Saudi Arabia
Centre for the
Fourth Industrial
Revolution

KACST aramco KFUPM MINISTRY OF COMMUNICATIONS AND INFORMATION TECHNOLOGY

Towards Saudi Arabia's Quantum-Enabled Future

Piloting the World Economic Forum's Quantum Economy Blueprint

December 2025

Table of Contents

List of Abbreviations

C4IR	Centre for the Fourth Industrial Revolution
CST	Communications, Space and Technology Commission
ETSI	European Telecommunications Standards Institute
GDP	Gross Domestic Product
IAU	Imam Abdulrahman Bin Faisal University
IEEE	Institute of Electrical and Electronics Engineers
IEC	International Electrotechnical Commission
IP	Intellectual Property
ISO	International Organization for Standardization
ISU	Internet Service Unit
ITU	International Telecommunication Union
IYQ	International Year of Quantum Science and Technology
KACST	King Abdulaziz City for Science and Technology
KAUST	King Abdullah University of Science and Technology
KFUPM	King Fahd University of Petroleum and Minerals
KSU	King Saud University
MCIT	Ministry of Communications and Information Technology
NCA	National Cybersecurity Authority
NDMO	National Data Management Office
NIST	National Institute of Standards and Technology
NTDP	National Technology Development Program
PQC	Post-Quantum Cryptography
PSU	Prince Sultan University
QCaaS	Quantum Computing as a Service
QKD	Quantum Key Distribution
R&D	Research & Development
SABIC	Saudi Basic Industries Corporation
SDAIA	Saudi Authority for Data and Artificial Intelligence
SMEs	Small and Medium-sized Enterprises
WQD	World Quantum Day
⃁	Saudi Riyal

Foreword

Dr. Basma AlBuhairan
Managing Director
C4IR Saudi Arabia

It is with great anticipation and enthusiasm that we introduce “Towards Saudi Arabia’s Quantum-Enabled Future: Piloting the World Economic Forum’s Quantum Economy Blueprint.” This work represents an important step in the Kingdom’s journey toward a technologically advanced and diversified economy, and it reflects the Kingdom’s commitment to fostering innovation.

Building upon the foundational insights gathered from our previous landscape report, this roadmap represents a significant leap forward. It is the culmination of dedicated effort and strategic foresight, charting a clear course for Saudi Arabia to harness the transformative potential of quantum technologies. We are the first country to pilot the World Economic Forum’s Quantum Economy Blueprint, a framework that provides a robust and comprehensive approach to developing a thriving quantum economy. This endeavor confirms the Kingdom of Saudi Arabia’s commitment to adopting cutting-edge technologies for economic diversification and societal well-being. The journey to this milestone has been truly collaborative and part of the Quantum Economy Project, the C4IR’s flagship project 2024-2026. This project aims to implement and localize the World Economic Forum’s Quantum Economy Blueprint in Saudi Arabia. From celebrating the global significance of World Quantum Day to hosting insightful webinars, publishing engaging blogs, and facilitating hands-on workshops and seminars. These activities have been instrumental in developing knowledge assets that support national exploration and policy thinking on quantum technologies, while cultivating collaborative frameworks and knowledge sharing within the quantum technology stakeholder community, and promoting the importance of quantum technologies to the public and decision-makers, all of which are essential for accelerating our quantum ambitions.

As we look ahead, the promise of quantum technologies, from ultra-secure communication to revolutionary computing and advanced sensing, holds the key to addressing some of humanity’s most pressing challenges and unlocking unprecedented opportunities. This roadmap is not merely a document; it is a living commitment to fostering an environment where innovation thrives, talent flourishes, and the benefits of the quantum age are realized for all.

I extend my deepest gratitude to all the collaborators, experts, and stakeholders who have contributed their invaluable insights and dedication to this undertaking. Together, we are laying the groundwork for a quantum-enabled future that will redefine industries, enhance national capabilities, and secure Saudi Arabia’s position as a global leader in the new technological frontier.

Foreword

Prof. Tristan Farrow
NEOM Education, Research, and Innovation Sector

Quantum technologies are too strategically important to be left vulnerable to fragile global supply chains. They will shape the next era of economic growth, national security, and scientific discovery. Once confined to laboratories, they are poised to drive breakthroughs impacting critical infrastructure and long-term competitiveness.

This quantum frontier presents both a historic opportunity and a challenge for Saudi Arabia. Supply chains for raw materials, critical components, and specialised systems remain fragile, globally dispersed, and often dominated by a few vendors, sometimes in geopolitically sensitive regions. Yet the opportunity lies in timing: quantum is still at an early stage but the window to act is closing. Nations that invest consistently now will shape the standards, ecosystems, and markets of the future. Those who hesitate could face prohibitive barriers to entry.

Building research and innovation capabilities, industrial capacity, and a quantum-ready workforce takes more than a decade. Saudi Arabia's advantage is clear: over the past 10–15 years, other nations have made significant investments in quantum technologies and have learned what works and what does not. By leveraging global experience, forming strategic partnerships, and focusing on proven pathways that align with priority missions and synergise with parallel investments into say semiconductors, the Kingdom can accelerate progress and leapfrog into a position among leading nations.

The potential rewards are substantial. Applications in mining, oil and gas, water management, logistics, communications, space, semiconductors, biotechnology, and pharmaceuticals will be profoundly transformative.

Urgent, coordinated, and sustained action is required. Government, industry, research organizations, and regulators will need to work together with a shared vision to realise Saudi Arabia's quantum ambitions and secure technological competitiveness, strengthen the industrial base, and inspire a new generation of talent.

Anchored in Vision 2030, this roadmap frames quantum technologies as a driver of economic diversification and provides clear, actionable policy recommendations to achieve this goal.

Executive Summary

This roadmap pilots the World Economic Forum's Quantum Economy Blueprint, charting a course for Saudi Arabia to harness quantum technologies for economic diversification and societal well-being. It is built upon three pillars, structured around seven key themes. Each thematic section provides actionable recommendations to build capabilities, drive innovation, and ensure responsible development in alignment with Vision 2030. These pillars and themes are further synthesized in Table 1, which presents the key messages and policy recommendations shaping national implementation.

The first pillar, Building Capabilities, aims at understanding the quantum value chain and assessing Saudi Arabia's access to critical hardware infrastructure, supply chain robustness, and workforce endowment. Based on this analysis, and to fully leverage its existing advantages, Saudi Arabia should make a concerted effort to develop a pool of specialized talent, establish a national quantum center and dedicated foundries to secure reliable access to essential hardware and supply chains.

The second pillar, Driving Innovation, focuses on translating these capabilities into tangible economic value. This would be achieved by implementing a mission-driven funding model that bridges the gap between research and commercialization, creating a national quantum innovation hub to accelerate technology transfer and launching a coordinated awareness campaign to ensure strategic alignment and informed investment across government and industry.

The third pillar, Ensuring Responsibility, focuses on building public trust and securing the nation's digital future. This involves establishing proactive governance and a national authority to lead standardization efforts, ensuring that quantum development is ethical, interoperable, and aligned with global best practices. Critically, it addresses the urgent cybersecurity challenges posed by quantum advancements, recommending a strategic integration of post-quantum cryptography to protect existing digital infrastructure. This forward-looking approach ensures that Saudi Arabia not only capitalizes on the immense opportunities of the quantum era but also builds a secure and prosperous future, solidifying its position at the forefront of technological innovation.

Table 1: Key messages and policy recommendations from the quantum roadmap

Theme/ section	Key Message	Policy Recommendations
1.1 Value Chain Analysis	Quantum technologies offer vast opportunities. A national strategy leveraging Saudi strengths ensures leadership and avoids dependency.	↗ **Prioritize investment** to remove barriers in quantum progress, scale-up fabrication, and nurture and retain top talent. ↗ **Scale-up domestic capability** via expanding specialized laboratories. ↗ **Pursue a dual-track strategy** for competitiveness and independence.
1.2 Hardware & Supply Chain	Quantum technologies need resilient, locally supported supply chains.	↗ **Create a national quantum center** to coordinate the national effort. ↗ **Map and close critical supply chain gaps.** ↗ **Develop global partnerships and domestic fabrication,** and manufacturing.
1.3 Workforce Development	Quantum technologies need resilient, locally supported supply chains.	↗ **Expand quantum education** and vocational training. ↗ **Strengthen academia-industry ties** through joint projects and mission-led strategy. ↗ **Promote quantum literacy** for policymakers and industry managers. ↗ **Attract global talent** and expertise.
2.1 Innovation & Commercialization	Focused funding and global alignment on standards, interoperability, and governance, help turn research into economic value.	↗ **Prioritise industry use-cases** with potential commercial outcomes. ↗ **Use public procurement** to kick-start formation of early markets and to grow investor confidence. ↗ **Create national hubs** and align with global standards.
2.2 Awareness	Public confidence underpins governance and strategic investment.	↗ **Launch national dialogues**, industry forums, and quantum ambassador programs. ↗ **Develop coordinated central quantum awareness initiatives**, outreach programs. ↗ **Share relatable success stories** to inspire trust.
3.1 Governance & Standards	Adaptive governance ensures innovation with trust and accountability.	↗ **Form a national quantum governance program to coordinate strategy, funding and regulations.** ↗ **Train regulators and officials** for foresight exercises. ↗ **Develop certification and regulatory sandboxes** for technology testing and validation.
3.2 Cybersecurity	Setting and updating national encryption standards, to be ready for the post-quantum era.	↗ **NCA is working on updating the National Strategy for Cybersecurity** that has initiatives related to managing the cyber risks related to emerging technologies, including Quantum Computing.

Source: Authors' elaboration

Introduction

Over the next decade, Quantum Technologies (QT), are expected to move from use-cases to widespread adoption. These technologies are foreseen to vastly accelerate computing power, high-fidelity sensors, and communications security, unlocking practical applications and reshaping key economic sectors.

These technologies use the laws of quantum mechanics, the science of how atoms and electrons behave, to surpass the performance of today's classical technologies. They encompass three subfields, computing, communication, and sensing:

Quantum computers. Next-generation computers are expected to solve complex problems at speeds far beyond those of today's most advanced systems, potentially transforming key industries in Saudi Arabia. In energy, they can boost efficiency in oil and gas operations by improving how underground reservoirs are modeled and how extraction methods are designed. In healthcare, they can speed up drug discovery for diseases prevalent in the region, like diabetes, and enable personalized treatments, supporting Saudi Arabia's Vision 2030 goal of a technologically advanced healthcare system.

Quantum communications. This is anticipated to offer stronger security than today's encryption, protecting critical infrastructure in energy, finance, data centres, and defense. As Saudi Arabia develops smart cities and grows its digital economy, quantum-secure networks will bolster cybersecurity, thereby reduce risk and encourage investment, and reinforce the Kingdom's leadership in secure digital infrastructure.

Quantum sensors. Measures time, gravity, and magnetic fields with exceptional precision. In Saudi Arabia, they could be used to map oil and gas reserves more accurately and non-invasively. This would improve extraction efficiency, lower costs and environmental impact, and extend the life of existing fields.

The Impact Of Quantum Technologies on Cutting-Edge Technologies

Quantum technologies are expected to act as a key enabler of other disruptive technologies, creating powerful synergies with other innovations. For instance, quantum computing could improve AI algorithms efficiency and solve optimization problems quickly. Quantum communication can secure robot communication and provide quantum authenticated access, while quantum sensing can enhance navigation and sensor precision in robotics. In sustainability and climate tech, quantum computing could improve computing power for material discovery, enhance the simulation of complex systems like climate models, and optimize production processes to reduce emissions. The rise of quantum computing poses an existential risk to classical cryptography but also presents new opportunities for cybersecurity solutions -like QKD- with quantum communication enabling new security protocols and improving security standards using processes such as quantum random number generation.

Why Does Saudi Arabia Need a Quantum Economy Roadmap?

Countries should develop their own quantum agenda to avoid a Quantum Divide, where some nations possess advanced quantum capabilities while others do not. A quantum national strategy is essential to prevent falling behind as quantum technologies mature and their economic impacts become more significant. Moreover, to leverage the transformative potential of quantum computing, communication, and sensing. The ultimate goal of this roadmap is to support public and industry decision-makers in shaping policy and investment, and act as a knowledge-asset to inform future policy considerations and national planning for quantum technologies. It uses insights from the Quantum Economy Blueprint to help to create a value-driven quantum strategy for Saudi Arabia.

What is this Roadmap?

The Quantum Economy Blueprint, developed by the World Economic Forum, provides a structured framework to help countries build their national quantum ecosystems. It guides governments, industry and academia in developing quantum computing, communications and sensing in a coordinated and sustainable way(Quantum Economy Blueprint, 2024). Saudi Arabia, through the Centre for the Fourth Industrial Revolution (C4IR Saudi Arabia), is the first country piloting this Blueprint to inform the development of the national quantum strategy. The Centre is acting as a bridge between global expertise and the local ecosystem, coordinating stakeholders across government, academia, and industry to analyse and adapt the Blueprint for Saudi Arabia's needs.

The Blueprint is structured into 31 building blocks, grouped into 9 overarching themes and distributed across 5 development phases, reflecting the full journey of national quantum development, from initial exploration to long-term implementation and governance. For this pilot, the Roadmap, focuses on 16 building blocks across seven themes (See Table 2), prioritizing those most aligned with the Kingdom's current strategic maturity and areas where early impact can be achievable. This initiative establishes a realistic foundation for future expansion. It also supports the Kingdom's ambition to diversify its economy, foster high-quality job creation, and build sovereign capabilities in key areas like quantum-ready cybersecurity.

Who is the Roadmap's Intended Audience?

The intended audience includes decision makers in both the public sector and industry, particularly those operating in sectors where quantum technologies have expected a potential impact, such as cybersecurity and telecommunications, healthcare and life sciences, environmental monitoring, advanced manufacturing and metrology, as well as logistics and optimization. In addition to professionals actively engaged in these fields, this content also speaks to technology enthusiasts and individuals exploring future career directions.

Who Developed this Roadmap?

C4IR Saudi Arabia is leading the pilot of the Quantum Economy Blueprint, acting as a bridge between the World Economic Forum's global expertise and the local quantum ecosystem. We coordinate the analysis and adaptation of the Blueprint to the Saudi context, bringing together national and global stakeholders from government, academia, and industry through thematic workstreams that address its core building blocks. Our role is to ensure that insights are translated into realistic, actionable plans to help shape the national quantum economy.

The C4IR's Quantum Economy project is made of five workstreams, each led by stakeholders from our community of practice. C4IR Saudi Arabia and King Abdulaziz City for Science and Technology (KACST) lead the work on Transformative Capabilities and Creating Awareness; King Fahd University of Petroleum and Minerals (KFUPM) leads Access to Hardware Infrastructure and Supply Chain, as well as Workforce Development; Saudi Aramco leads Open Innovation and Commercialization; and Ministry of Communications and Information Technology (MCIT) leads Governance, Responsible Innovation, and Standardization, and the National Cybersecurity Authority (NCA) is the competent authority nationally in charge of cybersecurity in the Kingdom, And the national reference in its affairs.

Finally, *Towards Saudi Arabia's Quantum-Enabled Future* presents a strategic roadmap to position Saudi Arabia as a key contributor in the quantum era. This roadmap is structured as a practical guide, organized into three main sections and their subsections. **Section 1: Building Capabilities** covers (1.1) *Transformative Capabilities*, providing a self-assessment and value chain analysis; (1.2) *Access to Hardware Infrastructure and Supply Chain*, outlining strategies to secure reliable resources; and (1.3) *Workforce Development*, focusing on cultivating specialized talent. **Section 2: Driving Innovation** examines (2.1) *Open Innovation and Commercialization*, emphasizing pathways from research to market, and (2.2) *Creating Awareness*, aimed at policymakers, industry leaders, and the public. **Section 3: Ensuring Responsibility** addresses (3.1) *Governance, Responsible Innovation and Standardization*, to guide ethical and interoperable development, and (3.2) *Cybersecurity*, highlighting measures to protect digital infrastructure in the quantum era. Together, these sections offer decision-makers in the public sector and industry a roadmap of actionable insights and policy recommendations for advancing Saudi Arabia's role in the global quantum economy.

Table 2: Different phases along the quantum strategy development and implementation journey

Phase / Themes	1 Discovery phase (QT early discoveries)	2 Initial strategic considerations (no structured responsibility yet e.g. no ministry tasked)	3 Initial priorities defined (responsibilities allocated e.g. ministry tasked)	4 Strategy defined, no implementation plan (including no funding plan)	5 Strategy and implementation plan (including funding plan)
Transformative capabilities		Self-assessment			
		Value chain analysis			
Access to hardware infrastructure and supply chain		Long-termism and priority matching	Supply chain mapping		
			International nature of quantum supply chain		
			Adjacent supply chain capabilities		
Open innovation and commercialization	Encouraging collaboration and pre-competitive environment				Public and private sector strategies
	Trade strategies			Technology transfer and commercialization initiatives	
Creating awareness	Multilevel public dialogue				
	Educating decision- and policy-makers				
	Awareness-building tools and methods				
Workforce development	Education initiatives				
			Upskilling and cross-skilling strategies		
			Global, regional and national talent pipeline strategy		
				Public-private partnerships	
	New job creation potential				
National and economic security			Government defence investment priorities		
			Geostrategic cooperation and protection strategies		
Cybersecurity and privacy	Cyberthreat and risk analysis		Government regulations and directives		
	Cybersecurity implementation and migration plans				
	Cross-industry collaboration and awareness building				
	Privacy impact of other QT				
Governance, responsible innovation and standardization	Definition of common values		Operationalizing responsible innovation		
					Technology-enabling regulation
				Standardization strategies	
Sustainability			Strategies for sustainable QT		Energy consumption benchmarking strategies
			Incentivization strategies for sustainability use cases		
				Focus areas for positive impact on environment	

Building blocks addressed in this report

Building blocks not addressed in this report

Source: (Quantum economy blueprint, 2024)

Section 01

Building Capabilities

Quantum technologies are emerging as a cornerstone of technological leadership and competitiveness. For Saudi Arabia, they represent both an opportunity and a challenge: to diversify the economy, build independent capabilities, and position the Kingdom as a global leader in this transformative domain. Building the required capabilities requires focusing on three critical areas:

1. **Value chain analysis.** Saudi Arabia must map and strengthen its role across the quantum value chain, from upstream materials and hardware to software and services. While equipment, middleware, and components currently capture most of the market value, the long-term opportunity lies in applications, services, and software.

2. **Infrastructure & supply chain resilience.** Building a layered, independent quantum infrastructure is essential to reduce dependence on fragile global supply chains. National facilities, phased co-development, and international partnerships will underpin resilience.

3. **Workforce development.** Human capital is as vital as infrastructure. A quantum-ready workforce requires structured education pipelines, industry-academia collaboration, and alignment with national economic priorities.

1.1 Value Chain Analysis

Quantum technologies are creating new opportunities across sectors, driving economic value and societal benefits. By adopting a clear strategy that leverages Saudi Arabia's strengths and addresses potential weaknesses Saudi Arabia can position itself as a key player in quantum innovation and avoid falling behind.

Quantum technologies are opening new opportunities across sectors like energy, finance, healthcare, communications. Quantum technologies are forecasted to create over $200 billion (⃁750 billion) in economic value globally between 2025 and 2030, driven by applications in simulation, optimization, machine learning, and cryptography (The Quantum Insider, 2024).

A value chain captures the activities and entities involved in creating, producing, and delivering products or services. Mapping the quantum value chain enables policymakers, investors, and companies to identify technological dependencies, reduce risks, and target resources more effectively.

Value Chain Segments

A value chain is a set of activities and entities involved in creating, producing, and delivering products or services, capturing how value flows across the ecosystem. Mapping the value chain supports decision-makers in both government and industry in making informed policy and investment decisions.

Quantum technologies are forecasted to create over

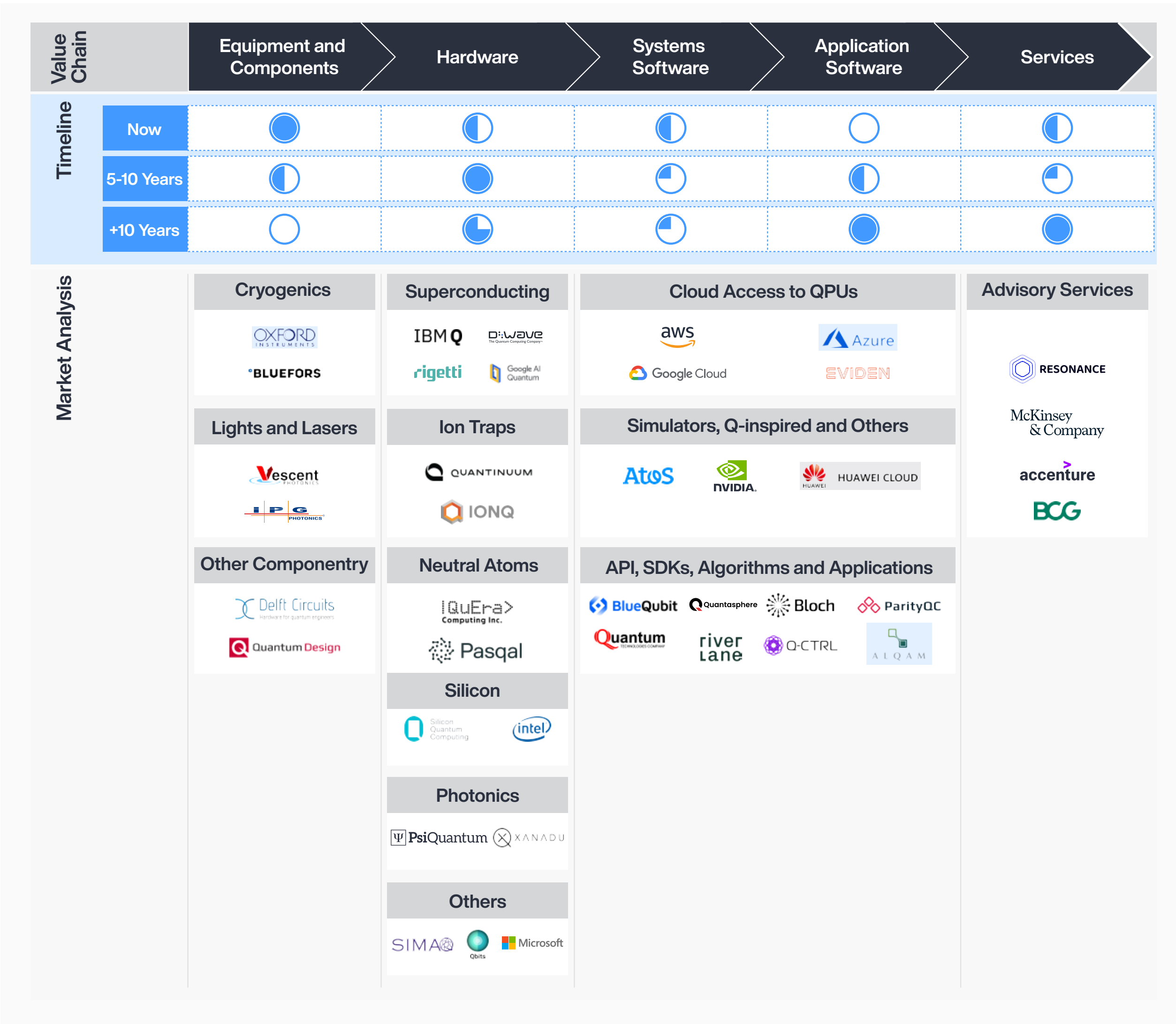
$200 billion (⃁750 billion)

in economic value globally between 2025 and 2030.

Each segment of the quantum value chain is essential because each segment has distinct roles, investment requirements, and market dynamics. A clear segmentation allows stakeholders to map where technological capabilities and business opportunities currently reside, as well as anticipate where they are likely to emerge. It also provides a structured framework for investors, policymakers, and companies to allocate resources effectively, reducing risks by targeting the most strategically relevant or high-growth areas. The quantum value chain (see Figure 1) has five major segments:

- **Equipment & components** – Raw materials (rare earths, isotopes, helium-3), quantum control systems, lasers, detectors, cryogenics, and vacuum chambers. This segment currently attracts the most value, as it is hardware-agnostic and lower risk.
- **Hardware** – Quantum processors and systems across modalities. Despite engineering challenges, this area is advancing rapidly and remains central to the ecosystem.
- **Systems software** – Qubit control, error correction, and compilers bridging hardware and algorithms. This layer is critical for scaling.
- **Application software** – Algorithms tailored to specific industries such as finance, energy, and life sciences, driving differentiated value.
- **Services** – Professional and technical services enabling adoption, common in early-stage markets.

At present, margins are highest in equipment and components, as these products serve multiple modalities. Over the next decade, value is expected to shift toward hardware and then to application software and services. In the long term, application software and cloud-based services will dominate value creation, while hardware and components become standardized and more widely accessible (McKinsey, 2025).
See Figure 1.



No market value captured · A Limited market value captured · Some market value captured · Significant market value captured · Full market value captured

Source: Authors' elaboration based on (McKinsey & Company, 2025) and (The Quantum Insider, 2025)

Figure 1: Quantum value chain: projected value contribution by segment, time horizon, and key industry actors including Saudi startups

Current State and its Importance for Saudi Arabia

Saudi Arabia is currently investing in parts of the quantum value chain. The country's semiconductor base at King Abdulaziz City for Science and Technology (KACST) and King Abdullah University of Science and Technology (KAUST) can lay the foundation for an initiative such as a national Quantum Foundry, fabricating components and systems for photonic, superconducting, and semiconducting devices. Facilities for lithography, deposition, etching, and advanced materials provide the groundwork. Private firms such as Qbits, AlQam, Bloch, Quantasphere, and SIMAQ are contributing services and applications across computing, communications, and satellite-based systems. Research infrastructure is also expanding, with national laboratories and universities building laboratories for superconducting circuits, optics, fiber-optic communications, and post-quantum cryptography.

Policy Recommendations

- **Policymakers aiming to maximize economic returns should first prioritize fostering capabilities in critical bottlenecks of the quantum value chain, including raw materials, fabrication of quantum components and integration in testbeds to validate use-cases with industry**. For Saudi Arabia, this will also require making investments in developing critical talent, and retaining it in research-active roles. While technology provides the vector for economic growth, it is the human element, the talent, that will unlock and sustain the competitive advantage in the global digital economy.

- **Countries seeking secure supply chains, strategic investments in equipment, components, and hardware remain critical** to ensuring domestic control over foundational technologies and reducing reliance on imports and global supply chains. For Saudi Arabia, this involves developing domestic capabilities, expanding specialized laboratories, and **integrating strategically with national efforts to localize semiconductor production.** These efforts strengthen resilience, safeguard supply chains, and ensure resilience against potential supply chain disruptions.

- Finally, **Saudi Arabia should adopt a coordinated whole-system dual-track strategy that balances economic competitiveness with technological independence considerations.** This entails building a robust domestic ecosystem around critical bottlenecks in the quantum value chain focussed on segments that align with the country's economic priorities and competitive advantages.

1.2 Access to Hardware Infrastructure and Supply Chain

> Quantum technologies are strategically important and too valuable to remain dependent on fragile global supply chains. Resilient quantum supply chains require more than hardware. They demand layered development, phased co-investment, and proactive closure of vulnerabilities.

Quantum technologies are of strategic national importance and too valuable to remain dependent on fragile global supply chains.

A resilient national strategy must secure upstream inputs, build enabling infrastructure, nurture human capital, set interoperability standards, and create initial market demand through government procurement, aligned with industry needs.
By treating capital investments into quantum infrastructure as national infrastructure, and investing comprehensively across hardware, middleware, software, and workforce. Saudi Arabia can fortify its economic competitiveness, expand its industrial base, and position itself as a global leader in the quantum era.

Resilient quantum supply chains require more than just hardware procurement. They need layered co-development, phased investments coupled to the proactive identification and closure of systemic vulnerabilities, without which the nascent ecosystem would remain vulnerable. Today, critical components such as cryogenic systems, stabilized lasers, or single-photon detectors are manufactured by a limited number of vendors. Similarly, key raw materials, such as rare earths, isotopes, helium-3, specialist semiconductor and diamond substrates, are dominated by a handful of suppliers. This structural fragility exposes Saudi Arabia to dependency on technologies that underpin future economic competitiveness and national resilience.

A layered story. Building resilience is like growing an ecosystem: national infrastructures such as fabrication plants, laboratories and testbeds form the foundation. These support materials and components, in turn, enable system integration and validation through testing. The ecosystem as a whole underpins the basic needs to develop precision engineering and the critical middleware required to operate the systems, on which applications such as secure communication, navigation, timing, sensing, and computing depend.

- **Phased co-development.** Resilience requires phased, overlapping action. In the first year, the focus is on securing upstream inputs, launching pilot facilities, and expanding the workforce. Over the next one to five years, attention shifts to demonstrating mission-led industrial applications while establishing testbeds, sandboxes, and interoperability standards. Between years three and six, efforts concentrate on scaling production and integrating technologies into existing infrastructure. Beyond the six-year mark, the emphasis moves toward ensuring sustainability, aligning exports, and achieving global leadership in designated areas.

- **Co-vulnerabilities.** Correlated vulnerabilities span the QT value chain, threatening resilience and deterring investment. These include skill gaps in cryogenics, systems engineering, control software, and fabrication, as well as dependence on overseas foundries and cleanrooms. Risks arise from a combination of a high concentration of vendors in areas such as lasers, cryogenics, and detectors, and with misaligned investment priorities. Fragmented standards continue to limit interoperability, while funding gaps – particularly for SMEs and in bridging the 'Valley-of-death' – undermine continuity. Weak integration between hardware and software, along with scarce application-specific inputs such as helium-3, specialized isotopes and rare earth elements, further compound the risks. Finally, divergent export controls restrict collaboration with allies, exacerbating systemic fragility across the ecosystem.

Current State and its Importance for Saudi Arabia

Developing quantum infrastructure is a whole-system strategic pathway for Saudi Arabia to achieve Vision 2030 goals by diversifying the economy, strengthening security, and creating high-tech jobs. Building local supply chains enhances economic competitiveness and reduces reliance on foreign vendors.

Saudi Arabia already has a solid foundation. Internet Service Unit (ISU) at KACST launched the Saudi Quantum Network (SQN) Alliance to pilot quantum communication infrastructure across the Kingdom. By bringing together global leaders such as Microsoft and Cisco with local partners like Salam and Cybrani, the alliance is closing the gap between experimental research and practical deployment. It also provides a real-world testbed for validating quantum technologies.

On the hardware side, the Kingdom benefits from clean rooms at KACST and KAUST for nanofabrication, photonics laboratories at KACST and King Saud University (KSU), and a superconducting quantum circuits lab at KFUPM. KAUST hosts approximately ten faculty laboratories in quantum and photonic devices, including work on qubits (colour-centers) and applied quantum phenomena for sensing and communications, supported by advanced nanofabrication and characterization facilities.

Yet challenges persist, the number of quantum-specialized laboratories is limited compared to global leaders, slowing research and hardware innovation, amplified by limited numbers of quantum engineers and fabrication technicians. This constrains scaling of domestic technology development. Additionally, Saudi Arabia's cloud policies emphasize data localization and regulatory compliance, encouraging cloud service providers to operate local data infrastructure and ensure alignment with national cybersecurity and data protection standards. Moreover, the absence of a unified national plan hampers coordination and long-term investment.

Global Perspective

Global initiatives highlight three success factors: sustained infrastructure investment, national whole-system coordination, and international cooperation. The UK integrates hubs and testbeds under its National Quantum Technologies Programme. Canada's strategy emphasizes supply chain security. Australia combines domestic capability-building with alliances like AUKUS and the Quad. China's Made in China 2025 prioritizes domestic component fabrication, already producing dilution refrigerators.

> **Saudi Arabia is a potential leader in quantum technologies because of its promising human capabilities and progressive leadership. A National Quantum Innovation Hub will drive innovation – attracting quality talent and capital.**
>
> Uzma Siddiqui
> CEO and Co-Founder of Quantasphere

Global public investment in quantum technology has surpassed **$40 billion** (⃁150 billion) and continues to grow.

China leads global investment with **$15 billion** (⃁56.3 billion).

The EU follows with **$10 billion** (⃁37.5 billion), driven primarily by German spending.

The United States ranks third, allocating **$4 billion** (⃁15 billion).

Source: (The Quantum Insider, 2025)

Policy Recommendations

- **Establish a national quantum center** with dedicated units for computing, communications, sensing, and imaging, managing shared facilities to increase utilization.
- **Conduct a comprehensive supply chain assessment** to map national, regional, and international capabilities and vulnerabilities, resulting in a service catalogue and a clear-sighted national strategy to plug critical gaps. Find a preliminary supply chain assessment in Appendix.
- **Build strategic international partnerships** to mitigate export risks and strengthen resilience.
- **Invest in domestic component manufacturing** to integrate into the global supply chain and support industry growth.

In Focus

Bluefors: How a National Strategy Transformed a Research Venture into a Global Leader

Bluefors, founded in 2008 in Helsinki, was created by scientists and engineers to meet the need for reliable cryogenic systems capable of cooling to near absolute zero for quantum computing labs. Its growth was closely tied to Finland's national quantum ecosystem, coordinated by InstituteQ, which links research, education, and industry. With about €274 million (⃁1.2 billion) invested nationally in quantum R&D, Finland has become a hub for global quantum technologies, producing successful spin-offs such as Bluefors and IQM.

Starting with a small production line for European universities, Bluefors quickly gained an international reputation for quality and reliability, expanding into the US and Asia. Today, it employs more than 700 people, generates annual revenues above €200 million (⃁810 million), and has supplied over 1,500 cooling systems worldwide, establishing itself as a cornerstone of the quantum value chain.

Source: (Bluefors, 2025)

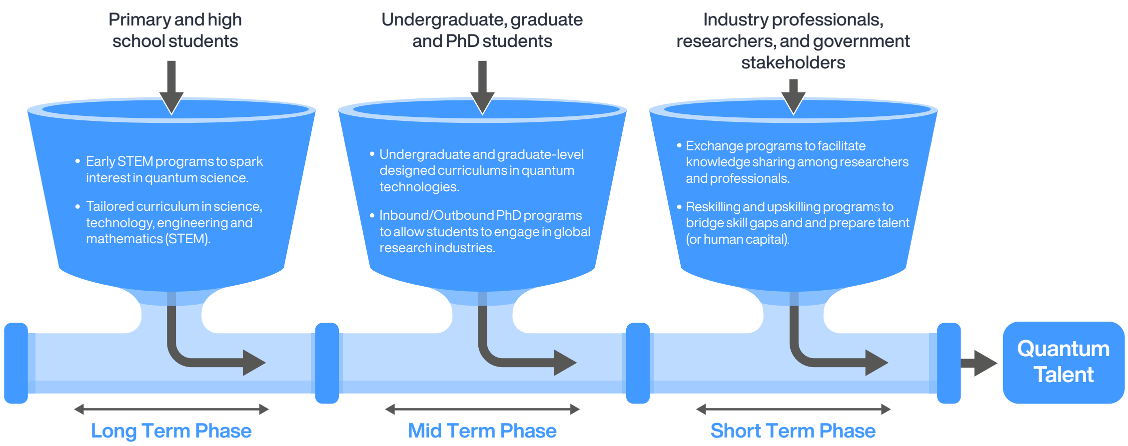
1.3
Workforce Development

Talent is as critical as infrastructure. By cultivating technicians, engineers, and software specialists through education, career pathways, and upskilling, and ensuring quantum literacy among policymakers and industry leaders Saudi Arabia can unlock innovation and position itself at the forefront of the global quantum economy.

A quantum-ready workforce, spanning technicians, engineers, software specialists, and quantum-literate policymakers, is as vital as infrastructure. Specialized education, career pathways, and upskilling programs are the foundation for innovation and competitiveness.

Building such a workforce is a sustained, multi-stage endeavor that progresses from early STEM education to advanced research and industry deployment. As shown in Figure 2, this trajectory spans the full spectrum of education and career stages. To support each stage effectively, four priority areas form the foundation of the quantum talent pipeline:

- **Comprehensive education:** National curricula from technical training to advanced research, supported by apprenticeships and regional hubs.
- **Career pathways:** Opportunities across academia, industry, and government labs, supported by mobility and incentives to retain talent.
- **Continuous training:** Professional development and upskilling programs for mid-career engineers and policymakers.
- **Talent alignment:** Matching skills to high-impact sectors such as aviation, energy, and biotech.



Source: (Centre for the Fourth Industrial Revolution Saudi Arabia, 2024)

Figure 2: The quantum talent pipeline: from early education to advanced specialization

Current State and its Importance for Saudi Arabia

Saudi Arabia's universities offer specialized programs at KFUPM, for example, through its undergraduate and Master of Science programs in quantum computing. Launched between 2020 and 2024, these programs have already graduated over 50 students contributing to the national initiative. Despite this progress, the number of quantum specialists remains small compared to global demand, and competition for talent is intense.

Global Perspective

The US National Quantum Initiative, Europe's Quantum Flagship, and Japan's Vision of Quantum Future Society all prioritize talent pipelines, with programs ranging from K-12 STEM* to professional training. Their experiences show that early

*K-12 STEM refers to Science, Technology, Engineering, and Mathematics education in kindergarten through 12th grade.

engagement, cross-sector collaboration, and structured industry-academia partnerships are essential.

Policy Recommendations

- **Launch targeted funding** to bridge education and hands-on research, ensuring students graduate with practical experience.
- **Significantly scale-up postgraduate quantum engineering programs** and vocational quantum fabrication training programs.
- **Develop a tiered national quantum education framework**, spanning schools to advanced specialization.
- **Formalize industry-academia partnerships** through internships, joint projects, and certifications.
- **Recognize 'quantum engineering'** as a professional category to elevate career pathways.
- **Align talent development with national economic priorities,** ensuring that jobs extend beyond PhD-level expertise.
- **Build quantum literacy among policymakers** to enable informed and forward-looking decisions.
- **Attract and retain international quantum talent** to Saudi Arabia.

In Focus

KFUPM's Quantum Leap

Since 2020, KFUPM has launched over 40 specialized programs to fuel Vision 2030, including Saudi Arabia's first undergraduate and master's programs in quantum computing. These programs go beyond theory; students study gate-based quantum computation, quantum algorithms, cryptography, and hardware, while industry partnerships ensure exposure to real-world applications.

By 2025, more than 50 graduates had already entered the workforce, spearheading quantum initiatives across sectors. With 13 dedicated courses and over six faculty members, KFUPM has built a rare pipeline: locally trained talent with global research experience (KFUPM, 2024).

The speed with which KFUPM established itself as a hub for quantum education, bridging academia, industry, and international research networks to produce the Kingdom's first generation of quantum specialists, shows that it can be done at scale across Saudi Arabia.

Between 2020 and 2024

50+	4	9	+6
graduate and undergraduate **KFUPM students** graduated from quantum computing programs	undergraduate courses	graduate courses	teaching faculty

Source: Authors' elaboration based on (King Fahd University of Petroleum and Minerals, 2024)

KFUPM and Pasqal MoU signing ceremony at the Aramco Entrepreneurship Summit held at the King Abdulaziz Center for World Culture (Ithra) in October 2024.

Source: KFUPM Media

Section

02 Driving Innovation

Driving innovation converts foundational capabilities into tangible outputs and outcomes. This relies on fostering *Open Innovation and Commercialization* to bridge the critical gap from lab to market, turning research into valuable products. Success also requires a concerted effort in *Creating Awareness*. Informing policymakers is essential for securing strategic funding and developing effective regulations, while educating industry managers and the public builds a strong talent pipeline and market for the future, fostering social acceptance.

2.1 Open Innovation and Commercialization

The Kingdom has invested heavily in research, education, and innovation support, reaching 31st place globally. To turn this into real value results like patents, startups, and commercial solutions, it needs to focus funding on clear goals, build a national hub for quantum tech, and align with global standards.

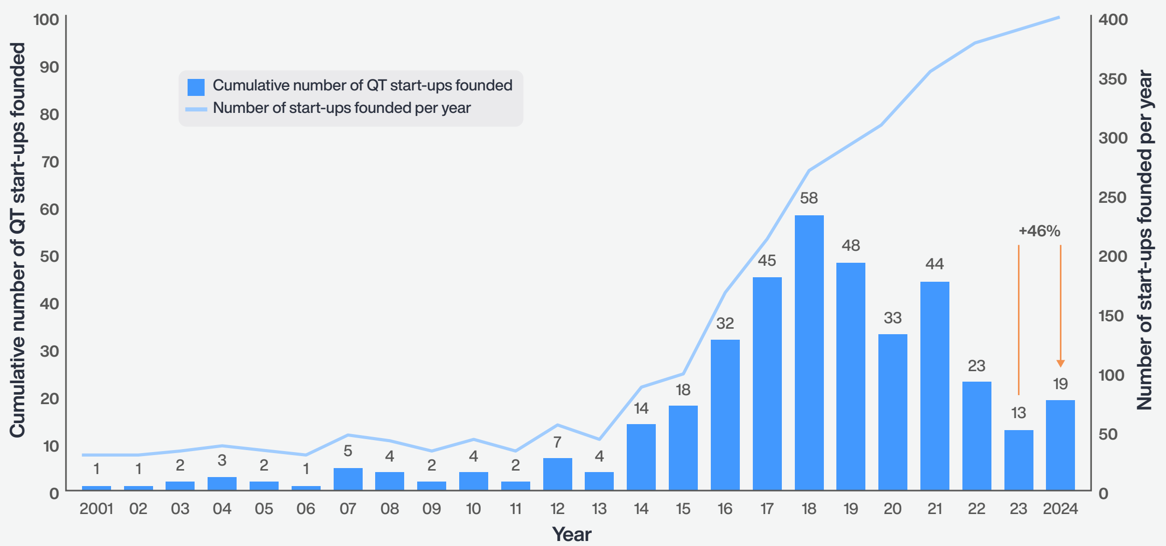
Governments around the world and industry are intensely interested in quantum technologies. Their disruptive potential touches on almost all aspects of modern life, such as GPS-free navigation, through-ground sensors, or hyper-resolution medical MRI scanners. The potential for breakthroughs exceeds what can be imagined today. Saudi Arabia's strategic industries that could be disrupted by quantum technologies include semiconductors, mining, oil and gas, water treatment, telecommunications and space, defense, logistics, healthcare, finance, and biotechnologies including pharmaceuticals. The immense complexity and breadth of quantum applications mean no single organization can master the field alone, making the principle of open innovation critical for accelerating advancement. This approach moves away from a secretive, closed-off R&D process and instead promotes collaboration with external partners, like universities and startups, to source outside ideas and find commercial paths for internal innovations.

The global commercialization of quantum technology is accelerating, while Saudi Arabia is still in the early stages of ecosystem development. Across the world, quantum startups grew 46.15% in 2024 (Figure 3), with private investments reaching $2.6 billion (⃁9.7 billion), a 50% increase from the previous year (The Quantum Insider, 2025). Public investment rose 19% during the same period, outpacing private activity. The global ecosystem now includes 1695 companies and over 100 documented use cases, positioning early adopters to attract investment and secure long-term competitiveness. Saudi institutions, national champions, and startups are making promising moves, but significant gaps remain in translating scientific advances into market-ready solutions. This section examines how leading countries enable open innovation and commercialization, compares these strategies with the Saudi context, and concludes with three targeted policy recommendations tailored to national priorities

Saudi Arabia ranking in Global Innovation Index (GII):

31st	**in input** (research and funding)
61st	**in output** (products, services, or technologies)

Source: (World Intellectual Property Organization, 2025)



Source: (The Quantum Insider, 2025)

Figure 3: Annual and cumulative number of quantum technology start-ups founded (2001–2024)

Global Ecosystem

1695 companies

102 use cases

19% increase in public investments for start-ups compared to private investments in 2024

Source: (The Quantum Insider, 2025)

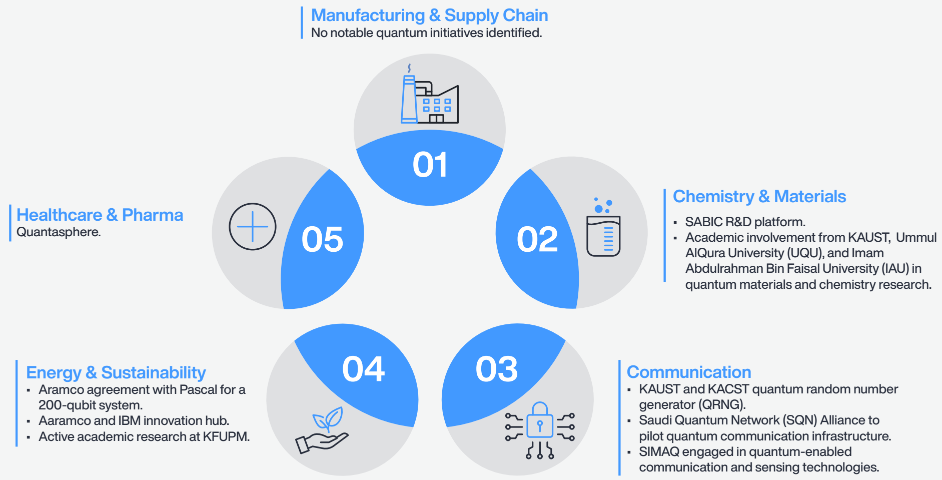
Current State and its Importance for Saudi Arabia

Fostering open innovation and advancing the commercialization of emerging technologies are pivotal focus areas for Saudi Arabia, supporting the Kingdom's drive to realize the ambitious goals outlined in Vision 2030 and to position itself as a global leader in innovation and knowledge-driven economic growth. They directly support diversification of the economy by expanding non-oil exports, strengthening private-sector participation in high-tech industries, increasing SMEs contributions to GDP, and attracting foreign investment.

Saudi Arabia is building momentum in quantum technologies, with initiatives spanning large national companies, startups, and research institutions. Major players such as Saudi Aramco, Saudi Telecom Company (stc), Saudi Basic Industries Corporation (SABIC), and NEOM are exploring applications in energy efficiency, secure communications, and smart infrastructure, while startups like SIMAQ and Quantasphere highlight the growing entrepreneurial role in the ecosystem.

The National Technology Development Program (NTDP) acts as a key enabler in this landscape. Through initiatives such as MVPLAB, NextEra, Fuel, and Connect, NTDP provides capital, incubation, and commercialization support that strengthen the innovation pipeline. By doing so, it enhances mission-driven funding, expands shared infrastructure, and increases international visibility, while advancing a globally competitive quantum ecosystem through innovation, talent development, and strategic global partnerships that position Saudi Arabia as a leader in next-generation technologies.

Despite this progress, quantum related activities remain uneven across sectors. As examples shown in Figure 4, engagement is strongest in healthcare, energy, communications, and chemistry, driven by initiatives like the Aramco–Pasqal collaboration, SABIC's research projects, and startup-led pilots. Yet critical Vision 2030 sectors, including manufacturing, logistics, and supply chain management, remain largely untapped. These gaps represent opportunities for NTDP and its partners to expand cross-sector pilot programs and innovation testbeds that can accelerate commercialization and attract international investment.



Source: Authors' elaboration based on (Quantasphere, 2025), (Aramco, 2024), (Saudi Press Agency, 2025), (Extrapolations, 2025) (Capilano ICS, 2025), (SIMAQ, 2025)

Figure 4: Quantum technologies related activities in Saudi Arabia categorized by sector*

Note: The list of examples is not exhaustive.

Furthermore, Saudi Arabia continues to build its capacity to translate quantum research into market-ready solutions. At this stage, mission-driven public funding models, shared infrastructure, and early-stage technology transfer facilities remain under development. Ecosystem visibility and data sharing mechanisms are still maturing, affecting the country's ability to attract strategic international investment. Furthermore, Saudi Arabia's innovation performance shows a gap between inputs and outputs: while ranked 31st globally in research and funding, it falls to 61st in producing tangible outcomes such as commercialized technologies (World Intellectual Property Organization, 2025).

Global Perspective

Around the world, leading quantum nations have accelerated commercialization by integrating open innovation models with clear national strategies. Success depends not only on research excellence but also on connecting R&D to market needs, lowering barriers for startups, creating early customers for quantum products, fostering geographic clusters, and aligning with international standards. These approaches have created dynamic ecosystems where private investment, research institutions, and industry work together to deliver measurable impact.

- A first lesson from global experiences is the role of **mission-driven funding** in linking public investment directly to commercialization outcomes. The UK, for example, combines mission-based targets, such as deploying quantum sensors in healthcare or operational quantum computers, with structured commercialization programs like Innovation to Commercialization and Catapults. This ensures public funding translates into real-world applications, industry participation, and a steady pipeline of spinouts and products (Department for Science, Innovation and Technology, 2023). For Saudi Arabia, adopting a mission-to-market approach would help close the mentioned current gap between research inputs (ranked 31st globally) and commercialization outputs (61st).

- Equally important is the creation of **demand-side pull.** Global leaders stimulate markets early by positioning the government as a first customer, embedding quantum solutions in public procurement, or mandating pilot deployments in strategic sectors. China's integration of quantum key distribution into financial networks, or Canada's Post-Quantum Cryptography (PQC) pilots in critical infrastructure, show how demand can be deliberately cultivated. For Saudi Arabia, where sectors such as energy, logistics, and healthcare are state-led, leveraging procurement to absorb early quantum products would de-risk commercialization for startups and SMEs.

- Another enabler is **cluster-based innovation and testbeds.** Countries like Finland have built national infrastructures such as the Finnish Quantum-Computing Infrastructure (FiQCI), which allow startups, SMEs, and universities to access capabilities without prohibitive costs. By reducing duplication, expanding participation, and providing shared testbeds, these ecosystems shorten the path from lab to market (Ministry of Economic Affairs and Employment of Finland Helsinki, 2025). For Saudi Arabia, Aramco's Quantum Valley initiative could evolve into such a commercialization nucleus, hosting pilots, IP transfer, and cross-sector testbeds to ensure underdeveloped areas like manufacturing and supply chains join early.

- Finally, the ability to **scale commercialization globally** depends on standards and trade frameworks. The United States has strengthened its ecosystem by shaping ISO/IEC standards through NIST (National Institute of Standards and Technology), modernizing export controls, and embedding quantum into broader trade agreements like the CHIPS and Science Act and IPEF (National Institute of Standards and Technology, 2024; Bureau of Industry and Security, 2024; U.S. Congress, 2022). Without similar participation, countries risk exclusion from global supply chains. For Saudi Arabia, aligning early with international standards bodies and preparing export readiness will be critical to attract foreign investment and embed Saudi firms in global quantum markets. From a commercialization perspective, the priority is to ensure that these standards translate into market access, investor confidence, and international competitiveness. (Further details on standards, including quantum computing benchmarks, sensing calibration, and communication protocols, are provided in Section 3.1 Governance, Responsible innovation and Standardization.

Quantum technologies are a strategic imperative for Saudi Arabia, central to Vision 2030 and vital to transforming finance, mining, and healthcare. Through international alliances and a unified national strategy, the Kingdom can become the region's quantum hub, driving growth, jobs, and technological leadership in the emerging quantum era.

Dr. Fadi A. AlShammary
Senior Vice President at Saudi Arabian Public Investment Fund (PIF)

Policy Recommendations

To unlock the full potential of quantum technologies, Saudi Arabia needs a commercialization framework that translates research excellence into market-ready solutions guided by four levers: mission-driven funding, demand-side pull, cluster-based testbeds, and global standards and trade alignment.

- **Mission-driven funding** should tie public R&D investment to clear commercial outcomes by requiring industry participation, proof of viability, and co-investment. Aligning funding with market impact will narrow the input–output gap, speed up technology transfer, and expand the role of SMEs and startups.

- **Demand-side pull** is critical to de-risk adoption and build early markets for quantum solutions. Strategic use of government procurement and pilots in priority sectors such as energy, healthcare, and logistics can stimulate demand, give startups their first customers, and showcase tangible value that attracts private investment.

- **Cluster-based testbeds** will lower barriers for innovators and expand participation in the ecosystem. Establishing national quantum hubs and open-access facilities would provide startups, universities, and industry with access to essential infrastructure at a lower cost. Beyond reducing duplication, such hubs would coordinate fragmented efforts, offer visible platforms to international collaboration, and accelerate commercialization in underdeveloped sectors, such as manufacturing and supply chains. Appendix II provides more details on the innovation services.

- **Standards and export readiness** will be decisive for Saudi firms to compete globally. Early participation in international standards bodies will build interoperability and trust, while modernized export controls, aligned with recognized frameworks such as dual-use classifications and the Wassenaar Arrangement, will reinforce credibility, attract investment, and integrate national companies into global supply chains. (Technical details are provided in Section 3: Governance, Responsible Innovation and Standardization.)

In Focus

Aramco-Pasqal Collaboration, Leading Quantum Advancement via Strategic Partnership

The Aramco–Pasqal collaboration is a landmark for Saudi Arabia's quantum ecosystem, focused on developing a 200-qubit neutral-atom system that bridges R&D with industrial applications in energy. Combining Pasqal's innovation with Aramco's operational expertise, and supported by Wa'ed Ventures (the venture capital arm of Saudi Aramco), the partnership accelerates deployment, fosters localization, and builds talent and infrastructure. Aramco-Pasqal Collaboration's roadmap spans three stages: short-term deployment and training, mid-term scaling of solutions and R&D, and long-term goals of GDP contribution, and global leadership aligned with Vision 2030 (Aramco, 2024).

Aramco signs agreement with Pasqal to deploy the first quantum computer in the Kingdom of Saudi Arabia
Source: Aramco Media

> As the first VC firm backing and localizing quantum technologies to the Kingdom, we see this field as a cornerstone for Saudi Arabia's transition into a knowledge-based economy. Recognizing the outsized economic value that quantum will create over the coming decade across trillion-dollar industries like energy and logistics, we moved early by investing in Pasqal to bring this capability to the Kingdom. We are laying the groundwork to place Saudi Arabia at the heart of the emerging global quantum economy by localizing and commercializing quantum applications here at home, and to make the Kingdom a launchpad for solutions with worldwide impact.

Anas Algahtani
CEO of Wa'ed Ventures

2.2
Creating Awareness

Promoting broad understanding and confidence in quantum technologies to enable informed governance, strategic investment, and societal alignment.

Creating awareness focuses on fostering a broad understanding and public trust of quantum technologies among various stakeholders. Creating awareness is underpinned by two main categories: educating policy and decision-makers and fostering multi-level public dialogue. Educating policy and decision-makers is essential for effective governance and strategic investment. This involves demystifying quantum concepts for senior industry stakeholders and government officials, highlighting the technology's strategic importance for national competitiveness and solving global challenges. A multi-level public dialogue is crucial for building trust, managing expectations, and ensuring the wider community is informed about both opportunities and challenges presented by the emerging quantum economy.

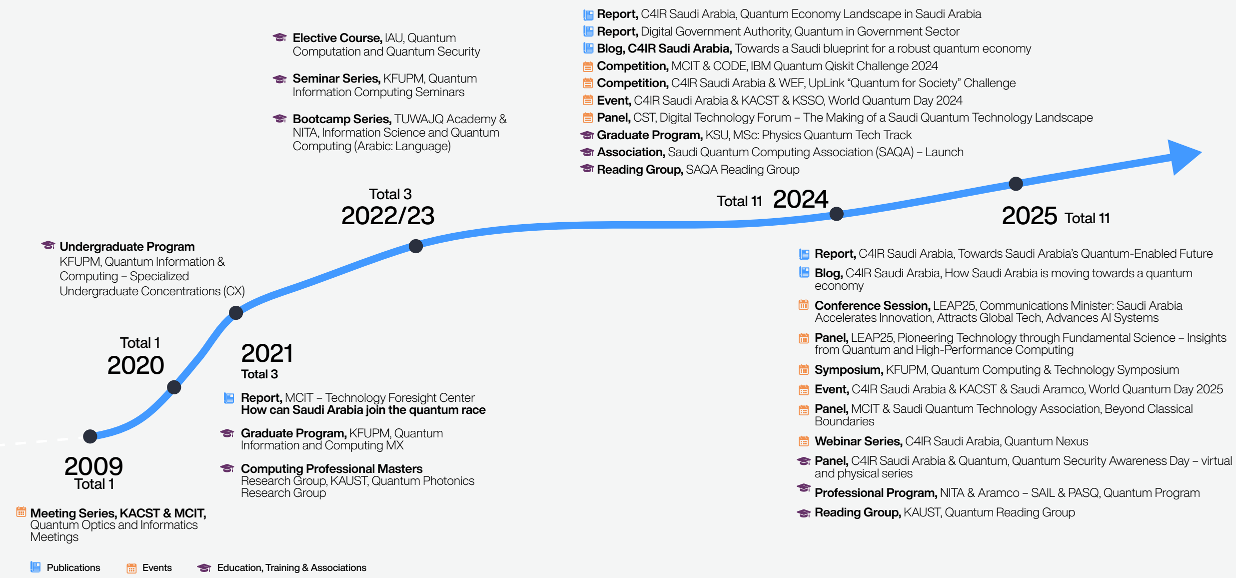
Adoption of quantum technologies will require new and innovative workforce programs along with use cases that engage industry directly with that workforce.

Joe Queenan
Executive Director, SC Quantum

Current State and its Importance for Saudi Arabia

Awareness of quantum technologies is a prerequisite for their wider adoption. The integration of emerging technologies like quantum communications, sensing, and computing is instrumental for helping to realize Vision 2030's ambitions of economic diversification and the transformation of the national workforce. Saudi Arabia's quantum awareness-building journey began with policy-level framing. As early as 2021, a foresight report commissioned by the MCIT mapped lean entry points for the Kingdom into the global quantum race. This was followed by the Digital Government Authority's 2024 Quantum in Government Sector brief and C4IR's 2024 Quantum Economy Landscape report, both reinforcing the urgency of proactive, cross-sector engagement. These foundational documents were accompanied by high-visibility platforms such as World Quantum Day (WQD 2024–2025), the Communications, Space and Technology Commission (CST)' Digital Technology Forum, and ministerial addresses at LEAP25. These events elevated the profile of quantum among policymakers, industry leaders, students, and the public. The Saudi Quantum Computing Association (SQCA), and the Saudi Quantum Technology Association, both launched in 2024, add a non-profit channel for community coordination and public education. SQCA is collaborating closely with C4IR Saudi Arabia on initiatives like World Quantum Day, Quantum Nexus webinar series and Reading Group sessions.

Parallel to public engagement, the academic and research institutions has shown increasing traction in quantum literacy and skills development. KACST's quantum photonic symposium (from 2009), KAUST's self-organized study group (from 2023) and KFUPM Symposium on Quantum Computing & Technology in early 2025 reflect growing institutional maturity. This has been complemented by Tuwaiq and National IT Academy's (NITA) information science and quantum computing bootcamps provided in Arabic-language which aim to increase accessibility and inclusion. Building on these efforts, several Saudi universities now offer quantum-focused curricula, including KSU, Jazan University, IAU, Prince Sultan University (PSU), Tuwaiq Academy, and KAUST. Further details are available in the Quantum Economy Landscape report (C4IR Saudi Arabia, 2024). All the activities are summarized in Figure 5.



Source: Authors' elaboration based on the team's research, surveys and interviews.

Figure 5: Quantum activities and initiatives launched in saudi arabia 2009-2025*

Note: This list is non-exhaustive.

There is limited awareness about quantum technology among the general public and policymakers. Furthermore, the level of awareness is not measured; therefore, no baseline exists to enable evidence-based policy. All this together jeopardizes national progress and preparedness. As a result, in addition to the international hype of the technology, this can lead to unrealistic expectations and misdirected investments. While Saudi Arabia's quantum awareness efforts are gaining momentum, driven by events, policy reports, and grassroots initiatives like non-profit associations, they remain fragmented across ministries and institutions. Messaging tends to cluster around major events (e.g., WQD, LEAP) without year-round continuity or coordinated follow-up. This results in risk of duplicative effort, inconsistent impact, and public confusion.

To contextualize this challenge, recent surveys on quantum familiarity in the United States show a mixed landscape. While 34% of the public feels "very familiar" with the topic, a larger group of 40% remains "not familiar" at all (MIT Initiative on the Digital Economy, 2025)z. This distribution reflects similar awareness levels in other technologically advanced nations, such as France and Germany, indicating a common hurdle in achieving widespread quantum literacy. Crucially, a comparable baseline of public and stakeholder awareness within Saudi Arabia is currently unknown, highlighting a critical information gap that must be addressed to tailor an effective national awareness strategy.

Familiarity levels on quantum computing (US)

40%
"not familiar"

26%
"somewhat familiar"

34%
"very familiar"

Souce: (MIT Initiative on the Digital Economy, 2025)

Digital Technology Forum - "The Making of a Saudi Quantum Technology Landscape" session
Source: Communications, Space & Technology Commission Media

The Quantum for Society Challenge Top 10 Innovators visiting the historic site of At-Turaif in Diriyah as part of their visit to Saudi Arabia
Source: C4IR Saudi Arabia

KFUPM Symposium of Quantum Computing & Technology
Source: KFUPM Media

Global Perspective

Several international initiatives offer valuable insights into awareness assessment, effective awareness creation and public engagement strategies for quantum technologies.

- **The EU's Quantum Flagship and Quantum Europe Strategy** provides valuable case studies in assessing public awareness and sentiment. Surveys conducted in France and Germany revealed strong general awareness of quantum technologies but limited in-depth understanding. Notably, applications in healthcare and energy generated the highest public interest. These findings underscore the importance of targeted surveys to inform and shape effective communication strategies. Nevertheless, these consistent engagements will likely culminate in a legally binding framework, the Quantum Act 2026, designed to position Europe as a quantum leader by 2030.

- **UK's National Quantum Technologies Programme** provides a structured example by explicitly including public engagement and social context as a key focus area within its national strategy. These highlights dedicating strategic resources to public engagement within the national quantum strategy. The National Quantum Computing Centre had led the "Responsible Quantum Industry Forum". This forum brings together industry leaders to establish and share best practices for the ethical development of quantum technologies.

Moreover, a number of dedicated public engagement initiatives are funded to simplify quantum technologies to the public. The Quantum Ambassadors Program, as an example, was established to bring quantum mechanics into schools. Another example, Quantum City, a project by the UK's National Quantum Technologies Programme, demonstrates the impact of living in a quantum-enabled future.

- **World Quantum Day and the International Year of Quantum** Established in 2021 by an international coalition of scientists, World Quantum Day is celebrated annually on April 14, reflecting the first three digits of Planck's constant (4.14) and symbolising the foundations of quantum mechanics. Conceived as a decentralised, bottom-up initiative, it aims to broaden public understanding of quantum science and its societal applications. In 2025, WQD was embedded within the UN-proclaimed International Year of Quantum Science and Technology (IYQ), coordinated by UNESCO, to mark 100 years since Heisenberg's seminal 1925 paper. The IYQ has transformed WQD from a single-day observance into a year-long global campaign, with a focus on equitable access to quantum education, inclusive participation, and highlighting quantum's potential to address societal challenges. This alignment has created a unified international platform for engagement, with Saudi Arabia contributing prominently through its expanded 2025 activities.

INTERNATIONAL YEAR OF
Quantum Science
and Technology

The opening ceremony for the International Year of Quantum Science and Technology (IYQ), at the UNESCO Headquarters in Paris
Source: 2025 International Year of Quantum Science and Technology (IYQ)

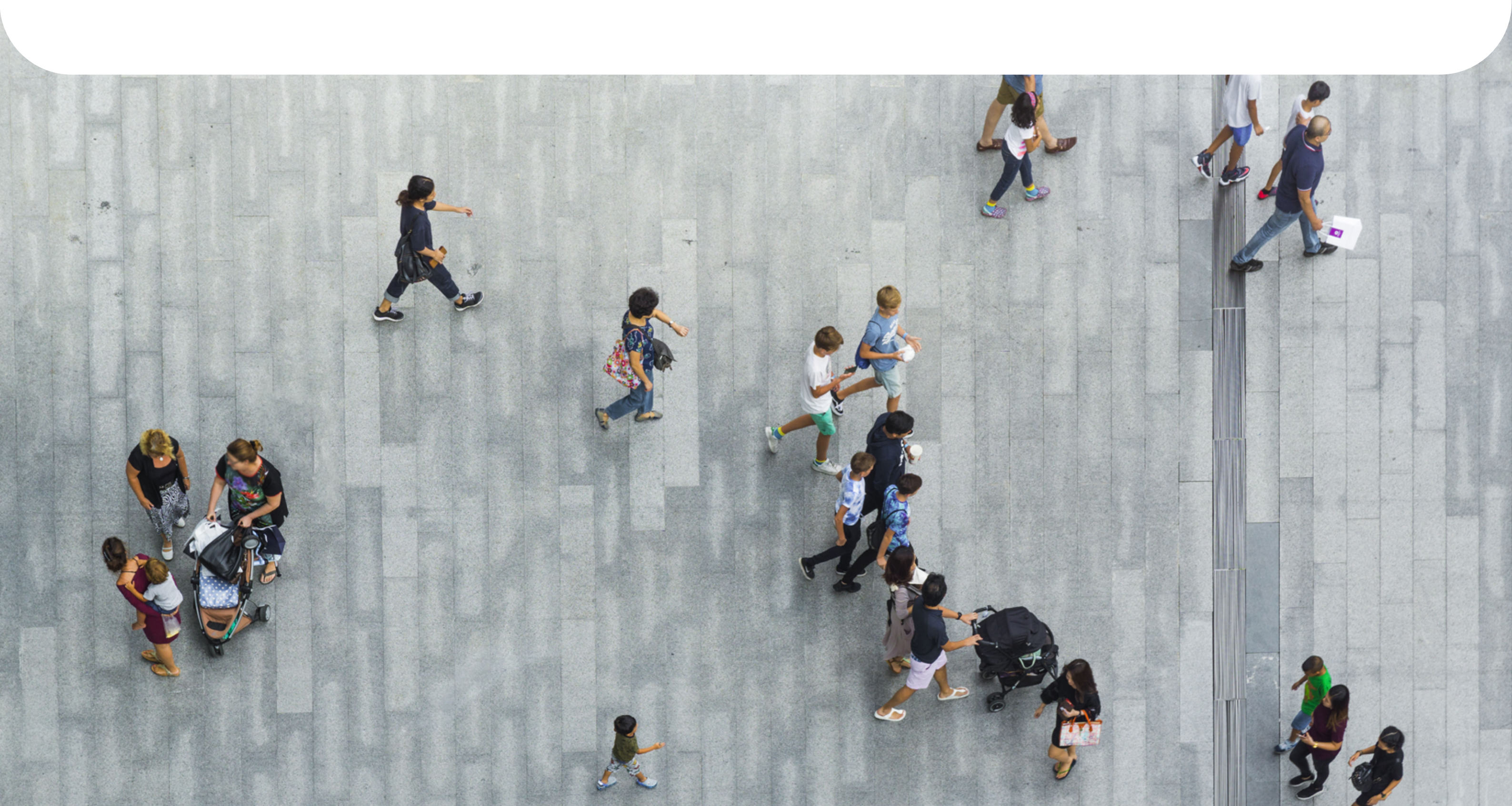
Policy Recommendations

Based on these global insights, several policy recommendations emerge for Saudi Arabia:

- Measuring the level of understanding of quantum technologies and their strategic importance and societal benefits to enable **evidence-based policy.**

- To deepen the current quantum awareness efforts, the focus should shift from the general public towards a **targeted awareness campaign** aiming at
  - Decision makers in both the public sector and industry, to be aware of the strategic importance and societal benefits when making decisions
  - Youth, STEM communities, and K-12 educational institutions, to have a future-ready workforce.

- Launch **multilevel public dialogues,** such as industry forums and quantum-ambassador programs, to foster trust, manage expectations, and disseminate reliable information about quantum capabilities and uncertainties.



In Focus

Saudi Arabia's Engagement in World Quantum Day (2024–2025)

Saudi Arabia's inaugural World Quantum Day celebration in 2024 marked an important landmark in national quantum outreach. Led by the C4IR Saudi Arabia in partnership with KACST and King Salman Science Oasis. This two-day program combined high-level panels on quantum science and innovation with technical seminars, exhibitions from leading institutions, and hands-on student activities. Discussions addressed integrating quantum technologies into the economy, embedding quantum literacy in education, and fostering collaboration between government, academia, and industry. The event is listed as the Kingdom's first contribution on the official WQD platform. It was featured in major publications including SPA, Sabq, Al-Madina, Makkah Newspaper, and more, highlighting the event's key discussions and innovations in quantum technologies.

Celebration of World Quantum Day 2025 in Riyadh, with participation from government, industry, and academia
Source: C4IR Saudi Arabia

In 2025, the Kingdom's WQD activities were aligned with the UNESCO-led IYQ, commemorating the centenary of quantum mechanics. Under the theme "Discovering Quantum Possibilities: A Day of Exploration and Inspiration", C4IR Saudi Arabia, KACST and Aramco hosted a major gathering in The Garage in Riyadh. Featuring global experts, interactive awareness experiences highlighting real world examples of how Saudi Arabia is collaborating with leading institutions today, and advanced technical sessions with the Saudi Quantum Computing Association. The campaign reached more than six million people online and a total of 31 media mentions, 17 in English and 14 in Arabic, consolidating Saudi Arabia's position as a regional leader in quantum engagement.

Key milestones included the launch of Quantum Valley and the conclusion of the Quantum for Society UpLink Challenge, recognising ten innovators from 100 global submissions. Launched in November 2024, the challenge sought early-stage quantum technology solutions in alignment with the UN Sustainable Development Goals. The Challenge aimed to identify and help early-stage startups develop scalable-quantum solutions in critical areas, such as climate change and healthcare. It also supported in building a network of business leaders, policymakers, and academics to ensure quantum tech aligns with sustainability goals.

Highlights from WQD 2024 & 2025

40+
speakers

20+
expert-led speeches and discussions

132K+
livestream views

450+
attendees

Quantum for Society Uplink challenge

100
global submissions

10
winners

7
sustainable development goals impact areas

13
ecosystem partners

Top Innovators of the UpLink "Quantum for Society" Challenge announced on stage at World Quantum Day 2025 in Riyadh
Source: C4IR Saudi Arabia

Celebration of World Quantum Day 2025 in Riyadh, with participation from government, industry, and academia
Source: C4IR Saudi Arabia

Building widespread awareness of quantum technology is crucial for bridging the gap between complex science and real-world application. Global initiatives like World Quantum Day are vital for this, creating a powerful annual momentum that helps cultivate the future talent pipeline and encourages industries to prepare for the profound transformations the field will create.

David Keyes
Professor and Founding Dean of Mathematical and Computer Sciences and Engineering at KAUST

Section 03 Ensuring Responsibility

Ensuring responsibility is vital for building public trust in quantum technologies. This demands proactive *Governance, responsible innovation, and standardization* to steer development ethically and create common rules. It also requires a sharp focus on *Cybersecurity*, to defend against quantum threats with post-quantum cryptography and to build new protections using quantum cryptography. Integrating strong ethical governance with advanced cybersecurity is fundamental for ensuring that innovation proceeds safely and sustainably.

3.1 Governance, Responsible Innovation and Standardization

A trusted and resilient quantum ecosystem requires governance models that are coherent, values-based, and globally aligned. By focusing on regulating applications rather than platforms, adopting anticipatory and risk-based oversight, and investing in robust standards and international coordination, Saudi Arabia can ensure that quantum technologies evolve responsibly, enhancing public trust, enabling cross-border interoperability, and supporting long-term economic and technological resilience.

To foster innovation while safeguarding public trust, Saudi Arabia's regulatory approach to quantum technologies should be proportionate, adaptive, anticipatory, and timely intervening only where clear risks exist. The focus should be on regulating applications, not platforms, ensuring flexibility for research and commercialization. The overarching goal is to enable a vibrant, safe, and interoperable quantum ecosystem that catalyses growth rather than constrains it. There are four core priciples that shape how governance and standardization are approached in this context:

- **Light-touch, risk-based regulation**
  The default posture should encourage innovation through minimal intervention, adjusting only as technologies mature and risks become more defined. Regulation should evolve alongside the technology lifecycle, balancing innovation incentives with appropriate safeguards.

- **Standards and interoperability**
  Early clarity on interoperability and security standards will accelerate adoption, prevent fragmentation, and ensure consistency across platforms. Standardization should span quantum computing, sensing, and communication, guided by global frameworks (ISO/IEC, ITU, ETSI, IEEE).

- **Regulatory capability-building**
  Effective governance requires trained regulators, policymakers, industry managers, and law enforcement officials. Continuous training, foresight exercises, and multi-stakeholder dialogue will ensure readiness to address emerging risks and opportunities.

- **National governance and coordination**
  Oversight should be centralized through a National Quantum Governance Body, bringing together regulators, industry, academia, and international partners. This body would coordinate strategy, assess risks, and ensure alignment with international standards while avoiding overlapping mandates. Its regulatory focus should remain application-specific, avoiding one-size-fits-all.

Operationalizing Responsible Innovation

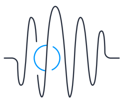
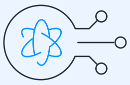
Embedding ethical governance in quantum R&D is essential. Principles such as transparency, accountability, inclusiveness, equitability, and accessibility should guide all initiatives. These values, aligned with the World Economic Forum's Quantum Computing Governance Principles (2022), build public trust and enable the transition from voluntary guidelines to formal regulation as the sector matures.

Responsible innovation should translate ethics into practice. This entails automatic ethical review in R&D, stakeholder engagement on privacy and fairness, and proactive management of dual-use risks. Anticipatory governance should rely on regular foresight-planning exercises to identify emerging policy needs.

Standardization as an Enabler

Standardization underpins quantum ecosystem maturity by ensuring quality, compatibility, and global trust. Current initiatives (see table 3) demonstrate best practice. These initiatives underscore the importance of shared specifications and interoperability, fostering trust, and enabling secure hybrid quantum–classical systems and cross-border collaboration.

Table 3: Key international standardization initiatives in quantum computing, sensing, and communication

Field	Standardization Examples
Quantum Computing 	– ISO/IEC 4879:2024 – establishes core terminology for quantum information technology. – IEEE projects – define benchmarking methods and control architectures for quantum processors. – NIST PQC standards (2024) – set post-quantum cryptography algorithms, providing a hardware-neutral baseline for hybrid classical–quantum systems.
Quantum Sensing 	– IEC/ISO JTC 3 – developing calibration and interoperability standards. – BIPM (International Bureau of Weights and Measures) – building traceability frameworks for quantum metrology. – NIST programs – advancing measurement standards for devices like atomic clocks and magnetometers. – CEN/CENELEC – working on performance classifications for industrial applications in navigation, geophysics, and medical imaging.
Quantum Communication 	– ITU-T Y.3800 series – defines architectures and requirements for QKD networks. – ISO/IEC 23837 – specifies security evaluation procedures for QKD hardware modules. – ETSI standards – publish integration profiles for telecom and cloud networks. – IEEE P1913 – develops software-defined networking (SDN) interface specifications for quantum-classical interoperability.

Sources: (NCA, 2024) (ISO/IEC, 2024) (ITU, 2020–2023) (ISO/IEC, 2022–2023) (ETSI, 2017–2022)

Current State and its Importance for Saudi Arabia

For Saudi Arabia, governance and standardization in frontier technologies are integral to Vision 2030's ambition of building a diversified, innovation-driven economy. Grounding quantum development in clear principles and internationally recognized standards will ensure that national initiatives are ethical, trusted, and globally competitive. This foundation also strengthens confidence among investors and partners, enabling the Kingdom to secure a strong position in emerging global value chains.

Saudi Arabia brings important advantages to this effort. Governance has already been embedded in national strategies for artificial intelligence, data, and digital infrastructure, supported by strong regulatory institutions and active participation in international forums. The Kingdom's established leadership in AI governance, exemplified by the National Data Management Office (NDMO) and the Saudi Data and AI Authority (SDAIA), provides a proven model and institutional expertise that can be directly leveraged for quantum technologies. Additionally, the Saudi Standards, Metrology and Quality Organization (SASO) joined the ISO/IEC JTC 3, a joint technical committee focused on developing international standards for the emerging field of quantum technologies, such as its work on the standardized quantum vocabulary (ISO/IEC 4879).

Although quantum governance is still in its early stages, early intervention offers the opportunity to design frameworks that reflect national priorities while aligning with global practices. Early engagement in international standard-setting will ensure interoperability and open pathways for investment, scaling, knowledge exchange, and talent development, positioning Saudi Arabia as a trusted and forward-looking participant in the quantum economy.

Global Perspective

There is widespread international consensus that, without common standards, the quantum ecosystem is vulnerable to fragmentation, constrained interoperability, and delayed commercialization. Globally, this challenge has been addressed through a range of coordinated approaches:

- **Establishing national bodies to lead standardization**

  A defining feature of leading quantum nations is the establishment of national or regional bodies with authority to coordinate standardization, often structured as multi-stakeholder consortia that bring government, industry, and academia together.

  In the **United States**, the **Quantum Economic Development Consortium (QED-C)**, anchored by NIST, plays this role by aligning more than 200 members around priorities in post-quantum cryptography, benchmarking, and certification. This structure ensures that standards are both technically robust and responsive to market needs.

  In **Japan**, the **Quantum Strategic Industry Alliance for Revolution (Q-STAR)** serves as the national mirror committee to ISO/IEC JTC 3. Beyond coordinating technical contributions in computing, metrology, and communication, Q-STAR's remit includes ethics and trust in implementation, enhancing the legitimacy and acceptance of Japan's frameworks.

  Europe has pursued a dual approach. The Quantum Industry Consortium (QuIC) provides an industry-wide platform under the EU Quantum Flagship, representing European companies in standards development and policy discussions. In parallel, the **ETSI Industry Specification Group for QKD (ISG-QKD)** develops globally recognized standards for quantum key distribution and hybrid communication networks, giving Europe a long-standing role in shaping interoperability.

19 number of consortia in America

10 number of consortia in Asia-Pacific

47 number of consortia in Europe, the Middle East and Africa

Souce: (The Quantum Insider, 2025)

- **Integrating standardisation into infrastructure development**

  The **European Union's** European Quantum Communication Infrastructure initiative merges quantum infrastructure projects with standardization, especially for quantum key distribution. The European Telecommunications Standards Institute (ETSI) oversees encryption standards, hybrid communication protocols, and transition plans. At the same time, the European Committee for Standardization and the European Committee for Electrotechnical Standardization (CEN/CENELEC) support hardware qualification. Europe's practical integration of workforce training frameworks (such as the European Competence Framework for Quantum Technologies (CFQT) alongside technical standards has effectively prepared both the infrastructure and human capital for deployment.

  China integrates standardization directly into national quantum infrastructure projects via the Standardization Administration of China agency. This approach is actively setting domestic standards and engaging internationally through ISO/IEC working groups. China's rapid transition from standard creation to infrastructure implementation has enabled swift commercialization, demonstrating the value of tight coupling between standards and infrastructure planning.

- **Piloting certification and testbeds**

  Singapore emphasizes hands-on validation of standards through dedicated testbeds for QKD and hybrid quantum-classical systems. Its approach of using independent testbeds for interoperability testing has fostered trust and accelerated standard adoption within industry and government sectors. A prime example is the National Quantum-Safe Network, which serves as a live proving ground where commercial partners, such as banks and telecommunication companies, can deploy and test QKD equipment from multiple vendors in a real-world setting. This practical validation of how different systems operate and integrate over the nation's actual fiber network provides direct proof of their reliability and interoperability. This, in turn, is building the necessary confidence for wider commercial and governmental adoption.

- **Embedding standards in talent and ethics frameworks**

  The EU developed CFQT to standardize quantum workforce roles. This effort is directly aligning education and skill sets with emerging technology standards. It underscores the advantage of parallel investments in human and technological capabilities for long-term ecosystem resilience.

  Both **Japan and the EU** explicitly embed ethical principles into their technical standardization processes, intertwining transparency, security, and human-centric considerations with interoperability. Their approach exemplifies how coupling technical standards with ethical governance strengthens public trust and encourages responsible innovation.

Policy Recommendations

- **Establish a national quantum governance and standards program** to coordinate strategy, funding, and regulation under a unified mandate. The cybersecurity aspects will be covered in the National Cybersecurity Strategy.
- **Invest in regulatory capabilities** through training programs and foresight exercises for government and industry stakeholders.
- **Adopt anticipatory regulation**, introducing guidance early enough to support development but not so early as to inhibit innovation.
- **Develop national testbeds and sandboxes for certification and interoperability** to validate technologies prior to market deployment.
- **Integrate standards into infrastructure and education** to link technical competence with ethical and governance training.

In Focus

UK Approach to Regulating Quantum Technology Applications

The Regulation of Quantum Technology Applications report was published in 2024 by the UK's Regulatory Horizons Council (RHC), supported by Royal Holloway, University of London, as part of the UK National Quantum Strategy. It provides policymakers with guidance on how to regulate quantum technologies in a way that balances innovation with effective risk management.

REGULATORY HORIZONS COUNCIL

Regulating Quantum Technology Applications

February 2024

The report does not call for creating a new dedicated regulator. Instead, it recommends embedding quantum oversight into existing sectoral regulatory frameworks such as finance, health, and critical infrastructure. This application-specific approach ensures agility, avoids duplication, and builds on established regulatory expertise, while maintaining coherence across different domains. It emphasizes that governance should be principle-based, proportionate, and adaptive.

Regulation should evolve in step with technological progress, introduced early enough to prepare institutions but not so early that it hinders market development. By promoting innovation-friendly oversight while safeguarding against systemic risks, the UK's approach offers an important reference for countries developing governance frameworks for quantum technologies.

Source: (Regulatory Horizons Council, 2024)

3.2 Cybersecurity

> Building quantum technologies secure by design is an imperative, embedding trust and resilience from the start and avoiding the cybersecurity oversights of the internet era.

Mitigating emerging risks to Saudi Arabia's cyberspace and critical infrastructure is a national priority. Among transformative technologies, quantum computing stands out as both a disruptive risk and a strategic opportunity. It redefines cryptography, amplifies the capabilities of artificial intelligence, and could enable undetectable cyberattacks. Without proactive safeguards, these advances could outpace traditional cyber defenses.

A **secure-by-design approach**, embedding security principles from the inception of quantum technologies,is essential to ensure that innovation strengthens.

The Quantum Threat Landscape

Quantum computing's unparalleled processing power threatens the foundations of today's encryption. Within the next decade, it may be capable of breaking widely used asymmetric cryptography, including RSA, Diffie–Hellman, and Elliptic Curve algorithms. This would jeopardize the confidentiality and integrity of global digital communications, both present and archived, since encrypted data captured today could be decrypted in the future ("harvest now, decrypt later" attacks).

The timeline for the quantum threat remains uncertain, but leading experts estimate that a sufficiently powerful quantum computer could emerge in the early 2030s. Yet, a quantum breakthrough could occur sooner, or later, than anticipated. The "harvest now, decrypt later" scenario heightens this urgency: threat actors may already be collecting encrypted data today, intending to decrypt it once quantum capabilities mature. This means that even in the absence of a fully operational quantum computer, data encrypted today is already at risk of future exposure.

To mitigate these risks, developing and deploying quantum-resistant cryptography is paramount. This demands a concerted effort among cryptography, quantum computing, and cybersecurity experts to design, test, and implement new encryption algorithms capable of withstanding quantum attacks. Governments and organizations must adopt a proactive and coordinated approach to managing this emerging threat, integrating quantum-safe strategies into their long-term digital resilience frameworks.

Quantum disruption extends beyond encryption. It will reshape the cybersecurity landscape, disrupting authentication, eroding data integrity, and exposing industrial control and operational technology systems. These shifts introduce complex interdependencies, making systems harder to secure, manage, and maintain.

If unaddressed, quantum-enabled threats could lead to:

- Unauthorized access and manipulation of sensitive or classified information.
- Disruption of critical infrastructure such as energy, finance, and transportation.
- Loss of public trust in digital systems and institutions.
- Long-term exposure of previously encrypted data.
- Strategic and economic advantages for adversaries with decryption capabilities.

The threat actors who could potentially exploit the quantum threat include:

- Nation-state actors seeking to gain a strategic advantage through cyber espionage or disruption of critical infrastructure.
- Sophisticated criminal organizations seeking to profit from unauthorized access to sensitive information.
- Organized cybercriminal groups could utilize quantum computing to scale extortion and fraud.
- Competitors seeking a commercial advantage through cyber espionage or business disruption.
- Decrypt previously captured communication and archives.
- Malicious threat actors could impersonate trusted software, websites, and users by forging digital signatures and certificates.
- Employ quantum-aided search and optimization for vulnerability scanning and exploitation.
- Monetize capability through decryption-as-a-service, data resale, and targeted extortion.

Learning from the Past: Designing Security In

The early internet was built for connectivity, not security. The absence of security-by-design principles in protocols like TCP/IP still leaves lasting vulnerabilities. Quantum technologies, as in its early development, offer a chance to **embed cybersecurity from the ground up.**

Global quantum initiatives should adopt secure-by-design and safe-by-design frameworks that integrate cybersecurity, privacy, and resilience at every stage, from hardware architecture to cryptographic standards and ecosystem governance.

From Urgent Threat to Strategic Lead

Timely action can transform the quantum challenge into a competitive advantage. Developing a national quantum-safe readiness and post-quantum cryptography migration strategy, grounded in clear risk analysis, phased cryptographic transition, and capability benchmarks, will ensure Saudi Arabia enters the quantum era with controlled risks and enhanced resilience.

The window for transition is narrow. With NIST publishing the first PQC standards in 2024 and planning to deprecate RSA and ECC by 2030–2035 (NIST, 2025), governments and industries worldwide must modernize their cryptographic infrastructure within the decade.

By acting now, and by adopting a secure-by-design approach, Saudi Arabia can secure its digital future, safeguard critical infrastructure, and lead the development of a trusted, resilient quantum ecosystem.

Table 4 summarizes the main quantum-enabled cybersecurity threats across sectors, explaining their potential impacts on digital ecosystems and outlining prioritized mitigation actions to guide a secure-by-design transition.

+20 billion
digital devices worldwide will need upgrading or replacement to support quantum-safe cryptography in the next 10–20 years

Source: World Economic Forum, 2022

$4.40 million
(⃁16.50 million) is the global average cost of a data breach

Source: IBM, 2025

Table 4: Quantum-enabled threats

Type of Risk & Who's at Risk	Threat	Why It Matters	What Organizations Should Do
Cryptographic Breakthrough Risks *G & CI, B & SC*	Quantum computers may break classical public-key and weaken symmetric encryption.	Exposure of national, defense, and commercial secrets; loss of trust in digital systems.	Begin migration to post-quantum standards (National Cryptographic Standard); update encryption inventories and policies.
Harvest Now, Decrypt Later Attacks *G & CI*	Encrypted data stolen today could be decrypted once quantum tools mature.	Historical and long-retained data (defense, energy, finance) could be revealed years later.	Encrypt new data with PQC; identify and re-encrypt sensitive archives; classify long-lived data assets.
Quantum Interference in Critical Networks *G & CI*	Quantum tampering or hybrid-system gaps may disrupt timing, GPS, or telecom networks.	Service disruption in navigation, financial transactions, or critical infrastructure.	Audit timing and network systems; implement tamper-resistant synchronization and hybrid-network standards.
Quantum-Era Supply-Chain Integrity *B & SC*	Unverified hardware, firmware, or updates could embed malicious quantum-enabled components.	Compromise of national or industrial systems through trusted vendors.	Require certification and transparency of quantum components; use multi-signature verification and integrity checks.
Transition Vulnerabilities & Downgrade Attacks *B & SC*	Attackers exploit gaps during algorithm transitions or force weaker encryption.	Data breaches may occur during PQC rollout or through unnoticed downgrades.	Phase upgrades under strict monitoring; enforce National cryptographic standards and anomaly detection.
Quantum Impact on Emerging Tech (AI & Blockchain) *B & SC*	Quantum computing may break blockchain signatures or manipulate AI/ML models.	Risks to digital assets, smart contracts, and AI-driven business integrity.	Transition to quantum-safe blockchain protocols; apply adversarial testing and continuous AI model validation.
Quantum-Forged Identities & Privacy Loss *C & EU*	Quantum attacks could forge digital signatures or reveal hidden network identities.	Identity theft, impersonation, and loss of online anonymity for citizens and users.	Support PQC-based digital ID systems; strengthen MFA; adopt quantum-resilient VPNs and privacy tools.
Governance & Policy Readiness **Cross-Sector**	Legacy governance and standards may not address post-quantum threats.	Fragmented national response and inconsistent compliance.	Integrate quantum-readiness mandates into national cybersecurity frameworks and sectoral regulations.
Quantum Transition & Adversary Acceleration **Cross-Sector**	Criminals or state actors may weaponize "decryption-as-a-service" or automated quantum attack toolkits.	Accelerated cybercrime and espionage with global reach.	Strengthen international cooperation, intelligence sharing, and global norms against quantum misuse.

G&CI: Government and Critical Infrastructure; B&SC: Businesses & Supply Chains; C&EU: Citizens & End Users; CS: Cross-Sector (All Domains)

Source: Authors' elaboration based on (NIST, 2022) (QED-C, 2022) (NCSC, 2023) (ENISA, 2021) (NEDO & NICT, 2022–ongoing) (VTT/InstituteQ Finland, 2022–2025) (CSA & IMDA, 2023) (CSE, 2020–ongoing)

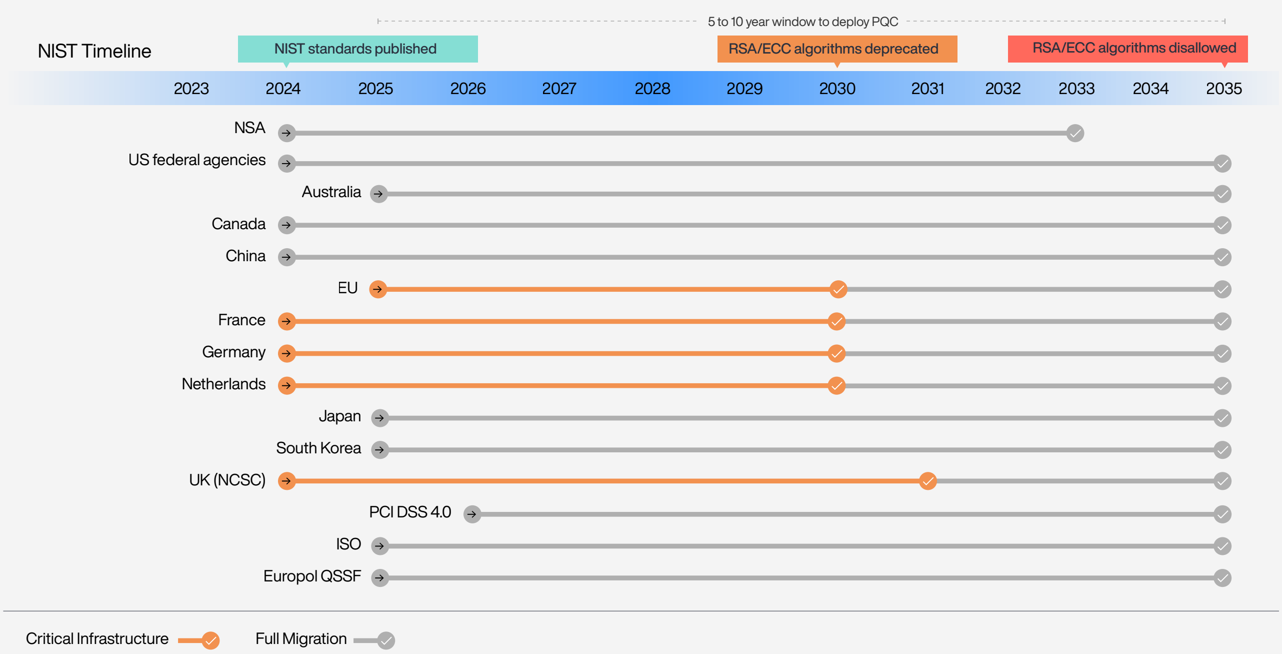
Current State and its Importance for Saudi Arabia

The relevance of this topic to Saudi Arabia lies in its direct contribution to Vision 2030 objectives, particularly in advancing digital transformation, economic diversification, and secure technological growth. As the Kingdom accelerates its transition toward a data-driven economy, key sectors—including finance, energy, healthcare, and public services—are increasingly reliant on digital infrastructure and cryptographic systems. The advent of quantum technologies introduces long-term risks to these systems, raising critical considerations for data protection, digital trust, and infrastructure resilience.

The National Cybersecurity Authority (NCA) is Saudi Arabia's central body to safeguard the State's vital interests, national security, critical infrastructures, priority sectors, and government services and activities. NCA has multiple responsibilities and task, including setting cybersecurity policies, governance rules, frameworks, rules, standards, developing the national strategy for cybersecurity, managing national cybersecurity risks, and updating national cryptographic policies and standards. NCA oversees all cybersecurity aspects related to quantum computing and working closely with public and private stakeholders, to strengthen cybersecurity in the Kingdom to mitigate risks, boost trust, and enable growth.

Global Perspective

The global race for quantum capabilities has made cybersecurity a top national priority. Nations are racing to develop quantum capabilities while simultaneously preparing the threat they pose to existing encryption. Leading governments have begun reassessing risk models, regulatory frameworks, and infrastructure resilience through a quantum lens. This urgency stems from evidence that state-sponsored groups are already stockpiling encrypted data, expecting to decrypt it later with powerful quantum computers. What was once a long-term research concern is now a strategic imperative. The graphic below (Figure 6) maps how leading national security agencies, regulators, and standards organizations have set phased milestones for critical infrastructure and full migration. It highlights both early movers and lagging stakeholders, underscoring the imperative to synchronise policy mandates, technical upgrades, and workforce readiness before legacy encryption becomes a liability.



Source: (PQShield Ltd, 2025)

Figure 6: Global PQC Migration Timelines, Milestones From National Security Agencies And Regulators Aligned To Nist's 2024–2035 Transition Window

Governments are prioritizing PQC due to its immediate deployability via classical infrastructure, scalability through software updates, and cost-effectiveness. Hybrid models are also emerging as transitional solutions. While quantum key distribution offers theoretically unbreakable key exchange, its hardware reliance, limited range, readiness level and security vulnerabilities restrict practical use for now. A staged PQC transition, supported by cryptographic inventories, risk modeling, and regulations, is considered a viable long-term data protection and cybersecurity strategy.

Against this backdrop, several countries have launched dedicated national initiatives to manage the quantum cybersecurity transition. These programs vary in maturity and scope, but most share a common structure: defining clear policy mandates, aligning with emerging PQC standards, conducting sector-specific risk assessments, and piloting cryptographic upgrades. Certain countries are investing in quantum-secure infrastructure such as QKD networks, while others are focusing on software-based PQC deployment across legacy systems. Public-private collaboration, regulatory support, and interoperability with global standards have emerged as critical enablers. In Appendix III, selected national strategies illustrate the range of approaches governments are using to prepare for a quantum-resilient future.

Policy Recommendations

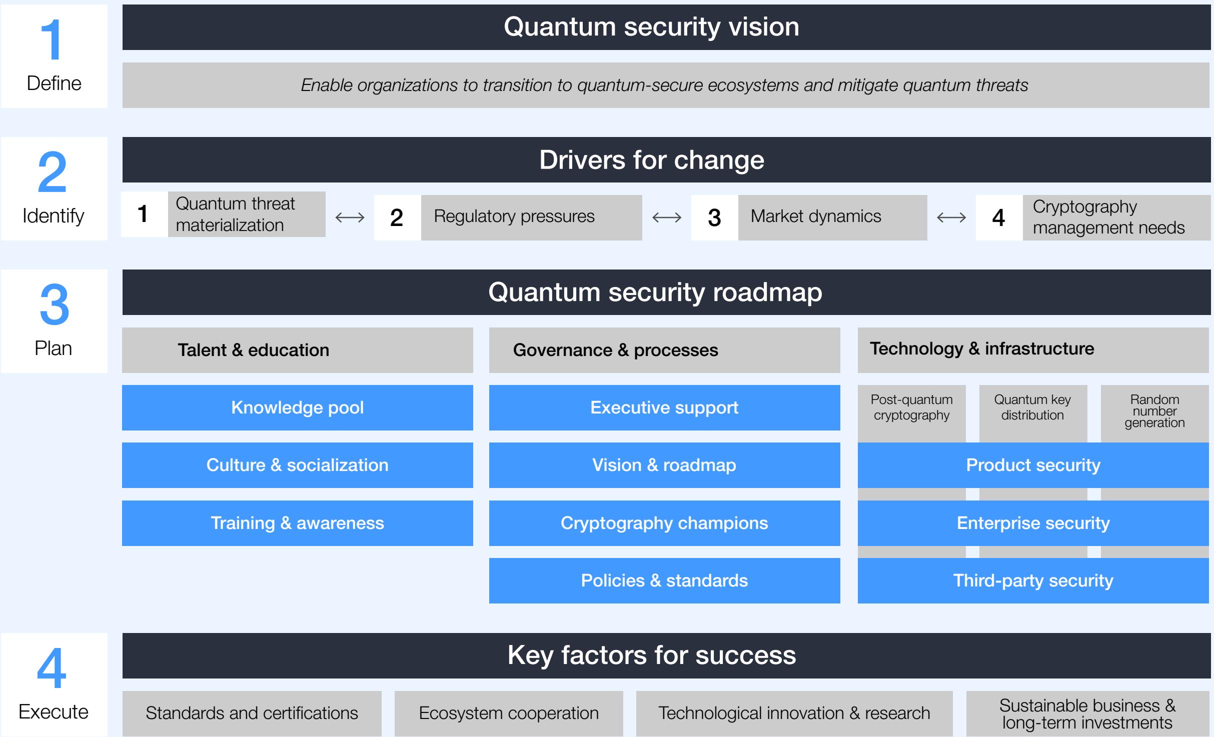
Although the precise timeline for quantum impact remains uncertain, early preparation for the transition to PQC and QKD will enable a smoother, more efficient migration and position stakeholders to capture strategic advantages. NCA responsibilities include developing and updating the National Strategy for Cybersecurity, which includes initiatives for setting national cybersecurity policies and frameworks, managing national cybersecurity risks, and updating national Cryptographic policies and standards. NCA works closely with all stakeholders to strengthen cybersecurity in the Kingdom to mitigate risks, boost trust, and enable growth. NCA is working on updating the National Strategy for Cybersecurity that has initiatives related to managing the cyber risks related to emerging technologies, including Quantum Computing.

In Focus

The World Economic Forum's Quantum Readiness Toolkit

As part of its global leadership on quantum security, the World Economic Forum convened with a multi-year, multi-stakeholder initiative to address the urgent need for coordinated quantum-safe migration. This effort brought together senior leaders from government, industry, academia, and standards bodies to co-develop a consensus-based framework for managing the transition from vulnerable cryptographic systems to quantum-resilient infrastructure.

The initial outcome was the Quantum-Secure Transition Framework, which structures the journey into four phases: defining a quantum security vision, identifying drivers for change, planning an organization-wide roadmap, and executing through enablers such as standards, ecosystem cooperation, and sustainable investment. As illustrated in Figure 7, the framework provides a visual roadmap linking vision and drivers to practical actions across talent, governance, technology, and investment, offering a common language for aligning priorities within the tightening PQC transition window.



Source: World Economic Forum, 2022

Figure 7: Quantum-secure transition framework: a four-phase model guiding the shift to quantum-secure ecosystems through vision, drivers, roadmap, and execution

Building on this foundation, the Forum launched targeted working sessions in 2023 to translate strategic guidance into operational practice. These engagements focused on three critical domains, talent and education, governance and processes, and technology and infrastructure, and distilled insights into a practical Quantum Readiness Toolkit. The Toolkit sets out five interlinked principles for achieving quantum cyber-readiness: embedding quantum risk within governance structures, ensuring organization-wide awareness of emerging threats, integrating quantum risk management into existing cybersecurity processes, making strategic technology choices that enable crypto-agility, and fostering collaboration across ecosystems to address systemic vulnerabilities. As shown in Figure 8, these guiding principles provide a practical framework for organizations to manage quantum risk in a structured and proactive way.

Ensure the organizational governance structure institutionalizes quantum risk
The quantum threat requires organizations to align their governance structure to their quantum cyber readiness transition by defining clear goals, roles and responsibilities and creating leadership buy-in to enforce change effectively.

Raise quantum risk awareness throughout the organization
Demystifying the quantum threat is key. This requires that not only quantum cyber readiness experts but also senior leaders and risk managers understand the risk and impact of the threat to the organization.

Treat and prioritize quantum risk alongside existing cyber risks
A quantum cyber-ready organization follows a structured approach to evaluate and manage quantum risk and integrates mitigating this risk into existing cyber risk management procedures.

Make strategic decisions for future technology adoption
Managing quantum risk provides organizations with opportunities to reassess their technology landscape, specifically the use of cryptography. To make the most out of technology solutions that help mitigate quantum risk, organizations should make strategic technology decisions that support "crypto-agility" to achieve their security objectives.

Encourage collaboration across ecosystems
Quantum risk is a systemic risk. An effective quantum security strategy includes collaborating and sharing information with other organizations to identify risks throughout the ecosystem and suppliers to jointly mitigate such risks.

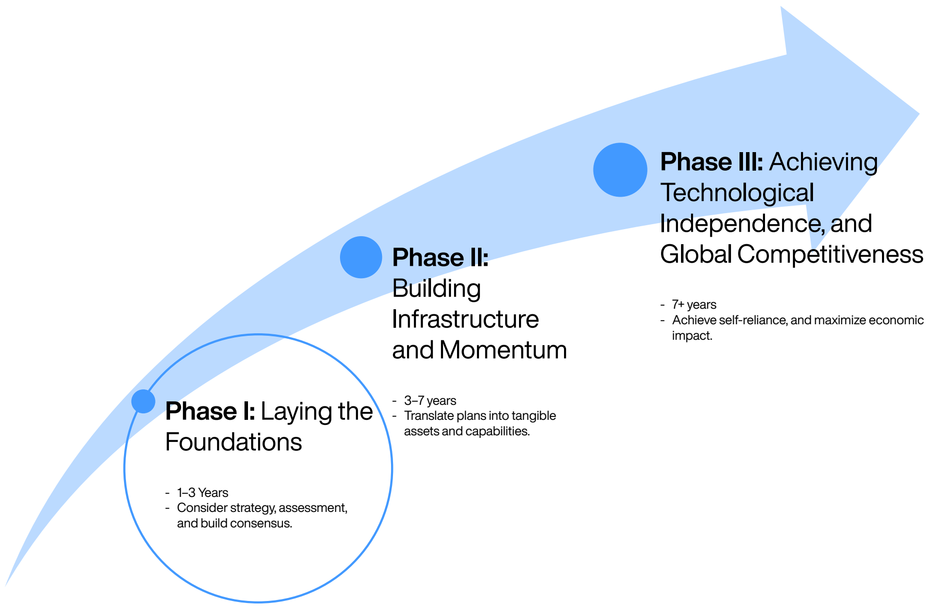
Source: World Economic Forum, 2022

Figure 8: Guiding Principles For A Quantum-Secure Transition

Equipped with tested practices, measurable smilestones, and sector-agnostic guidance, the Toolkit enables organizations to conduct cryptographic inventories, model risk exposure, pilot PQC and hybrid solutions, and integrate security requirements into supply chains.

The Way Forward

To translate the report's findings into a practical path forward, this section proposes a three-phase roadmap for national action. The suggested structure, spanning from readiness to resilience and, ultimately, competitiveness, is designed to guide policymakers, institutions, and stakeholders in aligning their efforts over time. While quantum technologies are still in early stages of global development, well-sequenced, and overlapped, national action can help Saudi Arabia prioritize investments, coordinate implementation, and avoid fragmented or duplicative efforts.
Internationally, leading countries such as the United States, Germany, the United Kingdom, China, and Japan have adopted staged quantum strategies that begin with research and capability mapping, proceed to infrastructure development and talent pipelines, and culminate in strategic autonomy and industrial competitiveness. This phased model ensures that momentum is sustained, resources are optimized, and stakeholder roles are clearly defined at each stage. Moreover, the quantum field presents unique complexities and long development timelines. A clear multi-phase roadmap provides the necessary structure for navigating uncertainty while enabling flexibility as the technology and ecosystem evolve. The suggested three phases are outlined below (Figure 9). While some of the recommended actions are already underway, they now need to be connected and sequenced as part of a broader national plan. Phase II preparation should ideally begin during Phase I, enabling the process to remain agile and responsive to future development.



Source: Authors' elaboration based on the team's research, surveys and interviews

Figure 9: A three-phase proposed roadmap for national action

Phase I: Laying the Foundations *(Near-Term: 1-3 Years)*

The first phase is about **strategy, assessment, and building consensus**. Before constructing the quantum ecosystem, we must survey the landscape and draw borderlines. This phase focuses on immediate, **high-impact actions** that create the necessary momentum and strategic direction. The following are proposed actions and KPIs:

- **Establish foundational governance**. Establish a Quantum Program to ensure clear roles and responsibilities and ensure coordinated national effort.
  Proposed KPI: Establishing a body with a unified mandate for strategy, funding, and regulation.

- **Launch national assessments.** Initiate a trio of foundational studies; a SWOT analysis to map Saudi Arabia's current capabilities, a value chain analysis to pinpoint economic opportunities,

and a comprehensive mapping of domestic and international supply chains to identify strategic vulnerabilities and dependencies.
Proposed KPIs: Conducting SWOT, Value Chain and Supply Chain Analysis.

- **Create demand.** Immediate efforts should focus on creating demand and supporting early-stage deployment. The government can act as a "first customer" reducing investment risk.
Proposed KPI: Budget allocation for procurement for early-stage quantum solutions.

- **Seed the talent pipeline.** Create targeted funding programs that connect university curricula with hands-on research and form initial strategic international partnerships to jumpstart knowledge transfer.
Proposed KPIs: i) Number of educational institutions adopting a Quantum curricula, **ii)** Number of training programs in quantum information science, **iii)** Number of students enrolled in these training programs.

- **Create awareness.** Launch a centralized national awareness program to educate policymakers, industry leaders, and the public, managing expectations and building the broad-based support needed for a long-term national initiative.
Proposed KPI: Establish the first 'national deep-tech familiarity index', to serve as a baseline of understanding and to measure progress.

Phase II: Building Infrastructure and Momentum *(Medium-Term: 3-7 Years)**

With the strategic foundation in place, the second phase is about **translating plans into tangible assets and capabilities.** This is where the physical and intellectual infrastructure of the quantum future is built. This phase accelerates the journey from research to real-world application. The below are suggested actions:

- **Construct core quantum facilities.** Establish a flagship National Quantum Center and a Quantum Foundry. These central hubs, supported by shared cleanrooms and laboratories, will become the heart of Saudi Arabia's research and development efforts (infrastructure) in quantum technologies.

- **Scale the quantum workforce.** Move from initial funding to implementing a tiered national quantum education framework, strengthening industry-academia partnerships with formal internship and co-op programs to create a steady flow of talent, and a direct pathway to jobs.

- **Adopt a mission-driven funding model.** Direct public investment towards solving specific "grand challenges" that align with Vision 2030. For example, optimizing national logistics, developing novel materials through quantum simulation, or enhancing resource discovery for the energy sector. Success will be measured by tangible commercialization outcomes like patent filings, viable prototypes, industry-led pilot projects, and the successful launch of new quantum startups.

- **Accelerate commercialization.** Create national quantum innovation hubs and sandboxes, in anchor assets like NEOM and Aramco, to bridge the lab and the market. By hosting pilots, IP transfer mechanisms, and cross-sector testbeds, these hubs and sandboxes integrate areas like manufacturing and supply chains early in the innovation cycle.

*Unlike 'Phase I' this section doesn't include KPIs because establishing KPIs for later phases is constrained at this stage due to unresolved uncertainties, such as quantum modalities to be pursued, and operational interdependencies between Phase I, Phase II, and Phase III.

Phase III: Achieving Technical Independence and Global Competitiveness *(Long-Term: 7+ Years)**

- The final phase represents the **maturation of the ecosystem.** The focus shifts from building capabilities to achieving self-reliance, **maximizing economic impact, and shaping the global quantum landscape.** A set of suggested actions include:

- **Establish technological independence.** Invest heavily in local component manufacturing to reduce reliance on foreign supply chains. Develop and deploy Quantum Key Distribution networks for ultra-secure national communications.

- **Mature the ecosystem.** Formally recognize "Quantum Engineer" as a professional category with structured certification pathways, solidifying the talent pipeline.

- **Achieve full-scale PQC migration.** Conclude the migration plan started to be inclusive across the entire economy.

- **Reap the economic rewards.** Realize widespread commercialization of quantum solutions that are deeply integrated into strategic Vision 2030 sectors, driving economic diversification and establishing Saudi Arabia as a global competitor.

Finally, the transition to a quantum-enabled economy will span decades and involve significant technical and geopolitical uncertainty. Achieving Saudi Arabia's quantum goals depends on managing systemic, non-technical risks across funding, coordination, and institutional capacity

- **Funding and investment risks.** Quantum technology development requires long-term commitment across research and commercialization. Inconsistent or misdirected funding could stall private investment. Mitigation requires a mission-oriented funding model linked to the national roadmap, ensuring multi-year financial commitments aligned with high-impact sectors such as energy and logistics. Public procurement should be used to stimulate early markets and attract private co-investment.

- **Coordination and alignment gaps.** Fragmentation across ministries, universities, and national programs risks duplication, inefficiency, and dependence on fragile global supply chains. Failure to align standards early could isolate Saudi Arabia from global markets. The creation of a National Quantum Center with authority to coordinate strategy, manage shared infrastructure, and oversee standardization is essential. A national supply chain review and investment in domestic manufacturing will strengthen resilience.

- **Institutional and change management inertia.** Slow adoption and limited regulatory expertise could delay implementation. The most immediate risk is the post-quantum cryptography transition, where delays could expose sensitive data to future decryption. Building regulatory capacity through targeted training and adopting adaptive, risk-based governance will help ensure progress while maintaining innovation.

* Unlike 'Phase I' this section doesn't include KPIs because establishing KPIs for later phases is constrained at this stage due to unresolved uncertainties, such as quantum modalities to be pursued, and operational interdependencies between Phase I, Phase II, and Phase III.

Appendix I: Selected Platforms for the Global Supply Chain Mapping

Platform	Materials	Enabling Infrastructure	Control Hardware
Superconducting	– Superconducting materials such as Aluminum (Al), Niobium (Nb), Tantalum(Ta) – Low dielectric materials (sapphire (Al_2O_3, high resistivity silicon(Si) – Conductor materials for wiring (copper(Cu), niobium titanium alloy(NbTi)	– Nanofabrication deposition of thin film by Physical vapor deposition, chemical vapor deposition, atomic layer deposition), lithography Photolithography, Electron Beam Lithography, etching) – Dilution refrigerator – Cryogenic chip packaging – Quantum plane (Readout resonators, Microwave drive lines, Flux bias lines, Interconnects) – Vacuum chamber	– Control Plane (DAC (Digital to Analog Converter), Processor / Integration, Heat management)) – RF and Microwave systems (AWG, LO, Cables) – Programmable Gate Arrays (FPGAs) – Low Temperature Electronics such as filters,Amplifier,Attenuator
Trapped ion	– Ions such as (Calcium, Beryllium, Ytterbium, Strontium, Barium) – Electrode materials such as (Gold,Aluminum, Molybdenum, Titanium)	– Laser systems – Ultra-High Vacuum (UHV) – Ultra-stable reference cavities and frequency locks – Nanofabrication – Fluorescence detection (PMT camera) – Cryogenic environment & electrical system – Magnetic shielding	– Control Plane – RF and microwave – Field-Programmable Gate Arrays (FPGAs) – Timing Electronics – Electronics for optics such as (Beam Shaping & Steering)
Photonic	– Photonic thin film materials: such as (silicon dioxide (SiO_2), (silicon nitride (Si_3N_4), (lithium niobate ($LiNbO_3$)) on insulator – Quantum light source such as: (Quantum dots (indium arsenide, (InAs)/ gallium arsenide, (GaAs), and defect centers in diamond, and silicon carbide (SiC)) – Nonlinear crystals such as (Beta Barium Borate (BBO), Potassium Dihydrogen Phosphate (KDP,), lithium niobate ($LiNbO_3$)) – Photon detection materials (silicon)(Si), indium gallium arsenide(InGaAs), niobium nitride(NbN), tungsten silicide WSi))	– Nanofabrication – Polarizing optics (PBS, wave plates) – High-quality optics (lens, mirrors) – Single photon detectors (APD, SSPD) – Vibration isolation (Optical tables) – Entanglement Sources – Squeezing sources	– Control Plane: such as (lasers and modulation drivers, Processor / Integration, temperature management, fiber network) – RF and microwave systems (AWG, LO, Cables) – Field-Programmable Gate Arrays (FPGAs) – Timing Electronics (clock, timing triggering – Electronics for optics and isolation (phase-locked, Beam Shaping & Steering)
Color-center qubits	– Nitrogen-vacancy (NV) center in diamond, – Silicon-vacancy (SiV), – Tin-vacancy (SnV) in diamond – Divacancy (VV), – Silicon vacancy (VSi) in silicon carbide.	– Fabrication (Ion implantation, electron irradiation, High-temperature annealing) – Polarizing optics (PBS, wave plates) – High-quality optics (lens, mirrors) – Single photon detectors (APD, SSPD) – Vibration isolation (Optical tables) – 3D Nanoscale scanning and positioning systems	– Control Plane: lasers and modulation drivers, Processor / Integration, temperature management, fiber network – RF and microwave systems (AWG, LO, Cables) – Field-Programmable Gate Arrays (FPGAs) – Timing Electronics (clock, timing triggering) – Electronics for optics and isolation (phase-locked, Beam Shaping & Steering)

Source: Authors' analysis

Appendix II: Accelerating ‘Deep Tech’ Commercialization through Innovation Services

A world-class quantum innovation ecosystem requires a coherent framework that embeds strong research values, cultivates talent, accelerates technology transfer, and forges durable partnerships between public and private sectors. Quantum technologies are considered ‘deep tech’ and require specific innovation services designed to accelerate their development, rapid scaling and field-deployment. An effective organizational framework and operational mechanism to accelerate research-impact and human-capital development is described here, benchmarked to leading global centres of innovation, and bring together best-practises under one umbrella organization.

A differentiator of the Innovation Services outlined here is that they integrate best practices from around the world, including fast-prototyping and scale-up, a project management office with translation specialists, and joint ventures with industry. These services are not commonly grouped within a single hub yet are vital for research translation. Synchronising these services offers synergies that add up to more than the sum of the parts and can result in significantly better outcomes and higher impact.

- **Training and education**
  Targeted programs develop entrepreneurial and ethically grounded quantum-ready researchers and innovators. Partnerships with universities and industry support project-based learning, industrial internships, innovation challenges, and part-time industry-based PhDs to build a resilient innovation workforce.

- **Project Management Office (PMO)**
  A central PMO, staffed by technical and business experts, oversees technology translation and industry partnerships, ensuring effective delivery, accountability, and alignment with national RDI priorities.

- **Funding for technology de-risking**
  Dedicated grant programs promote early-stage prototyping, MVP development, and proof-of-concept testing, applying global best practices such as DARPA’s mission-led model. These mechanisms help bridge the lab-to-market “Valley of Death” and attract private co-investment.

- **Mission-led partnerships and scale-up facilities**
  Strategic public-private and international collaborations drive mission-oriented innovation. Shared fabrication and scale-up facilities enable efficient prototyping and small-batch production, bridging the gap between research outputs and industrial deployment.

- **Business and commercialisation services**
  A coordinated suite of services supports idea evaluation, market analysis, IP management, and investor engagement. Start-ups benefit from incubators, accelerators, and access to networks providing legal, financial, and technical expertise.

- **Research culture and values**
  Embedding excellence, integrity, openness, and collaboration within institutional practice establishes a culture of trust and accountability. Continuous improvement and systematic feedback mechanisms sustain performance and user confidence.

Appendix III: Selected International Quantum Cybersecurity Initiatives and Transition Strategies

Quantum Strategy / Initiative	Cybersecurity Mitigation Focus	Key Deliverables	Timeline
USA: National Institute of Standards and Technology (NIST) – PQC Standardization Initiative	– PQC algorithm standardization – Federal cryptographic transition guidance – Public and agency pilots	– Final PQC algorithms (CRYSTALS-Kyber, Dilithium) – Drafts SP 800-208 (migration planning) and SP 800-257 (inventory) – Migration toolkit and technical resources	– Algorithms announced: 2022 – Guidance: 2023–2024 – Full transition goal: 2030
USA: Quantum Economic Development Consortium (QED-C) – Quantum-Safe Migration Guide	– Enterprise cryptographic migration – Risk management and planning tools – Industry alignment with NIST	– 2022 Migration Framework – Organizational checklists – PQC-readiness lifecycle resources	– Guide published: 2022 – Updates: 2023–ongoing
UK: National Cyber Security Centre (NCSC) – SparQ Programme	– Sector-specific readiness assessments – Hybrid cryptography trials – Playbook for public sector transition	– Government Playbook (2023) – Sectoral transition templates – Interagency pilots	– Playbook: 2023Pilots: 2024–2025Target readiness: 2035
EU: European Union Agency for Cybersecurity (ENISA) – PQC Readiness Reports	– Crypto-agility guidance – Sectoral risk mapping – Public-private migration planning	– EU-wide readiness reports (2022–2024) – PQC adoption strategies – Integration with OpenQKD pilots	– Reports: 2022–2024 – Ongoing updates aligned with EU Quantum Flagship
Japan: New Energy and Industrial Technology Development Organization (NEDO) & National Institute of Information and Communications Technology (NICT) – PQC CARD® Initiatives	– PQC R&D for embedded systems – Hybrid PQC-ECC in telecom (SoftBank) – International standards contribution	– PQC CARD® prototype – IETF drafts (e.g., hybrid TLS) – Telecom field trials	– Field trials: 2022–ongoing – Alignment with global PQC timelines
Finland: VTT Technical Research Centre, SSH Communications Security, Bittium, and InstituteQ – BlimPQC and National Cryptographic Strategy	– PQC for IoT and constrained devices Hybrid PQC-QKD between government nodes – National cryptographic policy design	– Veturi-funded R&D – BlimPQC project – InstituteQ strategy framework	– BlimPQC: 2022–2025 – National strategy announced: 2025

Source: Authors' elaboration based on (NIST, 2022) (QED-C, 2022) (NCSC, 2023) (ENISA, 2021) (NEDO & NICT, 2022–ongoing) (VTT/InstituteQ Finland, 2022–2025) (CSA & IMDA, 2023) (CSE, 2020–ongoing)

Quantum Strategy / Initiative	Cybersecurity Mitigation Focus	Key Deliverables	Timeline
Singapore:Cyber Security Agency of (CSA) & Infocomm Media Development Authority (IMDA) – National Quantum-Safe Network and Migration Guidelines	– National QKD network infrastructure – PQC migration guidelines – Telecom and finance pilot testing	– National Quantum-Safe Network (NQSN+) – CSA PQC Guidelines (launching 2025) – Quantum Infrastructure-as-a-Service (QIaaS)	– NQSN+: 2022–ongoing – CSA Guidelines: 2025
Canada: Communications Security Establishment (CSE)– Cryptographic Modernization Program (CMP)	– Cryptographic inventory of federal systems – Centralized PQC planning and procurement	– Enterprise architecture for cryptographic modernization – PQC-capable procurement frameworks	– Active since early 2020s – Ongoing alignment with NIST

Source: Authors' elaboration based on (NIST, 2022) (QED-C, 2022) (NCSC, 2023) (ENISA, 2021) (NEDO & NICT, 2022–ongoing) (VTT/InstituteQ Finland, 2022–2025) (CSA & IMDA, 2023) (CSE, 2020–ongoing)

Contributors

Authors

Hani AlHemsi
Director of Technology Development, MCIT

Maha AlKanhal
Seconded Fellow, C4IR Saudi Arabia

Shuroog AlOgbi
Quantum Lab Engineer, KFUPM

Maha AlOtaibi
Seconded Fellow, C4IR Saudi Arabia

Saad AlOwayyed
Quantum Economy Lead, C4IR Saudi Arabia, General Manager, KACST

Laila AlQahtani
Project Fellow, C4IR Saudi Arabia and the World Economic Forum

Muhammad AlSaiyari
Head of Quantum Computing, Saudi Aramco

Valeria Escliar
Advisor, C4IR Saudi Arabia

Muhamad Felemban
Center Director, KFUPM

Amnah Samarin
HPC Developer & Computational Geophysicist, Saudi Aramco

Co-authors

Ahmad Abuhaimed
Technology Development Specialist, MCIT

Abdulmalik AlGhonaim
Project Fellow, C4IR Saudi Arabia

Mohammed Alhabeeb
Consultant, Independent

Sumayh AlJameel
Lead IT System Analyst, Saudi Aramco

Ahmad AlRabiah
Researcher, Independent

Tarfa AlShubayli
Senior Policy & Strategy Engineer, Ministry of Energy (MoE)

Steering Committee

Basma AlBuhairan
Managing Director, C4IR Saudi Arabia

Adnan AlSaati
Advisor, C4IR Saudi Arabia

Mohamed Bourennane
Professor, Stockholm University

Tristan Farrow
NEOM Education, Research, and Innovation Sector

David Keyes
Professor and Founding Dean of Mathematical and Computer Sciences and Engineering, KAUST

Joe Queenan
Executive Director, South Carolina Quantum and CEO, Qllianse

Arunima Sarkar
Quantum Technologies, Thematic Lead, World Economic Forum

Acknowledgments

The Centre for the Fourth Industrial Revolution Saudi Arabia thanks the following individuals for their contributions.

Qamar Aftab
Investment Director, Wa'ed Ventures

Fawaz Alanazi
Consulting & Digital Studies Director, Digital Government Authority (DGA)

Shoog AlHamoud
Quality Control Data Analyst, CRTS Global

Mohammed AlJabr
Executive Manager, Operational Excellence, (NTDP)

Aroub AlKharashi
Assistant Project Manager, Research, Development, and Innovation Authority (RDIA)

Marius Almstedt
Director of Growth & Strategy, QAI Ventures

Abdullah AlRobaish
Project Fellow, C4IR Saudi Arabia

Fadi AlShammary
SVP, Public Investment Fund (PIF)

Abdullah Asmari
Founder/CTO, SIMAQ

Melisa Atassi
Engagement Lead, World Economic Forum

Ali ElKaafarani
CEO & Founder, PQShield

Rawan Eraqi
Technical Business Developer, Pasqal

Camille Georges
Specialist in Quantum Technology, World Economic Forum

Freeke Heijman
Founder and Chief Executive Officer, Heijman Consultancy

Daniel Loss
Quantum Computing Chair Professor, KFUPM

Somaya Madkhaly
Assistant Professor, Jazan University

Diego Mejias
Quantum Policy Team Lead, Department for Science, Innovation & Technology of the United Kingdom

Naya Nagy
Chief Scientist at Bloch, Assist Prof. at IAU

Shreyas Ramesh
Managing Director, Accenture

Kelly Richdale
Senior Advisor, SandboxAQ

Uzma Siddiqui
CEO and Co-Founder, Quantasphere

Kathryn Timerman
Chief Executive Officer, Chicago Quantum Exchange

Production

Nouf AlRoufaie
Communication Officer, C4IR Saudi Arabia

Mohammed Issa
Designer, Alef Publishing and Media

Endnotes

AL-KINANI, M., & Narayanan, N. (2025, June 18). Saudi Arabia ranks 17th globally in competitiveness index as it outshines economic heavyweights. Arab News. Retrieved September 5, 2025, from https://www.arabnews.com/node/2604922/business-economy.

Aramco. (2024, May 21). Aramco signs agreement with Pasqal to deploy first quantum computer in the Kingdom of Saudi Arabia. Aramco signs agreement with Pasqal to deploy first quantum computer in the Kingdom of Saudi Arabia. https://www.aramco.com/en/news-media/news/2024/aramco-signs-agreement-with-pasqal-to-deploy-first-quantum-computer-in-the-kingdom-of-saudi-arabia.

Bluefors Oy. Company. Bluefors. Retrieved October 15, 2025, from https://bluefors.com/company/

Bureau of Industry and Security. (2024, Sep 5). Department of Commerce implements controls on quantum computing and other advanced technologies alongside international partners. Department of Commerce implements controls on quantum computing and other advanced technologies alongside international partners. https://www.bis.gov/press-release/department-commerce-implements-controls-quantum-computing-other-advanced-technologies-alongside

Capilano ICS. (2025, January 1). NEOM's cutting-edge approach to cybersecurity. NEOM's cutting-edge approach to cybersecurity. https://capilano-ics.com/2025/01/01/neoms-cutting-edge-approach-to-cybersecurity/

Centre for the Fourth Industrial Revolution Saudi Arabia. (2024). Quantum Economy Landscape in Saudi Arabia. December 2024. C4IR Saudi Arabia. https://www.c4irsaudiarabia.org/docs/Quantum%20Economy%20Landscape%20in%20Saudi%20Arabia%20%20(23).pdf

CSA & IMDA. (2023). National Quantum-Safe Network (NQSN+). https://www.imda.gov.sg/about-imda/emerging-technologies-and-research/national-quantum-safe-network-plus.

CSE. (2020–ongoing). Canadian Cryptographic Modernization Program (CCMP). https://apps.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=1742.

Department for Science, Innovation and Technology (DSIT). (2023). National Quantum Strategy. National Quantum Strategy. https://assets.publishing.service.gov.uk/media/6411a602e90e0776996a4ade/national_quantum_strategy.pdf

Desouches, I. (n.d.). Quantum Initiatives Worldwide 2025. Qureca. Retrieved August 28, 2025, from https://www.qureca.com/quantum-initiatives-worldwide/

Ecns. (2024, 02). China makes breakthrough on dilution refrigerator for quantum computing chips. https://www.ecns.cn/news/sci-tech/2024-02-28/detail-ihcychvt6115663.shtml.

ENISA. (2021). Post-Quantum Cryptography: Current state and quantum mitigation. https://www.enisa.europa.eu/publications/post-quantum-cryptography-current-state-and-quantum-mitigation.

ETSI. (2017–2022). ETSI ISG-QKD specifications (e.g., ETSI GS QKD 011, ETSI GS QKD 014).

Extrapolations. (2025, May 8). Fast-tracking next-gen polymers: How SABIC is leveraging machine learning and physics. Fast-tracking next-gen polymers: How SABIC is leveraging machine learning and physics. https://extrapolations.com/fast-tracking-next-gen-polymers-how-sabic-is-leveraging-machine-learning-and-physics/

Grigorian, D. A., Erixon, F., Dugo, A., Pandya, D., & du Roy, O. (2025, March 27). Benchmarking Quantum Technology Performance: Governments, Industry, Academia and their Role in Shaping our Technological Future |. ECIPE. Retrieved August 28, 2025, from https://ecipe.org/publications/benchmarking-quantum-technology-performance/

IBM. (2025, 08 27). Cost of a data breach 2025. IBM. Retrieved August 27, 2025, from https://www.ibm.com/reports/data-breach

ISO/IEC. (2022–2023). ISO/IEC 23837 – Information technology — Security requirements, test and evaluation methods for quantum key distribution (QKD) devices.

ISO/IEC. (2024). ISO/IEC 4879:2024 – Information technology — Quantum computing — Vocabulary.

ITU. (2020–2023). ITU-T Y.3800–Y.3809: Framework and requirements for quantum key distribution networks.

King Fahd University of Petroleum and Minerals. (2024). Registration Records.

McKinsey & Company. (2025). Quantum Monitor 2025: From concept to reality. Quantum Monitor 2025: From concept to reality. https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/the%20year%20of%20quantum%20from%20concept%20to%20reality%20in%202025/quantum-monitor-2025.pdf?shouldIndex=false

Ministry of Economic Affairs and Employment of Finland Helsinki 2025. (2025). Finland's Quantum Technology Strategy 2025–2035. Finland's Quantum Technology Strategy 2025–2035. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/166272/TEM_2025_18.pdf

MIT Initiative on the Digital Economy. (2025). Quantum Index Report. https://qir.mit.edu/wp-content/uploads/2025/06/MIT-QIR-2025.pdf

Mosca, M., & Piani, M. (2024, Dec 6). Quantum Threat Timeline Report 2024. Global Risk Institute. Retrieved August 17, 2025, from https://globalriskinstitute.org/publication/2024-quantum-threat-timeline-report/

National Institute of Standards and Technology. (2024, Feb 9). New IEC/ISO Joint Technical Committee on Quantum Technologies—Inviting participants for the U.S. National Committee Technical Advisory Group. New IEC/ISO Joint Technical Committee on Quantum Technologies—Inviting participants for the U.S. National Committee Technical Advisory Group. https://www.nist.gov/news-events/news/2024/02/new-ieciso-joint-technical-committee-quantum-technologies-inviting

NCA. (2024, July 17). National Cybersecurity Strategy. The National Cybersecurity Strategy | NCA. Retrieved August 17, 2025, from https://nca.gov.sa/en/national-cybersecurity-strategy/

NCSC. (2023). SparQ Programme: Government Playbook for Quantum Transition. https://www.ncsc.gov.uk/.

NEDO & NICT. (2022–ongoing). PQC Research and Field Trials. https://www.nedo.go.jp. https://www.nict.go.jp

NIST. (2022). Post-Quantum Cryptography Standardization. https://csrc.nist.gov/projects/post-quantum-cryptography

Endnotes

NIST. (2025, 1 1). Post-Quantum Cryptography | CSRC | CSRC. NIST Computer Security Resource Center. Retrieved August 17, 2025, from https://csrc.nist.gov/projects/post-quantum-cryptography

PQShield Ltd. (2025). The Financial Market's Transition to Post-Quantum Cryptography. https://content.pqshield.com/the-financial-markets-transition-to-post-quantum-cryptography-1?hs_preview=mnewbwnb-181034414985

QED-C. (2022). Quantum-Safe Migration Guide. https://quantumconsortium.org/

Quantasphere Ltd. (2025). Quantasphere: Empowering healthcare with quantum computing. Quantasphere: Empowering healthcare with quantum computing. https://www.quantasphere.tech/

Quantum Economic Development Consortium (QED-C). (n.d.). Technical Advisory Committees. Technical Advisory Committees. https://quantumconsortium.org/tacs/

Quantum economy blueprint. (2024, January 16). World Economic Forum. https://www.weforum.org/publications/quantum-economy-blueprint/

The Quantum Insider. (2024). Annual Report: The Quantum Economy 2024. https://thequantuminsider.com/wp-content/uploads/2025/01/Public-Annual-Report-for-Publishing0115.pdf

The Quantum Insider. (2025). The Quantum Insider. The Quantum Insider. https://app.thequantuminsider.com/

Regulatory Horizons Council. (2024, February). Regulating Quantum Technology Applications. https://assets.publishing.service.gov.uk/media/65ddc83bcf7eb10015f57f9f/RHC_regulation_of_quantum_technology_applications.pdf

Saudi Arabia Centre for the Fourth Industrial Revolution. (2025). World Quantum Day 2025 Wrap Up Report. Saudi Arabia Centre for the Fourth Industrial Revolution. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.c4irsaudiarabia.org/docs/V5.0%20Wrap%20Up%20Report.pdf

Saudi Press Agency. (2025, April 15). Aramco, Pasqal sign agreement to deploy first quantum computer in Saudi Arabia. Aramco, Pasqal sign agreement to deploy first quantum computer in Saudi Arabia. https://www.spa.gov.sa/en/N2299500

SIMAQ. (2025). SIMAQ. SIMAQ. https://simaq.sa/

UK National Quantum Technologies Programme. (n.d.). NQTP | UK National Quantum Technologies Programme. NQTP | UK National Quantum Technologies Programme. https://uknqt.ukri.org/

U.S. Congress. (2022). CHIPS and Science Act, H.R. 4346, 117th Cong. CHIPS and Science Act, H.R. 4346, 117th Cong. https://www.congress.gov/bill/117th-congress/house-bill/4346

VTT/InstituteQ Finland. (2022–2025). National Cryptographic Strategy and BlimPQC Project. https://www.vttresearch.com/en/news-and-ideas/new-research-project-leads-finland-towards-quantum-safe-future.

WEF. (2022). Quantum Computing Governance Principles. https://www.weforum.org/publications/quantum-computing-governance-principles/.

World Economic Forum. (2022, 09 13). Transitioning to a Quantum-Secure Economy. Transitioning to a Quantum-Secure Economy. https://www.weforum.org/publications/transitioning-to-a-quantum-secure-economy/

World Intellectual Property Organization. (2025). Saudi Arabia ranking in the Global Innovation Index 2025. Saudi Arabia ranking in the Global Innovation Index 2025. https://www.wipo.int/edocs/gii-ranking/2024/sa.pdf

Yan, L. (2024, 11 4). China's self-developed superconducting quantum computer completes 270,000 tasks. ECNS Wire. https://www.ecns.cn/news/cns-wire/2024-11-05/detail-iheitrxu8654737.shtml

Saudi Arabia
Centre for the
Fourth Industrial
Revolution