriq[37] and the MIT Quantum Economic Advantage Calculator,[38] which highlight potential high-impact areas for early adoption and revenue generation. Additionally, public- and private-sector stakeholders often collaborate on R&D, which lowers financial barriers to entry. The number of quantum technologies in production today that started as pilots in enterprise labs and/or through public-private partnerships is growing across sectors.[39]

The strategies to overcome regulatory and societal barriers are covered in depth in the "Quantum Economy Blueprint" report.[40]

BOX 1

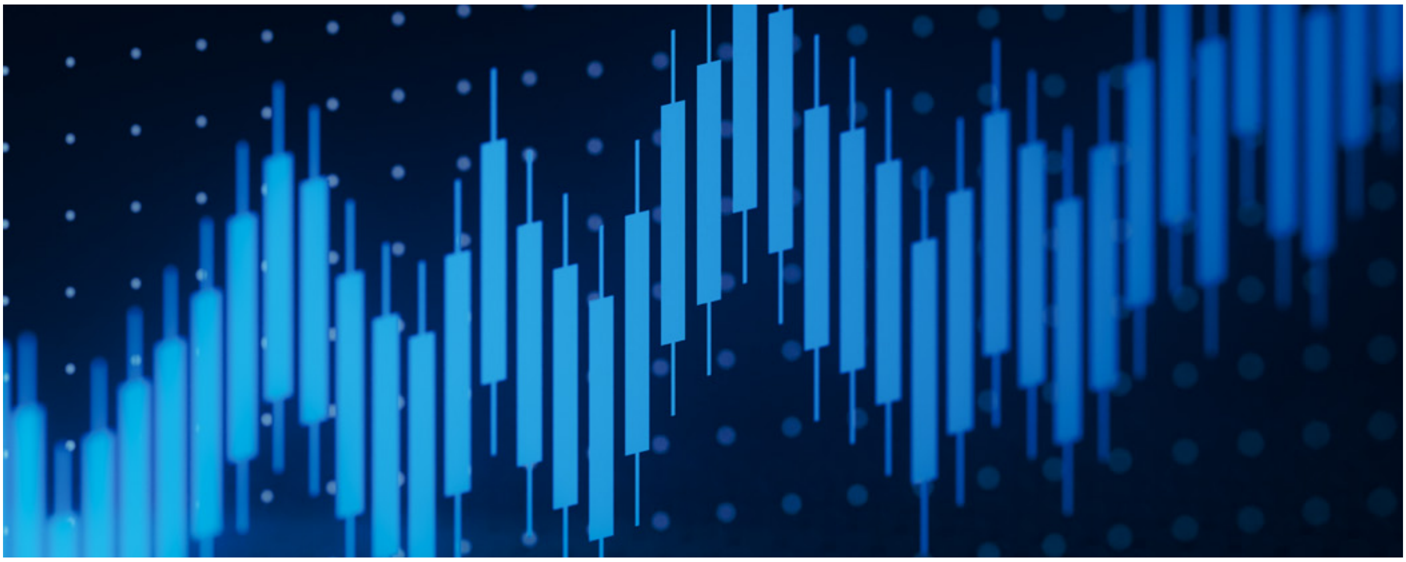
Creating new markets and transforming existing ones

In the realm of computing, quantum technologies are unlocking new benefits in finance. Toshiba's collaboration with financial institutions to develop quantum algorithms for currency arbitrage highlights the transformative potential of quantum computing in this sector. These algorithms can tackle multivariate problems, enabling efficient and more accurate financial models and strategies, which could potentially unlock up to $700 billion in value, according to McKinsey.[41]

Integration of quantum technologies into various industries will not only create new markets, but also transform existing ones from both a business and regulatory standpoint.[42] Quantum sensors, for example, are revolutionizing the medical industry. SandboxAQ is developing advanced diagnostic tools designed to detect cardiovascular diseases at their earliest stages, potentially saving millions of lives and reducing healthcare costs. The cost of heart disease in the United States, for instance, is about $239 billion each year.[43]

Quantum communication is set to redefine data security. British Telecom (BT) is working with QKD vendors to upgrade its infrastructure, ensuring secure communication channels while applying PQC.[44] This shift is critical for protecting sensitive information in an era of increasing cyberthreats. HSBC has also partnered with QKD vendors to enhance its data security framework, reflecting the financial sector's growing reliance on "defence in depth" strategies (which use multiple security measures to protect an organization's assets) provided by quantum-safe communications.[45]

To fully realize these opportunities, strategic investments in R&D are essential.



2.2 Economic diversification across industry sectors

As early adopters capitalize on the opportunities presented by quantum technology, they will drive technological progress and economic diversification. This will benefit not only the industries directly involved but also the broader economy, as innovations in one sector often spur advancements in others by creating multiplier effects.

For example, shorter drug-discovery cycles and new medical devices can reduce costs in the healthcare sector, while investments by the automotive sector in traffic optimization can lead to smarter and more sustainable cities, moving the global economy – and society – towards a brighter future.

Quantum innovations are driving real-world applications across various industries and promise to create significant value by transforming traditional paradigms.

2.2.1 Financial services

Quantum computing is revolutionizing the finance sector, particularly the insurance and capital markets. Optimizing reinsurance structures using quantum algorithms has the potential for more accurate risk assessment and pricing. This leads to better capital allocation and reduced costs for insurers.[46] As Marcin Detyniecki, Head of Research and Group Chief Data Scientist, AXA, notes, “Leveraging Quantum Computing to optimize reinsurance coverage, accelerating risk analysis and providing more sophisticated models for pricing” is key. He further emphasizes, “While the supremacy of quantum computing will not be felt in industrial use cases for some time, we are laying the groundwork for a disruptive future while delivering business value today by focusing on the hard problems the technology can solve.”

Investors benefit from enhanced portfolio optimization and risk management, resulting in more stable returns.[47] This aligns with the World Economic Forum’s emphasis on economic diversification by enabling more efficient financial systems and fostering innovation in risk management.

Quantum technologies create new fintech opportunities such as improved risk management and faster trading strategies. By enhancing financial infrastructure, these technologies allow for the creation of more sophisticated financial products, diversifying the financial ecosystem for institutions and consumers alike.[48]

FIGURE 5 **Implications for financial services**

Financial services
Themes of value creation

Financial services innovation

Quantum computing

Helping the economy diversify by enhancing fintech and risk-management sectors

- Reinsurance optimization
- Faster and more accurate risk assessment
- Effective high-frequency trading strategies

Real estate and insurance innovation with sensors

Quantum sensing

Aiding more precise decision-making in real estate and distribution sectors

- Enhanced fraud detection systems
- Distributed detection systems for enhanced fraud detection systems (in the future)
- Precise geolocation to help assess property value/risks for insurance

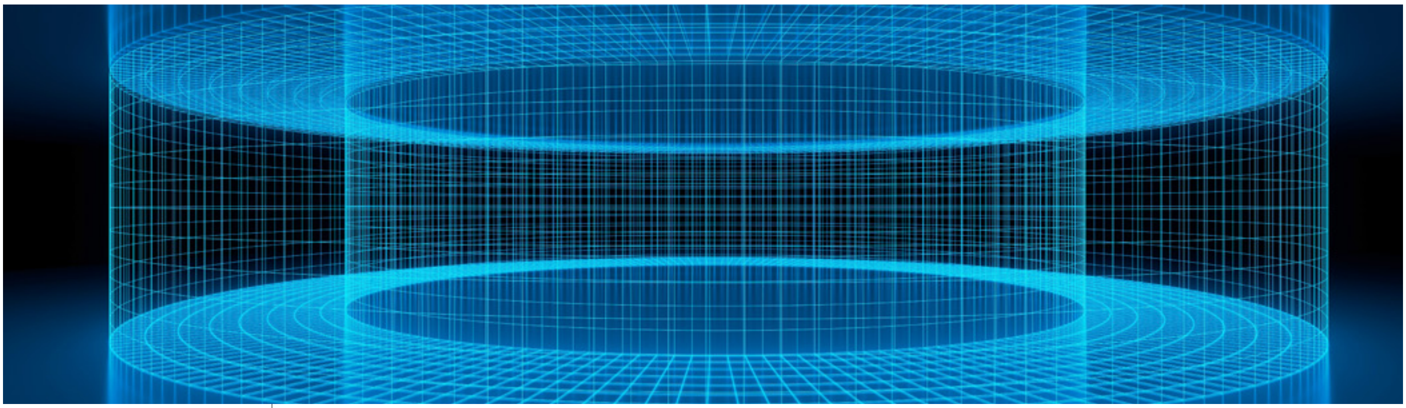
Cybersecurity and data integrity

Quantum communications and security

Fostering trust and growth in cybersecurity and secure financial services

- Physical encryption networks
- Distributed entanglement for precision timekeeping (in the future)
- Secure encryption and authentication

Source: World Economic Forum in collaboration with Accenture



2.2.2 Technology and telecommunications

In the technology and telecommunications sectors, quantum technologies are driving advancements in cryptographic agility. This ensures that systems can quickly adapt to new cryptographic standards, enhancing security against emerging threats, including those posed by quantum computers. This agility is crucial for maintaining the integrity and confidentiality of data in an increasingly interconnected world.[49] By securing communications and data, quantum technologies support economic diversification by protecting critical infrastructure and enabling new technological innovations.

Quantum computing optimizes information and communications technology (ICT) infrastructure, both enhancing data transmission and enabling more secure communication networks. Adoption of quantum technology would drive economic diversification in telecommunications, cloud computing and cybersecurity, creating high-value jobs in digital infrastructure management and innovation in the global communications sector.[50]

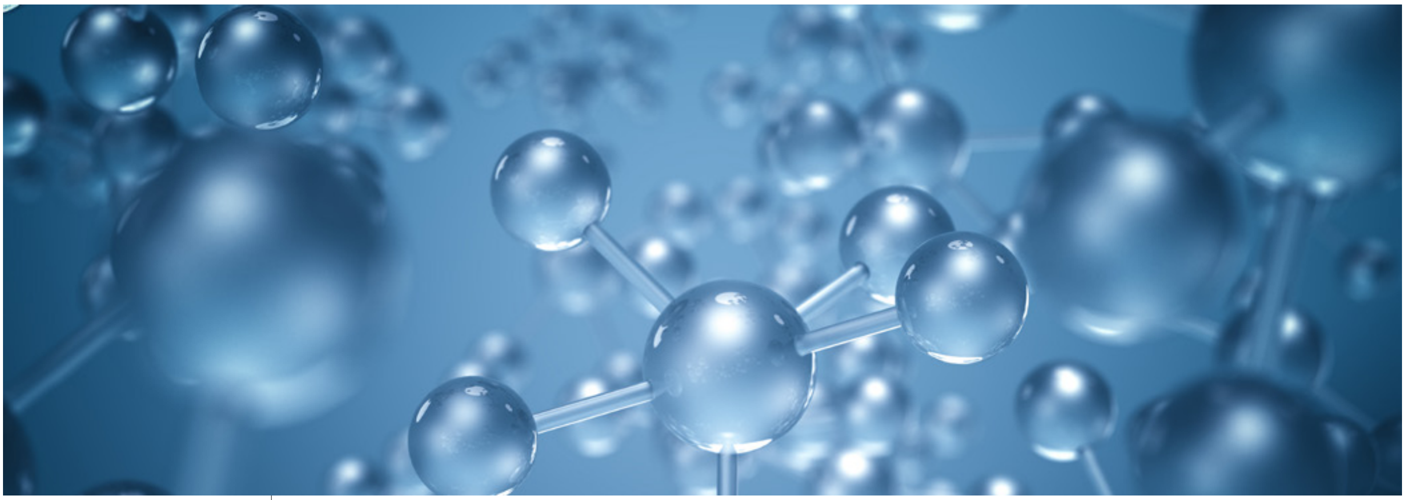
FIGURE 6 **Implications for technology and telecommunications**

Technology and telecommunications

Themes of value creation

Efficiency in resource management	Infrastructure and utility modernization	Secure infrastructure
Quantum computing	**Quantum sensing**	**Quantum communications and security**
Enables the modernization of telecommunications infrastructure	Contributing to greener, more efficient digital infrastructure and advancing sustainability in the sector	Driving economic growth in the cybersecurity and digital communication sectors
Network optimization	Infrastructure inspection	Quantum key distribution (QKD) for secure communications
Resource allocation	Advanced diagnostic imaging	Distributed entanglement for precision timekeeping (in the future)
		Infrastructure integrity

Source: World Economic Forum in collaboration with Accenture



2.2.3 Pharmaceuticals and healthcare

Quantum sensors are transforming healthcare diagnostics. The CardiAQ system uses magnetocardiography to provide non-invasive, radiation-free cardiac assessments. This technology enables faster and more accurate diagnosis of heart conditions, improving patient outcomes and reducing healthcare costs.[51] By enhancing diagnostic capabilities, quantum technologies contribute to economic diversification by improving healthcare delivery and fostering innovation in medical technologies.

Quantum technologies also accelerate drug discovery and enable personalized medicine, reducing healthcare costs and improving outcomes. Creation of new jobs in precision medicine and an enhanced healthcare innovation ecosystem drives economic diversification into biotechnology, genomics and digital health.[52]

FIGURE 7 **Implications for pharmaceuticals and healthcare**

Pharmaceuticals and healthcare

Themes of value creation

Healthcare and pharmaceutical innovation

Quantum computing

Accelerated breakthroughs, encouraging growth in pharmaceutical and biotech sectors

- High-throughout ligand interaction simulation
- Optimizing clinical trial design
- Genomic data analysis

Medical technology growth

Quantum sensing

Advanced diagnostics, enabling earlier disease detection and more personalized treatments

- High-precision medical imaging using quantum clocks for timing synchronization
- Early diagnosis of neurodegenerative diseases
- Advanced diagnostic imaging

Digital health and robust infrastructure

Quantum communications and security

Progress towards secure, digitally-driven health services, telemedicine and digital health management

- Secure medical-data transmission
- Quantum-secure health information exchanges

Source: World Economic Forum in collaboration with Accenture

2.2.4 Chemicals and advanced materials

Quantum computing is being leveraged to investigate environmental challenges, such as the remediation of PFAS (per- and polyfluoroalkyl substances), also called "forever chemicals".[53] Quantum simulations can model complex chemical reactions, leading to more effective methods for breaking down these persistent pollutants. This is a starting point for more efficient means of PFAS destruction, translating into improved public health and a cleaner earth. Similarly, by providing solutions to various environmental issues, quantum technologies support economic diversification by promoting sustainable practices and innovation in chemical processes.

Quantum technologies enhance material design and manufacturing processes, enabling more sustainable production methods. Economic diversification of advanced materials, nanotechnology and sustainable manufacturing sectors supports the development of green industries and reduces environmental impact.[54]

FIGURE 8 **Implications for chemicals and advanced materials**

Chemicals and advanced materials

Themes of value creation

Infrastructure and utility modernization	Efficiency in resource management	Secure manufacturing operations
Quantum computing	**Quantum sensing**	**Quantum communications and security**
Helps modernize public infrastructure, improve resource sustainability and enhance the reliability of critical systems	Drives growth in green technologies, sustainable manufacturing and resource-efficient industrial processes	Ensures secure manufacturing operations and data transmission
Material property prediction	Advanced quality imaging	Secure supply chain-data transmission
Catalyst design optimization	Last-mile quality control	Secure internal data communication
Molecular docking	Product quality check	

Source: World Economic Forum in collaboration with Accenture

2.2.5 Energy and utilities

In the energy sector, quantum technologies could be used to find new potential in enhancing vehicle-to-grid (V2G) energy systems. These systems allow electric vehicles to feed energy back into the grid, improving grid stability and efficiency. Quantum algorithms show promise to optimize the timing and amount of energy transfer, maximizing benefits for both the grid and EV owners.[55]

This can contribute to a more resilient and sustainable energy infrastructure. By optimizing energy systems, quantum technologies support economic diversification by fostering innovation in energy management and sustainability.

Quantum computing optimizes energy grids and accelerates resource exploration, driving new efficiency and sustainability. Adoption of quantum technology enables economies to diversify into the renewable energy, smart utilities and clean technology sectors, reducing reliance on traditional fossil fuels and fostering the growth of green industries.[56]

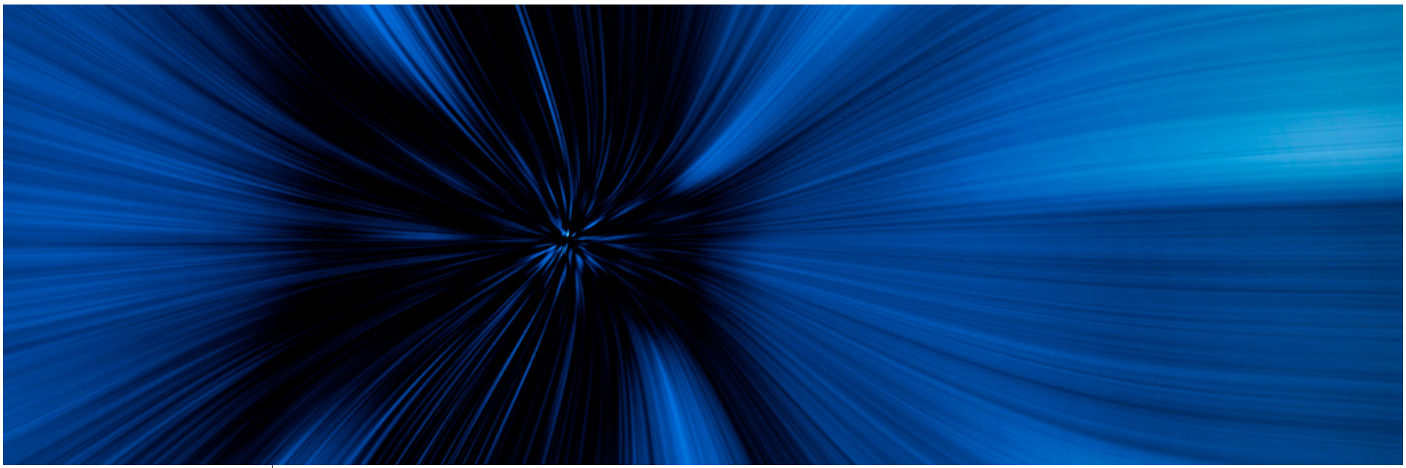
FIGURE 9 **Implications for energy and utilities**

Energy and utilities

Themes of value creation

Energy efficiency and green energy	Resource exploration and environmental monitoring	Secure energy infrastructure
Quantum computing	**Quantum sensing**	**Quantum communications and security**
Supports diversifiation into sustainable energy management, grid optimization and energy storage solutions	Drives diversification in resource management, mining and environmental sectors	Enables economies to invest in secure, resilient energy systems, fostering growth in energy cybersecurity and utility management
Energy grid optimization	Geophysical surveys	Secure communication networks for infrastructure
Tailings treatment	Advanced diagnostic imaging	Distributed entanglement for precise timekeeping (in the future)

Source: World Economic Forum in collaboration with Accenture



2.2.6 Automotives, aerospace and transportation

Quantum navigation systems, such as AQNav, are providing robust alternatives to GPS (Global Positioning System). These systems combine quantum sensors, which detect magnetic anomalies in Earth's crustal magnetic field, with AI to interpret the signals and eliminate external interference. This technology is crucial for applications where GPS signals may be unreliable or compromised. It enhances the safety and reliability of navigation across various terrains and conditions.[57]

By improving navigation systems, quantum technologies support economic diversification by enabling advancements in transportation and aerospace technologies.

Quantum technologies enhance navigation, traffic optimization and aerodynamics, contributing to smarter, more efficient transport systems. Economic diversification into smart mobility, autonomous vehicles and aerospace innovation creates opportunities for new industries in logistics and advanced transportation systems.[58]

FIGURE 10 **Implications for automotives, aerospace and transportation**

Automotives, aerospace and transportation

Themes of value creation

Transport optimization and urban mobility	Aerospace and navigation innovation	Secure communication
Quantum computing	**Quantum sensing**	**Quantum communications and security**
Supporting growth in urban mobility, smart city infrastructure and intelligent transport systems	Promoting diversification into aerospace engineering, maritime navigation and geophysical exploration	Encouraging investment in cybersecurity and secure communications industries
Traffic flow optimization	Navigation and geo-physical surveys	Data integrity and security
Route allocation	Ultra-precise sound detection	Secure military communication channels
Aerodynamics simulations		

Source: World Economic Forum in collaboration with Accenture

3 The quantum leap: Navigating the new frontier of use cases

Real-world use cases involving practical applications and industry engagement provide clarity on how different sectors can leverage quantum technologies.

3.1 Industry engagement and use cases

In today's dynamic technology landscape, the quantum economy has captivated the interest of visionary leaders across industries. High-profile use cases such as breaking cryptography, discovering new materials and optimizing financial decision-making would be the pride of any innovation programme, and would be transformative across sectors. Industry leaders who are actively engaging with the quantum ecosystem are showing progress via press releases, publications, prototypes, proofs of concept and even production.

3.2 Use case impact on each industry

Each industry represents a new opportunity space for quantum technologies. Opportunities are abundant, ranging from significant performance improvements to revolutionizing existing processes and creating new market opportunities. These advantages are tempered by threats such as cybersecurity risks, rapid technological changes and integration challenges. The high costs and complexity of quantum technologies are also a challenge.

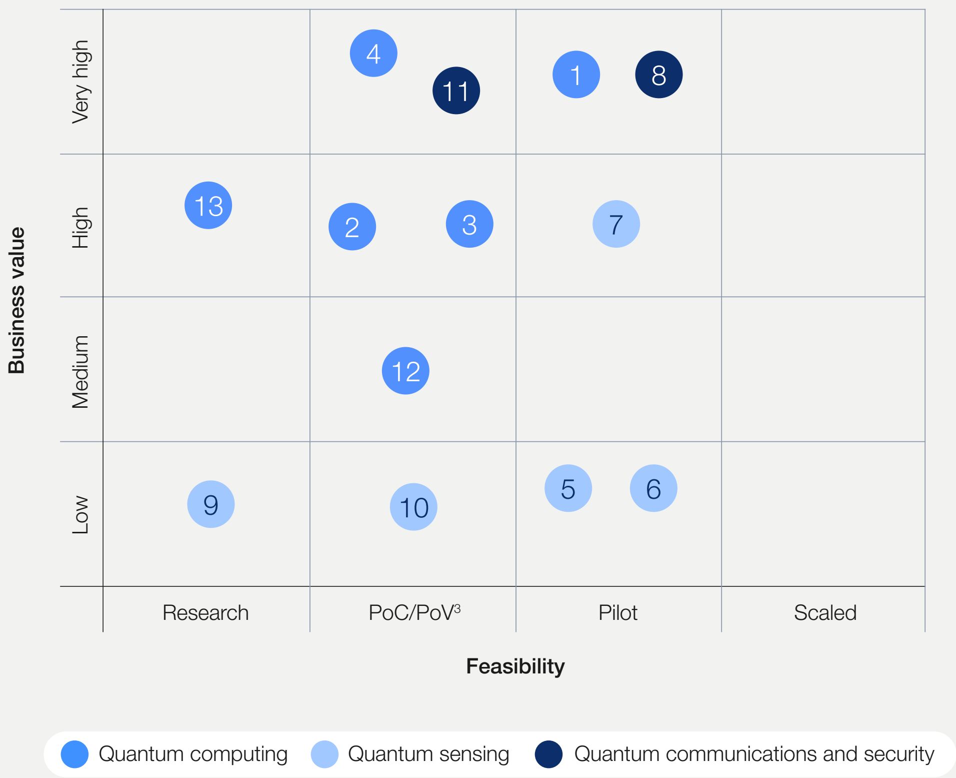
After discussing with members of the World Economic Forum's Quantum Economy Network community, the use cases across all industry sectors were mapped against feasibility versus business value. For more details of the mentioned use cases, refer to Section A.1 (Use case description), and for detailed explanation of the stages of development and placement criteria, refer to Figure 17 and Table 8 in Section A.2 (Use case placement assumptions).

3.2.1 Financial services

FIGURE 11

Use case impact analysis for financial services

1. Currency trading (being used by companies such as Toshiba and Dharma Capital)
2. Financial crash estimation in enterprises (Yapi Kredi Bank, D-Wave)
3. Reinsurance optimization (AXA)
4. Credit card payment fraud detection (Rigetti, HSBC, University of Edinburgh, National Quantum Computing Centre)
5. Detecting magnetic anomalies in transactions
6. Infrastructure integrity monitoring (gravimeters)
7. Accurate time stamps for financial transactions (quantum clocks)
8. More resilient keys for secure encryption and authentication (QRNG,[1] used by HSBC, Quantinuum)
9. Detection of tampering of ATM machines (quantum acoustic sensors)
10. Distributed quantum sensor detection systems
11. Physical encryption network (PQC/QKD,[2] used by HSBC, BT, Toshiba; JP MorganChase, Ciena, Toshiba)
12. Synthetic data generation for traditional ML
13. Settlement optimization of securities transactions (Bank of Italy, Intesa Sanpaolo, IBM, universities of Exeter and Verona)



Source: World Economic Forum in collaboration with Accenture

Note: [1] Quantum random number generator, [2] Post-quantum cryptography/quantum key distribution, [3] Proof of concept/proof of value

In the rapidly evolving landscape of financial services, prioritizing security while managing regulatory requirements is of paramount importance. Examples in optimization, ML and simulations offer a great start to challenge the existing technologies and systems used in businesses today that leverage conventional computing and sensing systems. To support strategic decision-making, here's a concise synthesis of the quantum technology use cases in financial services, focusing on actionable insights:

1. **Prioritizing an upgrade to quantum for banking transactions** by adopting approaches such as QRNG (use case 8), QKD and PQC (use case 11). These technologies can offer increased protections against future quantum computers in two ways: (1) protecting data that is stolen today from being decrypted later and (2) protecting future systems from being impersonated once a cryptographically relevant quantum computer (CRQC) is available to break encryption. Quantum communication and security is capable of scaling in the near term so strategic investments today will grow with time and safeguard financial infrastructure for years to come.

2. **Preparing for quantum computing applications in the optimization space**, which presents itself with several high-value use cases, such as currency trading, reinsurance optimization and fraud detection (use cases 1, 3 and 4). Although quantum methods are recognized as both proof of concept and pilot initiatives, they are not yet ready for industry-wide adoption due to the current limitations of quantum hardware. However, algorithms such as those in use case 1 demonstrate potential when used on a quantum-inspired system, offering an interim solution before transitioning to a fully developed quantum computing approach. Now is the time to prepare by developing quantum algorithms and proofs of concept (PoCs). This ensures readiness when the hardware matures, positioning an organization to be a first mover in quantum computing applications.

   David Craig, former chief executive officer of Refinitiv, emphasizes the significance of this preparation: "Quantum computing has the potential to disrupt financial markets by offering unparalleled computational power for complex modelling and optimization." By applying quantum computing to optimize financial portfolios, enhance risk analysis and improve trading strategies, organizations can leverage this transformative technology to gain a competitive edge.

3. **Leveraging quantum sensing for fraud prevention** using time-stamp verification (use case 7). Using quantum clocks, this is a practical application that can be implemented in the near term. Accurate time-stamping can mitigate fraud risk by ensuring transaction authenticity, making it a high-value initiative for policy-makers to consider as part of their broader fraud-prevention strategies.

These insights underscore the need for strategic investments in quantum technologies today, to not only address the current security challenges, but also ensure long-term competitiveness as the technologies mature for the finance industry.

3.2.2 Technology and telecommunications

FIGURE 12 **Use case impact analysis for technology and telecommunications**

1. Optimized network transformation (applied by Fujitsu, University of Toronto)
2. Packet routing (cyber business case)
3. Network traffic optimization and resource allocation
4. Site surveys (quantum gravimeters)
5. Data transmission and reliability (quantum clocks for time synchronization, used by BT)
6. More resilient keys for advanced mobile security (QRNG,[1] used by SK Telecom, Samsung Electronics, ID Quantique)
7. Infrastructure inspection (quantum enhanced LiDAR)[2]
8. Infrastructure integrity monitoring (quantum acoustic sensors used by QinetiQ)
9. Environmental monitoring (quantum sensor detection)
10. Secure communication channels (QKD,[3] used by China Telecom, QuantumCTek; BT, Toshiba; SPTel, SpeQtral; Boeing)

Source: World Economic Forum in collaboration with Accenture

Note: [1] Quantum random number generator, [2] Light detection and ranging, [3] Quantum key distribution, [4] Proof of concept/proof of value

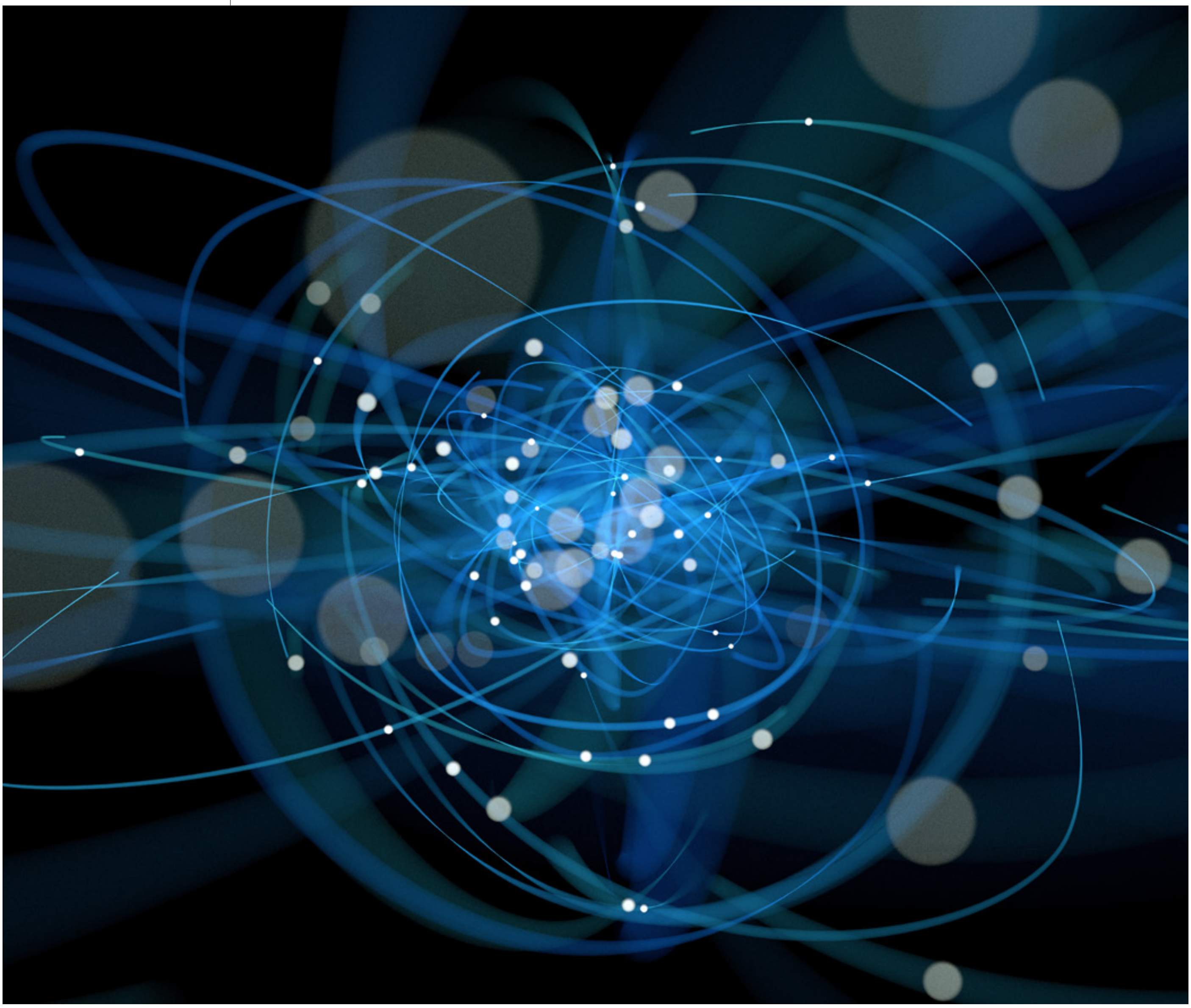
Quantum computing technologies have immense potential in the ICT industry, and technologies such as quantum sensing and quantum communication can improve telecommunications infrastructure. The following use cases provide actionable guidance on strategic decision-making for adopting quantum technologies in the ICT sector:

1. To ensure robust and secure communication, it is essential to **prioritize the implementation of PQC and QKD for defence in depth**. Use case 10 highlights QKD for secure communications as the most valuable and feasible use case in the near term due to its ability to detect eavesdropping and secure data transmission. Combining QKD with PQC offers a comprehensive defence in depth solution. This dual approach enhances the security framework, making it a critical focus area for pilot deployment in ICT. Together, QKD and PQC can be provided as a service, ensuring a more resilient and secure communication infrastructure. Additionally, scaled quantum cryptography management (QCM) solutions should be implemented across ICT operations (use case 10). As cybersecurity threats increase, quantum cryptography can provide advanced protections for critical infrastructure, making it a strategic priority.

2. **Investing in quantum sensing (QS) applications** such as infrastructure inspection and data transmission reliability (use cases 4, 5 and 7) offers high business value and feasibility for pilot testing. These technologies have the potential to improve the precision and reliability of next-generation ICT infrastructure (e.g. 5G and IoT), and investment in these areas can enhance operational efficiency.

3. **It is essential to develop PoCs for quantum computing** use cases like optimization problems, which hold potential for solving complex computational challenges, such as network traffic management (use cases 1, 2 and 3). The focus should be on developing PoCs to assess scalability.

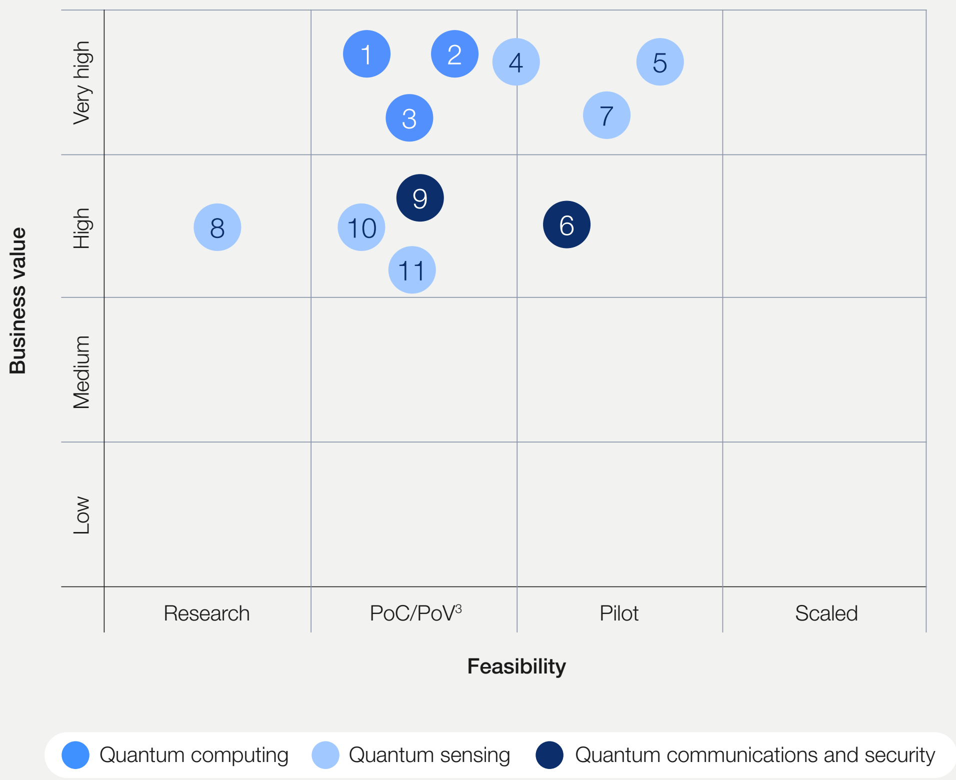
This approach ensures ICT remains at the forefront of secure, scalable and efficient infrastructure development, and will allow the ICT industry to progress jointly with quantum technology.



3.2.3. Pharmaceuticals and healthcare

FIGURE 13 **Use case impact analysis for pharmaceuticals and healthcare**

1. High-throughput ligand interaction simulation
2. mRNA secondary structure prediction (used by Moderna, IBM)
3. Optimization of clinical trial designs
4. Detection of cardiovascular diseases (quantum magnetometers, used by SandboxAQ)
5. High-precision medical imaging (quantum clocks for timing synchronization)
6. More resilient keys for secure encryption and authentication (QRNG)[1]
7. Quantum-enhanced advanced diagnostic imaging
8. Remote vital signs monitoring (quantum acoustic sensors)
9. Quantum-secure health information exchanges (PQC/QKD)[2]
10. Antibiotic simultaneous drug delivery and drug efficacy testing (diamond magnetometry)
11. COVID detection in breath (ultrasensitive biomarker detection)



Source: World Economic Forum in collaboration with Accenture

Note: [1] Quantum random number generator, [2] Post-quantum cryptography/quantum key distribution, [3] Proof of concept/proof of value

The pharmaceuticals and healthcare industry stands to gain significantly from quantum technologies. These technologies, leveraging natural elements, simplify complex computations, providing a competitive edge in solving theoretical and computational challenges. Given the stringent regulations in this industry, quantum technologies can enhance compliance and safety, reducing risks associated with human errors. The use cases include:

1. **Making targeted investments in computing and sensing** use cases in the research phase, such as high-throughput ligand interaction simulation (use case 1), detailed simulation of protein misfolding pathways (use case 2), and COVID detection in breath (use case 11), to unlock future breakthroughs. Computing technologies hold the potential to revolutionize drug discovery, disease diagnostics and pandemic preparedness. Investing now will ensure that organizations are well-positioned for long-term innovation and success as quantum sensing technologies are most mature for pilots.

2. **Developing early-stage computing and more mature quantum communication and security proofs of concept and value (PoCs and PoVs)** for nearer-term uses such as optimizing clinical trial designs (use case 3), quantum-secure health information exchanges (use case 9), and more resilient keys for secure encryption (use case 6). These use cases focus on improving the efficiency of clinical trials, securing sensitive health data, and preparing for the quantum cybersecurity challenges of tomorrow. Developing these solutions today will ensure scalability and future deployment

readiness. Use cases relating to security can be piloted in the nearer term than quantum computing.

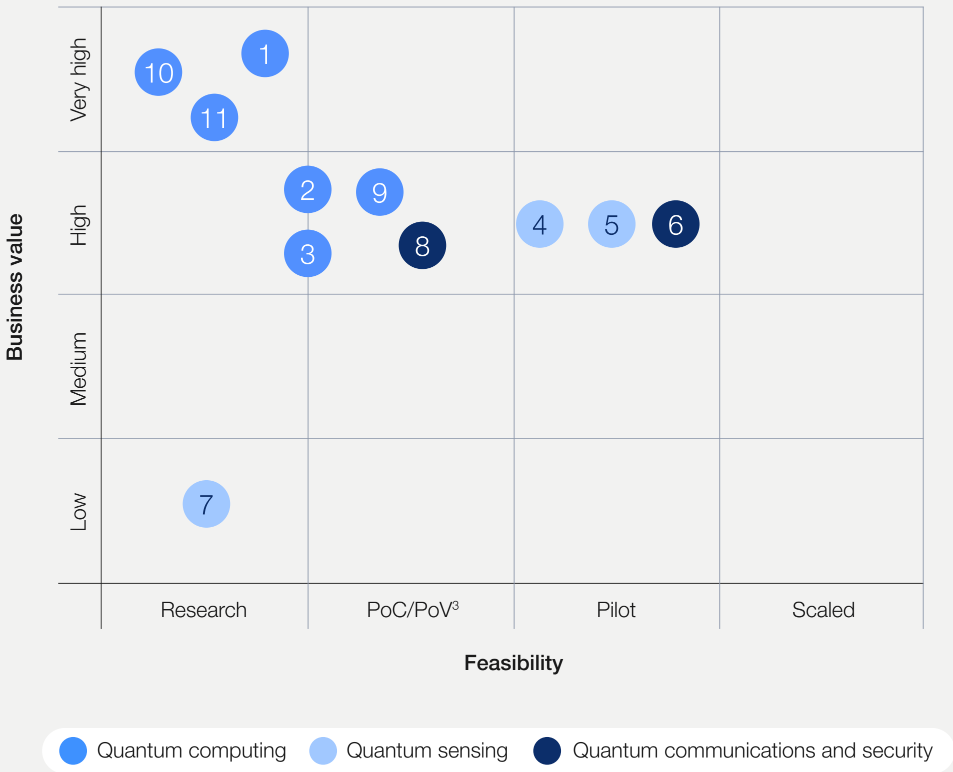
3. **Begin implementing pilotable quantum sensing** use cases such as high-precision medical imaging (use case 5), quantum enhanced diagnostic imaging (use case 7) and detection of cardiovascular diseases (use case 4) today, and apply the same techniques for detection of Parkinson's disease and foetal arrhythmia for future implementation. These pilots offer high feasibility and business value, allowing organizations to lead in early diagnostics and precision medicine. Immediate deployment of these pilots will enhance healthcare outcomes and lend a competitive edge to early adopters.

Decision-makers should start executing quantum technology projects to ensure the evolution of the R&D departments and the completion of industry digitalization. More customized treatments and better patient monitoring (customer-centricity) are key aspects of this evolution. This balanced approach will allow decision-makers to strategically manage resources across emerging and proven quantum technologies.

3.2.4. Chemicals and advanced materials

FIGURE 14 **Use case impact analysis for chemicals and advanced materials**

1. Quantum chemistry simulations of chemical compounds used in fabrication of OLED devices (used by Mitsubishi Chemical, IBM, Keio University, JSR)
2. Catalyst design optimization
3. Molecular docking
4. Product quality check (quantum magnetometer)
5. Quantum-enhanced quality imaging
6. More resilient keys for secure supply chain data transmission (QRNG)[1]
7. Last-mile quality control (quantum acoustic sensors)
8. Quantum-secure internal data communication channels (PQC/QKD)[2]
9. PFAS chemicals remediation (Accenture, ICHEC, IonQ)
10. Modelling of non-covalent interactions in water and methane systems (Cleveland Clinic, Michigan State University, IBM)
11. Simulation of N_2 triple bond breaking using a quantum-centric supercomputer (IBM, University of Colorado, RIKEN)



Source: World Economic Forum in collaboration with Accenture

Note: [1] Quantum random number generator, [2] Post-quantum cryptography/quantum key distribution, [3] Proof of concept/proof of value

The chemicals and advanced materials sector is experimenting with new approaches to tackle the huge sustainability challenges coming up ahead. Quantum technologies will aid in the reinvention of the supply chain process, discovery of new materials and solution of new computational problems. The use cases are summarized here:

1. **Investing in quantum sensing (QS) devices** to obtain improved supply chain quality control (use case 5) by considerably decreasing the costs of detecting disruptive faults in the supply chain. These devices will also have a huge impact in the R&D labs pushing the limits of precise measurement and improving quality control (use case 4).

2. **Developing proofs-of-concept for quantum chemistry**, taking advantage of natural quantum physical properties and new computational methods of quantum computers to address problems that are currently intractable. To capture value from the quantum era, organizations must invest in their teams and technologies early on. Quantum computing, by discovering new catalysts (use case 2) and remediating PFAS (per- and polyfluoroalkyl substances) (use case 9), can enable the discovery of new fertilizers that boost agriculture while reducing its carbon footprint. Quantum computing will also allow businesses to discover new pharmaceuticals (use case 3) that have the same quality as their predecessors but come at lesser cost.

3. **Prioritizing PQC** algorithms can offer increased protections against future quantum computers in two ways: (1) protecting data that is stolen today from being decrypted later and (2) protecting future systems from being impersonated once a cryptographically relevant quantum computer (CRQC) is available to break encryption. Using PQC algorithms or QRNG devices (use case 6) to protect these data is of high value for business and the industry should start implementing these pilots now.

4. **Develop a communication strategy that incorporates QKD**, recognizing that this technology is still in its early stages of development. Chemical and advanced material companies need to understand where and how to apply QKD devices to secure their internal communications (use case 8). This is a strategic investment for the long term to have next-generation infrastructures.

According to Stefan Hartung, chairman of the board of management of Robert Bosch, which has been exploring quantum technologies for nearly a decade, “Quantum technology will be a game changer in many areas – truly an ‘invented for life’ technology. It’s important that we open industrial areas of application and develop business models without delay.” By carefully considering timing and implementation, organizations can fully leverage the competitive advantages these technologies offer to the ecosystem.

3.2.5. Energy and utilities

FIGURE 15

Use case impact analysis for energy and utilities

1. Large-battery charging optimization
2. Tailings treatment (used by Accenture, Quantum City)
3. Optimization of supply-chain providers
4. Geophysical surveys (quantum gravimeters)
5. Vehicle-to-grid optimization (Accenture)
6. More resilient keys for secure supply-chain data transmission – QRNG[1] (Honeywell, Quantinuum)
7. Quantum-secure internal communications (PQC/QKD)[2]
8. Shallow subsurface imaging (Saudi Aramco)
9. Hydrogen gas-leak detection (quantum gas sensors, used by HYDRI consortium led by BP)
10. Continuous methane monitoring (quantum gas LiDAR,[3] QLM Tech, TotalEnergies)
11. Precise timekeeping (quantum clocks, Chronos Technology, Infleqtion, NPL, PNDC)

Source: World Economic Forum in collaboration with Accenture

Note: [1] Quantum random number generator, [2] Post-quantum cryptography/quantum key distribution, [3] Light detection and ranging, [4] Proof of concept/proof of value

The integration of quantum technologies into the energy and utilities sector promises to not only improve operational efficiencies and energy management but to also foster significant advancements in renewable energy and sustainable practices. As electric vehicles and renewable energy sources become increasingly prevalent, there is a pressing need to adapt and enhance energy infrastructures to meet this surge in demand. Advances in quantum sensing will soon enable new geological survey methods at previously impossible resolutions. Decision-makers and policy influencers need to consider the following insights:

1. **Implementing quantum computing pilots** to address the substantial challenges posed by the integration of new electric modalities into the energy grid (use case 1), fine fluid tailings treatment (use case 2) and enhanced seismic data processing and subsurface imaging efficiency has been demonstrated by Saudi Aramco's shallow subsurface imaging quantum application (use case 8). These technologies are critical for optimizing grid management, achieving breakthroughs in sustainability and cost efficiency, and advancing subsurface imaging capabilities, respectively.

2. **Utilizing quantum sensing technologies** to enhance environmental condition forecasts (use case 10) is essential for understanding the global impacts on the grid and other energy infrastructure. Early deployment of quantum sensors for geophysical research, resource exploration, seismology and environmental science will significantly enhance energy companies' readiness for future environmental changes and challenges (use case 4).

3. **Implementing post-quantum security protocols, QRNGs and QKD** to secure the grid today is essential for a better tomorrow. Electrical trading regulations are of huge importance in the market for energy stakeholders. They use very sensitive data, so finding ways to enhance the communication of

trading activities while safeguarding the integrity of the community will yield enormous value to business. Identifying critical communication channels to secure with PQC, QRNGs (use case 6) and QKD devices can enable secure, unrestricted exchange of confidential data among electricity market providers. This early implementation is essential for ensuring the long-term strategic advantage of these technologies.

It is imperative for strategic stakeholders to develop a comprehensive and well-structured plan to integrate quantum technologies across various departments. This integration is crucial not only for keeping pace with rapid technological advancements but also for leveraging these innovations to enhance operational efficiencies and maintain a competitive edge in the marketplace.

3.2.6. Automotives, aerospace and transportation

FIGURE 16 **Use case impact analysis for automotives, aerospace and transportation**

1. Aerodynamics simulation (applied by Airbus)
2. Modelling of corrosion in metals (Boeing, IBM)
3. Traffic-flow optimization (Volkswagen, D-Wave)
4. Navigation and environmental monitoring (Lockheed Martin)
5. Precise measurements in navigation and geophysical surveys (atom interferometry, applied by Boeing and AOSense; NASA's Goddard Space Flight Center and AOSense; NASA's Cold Lab Atom)
6. Precise timekeeping (quantum clocks, NPL)
7. Supply-chain optimization (BMW and Entropica Labs)
8. Navigation in GPS-denied environments (USAF and SandboxAQ)
9. Ultra-high accuracy automatic ground test equipment for rockets (single photon detector, Ariane Group and ID Quantique)
10. Quantum-secure internal data communication channels (PQC/QKD)[1]
11. Earth observation satellites scheduling optimization (Artificial Brain)

Source: World Economic Forum in collaboration with Accenture

Note: [1] Post quantum cryptography/quantum key distribution, [2] Proof of concept/proof of value

The automotives, aerospace and transportation industry are investing early, and quantum technologies are proving not just advantageous but essential to their business. By focusing on key use cases and implementing advanced technologies like quantum security and quantum navigation, businesses can secure critical infrastructure and ensure a resilient future.

The following insights can help the industry adopt the right strategic plans:

1. **In the research phase**, it's essential to **invest early in quantum computing** use cases like aerodynamics simulation (use case 1) and traffic flow optimization (use case 3). These technologies can solve intractable challenges in optimizing vehicle design and managing complex traffic systems. By investing in these areas now, companies will be better prepared for the future, enabling more efficient designs and significant improvements in logistics and traffic management as the technology matures.

2. **There is value in developing now for future pilots (PoC/PoV stage)**, where quantum technologies related to quantum sensing should be prioritized, particularly for environmental forecasting (use case 4) and synchronized operations (use case 6). These use cases focus on improving traffic flows and preventing catastrophic events, such as accidents and miscommunications in critical infrastructure. Developing these PoC applications today will pave the way for large-scale pilots and future implementations that can enhance safety and operational efficiency.

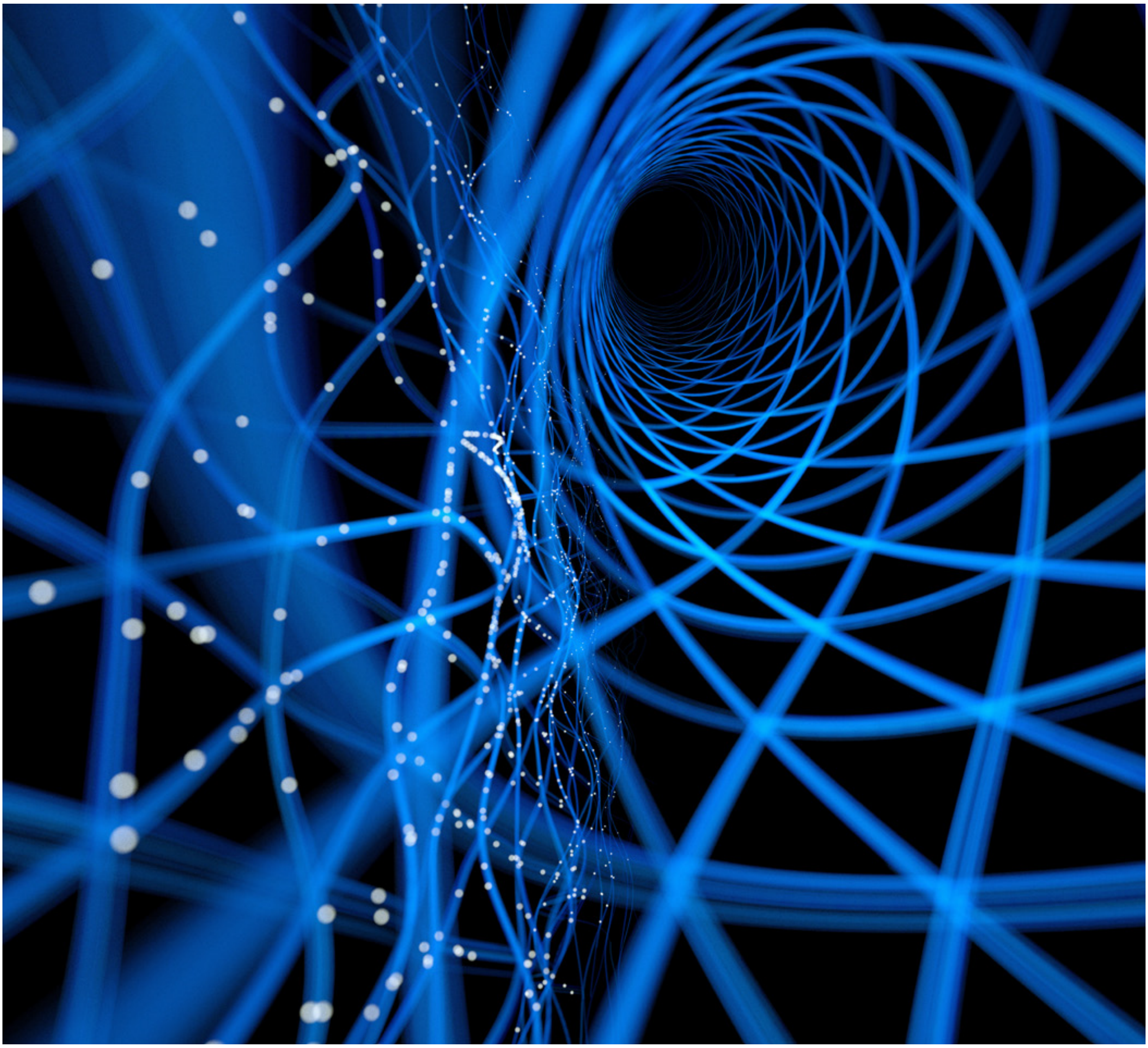
3. **Implementing pilot projects** in quantum sensing (use case 9) **today** is particularly useful due to its high feasibility and potential for immediate impact on operational efficiency. Solutions like QRNG devices and QKD (use case 10) can secure traffic flow data and protect critical infrastructure from eavesdroppers and cyberattacks. Similar to the advancements in navigation (use case 5), quantum navigation systems (use case 8) offer robust and precise navigation solutions, especially in environments where GPS signals are unreliable or unavailable. These quantum cryptographic protocols and navigation systems are sufficiently mature and should be implemented immediately to secure sensitive data transmissions and maintain the integrity of communications across automotive, aerospace and transportation networks.

Businesses should: invest early in research areas like aerodynamics simulation (use case 1) and traffic flow optimization (use case 3) to position the industry for future success; develop PoCs for environmental forecasting (use case 4) and synchronized operations (use case 6) to prepare for the pilot stage; deploy quantum security pilots today with PQC, QRNG and QKD devices to protect communication channels and infrastructure from cybersecurity threats; and implement quantum navigation systems to ensure resilient navigation/navigation improvement (use case 5) in GPS-denied environments. Together, these steps can ensure that the automotives, aerospace and transportation industries can overcome challenges and capitalize on the advantages quantum technologies offer, leading to enhanced operational efficiency and data security.

4

The business of quantum: How to get started

Leaders must consider the different pathways for businesses to integrate quantum technologies into their strategy and operations, thereby propelling the quantum economy forward.



4.1 Explorative initiatives

Businesses taking an exploratory approach are characterized by their R&D efforts in understanding and experimenting with quantum technologies. Companies can engage with the quantum ecosystem through partnerships with academic institutions, R&D collaborations and innovation hubs to explore the potential of quantum technologies.

4.1.1 Engaging with the ecosystem

One of the most effective ways businesses can explore quantum technologies is by forming partnerships or alliances with academic institutions and research organizations. This ecosystem will provide access to cutting-edge research and the latest developments in quantum technology. Collaborations with universities can facilitate joint research projects, allowing businesses to leverage academic expertise while providing practical applications and industry insights to academic researchers.

Innovation hubs and R&D collaborations also play a crucial role in the explorative approach. By joining forces with innovation hubs, businesses can participate in a community of innovators and researchers dedicated to advancing quantum technologies. These hubs often offer resources such as shared lab facilities, expert mentorship and networking opportunities, which can significantly accelerate a company's quantum learning curve.

4.1.2 Undertaking small-scale projects and pilot programmes

Another key element of explorative initiatives typically involves small-scale projects and pilot programmes designed to test and understand the potential impacts of quantum technologies on a business. These projects are essential for gaining hands-on experience without making substantial commitments. Businesses can start with pilot projects that focus on specific applications of quantum computing, sensing or communication, allowing them to assess feasibility, benefits and challenges.

For instance, a company might collaborate with quantum experienced entities to pilot a quantum computing project aimed at assessing the practical applications and potential benefits in their own context. By experimenting with quantum algorithms, the company can evaluate potential efficiency gains and identify any technical or operational hurdles. Similarly, a pilot programme in quantum sensing could involve testing quantum sensors for improved precision in environmental monitoring, offering valuable insights into the technology's practical applications.

4.1.3 Learning and adapting

By staying informed about the latest advancements in quantum technologies, businesses can remain agile and responsive to new opportunities and challenges. This involves regular engagement with the quantum community through conferences, workshops and seminars, where industry leaders and researchers share insights and breakthroughs.

Additionally, businesses can benefit from maintaining a flexible and open-minded attitude towards quantum technologies. Rather than committing to a specific technology or application prematurely, companies should focus on broad-based exploration, allowing them to identify the most promising areas for future investment and development.

4.1.4 Gaining insights from industry leaders

The experiences and insights of current industry leaders can provide valuable guidance for businesses aiming to engage with the quantum ecosystem. Companies that have successfully implemented explorative initiatives often share their lessons, highlighting both successes and challenges. These case studies can serve as practical examples for other businesses, offering strategies for effective engagement with quantum technologies.

For example, industry leaders in the insurance sector have explored quantum computing for risk and portfolio optimization, sharing their experiences of how quantum algorithms have helped accelerate the discovery of assets to cede or reinsure within a portfolio. Similarly, leaders in the health industry have experimented with quantum sensing for enhanced heart disease detection, providing insights into the human body quicker and with more accuracy.

Explorative initiatives represent a critical first step for businesses seeking to integrate quantum technologies. By engaging with the quantum ecosystem through partnerships, small-scale projects and continuous learning, companies can gain valuable experience and insights. This approach allows businesses to test the waters, understand the potential impacts of quantum technologies, and position themselves for future growth in the quantum economy.

The next section delves into the approach of building a dedicated quantum team, exploring how businesses can develop in-house expertise and capabilities to drive their quantum strategies forward.

4.2 Building a dedicated team

In this section, the focus is on highlighting different pathways for businesses to integrate people and resources for leveraging quantum technologies in their strategy and operations, thereby driving the quantum economy forward. Building a dedicated team is crucial for businesses seeking to own the innovation process in quantum tech (e.g. JPMorganChase and AXA). By investing in internal capabilities and creating a specialized team of application- and business-relevant expertise, companies can gain a competitive edge and effectively lead the market to meet their specific needs.

4.2.1 The importance of internal capabilities

A dedicated team allows a company to build proprietary quantum solutions, explore use cases specific to their business, and integrate quantum technologies into their operations. This internal approach represents a more committed strategy, where the company invests in its human resources to develop quantum expertise, ensuring that it remains at the forefront of quantum innovation.

4.2.2 Team structure and recruitment strategies

Creating a specialized quantum team involves careful planning of the team structure, recruitment strategies and training programmes. The team should be composed of a diverse set of roles that align with the business applications of quantum technologies.

4.2.3 Roles defined by business applications

Quantum technology is introducing specialized roles to leverage its unique capabilities. Those in the usual specialized roles, such as data scientists, will increasingly need an understanding of how to quantum-mechanically formulate problems. Quantum technologies are expected to become an integral part of various professional roles, outlined in Table 9 and Table 10 in Appendix A.3 (Roles needed in different sectors for each quantum technology).

In the financial services sector, quantum computing is utilized by quantitative analysts, portfolio managers, and fraud detection specialists to enhance data analysis and risk management. Quantum sensing aids financial data analysts and fraud detection specialists, while quantum communication ensures secure transactions and compliance by employing compliance and cybersecurity experts.

In pharmaceuticals and healthcare, quantum computing supports bioinformatics specialists and drug discovery scientists in processing complex biological data. Quantum sensing is crucial for medical device engineers and healthcare data scientists, and quantum communication secures patient data and manages health information for patient-data security officers, health information managers and compliance officers.

The chemicals industry benefits from quantum computing as material scientists and process engineers can optimize chemical processes. Quantum sensing helps develop chemical sensors and monitor environmental data, while quantum communication secures data transmission with the help of communication specialists and data security analysts.

The energy and utilities sector uses quantum computing for energy systems analysis and grid efficiency optimization. Quantum sensing aids in environmental monitoring and utility data analysis, and quantum communication ensures infrastructure security.

In automotives, aerospace and transportation, quantum computing optimizes supply chains and vehicle design. Quantum sensing enhances structural integrity and autonomous vehicle sensors, while quantum communication secures vehicle communication networks.

Finally, the technology and telecommunications sector employs quantum computing for developing algorithms and IT infrastructure. Quantum sensing improves telecom sensors and data transmission, and quantum communication secures network operations and cybersecurity.

4.2.4 Training and development

Training is essential to ensure that the dedicated team remains at the cutting edge of quantum technology. This includes:

- **Continuous education:** Offering courses and workshops on the latest quantum developments.
- **Certifications:** Encouraging team members to obtain certifications in quantum technologies.
- **Collaborations:** Facilitating internships and collaborative projects with leading quantum research institutions.

4.2.5 Timeline and investments

Building a dedicated quantum team is a long-term investment. Companies can expect the process to take several years, with the timeline depending on the complexity of the quantum technologies being integrated and the existing capabilities of the organization. Initial phases might involve forming a small core team and gradually expanding as the company's quantum capabilities grow.

Investing in a dedicated quantum team allows businesses to build in-house expertise, develop proprietary solutions and maintain a competitive advantage in this evolving market. This committed approach ensures that companies are well-positioned to harness the transformative potential of quantum technologies.

The following section will explore how businesses can allocate resources to quantum initiatives to drive growth and innovations.

4.3 Strategic investments

Investing directly in quantum technologies, whether through venture capital, acquisitions or internal funding, is crucial for businesses looking to capitalize on quantum advancements. These investments can accelerate the development and commercialization of quantum technologies. Examples of industries investing to progress quantum research, as well as public institutions and governments investing in quantum centres, highlight the diverse approaches and significant financial commitments being made to integrate quantum technologies into various sectors.

4.3.1 Pathways to investing in quantum technologies

The various pathways available are tailored to the maturity and strategic goals of the business. These include venture capital, acquisitions and internal funding, each offering unique advantages and opportunities for growth and innovation. (See Table 11 in Appendix A.4 for details.)

Venture capital

Venture capital (VC) is a critical pathway for funding start-ups in the quantum technology sector. This approach provides the necessary financial resources for early-stage companies to develop their innovations and bring them to market. For instance, in the finance sector, JPMorganChase and Mitsui have invested in Quantinuum, while Goldman Sachs and Morgan Stanley have backed D-Wave. Similarly, BlackRock has invested in PsiQuantum, showcasing significant interest from major financial institutions in quantum start-ups.

In the technology and telecommunications industry, Bezos Expeditions has invested in D-Wave, and Google Ventures has supported IonQ, enabling advancements in ion-trap technology. The pharmaceutical and healthcare sectors have also seen investments, with Amgen and Novo Holdings committing substantial funds to quantum computing start-ups. These investments highlight the broad appeal and potential of quantum technology across various industries.

Acquisitions

Acquisitions offer a rapid means to integrate quantum innovations into existing product lines, allowing companies to quickly leverage new technologies. In the technology sector, Keysight Technologies acquired Quantum Benchmark, and ORCA Computing acquired the Integrated Photonics Division of GXC. These acquisitions enable companies to enhance their technological capabilities and stay competitive. The pharmaceutical industry has also seen significant acquisitions, such as SandboxAQ's purchase of Good Chemistry, which combines AI and quantum tech for drug discovery. In the energy sector, Honeywell's acquisition of Cambridge Quantum Computing exemplifies how acquisitions can enhance quantum computing capabilities. These strategic moves demonstrate how acquisitions can accelerate the adoption and integration of quantum technologies in established companies.

Internal funding

Internal funding involves allocating a company's R&D budget to quantum projects, fostering proprietary solution development. This pathway allows businesses to develop unique quantum technologies tailored to their specific needs. For example, HSBC has created a quantum computing practice, and MUGT is using quantum computing to mitigate risks in the finance sector. In the technology and telecommunications industry, China Telecom has established a quantum technology group, and Deutsche Telekom AG's T-Systems offers quantum computing expertise and access to IBM Quantum resources.

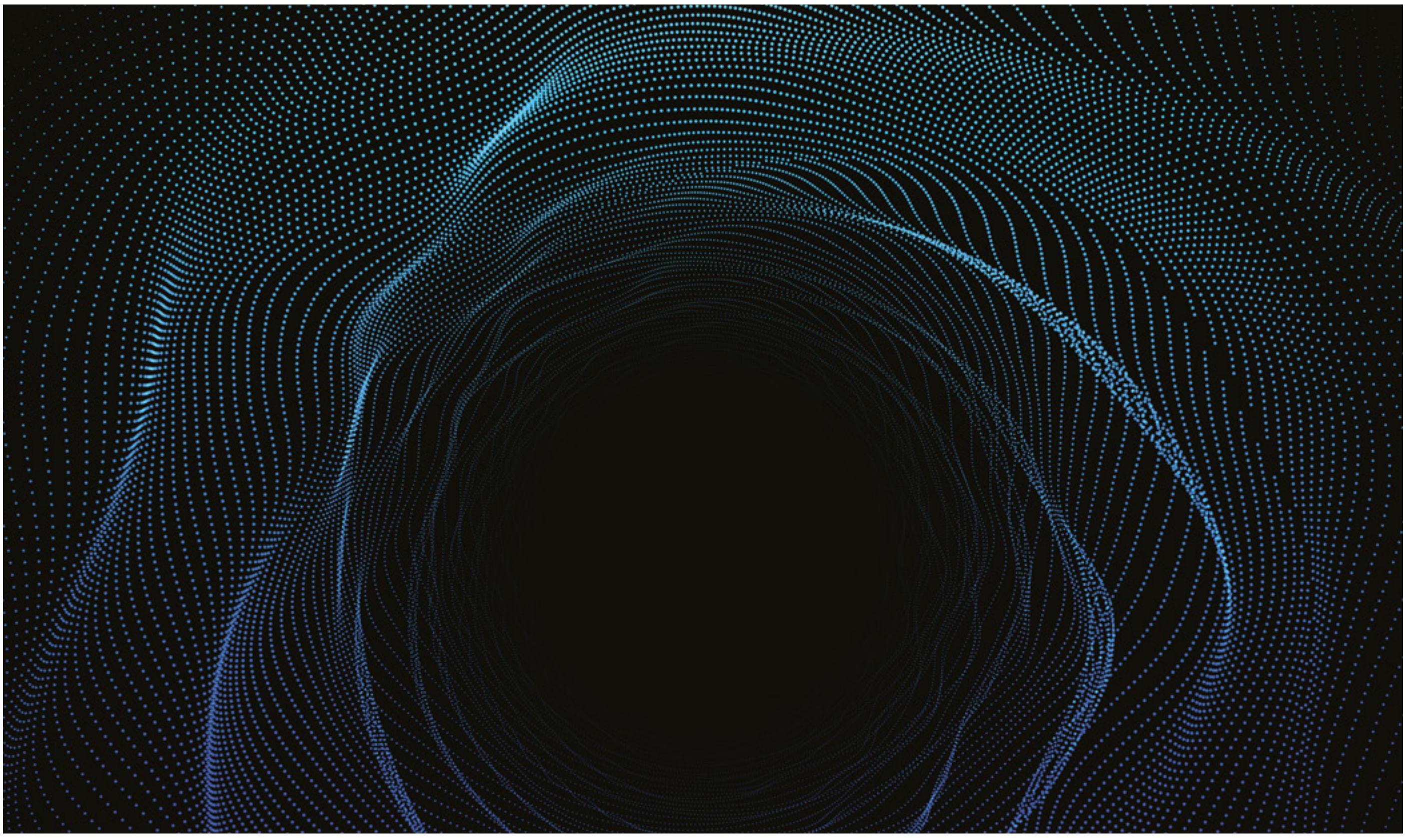
The pharmaceutical sector also benefits from internal funding, with Cleveland Clinic and IBM launching the world's first quantum computer dedicated to healthcare research. Additionally, companies like Volkswagen and Toyota are investing in quantum computing projects to optimize traffic flow and develop next-generation batteries, respectively. These initiatives underscore the importance of internal funding in driving innovation and maintaining a competitive edge in the quantum technology landscape.

4.3.2 Strategic considerations for investment

Strategic investments require careful planning and consideration of various factors. Companies must assess market potential, manage risks, stay informed about the regulatory environment, and engage with the collaborative ecosystem to maximize the impact of their investments.

TABLE 6 **Factors to consider for maximizing the impact of quantum technology investments**

Consideration	Description	Examples
Market potential	Evaluate the market potential of quantum technologies in relation to their business impacts within the respective industry.[59]	Refer to section "Quantum leap: Navigating the new frontier of use cases".
Risk management	Develop strategies to manage risks, such as diversification of investments and collaborations with research institutes and computing centres.[60]	Microsoft is developing a quantum computer using topological qubits as the qubit type.[61] They are also in partnership with Quantinuum to optimize a trapped ion quantum computer.[62]
Regulatory environment	Stay informed about regulatory developments to mitigate legal and operational risks.	The United Kingdom's Department for Science, Innovation and Technology released a report, "Regulating Quantum Technology Applications," which lays out a strategic blueprint for fostering a pro-innovation regulatory environment. The report offers a comprehensive framework through 14 targeted recommendations, organized into three pivotal themes: regulatory frameworks and governance, standards and international collaboration, and innovation funding and market development.[63]
Collaborative ecosystem	Engage with the broader quantum ecosystem through partnerships and collaborations.	The European Quantum Industry Consortium (QuIC), Europe's premier association for the quantum industry, operates as a collaborative hub throughout Europe, bringing together hundreds of SMEs, large corporations, investors, research and technology organizations and academic institutes, to build a strong, vibrant quantum ecosystem.[64]



4.3.3 Examples of investment in quantum research

Various industries and public institutions have made significant investments in quantum research, showcasing the potential and impact of strategic investments in this field. The technology sector, healthcare industry and government initiatives highlight how these investments drive innovation and development.

TABLE 7 **Examples of public- and private-sector investments in quantum research**

Consideration	Description	Examples
Technology sector	Major tech companies such as IBM, Google and Microsoft invest heavily in quantum computing research.[65]	*Use case:* IBM's development of Heron, a scalable quantum processor, and couplers to link Herons together to solve complex computational problems.
Healthcare	Pharma companies explore quantum computing for drug discoveries through internal R&D and collaborations.[66]	*Use case:* Biogen's collaboration with 1QBit to develop quantum algorithms for drug design.
Quantum centres	Governments establish quantum research centres, such as the quantum centre in Barcelona, to drive innovation.[67]	*Impact:* The Barcelona centre fosters collaboration, leading to breakthroughs in quantum communication technologies.
National initiatives	Countries such as the US and China as well as many European countries launch national and regional quantum initiatives with significant funding.	*Impact:* The US National Quantum Initiative Act drives substantial public funding into quantum research, advancing national security and economic competitiveness. Pasqal, a neutral atoms technology company, delivered two 100 qubits quantum processors on-premises in Europe – one to the Très Grand Centre de Calcul of the French Commission for Atomic Energy and Alternative Energies (CEA), and the other to the Jülich Research Centre in Germany, as part of the flagship high performance computer-quantum simulation programme.

Strategic investments in quantum technologies, whether through venture capital, acquisitions or internal funding, are essential for businesses aiming to capitalize on quantum advancements. By understanding the pathways to investment and considering strategic factors, companies can accelerate the development and commercialization of quantum technologies. This approach not only positions businesses at the forefront of the quantum revolution but also ensures they are well-prepared to harness the transformative potential of quantum computing, quantum sensing, and quantum communication and security.

Conclusion

As a veritable Cambrian Explosion of quantum technologies approaches, it brings with it significant benefits for early adopters in various industries. Just as the Cambrian Explosion marked a period of rapid diversification and innovation in life forms, the quantum revolution promises a surge in technological advancements and applications. These technologies are accompanied with certain risks such as intellectual property issues, resource limitations and unequal distribution of advancements. This report has outlined strategic measures to address these risks so that first movers can overcome them and ride on the benefits that the oncoming waves of quantum technologies bring. The symbiotic nature of AI and quantum technologies propel each other, offering both near- and long-term benefits.

FIGURE 17 **Action steps for businesses**

1

Conduct a risk assessment

Evaluate the potential risks associated with quantum technologies in your specific industry. Address technological readiness, intellectual property management and equitable distribution of advancements.

2

Engage with quantum ecosystems

Collaborate with quantum research institutions, start-ups and industry leaders to stay updated on the latest advancements. Participate in innovation hubs and R&D collaborations to leverage cutting-edge research.

3

Initiate pilot programmes

Start small-scale projects to test quantum applications and gather insights. Use these pilots to understand the feasibility, benefits and challenges of integrating quantum technologies into your operations.

4

Build a dedicated quantum team

Recruit and train a team with expertise in quantum technologies and their business applications. Develop internal capabilities to drive quantum strategies forward and maintain a competitive edge.

5

Invest strategically

Identify key areas for investment in quantum technologies. Allocate resources to quantum initiatives, considering market potential, risk management and the regulatory environment.

6

Monitor and adapt

Continuously monitor the progress of quantum initiatives. Adapt strategies based on emerging trends and outcomes to ensure long-term success and competitiveness.

Source: World Economic Forum and Accenture

To successfully navigate the emerging quantum economy and unlock economic growth across diverse sectors, organizations must establish a clear and actionable roadmap. Business leaders should begin by assessing the potential advantages and challenges of quantum technologies within their industry. This includes evaluating technological readiness, managing intellectual property concerns, and ensuring equitable access to advancements. Proactively identifying and addressing these challenges will enable organizations to effectively prepare for and capitalize on the opportunities that quantum technologies bring.

Engaging with the quantum ecosystem is crucial – businesses should collaborate with quantum research institutions, start-ups and industry leaders. Participation in innovation hubs and R&D collaborations can provide access to cutting-edge research and foster a community of innovators dedicated to advancing quantum technologies. In doing so, industry leaders can catalyse innovation and share risks, while public-private collaborations can amplify collective capabilities. Open innovation frameworks, built on mutual trust, can further accelerate the development and adoption of quantum technologies. The Forum is providing access to flagship industry- and societally-relevant applications for the ecosystem through the Quantum Application Hub.

Initiating pilot programmes is an essential step for testing quantum applications and gathering insights. Small-scale projects (PoCs/ PoVs) allow businesses to assess the feasibility, benefits and challenges of integrating quantum technologies into their operations. These pilots provide valuable hands-on experience and help organizations understand how to effectively implement quantum solutions in real-world scenarios. However, executing these projects will require the building of a dedicated quantum team. By recruiting and training a team with specialized knowledge in quantum technologies and their business applications, companies can drive their quantum strategies forward and maintain a competitive edge. This internal capability will be instrumental in exploring proprietary quantum solutions and integrating them into the organization's operations.

Strategic investment in quantum technologies is necessary to capitalize on their transformative potential. Businesses should identify key areas for investment, considering market potential, risk management and the regulatory environment. Allocating resources to quantum initiatives will accelerate the development and commercialization of quantum technologies, positioning companies at the forefront of the quantum revolution. Leveraging UpLink, the World Economic Forum's Quantum Economy Network[68] and the Centre for the Fourth Industrial Revolution Saudi Arabia[69] have launched the Quantum for Society Uplink Innovation Challenge.[70] This will enable ecosystem partners to support early-stage innovation by enabling capital infusion, engaging a mission-aligned ecosystem, fostering product-market fit, and shifting perceptions about quantum technologies' role in global sustainability efforts.

Finally, continuous monitoring and adaptation of quantum initiatives are essential for long-term success. Organizations must regularly review the progress of their quantum projects and adapt their strategies based on emerging trends and outcomes. This is a once-in-a-generation opportunity to reshape industries and solve complex global challenges. The World Economic Forum calls upon your organizations to explore and share your learnings to demonstrate the potential of quantum technologies in solving the toughest problems the world faces today.

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Special thanks to Sebastian Buckup, Head of Networks and Partnership, Centre for the Fourth Industrial Revolution; Member of the Executive Committee, World Economic Forum, Carl Dukatz, Innovation Strategy Managing Director, Accenture, and Cliff Farah, Accenture Managing Director Global Corporate Strategy and Growth for their ongoing support in initiating and scaling this team's efforts in quantum technologies for industrial and societal applications.

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Production

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Design and layout

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Appendix

A.1 Use case description

This section provides descriptions of all the use cases mentioned in Section 3.2.

A.1.1 Use cases covered in financial services

Quantum computing	
Currency trading (Toshiba and Dharma Capital)[71]	Currency arbitrage high-frequency trading (HFT) is a common algorithmic trading strategy in financial services. The key is to find as many profitable currency combinations (or trading paths) as possible and avoid unprofitable transactions or wrong trades. There are two industry-wide challenges in this use case. First, profitable arbitrage opportunities can be as short-lived as less than 1 millisecond. Existing technologies can hardly identify these opportunities due to speed limits. Second, it is difficult to consistently maintain a 50% higher trading success or profit rate, as the company would like to. These challenges form a bottleneck to all currency arbitrage HFT solutions on the market.
Financial crash estimation in enterprises (Yapi Kredi Bank and D-Wave)[72]	Focused on estimating financial crashes within a network of small and medium enterprises (SMEs) that are customers of Yapi Kredi Bank, the team have developed a quadratically constrained quadratic programme as a mathematical optimization model aimed at identifying significant vulnerabilities and potential failure points in this network. Solving this NP-hard problem[73] using classical methods is challenging; therefore, they have leveraged the quantum annealing technology of D-Wave[74] to efficiently explore the solution space and produce decision variables that indicate the likelihood of financial distress for each SME in the network.
Reinsurance optimization (AXA)	Reinsurance optimization involves the strategic evaluation and selection of reinsurance arrangements to maximize the benefits and minimize the risks associated with transferring insurance liabilities to reinsurers. It aims to optimize the reinsurance programme to achieve an optimal balance between risk reduction, cost-efficiency and capital utilization.
Credit card payment fraud detection (Rigetti, HSBC, University of Edinburgh and National Quantum Computing Centre)[75]	It involves the use of advanced algorithms and ML techniques to identify and prevent fraudulent transactions. By analysing transaction patterns, user behaviour and other relevant data, these systems can detect anomalies and flag potentially fraudulent activities. This helps financial institutions and payment processors to minimize losses, protect customers' financial information and maintain trust in the payment system. Continuous learning and adaptation of the models ensure that they stay effective against evolving fraud tactics.
Settlement optimization of securities transactions (Bank of Italy, Intesa Sanpaolo, IBM and the universities of Exeter and Verona)[76]	Transaction settlement is defined as the exchange of securities and cash between parties and is crucial to the financial market infrastructure. This case study considers the transactions occurring in TARGET2 (Trans-European Automated Real-Time Gross Settlement Express Transfer) Securities. Improving the settlement process by identifying the optimal set of transactions that will settle is a complex optimization task. Teams at Bank of Italy, Intesa Sanpaolo, IBM, University of Exeter and University of Verona are designing a variational quantum algorithm for the settlement optimization of securities to run on NISQ hardware, and to benchmark the results against classical and quantum-inspired solvers.
Quantum sensing	
Detecting magnetic anomalies in transactions	Quantum magnetometers can detect extremely subtle changes in magnetic fields. In a financial context, they could be used to detect fraudulent card readers (skimmers) at ATMs (automated teller machines) or point-of-sale terminals. The precise measurement capabilities can identify tampering or the presence of unauthorized devices.
Infrastructure integrity monitoring	Quantum gravimeters measure minute changes in gravitational fields. They can be used to monitor the structural integrity of physical locations where financial transactions occur, such as bank vaults and data centres. Any unauthorized entry or structural changes can be detected with high sensitivity, which can indicate potential fraud or security breaches.
Accurate timestamps for financial transactions	Quantum clocks offer extremely precise timekeeping. They can be used to create highly accurate timestamps for financial transactions, ensuring that transaction records are tamper-proof. Any discrepancies in transaction times can be detected immediately, helping to identify fraudulent activities.
Detect tampering of ATMs	Quantum acoustic sensors can detect minute vibrations and sounds. They can be used to monitor ATMs, vaults and other sensitive areas for unusual activities, such as drilling or tampering. The high sensitivity of these sensors ensures that even the smallest anomalies are detected, which can indicate an attempted fraud.

A.1.1 Use cases covered in financial services (continued)

Distributed quantum sensor detection systems	A network of quantum sensors can be deployed to create a comprehensive fraud detection system. These sensors can work together to monitor various parameters, such as electromagnetic fields, vibrations and gravitational changes, providing a multifaceted approach to fraud detection. The interconnected nature of the sensors could allow for real-time data sharing and analysis, enhancing the overall effectiveness of the system.
Quantum communication and security	
More resilient keys for secure encryption and authentication (HSBC and Quantinuum)[77]	Quantum RNGs can produce truly random numbers, which are crucial for generating secure cryptographic keys. These keys can be used to encrypt transaction data and authenticate users. The unpredictability of QRNGs makes it extremely difficult for fraudsters to break the encryption, thereby enhancing the security of financial transactions.
Physical encryption network (HSBC, BT and Toshiba; JPMC, Ciena and Toshiba)[78]	A physical encryption network leverages advanced cryptographic techniques and physical layer security to protect data transmission throughout communication networks. This approach combines traditional encryption methods with physical properties of the communication medium, such as QKD or optical encryption, to enhance security. It ensures that data remains confidential and tamper-proof, even against sophisticated attacks. This is particularly important for sensitive applications in government, financial services and critical infrastructure, where data integrity and security are of paramount importance.

A.1.2 Use cases covered in technology and telecommunications

Quantum computing	
Optimized network transformation (Fujitsu and University of Toronto)[79]	Fujitsu's Digital Annealer is utilized by telecommunications companies to optimize network configurations and reduce operational costs. In collaboration with the University of Toronto, Fujitsu applied this technology to transform legacy telecommunications networks, resulting in up to 30% reduction in operating costs and 80% reduction in transportation costs during the migration period.
Network traffic optimization and resource allocation[80]	Volkswagen uses D-Wave's quantum annealing technology to optimize traffic flow in urban areas. The technology can be adapted by telecommunications companies to optimize network traffic and resource allocation, improving operational efficiency.
Quantum sensing	
Site surveys	Quantum gravimeters offer unparalleled sensitivity in detecting subsurface density variations, making them ideal for site surveys and stability assessments. They enable precise evaluation of ground conditions, ensuring optimal placement of infrastructure like buildings, bridges and tunnels. This non-invasive technology minimizes environmental impact by reducing the need for extensive drilling or excavation. By identifying potential risks such as sinkholes or unstable soil early, quantum gravimeters improve construction safety and sustainability.
Data transmission and reliability (BT)[81]	BT Group employs quantum clocks, developed as part of the European Quantum Flagship project, for precise time synchronization across its global telecommunications network, crucial for accurate data transmission and network reliability.
Infrastructure inspection	Quantum-enhanced LiDAR technology provides high-resolution imaging for precise inspection of telecommunications infrastructure. By capturing detailed 3D maps, it allows companies to monitor structural integrity, detect vulnerabilities and optimize maintenance schedules. This technology also supports environmental monitoring, identifying risks like vegetation encroachment on cables or towers. Its precision and efficiency reduce costs and improve safety, making it invaluable for modern infrastructure management.
Infrastructure integrity monitoring[82]	QinetiQ develops quantum acoustic sensors for high-precision sound detection, which can be used by telecommunications companies to monitor infrastructure integrity and detect environmental changes affecting network performance.
Environmental monitoring	Quantum sensors enable enhanced environmental monitoring by detecting subtle changes in temperature, pressure or magnetic fields with exceptional precision. Telecommunications companies can use these sensors to assess environmental risks, such as soil erosion or vegetation growth, that could affect infrastructure stability. This proactive monitoring improves operational efficiency, minimizes maintenance disruptions and enhances network security by identifying potential issues before they escalate.

A.1.2 Use cases covered in technology and telecommunications (continued)

Quantum communication and security	
More resilient keys for advanced mobile security (SK Telecom, Samsung Electronics and ID Quantique)[83]	Quantum RNGs can produce truly random numbers, which are crucial for generating secure cryptographic keys. These keys can be used to encrypt transaction data and authenticate users. The unpredictability of QRNGs makes it extremely difficult for fraudsters to break the encryption, thereby enhancing the security of financial transactions.
Secure communication channels (China Telecom and QuantumCTek; BT and Toshiba; SPTel and SpeQtral; Boeing)[84]	China Telecom uses QuantumCTek's QKD technology to secure its communication channels, ensuring data transmitted over its network is protected against eavesdropping and cyberattacks, providing enhanced security for customers. British Telecom is working on a quantum-secured optical fibre network using Toshiba's QKD technology. SpeQtral is working on space-based QKD with SPTel's telecom infrastructure. Boeing is working on a quantum networking satellite Q4S based on QKD to be launched in 2026.

A.1.3 Use cases covered in pharmaceuticals and healthcare

Quantum computing	
High-throughput ligand interaction simulation	Quantum-inspired algorithms on classical computers use principles derived from quantum mechanics, such as superposition and entanglement, to enhance the simulation of ligand-protein interactions. This method enables the rapid evaluation of chemical compound libraries, identifying potential candidates for therapeutic drugs by predicting binding affinities and specificity with high precision.
mRNA secondary structure prediction (Moderna and IBM)[85]	The emergence of mRNA-based therapeutics has effected a paradigm shift in the landscape of medicine. Accurate prediction of mRNA secondary structure is critical in designing RNA-based therapeutics as it dictates various steps of an mRNA life cycle, including transcription, translation and decay. Moderna's application explores how quantum computers could enable scientists to predict mRNA secondary structures at greater scale, accuracy and efficiency than ever before. Moderna and IBM have examined the feasibility of solving the mRNA secondary structure prediction problem on a utility-scale quantum computer with sequence lengths of up to 60 nucleotides representing problems in the qubit range of 10 to 80.
Optimizing clinical trial designs	Clinical trials are essential for the development of new medical treatments, but they are often costly and time-consuming. By leveraging advanced algorithms and data analytics, the design of clinical trials can be optimized to improve efficiency and effectiveness. This includes selecting the right patient populations, determining optimal dosing strategies and predicting potential outcomes. Optimization techniques can help reduce the duration and cost of trials while increasing the likelihood of successful outcomes.
Quantum sensing	
Detection of cardiovascular diseases (SandboxAQ)[86]	Quantum magnetometers can detect extremely subtle changes in magnetic fields caused by heart activity. They are being used by SandboxAQ for early detection of cardiovascular diseases by monitoring anomalies in the heart's magnetic fields. Research is in progress to develop similar quantum sensors that can be used to detect quantum magnetic fields in the brain (MEG) for Parkison's disease detection, and to detect arrhythmias (of the heart) in the foetus.
High-precision medical imaging	High-precision medical imaging relies on accurate timing synchronization to produce detailed and reliable images of the human body. Quantum clocks, known for their exceptional accuracy and stability, can be used to synchronize the timing of imaging devices such as MRI (magnetic resonance imaging), CT (computed tomography) and PET (positron emission tomography) scanners. This synchronization ensures that the data collected from different sensors and imaging modalities are perfectly aligned, leading to higher-resolution images and more accurate diagnostics. The use of quantum clocks can significantly enhance the performance of medical imaging systems, enabling early detection and better treatment planning for various medical conditions.
Quantum-enhanced advanced diagnostic imaging	Quantum-enhanced imaging techniques utilize quantum technologies to significantly improve the resolution and sensitivity of devices like MRI and PET scanners. These advancements enable the detection of minute anomalies, facilitating earlier and more accurate diagnoses of conditions such as cancer and vascular diseases. Quantum sensors also enhance multi-modal imaging by precisely synchronizing data, leading to higher-resolution images. This technology holds great promise for improving diagnostic accuracy and treatment planning in critical medical cases.
Remote vital signs monitoring	Quantum acoustic sensors detect minute vibrations and sound waves, enabling non-invasive, real-time monitoring of vital signs like heart rate and respiratory rate. These sensors provide unprecedented sensitivity, crucial for telemedicine applications, where continuous monitoring is essential. Their integration into healthcare systems can detect irregularities early, improving outcomes, especially in remote or underserved regions. This technology represents a significant leap for personalized, remote healthcare.

A.1.3 Use cases covered in pharmaceuticals and healthcare (continued)

Simultaneous drug delivery and drug efficacy testing with antibiotics	Quantum-enhanced sensors enable simultaneous measurement of drug delivery rates and efficacy in real-time, offering unprecedented precision. This approach reduces the need for separate testing phases, significantly cutting costs and accelerating the development of regulatory drugs. Applied to antibiotics, it allows for quicker adjustments to formulations and dosages, improving patient outcomes while speeding up the go-to-market timeline for new treatments.
COVID detection in breath	Ultrasensitive biomarker detection technology can be used to identify specific biomarkers in a person's breath that indicate the presence of COVID-19. This non-invasive method leverages advanced sensors and analytical techniques to detect trace amounts of viral particles or related biomarkers with high accuracy and speed. It offers a rapid, convenient and reliable alternative to traditional testing methods, facilitating early detection and timely intervention to control the spread of the virus.
Quantum communication and security	
More resilient keys for secure encryption and authentication	QRNGs generate truly random numbers, enhancing the security of medical data transmissions. They can be used to encrypt patient records and other sensitive information, protecting them from cyberthreats.
Quantum-secure health information exchanges	Quantum communication technologies using PQC/QKD ensure the security of health data exchanges between entities, protecting against potential quantum computing threats and ensuring compliance with health privacy regulations.

A.1.4 Use cases covered in chemicals and advanced materials

Quantum computing	
Quantum chemistry simulations of chemical compounds used in fabrication of OLED devices (Mitsubishi Chemical, IBM, Keio University and JSR)[87]	Scientists at Mitsubishi Chemical, IBM, Keio University and JSR performed quantum chemistry simulations on IBM quantum devices to describe quantum computations of the "excited states" or high-energy states of industrial chemical compounds that could potentially be used in the fabrication of efficient organic light-emitting diode (OLED) devices.
Catalyst design optimization	Utilizing the gate model of quantum computing, researchers can simulate and optimize catalyst structures at the quantum level. This approach allows for the precise manipulation of atomic configurations, enhancing catalyst activity and selectivity for chemical reactions critical in industrial processes. It can have an impact on nitrogen fixation in the agriculture industry, for example.
Molecular docking	Molecular docking is a computational technique used to predict the preferred orientation of one molecule to a second when bound to each other to form a stable complex. This is crucial in drug discovery and development, as it helps in understanding the interaction between drugs and their target proteins. By simulating the docking process, researchers can identify potential drug candidates more efficiently, predict their efficacy and optimize their chemical structures to enhance binding affinity and selectivity.
PFAS chemicals remediation (Accenture, ICHEC, IonQ)[88]	The PFAS molecular bond analysis kit from Accenture, ICHEC and IonQ uses chemistry simulation on quantum computers to calculate the energies needed for breaking chemical bonds in PFAS molecules, which are human-made carcinogenic "forever chemicals".
Modelling of non-covalent interactions in water and methane systems (Cleveland Clinic, Michigan State University and IBM)[89]	Researchers use quantum computers in conjugation with high-performance classical compute to model non-covalent interactions in water and methane systems with quantum hardware performing experiments with up to 54 qubits. Their simulations on quantum processors are in remarkable agreement with classical methods. They have also tested the capacity limits of the quantum methods for capturing hydrophobic interactions with an experiment on 54 qubits. These results mark significant progress in the application of quantum computing to chemical problems, paving the way for more accurate modelling of noncovalent interactions in complex systems critical to the biological, chemical and pharmaceutical sciences.
Simulation of N_2 triple bond breaking using quantum-centric supercomputer (IBM, University of Colorado and RIKEN)[90]	Electronic structure problems in chemistry offer practical use cases around the hundred-qubit mark. The authors simulated molecular nitrogen triple bond breaking using a Fugaku supercomputer and an IBM quantum processor in a "quantum-centric supercomputing" architecture. The results show that such an architecture can produce good approximate solutions for practical chemistry simulation problems.

A.1.4 Use cases covered in chemicals and advanced materials (continued)

Quantum sensing	
Product quality check	Quantum magnetometers can be used for highly sensitive and precise measurements of magnetic fields, which are crucial in various industrial applications. In product quality checks, quantum magnetometers can detect minute defects or inconsistencies in materials and products that traditional methods might miss. This ensures higher quality standards, reduces waste and enhances the reliability of products, particularly in industries such as electronics, aerospace and manufacturing.
Quantum-enhanced quality imaging	These techniques improve the resolution and sensitivity of product quality imaging devices, enabling earlier and more accurate diagnosis of rips in the supply chain and making it possible to fix these. Quantum-enhanced imaging techniques utilize quantum properties to achieve higher resolution and sensitivity than classical imaging methods. These techniques can detect minute details and subtle changes in materials that would be difficult or impossible to observe with traditional imaging technologies. Throughout the supply chain, quantum-enhanced imaging can be used to monitor the condition of materials and products. For example, it can detect rips or damage in packaging, ensuring that products are not compromised during transportation and storage.
Last-mile quality control	Quantum acoustic sensors detect minute vibrations and sounds. In the final stages of the supply chain, quantum acoustic sensors can be deployed to perform thorough quality checks. This ensures that any issues that might have arisen during transportation or final assembly are identified and addressed before the product reaches the customer.

Quantum communication and security	
More resilient keys for secure supply-chain data transmission	QRNGs produce keys that are fundamentally unpredictable, making them highly secure. These keys can be used in encryption algorithms to encode sensitive supply-chain data, ensuring that the data cannot be easily decrypted by unauthorized parties.
Quantum-secure internal data communication channels	Quantum-secure internal data communication channels leverage PQC and QKD to protect data against quantum computing threats. PQC develops cryptographic algorithms resistant to quantum attacks, while QKD uses quantum mechanics to securely distribute encryption keys, ensuring any eavesdropping attempts are detected. Combining PQC and QKD ensures that sensitive information exchanged during transactions is protected from eavesdropping and tampering.

A.1.5 Use cases covered in energy and utilities

Quantum computing	
Large-battery charging optimization	Users can schedule the charging and discharging of large batteries based on energy prices to maximize profit, and this can be done using a quadratic unconstrained binary optimization (QUBO) approach. Using a quantum annealing algorithm with this QUBO model and live prices from the global electrical exchanges, users can find high-quality solutions for electricity trading, resulting in higher profits, lower computational costs and less strain on the power grid.
Tailings treatment (Accenture and Quantum City)[91]	Fine fluid tailings (FFT) are clay particles suspended in water and sand that result from the extraction of bitumen from oil sand ore. The current practice to treat tailings is to agglomerate the clays by using coagulation and flocculation. Traditionally, finding the optimal dosage of flocculants in tailings treatment involves numerous laboratory experiments. In a University of Calgary competition, Quantum City Challenge, Accenture won by using a hybrid quantum neural network to help find the best possible combination of flocculants and coagulants for tailings treatment. The quantum model is also benchmarked against state-of-the-art classical ML approaches.
Optimization of supply-chain providers	It involves using advanced analytics and optimization techniques to enhance the efficiency and effectiveness of the supply chain. By analysing data from various sources, companies can identify the best suppliers, optimize inventory levels, reduce lead times and minimize costs. This process ensures a more resilient and responsive supply chain, improves service levels and enhances overall operational efficiency. It also enables better decision-making and strategic planning, leading to a competitive advantage in the market.
Shallow subsurface imaging (Saudi Aramco)[92]	This quantum application is an industry-first, industrial-scale quantum computing use case developed and integrated with in-house seismic data processing software. The application utilizes both classical computers and quantum annealers, leveraging the best of both, enabling processing of tens of gigabytes of seismic data, making it the largest application of its kind handling such data volume.
Vehicle-to-grid optimization (Accenture)[93]	The usage of vehicle-to-grid (V2G) technology is implemented as a so-called feed-in reward programme – the utility provider offers participating EV users a reward price to feed into the energy grid at specific times. The utility provider can control the amount of feed-in energy depending on the prices. The optimal reward prices for this demo maximize the utility provider's profit. Finding them is the goal of a complex optimization problem that can be solved with classical, quantum and quantum-inspired methods.

A.1.5 Use cases covered in energy and utilities (continued)

Quantum sensing	
Geophysical surveys	Quantum gravimeters utilize advanced quantum sensing technology to measure minute changes in gravitational fields. This capability is essential for conducting geophysical surveys, providing highly accurate data that can aid in resource exploration, geological mapping and infrastructure assessments in the energy and utilities sector.
Hydrogen gas-leak detection[93]	The HYDrogen sensor for Industry (HYDRI) consortium is led by BP and was awarded a £2.5 million funding by InnovateUK to develop a pair of quantum hydrogen gas sensors. One is for operational safety, and the other for fugitive emissions monitoring. Using a single-photon avalanche detector (SPAD), it becomes feasible to detect the faint, otherwise undetectable light reflected off hydrogen gas and generate an image of the gas cloud. Moreover, integrating a SPAD with a highly accurate time-of-flight (ToF) sensor – a type of range-imaging camera capable of determining the distance between the light source and the detector – enables the creation of a 3D representation. This advanced imaging makes it possible to quantify the gas leak. Hydrogen is expected to play a vital role as a transition fuel as well as in net-zero energy systems. Decarbonized hydrogen production could provide energy for hard-to-abate sectors such as iron, steel, chemicals and heavy transport (including trucks, ships and aircraft). Hydrogen is invisible and odourless but highly flammable when mixed with air. Hence, the energy industry needs efficient sensors able to rapidly detect small concentrations for safety, and to quantify emissions.
Continuous methane monitoring (QLM Tech and TotalEnergies)[94]	Continuous monitoring of emissions in the oil and gas industry is a major challenge due to the stringent cost requirements of the industry and the obvious need for its high durability, long lifetime and complete autonomy. QLM's Quantum Gas Lidar technology meets these requirements, utilizing mature, robust and highly cost-effective and scalable near-infrared telecommunications components in a unique configuration for spectroscopic LiDAR. The technology provides highly accurate methane concentration imaging using an active scanning technique that can cover ranges of hundreds of meters. One of QLM's earliest industrial partners is TotalEnergies, which maintains a dedicated testing facility at TADI (Transverse Anomaly Detection Infrastructure) in Lacq, France.
Precise timekeeping (Chronos Technology, Infleqtion, NPL and PNDC)[95]	Chronos Technology is researching to demonstrate the broadcast of UK's NPL timing reference using a quantum clock provided by Infleqtion to the University of Strathclyde. This reference will be used by the university's Power Networks Demonstration Centre (PNDC) to synchronize its systems. This will reduce the reliance on Global Navigation Satellite Systems (GNSS) and improve the resilience of critical national infrastructure. The initiative establishes the evidence base for redistributing positioning, navigation and timing (PNT) data to air- and ground-based autonomous systems in a smart city infrastructure environment, and to accurately measure electricity grid performance, both of which rely on resilient timing reference.
Quantum communication and security	
More resilient keys for secure supply-chain data transmission[96]	Honeywell integrated Quantinuum's QRNG technology to strengthen the cryptography in its range of smart meters. QRNGs generate truly random numbers, enhancing the security of data and control instructions sent to critical infrastructure. They can be used to enhance authentication and strengthen data encryption.
Quantum-secure internal communications	PQC involves developing cryptographic algorithms that are resistant to attacks from quantum computers. QKD uses the principles of quantum mechanics to securely distribute encryption keys. The energy and utilities industry operates critical infrastructure, such as power grids, water supply systems and gas pipelines. Ensuring the security of communications related to the operation and management of these infrastructures is of paramount importance. PQC and QKD can provide robust security for these communications, protecting them from the emerging threats posed by quantum computing.

A.1.6 Use cases covered in automotives, aerospace and transportation

Quantum computing	
Aerodynamics simulations[97]	Airbus is exploring quantum gate model applications for complex aerodynamics simulations and optimization in aircraft design. By utilizing quantum computing techniques, Airbus aims to solve intricate aerodynamic problems that are computationally intensive for classical computers. These simulations help in optimizing the design of aircraft for better fuel efficiency, reduced drag and improved overall performance. The quantum gate model allows for more accurate and faster simulations, leading to innovative designs, reduced development time and enhanced safety and efficiency in aircraft manufacturing.
Modelling of corrosion in metals[98]	IBM has worked with Boeing to simulate corrosion processes to improve composites used in airframes. The researchers developed two new techniques to perform quantum simulations of a key step in the corrosion process known as water reduction.

Traffic flow optimization[99]	Volkswagen uses D-Wave's quantum annealing technology to optimize traffic flow and reduce congestion in urban areas. By leveraging quantum computing, Volkswagen could analyse vast amounts of traffic data in real time to identify patterns and predict traffic conditions. This enables the development of optimized traffic management strategies, such as dynamic traffic light control and route optimization for vehicles. The result is smoother traffic flow, reduced travel times, lower emissions and an overall improvement in urban mobility and quality of life for city residents.
Supply chain optimization (BMW and Entropica Labs)[100]	BMW has teamed up with Entropica Labs to use the Honeywell System Model H1 quantum computer. The aim of the undertaking is to examine supply chains and logistics for BMW.
Earth observation satellites scheduling optimization[101]	Artificial Brain worked on a quantum annealing algorithm to optimize real-time scheduling for multiple earth observation satellites. The algorithm could lead to solutions in the integration of EU space data with cutting-edge technologies like AI and quantum computing.
Quantum sensing	
Navigation and environmental monitoring[102]	Lockheed Martin uses quantum magnetometers for high-precision navigation and environmental monitoring in aerospace applications. By providing precise magnetic field measurements, quantum magnetometers improve the accuracy of navigation systems, ensuring safe and efficient operation of aerospace vehicles. They can monitor variations in the Earth's magnetic field caused by solar activity and space weather events. This information is crucial for predicting and mitigating the effects of space weather on satellites, communication systems and other aerospace infrastructure.
Ultra-high accuracy automatic ground test equipment for rockets (Ariane Group and ID Quantique)[103]	Rockets of European Space Agency's Ariane Group had been facing issues with conventional electro-pyrotechnics (devices that use electricity to provide ignition), and they were migrating to opto-pyrotechnics (devices that use lasers to provide ignition). ID Quantique teams used SNSPD (superconducting nanowire single-photon detector) to develop a dedicated fibre-optic integrity monitoring system of the opto-pyrotechnics used for the control of key phases of rocket launch.
Precise measurements in navigation and geophysical surveys (Boeing and AOSense; NASA's Goddard Space Flight Center and AOSense; NASA's Cold Lab Atom)[104]	Atom interferometry is a technique that can precisely measure gravity, magnetic fields and other forces.[105] Boeing and AOSense have used atom interferometry and successfully completed a four-hour test flight for navigation in real time without using GPS. NASA also partnered with AOSense using atom interferometry for precise measurements in aircraft navigation and geophysical surveys. Another team of NASA at Cold Lab Atom used this technique at the International Space Station (ISS) in a micro-gravity environment that allows for more precise testing than on Earth.
Navigation in GPS-denied environments (USAF and SandboxAQ)[106]	Quantum magnetometers can harness the Earth's crustal magnetic field to provide reliable navigation with no need for satellites or communications. This ensures safe and accurate navigation in environments where GPS may be compromised. The US Air Force is conducting real-time demonstrations of the systems.
Precise timekeeping[107]	Quantum clocks developed by the United Kingdom's National Physical Laboratory (NPL) can be used for ultra-precise timekeeping in aircraft systems. These quantum clocks provide unparalleled accuracy in time measurement, ensuring that all aircraft systems are perfectly synchronized. This precise timekeeping is crucial for navigation, communication and coordination of various onboard systems, leading to enhanced safety, efficiency and performance of aircraft operations. The collaboration between Rolls-Royce and NPL leverages cutting-edge quantum technology to push the boundaries of aviation innovation.
Quantum communication and security	
Quantum-secure internal data communication channels	PQC involves cryptographic algorithms that are resistant to attacks from quantum computers, ensuring long-term security of data. QKD, on the other hand, uses the principles of quantum mechanics to securely distribute encryption keys, providing an additional layer of security. Modern vehicles, especially connected and autonomous vehicles, rely heavily on data communication for various functions such as navigation, diagnostics and infotainment. In the aerospace industry, secure communication is critical for the operation of aircraft. Transportation systems, including railways, shipping and public transit, rely on secure communication for coordination and management. By integrating PQC and QKD in communication systems of connected vehicles, aircraft communication systems and transportation infrastructure, sensitive data can be protected, ensuring data integrity and confidentiality.

A.2 Use case placement assumptions

For each subsection in Chapter 3.2, the industry-specific matrices showing business value and technical feasibility for all use cases were created using inputs from the community. These inputs were organized through a detailed SWOT (strengths, weaknesses, opportunities and threats) analysis, using the definitions provided in Figure 17 and Table 8.

The different stages of development for quantum technologies, categorized as theoretical, experimental, prototype and commercial, have their respective timelines. Here's a detailed description of what each stage typically involves.

FIGURE 17 **Stages of development of quantum technologies**

Theoretical
10+ years

This is the earliest stage of any quantum technology. It involves fundamental research and mathematical modelling.

The focus is on theoretical proposals and simulations rather than practical implementation.

Discoveries are often conceptual, seeking to understand the quantum mechanics that could enable future technologies.

Practical applications are generally more than a decade away, and the feasibility of real-world applications may still be uncertain.

Experimental
6 to 10 years

At this stage, the theoretical concepts begin to be tested experimentally.

Laboratory set-ups are constructed to validate the principles observed in theoretical models.

It may involve creating early-stage devices that demonstrate quantum effects, though these devices are typically not yet capable of performing useful tasks.

The technology is in a proof-of-concept phase, where experimental results guide further refinements.

Prototype
3 to 5 years

This phase sees the development of functional prototypes that demonstrate how the technology could be applied in practical applications.

Efforts are made to increase the reliability and efficiency of the technology to a level suitable for commercial development.

The technology is often still under development in laboratory settings, but there is clear potential for commercialization within a few years.

Collaboration between research institutions and industry partners might begin to scale prototypes into viable products.

Commercial
1 to 2 years

The focus is on finalizing the product for market release.

Quantum technologies at this stage have proven functionality and reliability that meet commercial standards.

The efforts are directed towards manufacturing processes, market analysis and distribution logistics.

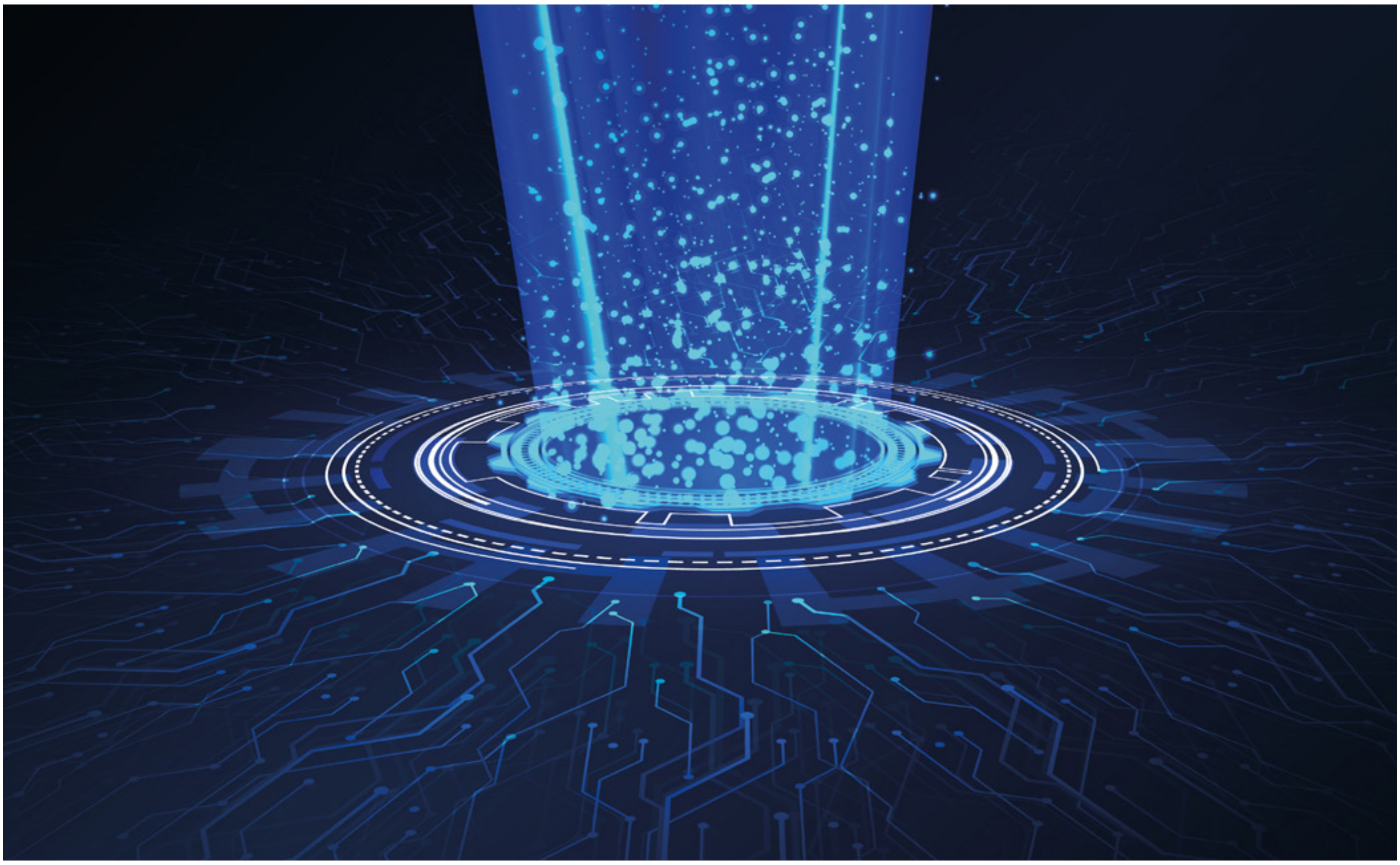
The technology is close to being launched on the market, with continued improvements and optimizations aimed at cost reduction and enhanced performance.

Source: World Economic Forum and Accenture

Each stage is crucial in the development of quantum technologies, transitioning from pure science to practical applications that can impact various industries and sectors. These may be further explained for each type of technology having its own maturity.

TABLE 8 **Use case placement for different quantum technologies**

Technology area	Quantum computing	Quantum sensing	Quantum communications and security
Theoretical (10+ years)	At this stage, the focus is on developing new algorithms, error correction methods and theoretical models for quantum computation. Researchers explore the limits of computational power and the types of problems quantum computers could solve one day.	Research is directed towards understanding and exploiting quantum effects to improve measurement precision. This includes the development of new sensing modalities based on quantum entanglement and superposition.	Work focuses on QKD and other protocols that utilize quantum mechanics for secure communication. Theoretical studies also focus on the integration of quantum communications with existing networks.
Experimental (6 to 10 years)	Efforts concentrate on building small-scale quantum processors to validate theories and refine quantum bits (qubits) coherence and control. This stage often involves demonstrating the quantum advantage for specific problems, albeit in a highly controlled experimental set-up.	Experiments validate the sensitivity and accuracy of quantum sensors under controlled conditions. Initial applications might be in high-precision laboratories or environments like space or underground facilities.	Testbeds for QKD and other quantum communication technologies are set up. Demonstrations often involve point-to-point secure communication under laboratory conditions or over limited outdoor distances, and miniaturization of the overall technology.
Prototype (3 to 5 years)	Larger, more reliable quantum processors are developed. The work includes integrating quantum systems with classical hardware and software to create more complete computing solutions, aimed at specific industries such as pharmaceuticals, materials science and finance.	Efforts aim to ruggedize and miniaturize quantum sensors for practical use cases such as geological surveying, navigation systems and medical diagnostics.	More robust and integrated systems capable of working with existing telecommunications infrastructure are developed. This includes building of repeaters, transceivers and other components essential for long-distance quantum communication.
Commercial (1 to 2 years)	Focus shifts to scalability, usability and integration with existing technology infrastructures. Commercial quantum computers might start as niche products for specific computational problems, with broader applications developing slowly as technology matures.	Quantum sensors are finalized for commercial deployment, focusing on reliability, ease of use and cost-effectiveness. They may start impacting a variety of sectors, including automotives, healthcare and telecommunications.	The technology is prepared for deployment in specific high-security applications, such as governmental communications, with gradual expansion into commercial sectors such as banking and cloud services.



A.3 Roles needed in different industries for each quantum technology

The specific roles within a quantum team will vary depending on the Industry and the intended applications of quantum technologies. Table 9 outlines the roles required in each Industry based on the type of quantum technology they are focusing on.

TABLE 9 **Indicative technical roles needed in different industries for each quantum technology**

Industry	Quantum technology	Roles
Financial services	**Quantum computing**	Quantitative analyst Portfolio manager Risk manager Data scientist Systems integrator Fraud detection specialist
	Quantum sensing	Financial data analyst Fraud detection specialist
	Quantum communication and security	Secure transaction specialist Compliance officer Cybersecurity expert
Pharmaceuticals and healthcare	**Quantum computing**	Bioinformatics specialist Clinical data analyst Drug discovery scientist Systems integrator
	Quantum sensing	Medical device engineer Healthcare data scientist Diagnostic specialist
	Quantum communication and security	Patient data security officer Health information manager Compliance officer
Chemicals and advanced materials	**Quantum computing**	Material scientist Process engineer Chemical analyst Data scientist Systems integrator
	Quantum sensing	Chemical sensor developer Environmental data scientist Laboratory technician
	Quantum communication and security	Secure communication specialist Data security analyst

TABLE 9 **Indicative technical roles needed in different industries for each quantum technology** (continued)

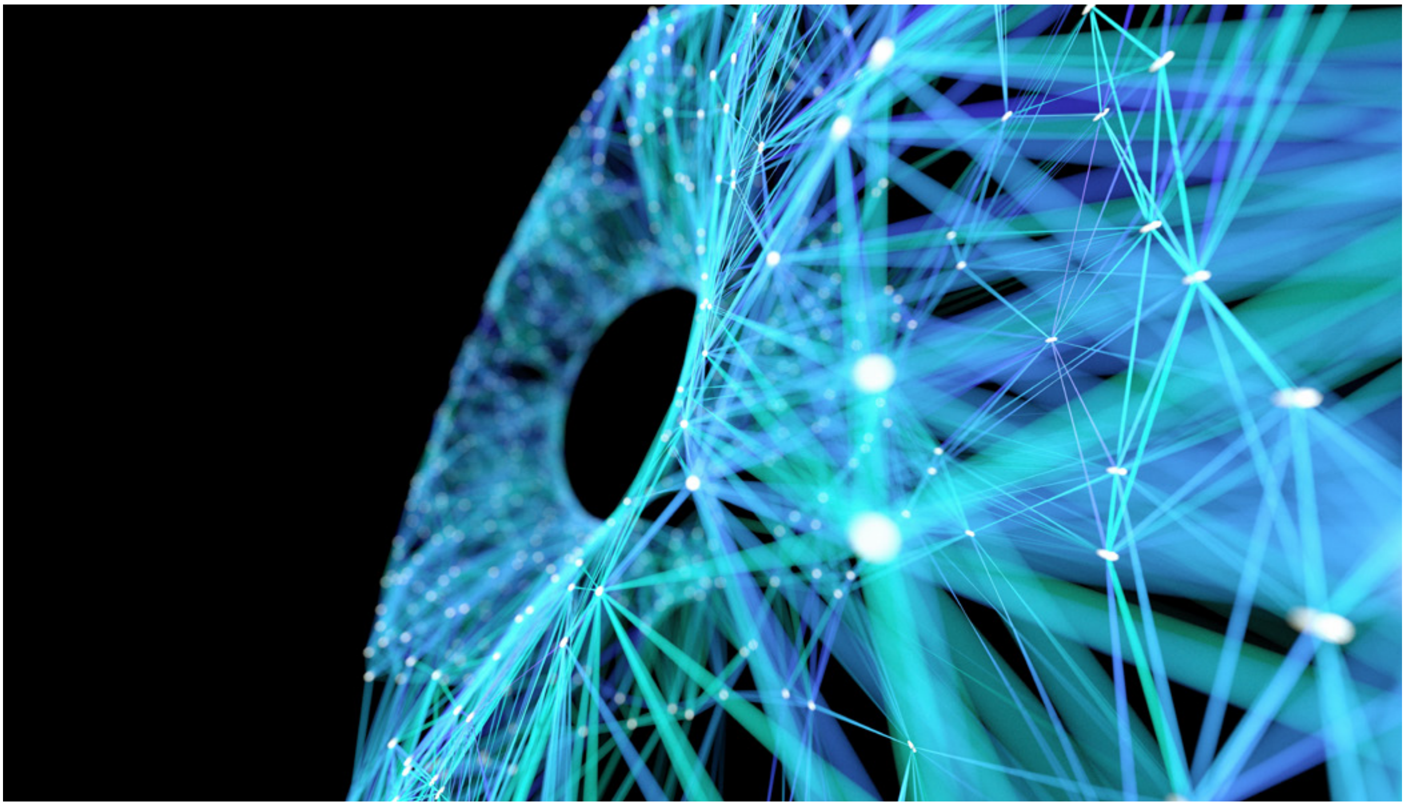
Industry	Quantum technology	Roles
Energy and utilities	**Quantum computing**	Energy systems analyst Renewable energy optimizer Grid efficiency expert Data scientist Systems integrator
	Quantum sensing	Sensor engineer Environmental monitoring specialist Utility data analyst
	Quantum communication and security	Infrastructure security analyst Communication network manager Cybersecurity expert
Automotives, aerospace and transportation	**Quantum computing**	Supply chain optimizer Vehicle design engineer Navigation systems analyst Data scientist Systems integrator
	Quantum sensing	Structural integrity specialist Autonomous vehicle sensor engineer Geospatial analyst
	Quantum communication and security	Vehicle communication specialist Transport security analyst Network security engineer
Technology and telecommunications	**Quantum computing**	Quantum algorithms developer Software engineer IT infrastructure specialist Data scientist
	Quantum sensing	Telecom sensor developer Data transmission analyst Network reliability engineer
	Quantum communication and security	Network engineer Cybersecurity specialist Communication systems analyst

Supporting roles

In addition to technical roles, integrating quantum technologies requires support from various other functions within the organization.

TABLE 10 **Indicative non-technical roles to deliver quantum technologies**

Function	Role	Responsibilities
Legal	Legal adviser	Manages intellectual property and ensures compliance with quantum technology regulations, and generally for most compliance-related functions.
Finance	Financial analyst	Evaluates the cost-benefit analysis of quantum technology investments and oversees budgeting. Generally, also works to evaluate risk.
Sales	Sales executive	Develops strategies to market quantum solutions to potential clients for each industry.
Marketing	Marketing specialist	Creates campaigns to promote the company's quantum capabilities and educates the market about quantum technology benefits that are specific for each industry.
Operations	Operations manager	Oversees the implementation and integration of quantum solutions in business operations.
	Project/delivery manager	Coordinates quantum projects, ensuring timely delivery and alignment with business objectives.



A.4 Different paths to investing in quantum technologies

TABLE 11 **Different paths to investing in quantum technologies**

Industry	Pathway	Description	Examples
Financial services	**Venture capital**	Provides necessary funding for start-ups to develop and market innovations.	JPMorganChase investment in Quantinuum[108] Mitsui to invest in Quantinuum[109] Goldman Sachs and Morgan Stanley investment in D-Wave[110] BlackRock investment in PsiQuantum[111]
	Acquisitions	Rapidly integrate start-up innovations into existing product lines.	
	Internal funding	Allocates R&D budget to quantum projects for proprietary solution development.	HSBC creates quantum computing practice[112] MUGT to use quantum computing for mitigating risks[113]
Technology and telecommunications	**Venture capital**	Provides necessary funding for start-ups to develop and market innovations.	Bezos Expedition investment in quantum start-up D-Wave to develop cloud-based quantum computing services[114] Google Ventures' investment in IonQ enabled it to advance ion-trap technology for quantum computing[115]
	Acquisitions	Rapidly integrate start-up innovations into existing product lines.	Keysight Technologies acquires Quantum Benchmark[116] Kipu Quantum acquires Anaqor's quantum platform[117] ORCA Computing acquires Integrated Photonics Division of GXC[118] IonQ acquires assets of Entangled Networks[119]
	Internal funding	Allocates R&D budget to quantum projects for proprietary solution development.	China Telcom establishes quantum technology group[120] Deutsche Telekom AG T-Systems offers quantum computing expertise and access to IBM Quantum computational resources[121]
Pharmaceuticals and healthcare	**Venture capital**	Provides necessary funding for start-ups to develop and market innovations.	Amgen's investment in Quantinuum[122] Novo Holdings announces intent to invest $200 million in quantum computing start-ups[123]
	Acquisitions	Rapidly integrate start-up innovations into existing product lines.	SandboxAQ buys Good Chemistry[124]

TABLE 11 **Different paths to investing in quantum technologies** (continued)

Industry	Pathway	Description	Examples
Pharmaceuticals and healthcare	**Internal funding**	Allocates R&D budget to quantum projects for proprietary solution development.	Cleveland Clinic and IBM launch world's first quantum computer dedicated to healthcare research and biomedical discoveries[125] Accenture Labs and Biogen apply quantum computing to accelerate drug discovery[126] Johnson & Johnson and Pasqal work to demonstrate practical benefits of quantum computing[127]
Chemicals and advanced materials	**Venture capital**	Provides necessary funding for start-ups to develop and market innovations.	BASF's business incubator Chemovator invests in Quantistry[128]
	Acquisitions	Rapidly integrate start-up innovations into existing product lines.	
	Internal funding	Allocates R&D budget to quantum projects for proprietary solution development.	SEEQC partners with BASF[129] Covestro and QC Ware collaborate on quantum algorithms for materials R&D[130]
Energy and utilities	**Venture capital**	Provides necessary funding for start-ups to develop and market innovations.	Chevron's investment in quantum computing start-up OQC for energy optimization and simulations[131]
	Acquisitions	Rapidly integrate start-up innovations into existing product lines.	Honeywell's acquisition of Cambridge Quantum Computing to enhance its quantum computing capabilities[132]
	Internal funding	Allocates R&D budget to quantum projects for proprietary solution development.	
Automotives, aerospace and transportation	**Venture capital**	Provides necessary funding for start-ups to develop and market innovations.	France taps quantum computing for aerospace design[133]
	Acquisitions	Rapidly integrate start-up innovations into existing product lines.	
	Internal funding	Allocates R&D budget to quantum projects for proprietary solution development.	Volkswagen's internal funding for quantum computing projects aimed at optimizing traffic flow[134] Toyota partners with Israel's Quantum Machines for quantum computing[135] Ford Motor Co.'s quantum research group uses quantum computing in developing EV battery materials[136] BMW and Capgemini benchmark quantum computing applications[137] PsiQuantum and Mercedes-Benz study quantum computers to accelerate EV battery design[138] Hyundai Motor Company uses quantum computers to develop next-generation batteries[139]

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