In collaboration with the Centre for the Fourth Industrial Revolution Saudi Arabia

WORLD ECONOMIC FORUM

Piloting the Quantum Economy Blueprint: Lessons from Saudi Arabia

WHITE PAPER

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Foreword

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Quantum technologies are rapidly transitioning from the laboratory into the realm of strategic policy-making. For governments, the question is no longer whether quantum matters, but how to act responsibly amid uncertain timelines, evolving capabilities and emerging risks. The greatest risks lie not only in technological unknowns, but also in fragmented efforts, delayed coordination and the lack of a shared approach to decision-making amid uncertainty.

Around the world, quantum ambition is accelerating, yet national readiness remains uneven. This unevenness underscores the need for frameworks that assist leaders in organizing early action, aligning diverse stakeholders and anticipating governance, security and ethical considerations before technological trajectories are fully defined. In this context, the World Economic Forum's *Quantum Economy Blueprint* provides a framework for value-led,[1] democratic access to quantum resources.

This publication reflects a collaborative effort between the World Economic Forum and the Centre for the Fourth Industrial Revolution Saudi Arabia to explore how such a global framework can be applied in national contexts. It is not intended as a prescriptive model to be replicated or a forecast of technological outcomes.

By sharing lessons from Saudi Arabia's piloting experience, we aim to assist policy-makers, regulators and industry leaders navigating similar uncertainty, and to enrich the global dialogue on the responsible, inclusive adoption of quantum technologies. As the field continues to evolve, collective learning across countries will strengthen quantum readiness. We hope this publication serves as a practical reference for those seeking to act early, balancing momentum with realism and innovation with responsibility.

Executive summary

Saudi Arabia's piloting of the *Quantum Economy Blueprint* shows how coordination transforms quantum readiness from aspiration to action amid uncertainty.

Quantum technologies are rapidly evolving from laboratory research to economic impact, introducing security challenges that demand near-term attention. Yet developmental trajectories remain inherently uncertain. This uncertainty confronts policy-makers with a strategic dilemma: uncoordinated action risks fragmented ecosystems, while delayed engagement threatens competitiveness and technological leadership. The World Economic Forum's 2024 *Quantum Economy Blueprint* addresses this by offering a structured, value-driven framework to systematically build quantum readiness.

Saudi Arabia, through the Centre for the Fourth Industrial Revolution Saudi Arabia, became the first country to operationalize the blueprint at a national scale. The pilot applied a six-phase methodology encompassing ecosystem mapping, stakeholder engagement, strategic prioritization, benchmarking and codevelopment, feasibility verification and roadmap formulation. The resulting national roadmap, *Towards Saudi Arabia's Quantum-Enabled Future*,[2] was published in December 2025 and provides context-specific recommendations for Saudi Arabia's quantum ecosystem. However, the broader lessons from the implementation experience itself remained to be captured. This white paper seeks to distil key operational and strategic lessons to guide countries and organizations seeking to adapt and implement the blueprint within their own national contexts (Table 1).

The Saudi experience underscores that quantum readiness depends as much on institutional coordination and sustained commitment as it does on technological progress. These findings carry implications well beyond a single national context. Countries at every stage of development are invited to pilot the blueprint, contribute implementation insights and engage in collective learning to strengthen quantum readiness globally.

TABLE 1 **Key lessons from the *Quantum Economy Blueprint* Saudi Arabia pilot**

Four operational lessons on implementing the blueprint emerged:	
National alignment	Anchoring quantum ambition to national development priorities while diagnosing current capabilities, dependencies and constraints
Phased approach	Breaking the quantum journey into stages of learning, alignment and commitment to maintain credibility and avoid premature investment
Multistakeholder alignment	Forging alignment from inception through structured mechanisms where government, academia and industry jointly shape priorities
Expectation management	Sustaining momentum through continuous management of diverse stakeholder perspectives and transparent communication about uncertainties
Five strategic lessons on cultivating quantum ecosystems emerged:	
Talent development	Defining specific quantum workforce needs and aligning education pathways, industry partnerships and career incentives around them
Hardware access	Mapping hardware dependencies early and developing diversified access strategies combining cloud platforms, partnerships and targeted investment
Innovation and commercialization	Bridging the research-to-market gap through mission-driven agendas, enabling infrastructure, government co-investment and support for spin-outs
Decision-maker awareness	Targeted engagement with senior policy-makers connecting quantum to national priorities
Governance and security foundations	Early establishment of standards and regulatory mechanisms, embedding responsibility through policy instruments and prioritizing post-quantum cryptography (PQC) planning

Introduction

Quantum readiness requires early, coordinated action amid uncertainty to prevent a widening technological divide and enable inclusive pathways forward.

The global economy stands at an inflection point where quantum technologies are fundamentally reshaping industrial competitiveness, national security and technological resilience. The strategic imperative for policy-makers has shifted decisively: the question is no longer whether quantum capabilities will prove consequential, but rather at what pace readiness should be cultivated and through which institutional mechanisms. The quantum economy emerges from three interdependent quantum technologies, each progressing along distinct maturity trajectories (Table 2).

TABLE 2 **Overview of quantum technologies**

Technology	Description	Current maturity
Quantum computing	Harnesses quantum mechanics principles to solve problems that classical computers cannot solve efficiently, from molecular simulation enabling drug discovery and materials design to optimization, transforming logistics and financial modelling	Currently in the early stages of development, with limited quantum advantage demonstrated in specific use cases
Quantum communications	Enables secure transmission of quantum information and will ultimately support distributed quantum computing and networked quantum sensors	Currently in pilot and demonstration phase, with quantum key distribution networks operational in limited regions
Quantum sensing	Achieves unprecedented precision in measuring time, gravity, magnetic fields and other physical properties, unlocking applications from GPS*-independent navigation to underground resource mapping and critical infrastructure monitoring	The most mature of the three technologies, with commercial applications already deployed in timing and navigation

Note: *Global positioning system

Source: World Economic Forum. (2025). *Embracing the quantum economy: A pathway for business leaders*; US Government Accountability Office. (2025). *Science & tech spotlight: Quantum sensors*. https://www.gao.gov/products/gao-25-107876.

These quantum technologies share fundamental interdependencies. They rely on overlapping supply chains, draw from common talent pipelines and require complementary enabling infrastructure. Importantly, they do not exist in isolation from other emerging technologies. Quantum computing is already being integrated with classical supercomputers to augment computational capabilities.[3] Quantum sensing enhances navigation and precision in autonomous systems, including in GPS-denied environments.[4] Quantum communications secure digital infrastructure.[5]

Recognition of these interconnections is essential; fragmented quantum initiatives that treat each quantum technology in isolation lead to misaligned investments and missed opportunities for coordinated development across the quantum technologies.[6] This convergence is forming a distinctive economic ecosystem that extends well beyond traditional quantum physics laboratories into manufacturing, energy, healthcare, finance and national security applications. Collectively, they are defining what is increasingly referred to as the quantum economy.

The global quantum landscape

Current estimates project that quantum computing could generate up to $1.3 trillion in economic value for four key industries (automotive, chemicals, financial services and life sciences) by 2035.[7]

Global public investment now exceeds $40 billion, with over 40 countries having launched quantum strategies since 2018 (Figure 1).[8]

FIGURE 1 | **The timeline of quantum technology momentum internationally**

2014
- **UK ▲** National Quantum Technologies Programme

2016
- **China ✳** 13th Five-Year Plan (quantum included)
- **Europe ✳** QuantERA ERA-NET Cofund

2017
- **China ✳** National Quantum Communication Network

2018
- **US ▲** National Strategic Overview for Quantum Information Science (QIS); National Quantum Initiative (NQI) Act
- **Europe ▲** Quantum Technologies Flagship
- **Japan ✳** Quantum Leap Flagship Program
- **Germany ▲** Framework Programme for Quantum Technologies

2019
- **Israel ▲** National Quantum Initiative
- **Netherlands ▲** National Agenda on Quantum Technology
- **US ▲** National Quantum Initiative (enacted)
- **Europe ✳** European Quantum Communication Infrastructure (EuroQCI) Declaration
- **China ✳** Committee for Quantum Standardization

2020
- **US ▲** Strategic Vision for Quantum Networks
- **Japan ▲** Quantum Technology and Innovation Strategy
- **India ▲** National Mission on Quantum
- **Europe ▲** Strategic Research Agenda
- **China ✳** Quantum Shield Action
- **Russia ✳** Quantum Computing Roadmap

2021
- **Taiwan, China ▲** Quantum National Program
- **Netherlands ▲** Quantum Delta
- **France ▲** National Quantum Strategy (Plan Quantique)
- **Austria ✳** Quantum Austria Funding Initiative
- **China ✳** 14th Five-Year Plan (quantum as frontier tech)
- **Europe ✳** European High Performance Computing Joint Undertaking quantum integration
- **South Korea ▲** National Strategic Plan for Quantum Science and Technology

2022
- **US ▲** CHIPS and Science Act quantum provisions; national storage mechanisms
- **Japan ▲** Vision of Quantum Future Society
- **Germany ✳** Quantum Systems Research Program update

2023
- **Ireland ▲** Quantum 2030
- **Australia ▲** National Quantum Strategy
- **India ▲** National Quantum Mission
- **Germany ▲** Quantum Action Concept
- **Denmark ▲** National Strategy for Quantum Technology
- **UK ▲** National Quantum Strategy
- **South Korea ▲** Quantum Science and Technology Strategy update
- **Japan ▲** Strategy of Quantum Future Industry Development
- **Canada ▲** National Quantum Strategy
- **Switzerland ▲** Swiss Quantum Initiative

2024
- **Singapore ▲** National Quantum Strategy
- **NATO ✳** Quantum Technologies Strategy
- **Romania ▲** National Strategy for Quantum Technologies
- **Japan ✳** Quantum Industry Development updates
- **Philippines ✳** Quantum Technology R&D Roadmap

2025
- **Spain ▲** Quantum Technologies Strategy
- **Italy ▲** Italian Strategy for Quantum Technologies
- **Norway ▲** Quantum Technology Initiative
- **Europe ▲** Quantum Europe Strategy
- **Slovenia ▲** Strategy for Development of Quantum Technology
- **Czechia ▲** National Strategy for Quantum Technologies
- **Finland ▲** Quantum Technology Strategy
- **Indonesia ✳** National Quantum Security Roadmap

2026
- **Switzerland ▲** National Quantum Strategy
- **UK ▲** Quantum Programme
- **China ✳** 15th Five-Year Plan (prioritizes quantum computing)

▲ Dedicated strategy ✳ Other policy milestone

Europe · Americas · Asia-Pacific · Multinational

Notes: Non-exhaustive, as of March 2026. ✳ Not a standalone national strategy: funding programmes, infrastructure projects or provisions in broader legislation.

Source: Adapted from Organisation for Economic Co-operation and Development (OECD). (2025). *An overview of national strategies and policies for quantum technologies*. Updated using data from the Quantum Insider database (a part of Resonance).

Delayed action on quantum readiness carries severe and compounding consequences. Just as the digital divide left 2.2 billion people offline,[9] the quantum divide threatens to entrench lasting disparities. Unlike the digital divide, quantum readiness cannot be remediated through technology transfer later. Quantum technologies have significant dual-use potential, serving civilian and military purposes simultaneously. This has prompted major international powers to implement targeted export controls and tighten restrictions on international collaboration.[10] Specialized talent pipelines, hardware supply chains and governance frameworks each demand years of concurrent development. They cannot be rapidly assembled once quantum systems achieve operational maturity.

Countries that postpone building foundational capabilities therefore face a compounding risk: widening capability gaps, growing vulnerability as quantum computing threatens to break existing encryption protocols and permanent exclusion from shaping the international standards and norms that will govern the quantum economy.[11]

Shared frameworks for quantum strategies

Quantum technologies present a distinct strategic challenge: policy imperatives emerge before technological maturity crystallizes. Unlike other emerging technologies, this urgency is not driven by consumer adoption or observable social risk. It is driven by the abrupt failure of cryptographic systems and critical infrastructure once quantum capability thresholds are crossed, with consequences that cannot be remediated by later intervention.[12]

Quantum strategies diverge sharply across countries, even as global investment accelerates. This reflects both uncertainty about which technical approaches, timelines and capability domains will prove most viable, and the reality that different national contexts will lead to distinct pathways.[13]

In such an environment, shared reference points become a strategic asset. International structured frameworks provide leaders from all countries with a common foundation for assessing quantum readiness, sequencing investments and aligning governance, supporting more efficient strategy development, ensuring national efforts remain internationally compatible and reducing the risk of a widening quantum divide.

These shared frameworks address four imperatives faced by countries when developing their quantum strategies:

1. **Acting despite technological uncertainty**: Quantum technologies face open questions across multiple dimensions: underlying physics, technology development pathways and societal implications (Table 3). A shared framework enables nations to advance systematically while these questions remain unresolved, rather than becoming paralysed by uncertainty or rushing to lock in specific platforms prematurely.

TABLE 3 **Key sources of uncertainty in quantum technology**

Type of uncertainty	Impact
Underlying physics (scientific/ontological)	Fundamental unknowns persist across all quantum technology domains. In quantum computing, questions remain around which qubit modalities (e.g. superconducting, trapped-ion, neutral atoms, photonics, topological) will ultimately prove viable, making early platform bets inherently high-risk. In quantum sensing, coherence time and real-world sensitivity limits remain unresolved. In quantum communications, photon loss and transmission distance remain open physical challenges.
Technology development (engineering)	Significant engineering challenges persist across all three quantum technology domains. Quantum computing faces hurdles in qubit control, cryogenic systems, materials, error mitigation and hardware–software integration. Quantum sensing confronts miniaturization and reliable field deployment. Quantum communications require scalable repeater networks and interoperability with existing infrastructure. Uncertainty around timelines, costs and performance constrains investment decisions across all domains.
Societal effects (sociotechnical)	Quantum breakthroughs carry broad societal implications across all three domains. Quantum computing threatens current cryptographic systems, with significant consequences for cybersecurity, privacy and economic structures. Quantum sensing raises concerns around precision surveillance and physical privacy. Quantum communications introduce questions around data and access equity. Geopolitical factors compound these uncertainties: export controls, talent mobility restrictions and strategic competition risk entrenching a quantum divide. Governance and regulatory frameworks remain underdeveloped across all domains.

Source: Authors' analysis based on Meckel, M. et al. (2025). *The Goldilocks zone of governing technology: Leveraging uncertainty for responsible quantum practices*. Quantum Economics and Finance. https://arxiv.org/pdf/2507.12957.

2. **Coordinating fragmented efforts**: Quantum capabilities are distributed across academic institutions, government laboratories and private-sector entities. Without coordination, actors duplicate investments and leave critical capability gaps unaddressed. Such frameworks establish common priorities and sequence implementation across the national ecosystem.

3. **Making strategic choices**: Not all nations can or should lead across all quantum domains. Such frameworks support rigorous self-assessment, enabling leaders to identify where to build domestic capability, where to partner internationally and where to adopt external solutions. Different entry points present distinct trade-offs: high-barrier, high-gain areas such as hardware and components require substantial capital but offer greater competitive advantages, while low-barrier, low-gain areas like software and tools allow faster entry with lower initial investment but potentially smaller strategic returns.

4. **Addressing risks proactively**: Quantum technologies introduce long-term security risks and supply chain dependencies requiring early intervention. Such frameworks integrate technology governance and resilience considerations from the outset, rather than as costly afterthoughts.

In short, international shared frameworks transform quantum from a collection of isolated technical initiatives into a coherent national strategy, enabling countries to progress from awareness to readiness and ultimately to sustained participation in the emerging quantum economy.

> **The Kingdom of Saudi Arabia shows that international collaboration in quantum is truly a two-way street: by opening up to expertise from around the world and piloting the Forum's *Quantum Economy Blueprint*, it both accelerates its own capabilities and contributes to a more inclusive global quantum ecosystem. Even though the United Nations Educational, Scientific and Cultural Organization's (UNESCO) International Year of Quantum has concluded, this leadership underlines why quantum technologies must remain high on national and international agendas.**
>
> Freeke Heijman, Vice-President, European Quantum Industry Consortium (QuIC)

The Forum's *Quantum Economy Blueprint*

> **Rather than prescribing uniform models, the blueprint provides a flexible and modular approach that countries can align with their national context and development stage.**

In response to the strategic significance of quantum technologies and the uncertainties they present, the World Economic Forum developed the *Quantum Economy Blueprint*.[14] The blueprint serves as a guide for policy-makers, industry and academia to build national quantum ecosystems, covering strategy development, workforce development, governance, security and responsible innovation. Rather than prescribing uniform models, it provides a flexible and modular approach that countries can align with their national context and development stage.

At its core, the blueprint is anchored in the values of responsible innovation and effective governance:

- Transparency in decision-making processes
- Accountability for outcomes
- Inclusiveness in stakeholder engagement
- Equity in access and benefit distribution
- Non-maleficence in application development
- Accessibility across societal domains
- Orientation towards collective welfare

These values function as strategic guideposts rather than prescriptive compliance requirements, enabling decision-makers to navigate inherent tensions between acceleration and precaution, openness and security, near-term opportunities and long-term public interest.

Building on this foundation, the blueprint comprises a set of interconnected thematic domains and structural building blocks that constitute functional quantum ecosystems: capability development pathways, governance and security frameworks, innovation enablement mechanisms and collaborative infrastructure. These thematic domains are designed for simultaneous consideration rather than sequential implementation, supporting holistic assessment of readiness levels and systemic interdependencies across national ecosystems (Figure 2).

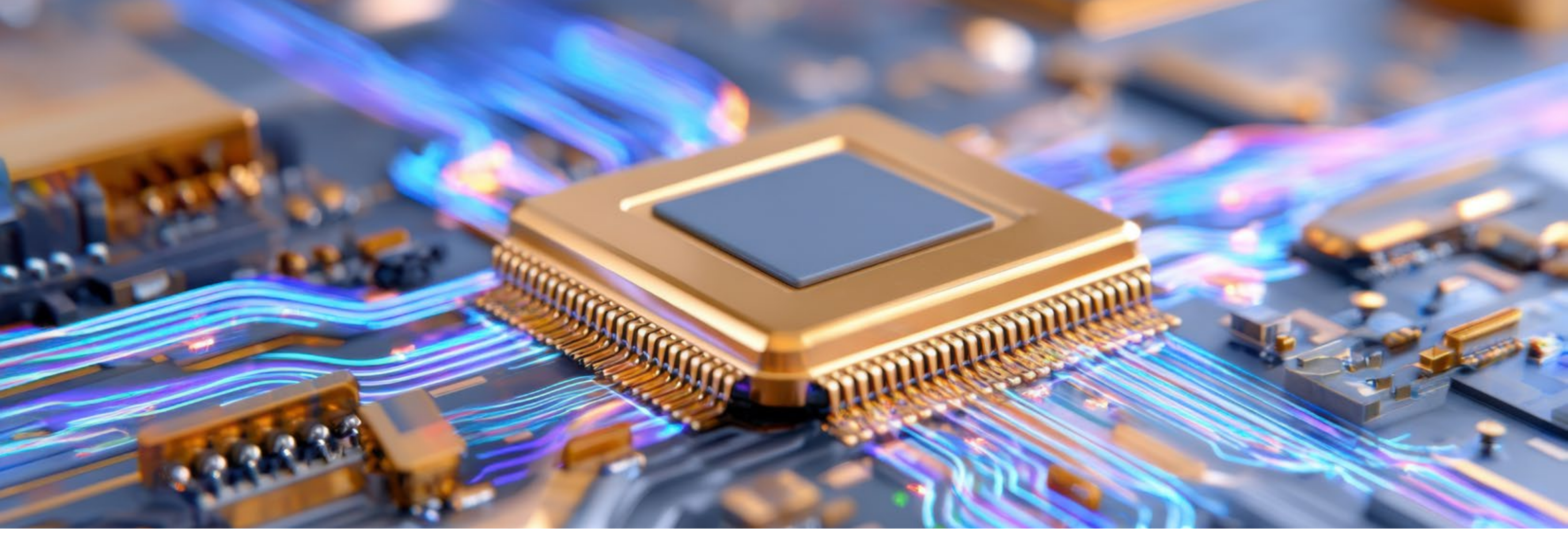

FIGURE 2 | ***Quantum Economy Blueprint* themes and building blocks**

Source: World Economic Forum. (2024). *Quantum Economy Blueprint*.

1 Saudi Arabia's leadership in piloting the blueprint

Saudi Arabia's operationalization of the blueprint reveals how a structured, multistakeholder process can convert fragmented quantum efforts into a cohesive national roadmap.

The pilot demonstrated that the framework can be effectively adapted to distinct national contexts, translating global guidance into concrete implementation pathways.

In 2024, Saudi Arabia became the first country to pilot the *Quantum Economy Blueprint* at a national scale, transforming the global framework into context-specific implementation pathways. The decision addressed a pressing challenge: while quantum activities were expanding across universities, national laboratories, corporations and start-ups, efforts remained fragmented and lacked formal coordination mechanisms.

The pilot served three strategic imperatives. First, Vision 2030's focus on economic diversification positioned quantum technologies as an enabler for knowledge-intensive job creation in priority sectors such as energy, healthcare and finance. Second, cultivating technological resilience required discerning which capabilities needed domestic development and which were suited to strategic partnerships. Third, post-quantum cryptography (PQC) posed immediate security implications as Saudi Arabia accelerated its digital transformation across government services and critical infrastructure.

The pilot demonstrated that the framework can be effectively adapted to distinct national contexts, translating global guidance into concrete implementation pathways. The pilot identified sectors where national strengths in energy systems and petrochemicals offered natural quantum applications while surfacing capability gaps that informed strategic prioritization.

The pilot advanced through six structured phases, led by the Centre for the Fourth Industrial Revolution Saudi Arabia in partnership with the World Economic Forum, to adapt the blueprint to Saudi Arabia's national context (Figure 3).

FIGURE 3 | **Phases of implementing the blueprint in Saudi Arabia**

Phase 1

Ecosystem mapping

Analysed Saudi Arabia's quantum landscape, mapping existing initiatives, education and research capabilities, industry engagement and infrastructure across the national ecosystem. This established a shared baseline identifying where activities concentrated and where critical gaps persisted.

Phase 2

Stakeholder engagement

Convened stakeholders across government, academia and industry through a steering committee and thematic workstreams to surface divergent perspectives on quantum urgency, technological feasibility and strategic priorities. This approach achieved stakeholder buy-in by reconciling perspectives that viewed quantum either as a long-term research pursuit or an immediate cybersecurity imperative.

Phase 3

Strategic prioritization

Contextualized the blueprint themes within Saudi Arabia's strategic environment, selecting 16 building blocks across seven thematic domains aligned with current institutional maturity and achievable near-term impact. This deliberate focus prioritized initiatives that could be implemented credibly within existing capacities, rather than pursuing comprehensive coverage prematurely.

Phase 4

Benchmarking and codevelopment

Assessed the Kingdom's quantum position relative to international peers, and codeveloped policy recommendations for each building block (Figure 4). This provided evidence-based framing for ambition levels and identified areas requiring accelerated development.

Phase 5

Feasibility validation

Conducted iterative technical review cycles with local and international quantum experts to stress-test feasibility and refine recommendations.

Phase 6

Roadmap formulation

Synthesized insights from previous phases into actionable implementation pathways with proposed timelines and ways forward.

Source: Centre for the Fourth Industrial Revolution Saudi Arabia.

Throughout the pilot, a steering committee comprising senior representatives from government, academia and industry provided strategic oversight across all six phases. Four thematic workstreams operated under co-leadership models involving government ministries, academic research institutions and industry representatives. This structure enabled the pilot to coordinate across institutional boundaries, sequence investments strategically and prioritize foundational enablers.

> **Quantum readiness requires both strategic foresight and disciplined experimentation. While architectural blueprinting sets technical direction, early adoption validates its business outcomes and usefulness.**
>
> Salih A. AlSubai, Technology Strategy and Architecture Vice-President, Saudi Telecom Company (STC)

The pilot resulted in a national quantum economy roadmap and policy recommendations tailored to Saudi Arabia's capabilities and strategic priorities, published in *Towards Saudi Arabia's Quantum-Enabled Future*.[15] These policy recommendations are organized across seven thematic domains, reflecting the 16 building blocks selected based on Saudi Arabia's current institutional maturity and near-term priorities (Figure 4).

FIGURE 4 | **Key messages and policy recommendations from Saudi Arabia's quantum roadmap**

Theme	Key message	Policy recommendations
Value chain analysis	Quantum technologies offer vast opportunities. A national strategy harnessing 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** by expanding specialized laboratories. **Pursue a dual-track strategy** for competitiveness and independence.
Hardware and supply chain	Quantum technologies need resilient, locally supported supply chains.	**Create a national quantum centre** to coordinate the national effort. **Map and close critical supply chain gaps**. **Develop global partnerships**, and domestic fabrication and manufacturing.
Workforce development	Talent is key to innovation; specialist quantum engineers and technicians drive capability and leadership.	**Expand quantum education** and vocational training. **Strengthen academia-industry ties** through joint projects and mission-led strategy. **Promote quantum literacy** for policy-makers and industry managers. **Attract global talent** and expertise.
Innovation and commercialization	Focused funding and global alignment on standards, interoperability and governance help turn research into economic value.	**Prioritize industry use cases** with potential commercial use. **Use public procurement** to kick-start formation of early markets and grow investor confidence. **Create national hubs** and align with global standards.
Awareness	Public confidence underpins governance and strategic investment.	**Launch national dialogues**, industry forums and quantum ambassador programmes. **Develop coordinated central quantum awareness initiatives** and outreach programmes. **Share relatable success stories** to inspire trust.
Governance and standards	Adaptive governance ensures innovation with trust and accountability.	**Form a national quantum governance programme** to coordinate strategy, funding and regulations. **Train regulators and officials** for foresight exercises. **Develop certification and regulatory sandboxes** for technology testing and validation.
Cybersecurity	Set and update national encryption standards to prepare for the post-quantum era.	**Saudi National Cybersecurity Authority is working on updating the National Strategy for Cybersecurity**, which has initiatives related to managing the cyber risks related to emerging technologies including quantum computing.

Source: Centre for the Fourth Industrial Revolution Saudi Arabia. (2025). *Towards Saudi Arabia's Quantum-Enabled Future: Piloting the World Economic Forum's Quantum Economy Blueprint*.

The pilot's implementation experience also yielded benefits while exposing challenges across strategic foundations, coordination, capabilities, awareness and process dimensions (Table 4).

TABLE 4 **Key benefits and challenges from the Saudi pilot**

	Benefits	Challenges
Strategic foundations	– Anchored quantum to Vision 2030 priorities – Early supply chain mapping revealed dependencies	– Balancing global best practices with local feasibility – Managing stakeholders' divergent views on urgency and timelines
Coordination	– Co-leadership cultivated shared ownership across sectors	– Varying institutional and technical readiness levels across stakeholders
Capabilities	– SWOT (strengths, weaknesses, opportunities and threats) and gap analysis surfaced hidden constraints	– Limited availability of quantum specialists amid rising global demand – Hardware accessibility mediated by geopolitical considerations
Awareness	– Shifted mindset from "What is quantum?" to "What is our role?"	– Translating concepts beyond expert communities – Expectation management across stakeholders
Process	– Generated reusable lessons for global community – Demonstrated viability of localizing frameworks	– No existing playbook, learning through iteration – Balancing ambition with realism

Source: Centre for the Fourth Industrial Revolution Saudi Arabia.

This white paper builds on those outcomes with a distinct yet complementary purpose: to extract transferable lessons from the implementation experience itself. It examines how those recommendations were developed and what the process revealed about advancing quantum readiness under sustained uncertainty.

2 Lessons from Saudi Arabia's pilot

Nine lessons from Saudi Arabia's pilot distil what it takes to move from quantum ambition to coordinated national action amid uncertainty.

The Saudi pilot of the *Quantum Economy Blueprint* generated two types of lessons: **operational lessons** on how to implement the blueprint, and **strategic lessons** on which efforts to prioritize. Analysing the pilot's results, consulting with participants and observing the implementation highlighted these lessons.

Section 2.1 examines operational lessons on implementing the blueprint amid uncertainty. These lessons stem from contextual localization, a phased approach, multistakeholder alignment, expectation management and intergovernmental alignment.

Section 2.2 explores strategic lessons and what to prioritize when building quantum capabilities. This includes human capital development, infrastructure readiness, innovation ecosystems, public awareness and governance frameworks.

The objective is to provide reference points for diverse national pathways to quantum readiness, not to advocate replication of Saudi Arabia's approach. Their relevance will vary depending on national context, stage of development and strategic priorities. Appendix A1 provides diagnostic questions to support self-assessment for each lesson.

2.1 Operational lessons for implementing the blueprint

Through the piloting process, several operational lessons emerged that may inform how public institutions, regulators and coordinating entities apply such frameworks in evolving national contexts.

OPERATIONAL LESSON 1

Localization through alignment with national priorities builds the foundation for meaningful progress

Global frameworks provide direction, but meaningful progress depends on aligning them with national priorities and institutional realities. Without clear links to domestic development goals and existing capabilities, quantum initiatives risk losing momentum when competing policy priorities emerge.

Saudi Arabia anchored the blueprint to Vision 2030 priorities from the outset. During the scoping phase, the country conducted a SWOT assessment of national quantum capabilities alongside a value chain analysis identifying potential economic applications. This dual approach connected quantum initiatives to national missions, including economic diversification, national security, healthcare innovation and Saudi Arabia's ambition to become a regional technology hub.

A persistent challenge emerged during this localization process: accurate self-assessment. Unlike digital transformation, where infrastructure and skills can be measured relatively objectively, quantum readiness spans multiple dimensions at varying maturity levels. These include research capability, industrial engagement, talent availability, policy frameworks and infrastructure access. Nations often overestimate visible activity, like academic output, while overlooking gaps in foundational enablers like specialized skills or infrastructure.

Countries benefit from grounding quantum initiatives in clearly defined national objectives while conducting rigorous, benchmarked capability assessments. Early diagnostics help prevent unrealistic ambitions and guide strategic prioritization across the quantum value chain.

Key takeaway: Localization provides the foundation for meaningful quantum readiness. Anchoring quantum ambitions to national priorities while systematically assessing capabilities, dependencies and constraints strengthens long-term momentum.

OPERATIONAL LESSON 2

Phased approaches convert uncertainty into manageable progression

Application of the blueprint highlighted the role of a phased approach in navigating early-stage uncertainty. Rather than forcing singular, high-stakes decisions, phased methodologies deconstruct uncertainty into manageable stages of learning, alignment and commitment.

Saudi Arabia's pilot progressed through six phases over approximately two years: ecosystem mapping, stakeholder engagement, strategic prioritization, benchmarking and co-development, feasibility validation and roadmap formulation. Each phase generated new insights that informed the next stage, enabling iterative refinement of priorities.

The incremental progression allows this structure to absorb external shifts (such as breakthroughs in quantum error correction) without disrupting completed work. It also accommodates uneven sectoral readiness, allowing stakeholders to contribute at varying levels of maturity rather than requiring uniform milestone achievement.

Breaking implementation into structured stages avoids two extremes: paralysis from over-analysis and premature commitment before clarity emerges. This sequencing allows nations to adapt to change while maintaining coherent, disciplined progression towards quantum readiness.

Key takeaway: Phased approaches deconstruct the quantum journey into stages of learning, alignment and commitment. This disciplined progression maintains credibility, enables adaptation and avoids risks of premature investment or paralysing over-analysis.

OPERATIONAL LESSON 3

Early multistakeholder engagement creates alignment that late-stage coordination cannot achieve

Quantum ecosystems span government, academia and industry. Alignment among these actors stems not only from analytical design, but from proactive engagement while priorities are still taking shape.

In Saudi Arabia, the pilot structured this engagement around four thematic workstreams co-led by representatives from different sectors:

- **Building foundation (led by academia)**: consolidated universities and research organizations to tackle infrastructure, education and workforce development

- **Cultivating innovation and ecosystem growth (led by industry)**: engaged major corporations and investment groups to concentrate on commercialization and industrial collaboration

- **Ensuring responsible use (led by government)**: worked with regulators and security agencies to ensure governance, security and regulatory frameworks

- **Unlocking societal benefits (led by the C4IR Saudi Arabia in collaboration with local partners)**: cultivated public awareness and societal engagement through World Quantum Day celebrations, webinar programming and strategic outreach in priority sectors

This structure enabled shared problem-solving across institutional boundaries.

Coordinating across institutional boundaries requires reconciling different sector timelines, priorities and definitions of success. Academic, government and industry stakeholders brought fundamentally different expectations about urgency and feasibility, and structured dialogue was required to reconcile these perspectives.

Early multistakeholder engagement helps surface conflicting assumptions and overlapping mandates before implementation begins. Establishing collaborative structures from the outset enables shared ownership of national quantum strategies.

Key takeaway: Early multistakeholder engagement surfaces conflicting assumptions, overlapping mandates and differing expectations about urgency and feasibility before implementation begins. This enables collaborative solutions and shared ownership of national strategy.

> **Engagement in planning Saudi Arabia's quantum economy has built working connections across diverse stakeholders that extend beyond quantum technologies to other research and development (R&D) sectors. It has also provided a welcome mandate to promote quantum computing within KAUST.**
>
> David E. Keyes, Founding Dean and Founding Director, Extreme Computing Research Center, King Abdullah University of Science and Technology (KAUST)

OPERATIONAL LESSON 4

Expectation management is as critical as technical planning

Deploying the blueprint revealed that momentum was influenced equally by expectation management and technical readiness. Stakeholder perceptions of quantum maturity vary widely, from optimism about near-term breakthroughs to scepticism about feasibility, shaping project pacing, confidence and sustained engagement.

The pilot addressed this through transparent communication about the evolving state of quantum technologies and the uncertainties surrounding timelines and capabilities. Discussions acknowledged the diversity of perspectives across stakeholders, particularly the dominance of quantum computing narratives compared with the more gradual development of sensing and communications. Equally important, sectors operate at different institutional speeds, and some approval processes diverged significantly from the project timeline.

This revealed that expectation management must account not only for perceptions of technological maturity but also for the institutional rhythms that govern how quickly different stakeholders can commit and act.

Unmanaged expectations undermine credibility and stakeholder engagement. Failing to anticipate institutional pacing constraints risks losing engaged stakeholders who support the vision but cannot match the timeline, fragmenting coalitions that took considerable effort to build.

Key takeaway: Sustaining momentum depends on active, continuous expectation management alongside technical progress. Countries benefit from recognizing diverse stakeholder perspectives and establishing transparent, collective sense-making mechanisms that address uncertainties and timelines.

2.2 Strategic lessons for cultivating a national quantum ecosystem

The lessons below detail findings from the blueprint's application. They offer practical guidance to policy-makers designing coordinated, future-ready quantum strategies.

STRATEGIC LESSON 1

Building a quantum-ready workforce

The blueprint identifies workforce development as a foundational pillar of a functioning quantum ecosystem. It emphasizes the importance of building quantum-literate talent pipelines spanning multiple levels of expertise, including researchers, engineers, technicians and policy-makers. Strengthening these pipelines requires coordinated investments in education, interdisciplinary training and inclusive participation to ensure that nations possess the human capital necessary to develop, deploy and govern quantum technologies.

Saudi Arabia's pilot illustrated how complex workforce development becomes in practice. Discussions across academia, government and industry revealed that "quantum talent" encompasses multiple roles extending far beyond quantum physicists alone. Workforce needs include algorithm designers, cryogenic engineers, fabrication specialists, systems engineers and application experts capable of translating quantum capabilities into industrial use cases. These distinct roles require different educational pathways, institutional partnerships and career structures.

Quantum education benefits from early exposure: foundational concepts introduced at school level build long-term literacy and interest. An integrated pathway from STEM (science, technology, engineering and mathematics) foundations through multi-disciplinary quantum engineering programmes strengthens the pipeline at every stage. Strong industry-academia partnerships help anchor talent locally by connecting education to real applications and employment opportunities, while national quantum strategies provide essential signalling functions that align institutions and sustain workforce momentum.

However, a recurring challenge emerged: workforce pipelines often develop without clear alignment to anticipated industry demand. This challenge is compounded by competition from adjacent fields such as artificial intelligence (AI), which intensifies the global race for technical talent. Without visible career pathways, sustained funding and clear national commitment, countries risk losing promising researchers and engineers to better-established technology sectors or international opportunities.

Key takeaway: Countries that clearly define the quantum workforce capabilities they require and align education pathways, industry partnerships and career incentives around those needs are better positioned to sustain long-term talent development and retain expertise within their national ecosystems.

> **The foundational requirement for the quantum era is not the hardware itself, but the development of human expertise. To truly lead this field, it is a necessity to cultivate the next generation of professionals, engineers and scientists, enabling them to bridge the gap between abstract physics and real-world industrial application.**
>
> Daniel Loss, Director, Interdisciplinary Research Center for Advanced Quantum Computing; Chair Professor, King Fahd University of Petroleum and Minerals (KFUPM)

STRATEGIC LESSON 2

Expanding access to quantum hardware and infrastructure

The blueprint highlights access to quantum hardware, materials and enabling infrastructure as a critical enabler of national ecosystem development. Given the high cost, technical complexity and geographic concentration of quantum hardware, policy-makers must consider long-term strategies to safeguard reliable access to quantum platforms while balancing domestic capability development with international collaboration.

Saudi Arabia's pilot demonstrated that hardware access influences multiple dimensions of quantum readiness simultaneously. Academic institutions, research centres and industry partners consistently emphasized that access to quantum processors and experimental infrastructure is essential for research productivity, workforce training and algorithm development. The pilot also revealed the importance of early supply chain mapping to understand dependencies across components, materials, fabrication processes and specialized equipment.

A significant strategic challenge lies in geopolitical constraints and emerging export controls that may limit hardware availability. High costs and technical barriers further concentrate quantum hardware in a small number of countries and companies, increasing the risk of a widening quantum divide between nations with established quantum infrastructure and those without.

Key takeaway: Hardware access is both a technical and strategic consideration. Countries that map hardware dependencies early and develop diversified access strategies – including cloud platforms, international research partnerships and targeted infrastructure investments – can participate meaningfully in the quantum ecosystem even where direct hardware ownership remains limited.

STRATEGIC LESSON 3

Bridging the research-to-market gap

The blueprint emphasizes the importance of linking research, development and commercialization to unlock the economic value of quantum technologies. Strong innovation ecosystems require collaboration across universities, start-ups, industry partners and government agencies to translate scientific advances into scalable products, services and applications.

Saudi Arabia's pilot revealed that the transition from research to commercial deployment remains one of the most persistent challenges in quantum development. While academic institutions produced strong research activity, investors and industry stakeholders emphasized the need for clearer pathways connecting research outputs to real-world applications. Discussions with industry participants highlighted three recurring conditions for investment: accessible infrastructure, credible government commitment to strategic applications, and demonstrable industry demand. Early engagement from major industry players such as Aramco provided validation and signalled market credibility, helping de-risk quantum investments for other potential adopters.

Another insight concerned the importance of structured pathways for university spin-outs and technology transfer, ensuring that research outputs can move towards application through clear intellectual property (IP) frameworks, proof-of-concept funding and industry partnerships.

Government leadership plays a catalytic role in this process. When governments actively coordinate, fund and promote the quantum agenda, it signals commitment, lowers perceived investment risk and creates conditions for mission-driven research agendas that connect laboratory advances to real-world applications.

Key takeaway: Closing the research-to-market gap requires mission-driven agendas, accessible infrastructure, government co-investment, support for spin-outs and technology transfer, and early industry adoption. Countries that align research with strategic priorities while cultivating industry partnerships are better positioned to capture value from quantum investments.

STRATEGIC LESSON 4

Building shared understanding among decision-makers

The blueprint identifies awareness and education among policy-makers and senior decision-makers as essential components of national quantum readiness. Building informed leadership across government institutions enables strategic planning, resource allocation and policy coordination that support long-term quantum development.

Saudi Arabia's pilot revealed that meaningful awareness does not emerge primarily through broad public campaigns. Instead, momentum developed when senior policy-makers began shifting from asking "What is quantum?" to asking "What is our role in it?". In the pilot, this shift occurred through targeted engagement at key moments in the roadmap process, supported by trusted technical experts who could translate complex concepts into policy-relevant terms.

A persistent gap remains, however, in framing quantum for audiences beyond expert communities. Anchoring the narrative in economic resilience, national security and technological leadership makes quantum tangible for decision-makers and builds the institutional backing needed for sustained investment and cross-government coordination.

Key takeaway: Securing decision-maker commitment requires strategic, targeted engagement rather than broad awareness campaigns. Success comes from connecting quantum to national priorities such as economic competitiveness, security and technological leadership through credible technical voices.

STRATEGIC LESSON 5

Embedding governance and security from the outset

The blueprint emphasizes that successful national or regional quantum strategies require governance frameworks to be integrated from the outset rather than added retrospectively. Drawing on the *Quantum Computing Governance Principles*,[16] the blueprint positions transparency, accountability, inclusiveness, equity, non-maleficence and accessibility as core elements guiding responsible quantum development.

Saudi Arabia's pilot showed that these principles become actionable only when anchored in institutional coordination and concrete policy instruments. Effective governance of quantum technologies depends on establishing dedicated regulatory and standards bodies early, ideally through government-initiated entities capable of aligning ethical oversight and standardization for responsible development. This approach would help reduce fragmentation across institutions and ensure that ethical principles are translated into operational practices rather than remaining aspirational statements.

Two dimensions proved particularly urgent. First, PQC migration requires years of preparation across government and critical infrastructure. Embedding PQC planning into national quantum roadmaps early allows countries to manage this transition systematically rather than reacting to threats under time pressure. Second, governance frameworks must also account for the evolving scope of quantum communications. Quantum communications strategy should encompass more than encryption alone. A comprehensive approach includes integrated quantum networking infrastructure capable of supporting distributed computing, advanced sensing and scalable secure communications.

Early integration of technology governance and security frameworks can help countries avoid the significantly higher costs and complexity associated with addressing these considerations retrospectively. Delayed engagement also risks limiting national influence over emerging international standards and governance norms shaping the quantum economy.

Key takeaway: Governance, ethics and security are not afterthoughts, they are foundational enablers that shape the trajectory of quantum readiness. Establishing standards and regulatory mechanisms early, embedding responsibility through concrete policy instruments and prioritizing PQC planning enables effective quantum preparedness. While encryption capabilities merit attention, quantum communications strategies benefit from encompassing broader networking infrastructure, including distributed computing and scalable applications.

> **Maintaining cyber resilience in the quantum era is both a sovereign and a global imperative. Aligning with international best practices in cybersecurity is a key first step, starting with cryptographic inventory, through risk assessment of critical infrastructure and data and finally through phased migration to PQC at all levels. Planning for and ensuring future cryptographic agility is also essential.**
>
> Kelly Richdale, Senior Advisor, SandboxAQ

Conclusion

While it is too early to fully assess the impact of Saudi Arabia's initiative, the pilot illustrates what is possible when global frameworks are translated into national action. Countries can advance credibly on quantum readiness even amid technological uncertainty. More importantly, the pilot helped transform fragmented quantum efforts into a coordinated community. Institutions from multiple sectors that had previously operated in isolation began working through shared structures, producing not only a roadmap but also enduring relationships, common language and collaborative mechanisms that extend beyond a single planning cycle.

The lessons captured in this white paper are not intended as a blueprint for direct replication. There is no one-size-fits-all approach to quantum readiness. National contexts vary in institutional capacity, resource availability, strategic priorities and development stages. In defining their own approach, countries and regions should critically assess their starting point, align quantum opportunities with long-term national objectives and build on what has proven effective in previous technology initiatives.

Countries at different stages will encounter different challenges. Those initiating strategic planning face questions of scope and prioritization. Those with established programmes confront coordination across institutions and scaling challenges. Those navigating geopolitical constraints must balance capability development with necessary international partnerships. All countries can participate in the quantum economy without necessarily occupying the entire value chain, whether through supplying specialized components, developing applications, training quantum-literate workforces or contributing to standards development.

Countries are invited to contribute to the ongoing evolution of the blueprint. Early-stage countries can pilot the framework and share implementation insights, while those with established programmes can document coordination models, scaling strategies and governance approaches that have proven effective. The World Economic Forum will continue to promote awareness of the blueprint among policy-makers and senior industry experts through roundtables, meetings and webinars, drawing on its Quantum Economy Network, the Centre for the Fourth Industrial Revolution affiliates and Forum partners. These collective contributions will continuously refine the blueprint, ensuring it remains practical and responsive to diverse national realities.

The risk of a widening quantum divide warrants attention. By sharing lessons and insights openly, supporting systematic planning and cultivating dialogue across borders and sectors, the global community can work towards a quantum future that is technologically advanced, equitable, secure and aligned with principles of responsible innovation and shared prosperity.

Appendix: Diagnostic questions for *Quantum Economy Blueprint* implementation

The following diagnostic questions translate the operational lessons presented in this paper, enabling systematic self-assessment during blueprint implementation. Designed for national quantum programme teams, policy-makers and technical advisers, these questions guide capability assessment and priority setting. Table 5 addresses operational diagnostic questions for quantum readiness implementation, while Table 6 examines strategic diagnostic questions for national quantum ecosystem development.

TABLE 5 **Operational diagnostic questions for quantum readiness implementation**

Operational lesson	Diagnostic questions
Localization through alignment with national priorities builds the foundation for meaningful progress	– Which national priorities would quantum technologies most directly advance, and how has this alignment been validated? – Where do current capability assessments rely on proxy indicators rather than direct measurements of institutional readiness?
Phased approach converts uncertainty into manageable progression	– What would constitute readiness to progress from planning to implementation in each phase? – Which assumptions embedded in the current roadmap are most vulnerable to near-term technological shifts?
Early multistakeholder engagement creates alignment that late-stage coordination cannot achieve	– What shared objectives across government, academia and industry remain unarticulated in current coordination structures? – Where do different stakeholder groups hold incompatible assumptions about roles, timelines or resource requirements?
Expectation management is as critical as technical planning	– What divergent understandings of quantum readiness exist among key stakeholders, and what drives these differences? – How are uncertainties about quantum maturity timelines currently being communicated across institutional boundaries?

TABLE 6 **Strategic diagnostic questions for national quantum ecosystem development**

Strategic lesson	Diagnostic questions
Building a quantum-ready workforce	– What specific workforce capabilities are required to execute planned quantum initiatives, and where do current education pathways fail to address these needs? – Which constraint most significantly limits talent pipeline development?
Expanding access to quantum hardware and infrastructure	– What dependencies in hardware access could delay or constrain planned initiatives, and how have these been stress-tested? – Where do current access strategies rely on single pathways that lack viable alternatives?
Bridging the research-to-market gap	– What prevents promising quantum research from reaching commercial application, and which barriers require coordinated intervention? – Where do research agendas lack clear connections to strategic applications or market demand?
Building shared understanding among decision-makers	– What specific strategic objectives drive senior leadership support for quantum initiatives, and how consistently are these articulated? – Which decision-makers essential to quantum strategy success have not yet been meaningfully engaged in shaping priorities?
Embedding governance and security from the outset	– How do current governance structures ensure that ethical principles translate into operational practice rather than aspirational statements? – What coordination challenges exist in PQC migration, and how do current plans address potential implementation delays?

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