Saudi Arabia
Centre for the
Fourth Industrial
Revolution

Quantum Economy Project
1st Workshop

6 February 2024, 10:00 am - 02:30pm (KSA time)
The Intercontinental Riyadh

Contents

1 Executive Summary

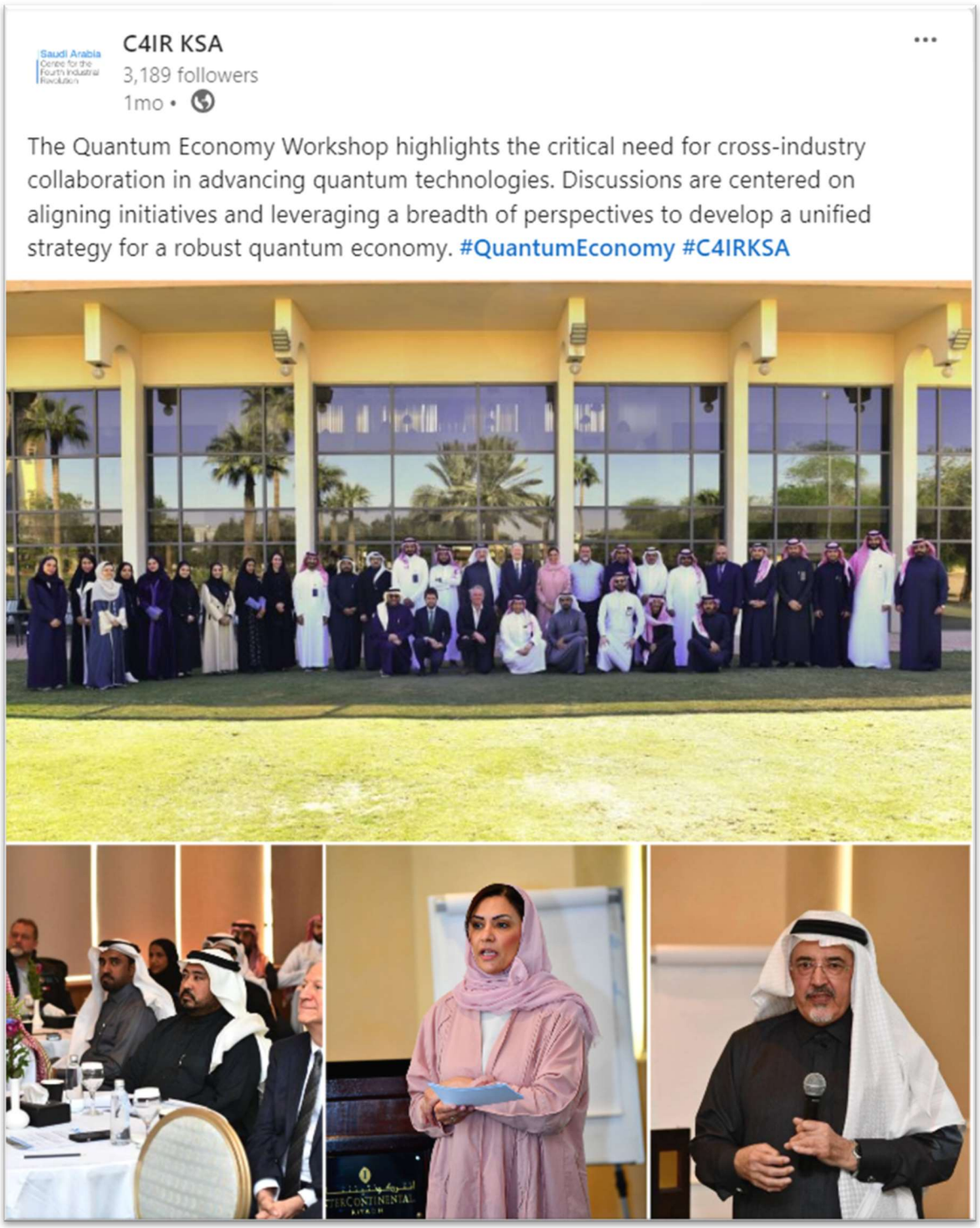
The Quantum Economy project, initiated by the Centre for Fourth Industrial Revolution (C4IR) affiliated with the World Economic Forum (WEF), was introduced with a workshop focusing on discussing the readiness and suitability of KSA for the quantum economy, aiming to assess the nation's preparedness for a national quantum initiative. The event brought together experts, researchers, and representatives from both the government and private sectors to analyze the current situation of quantum technologies in the Kinngdom and discuss the future of adopting the technology.

The workshop highlighted the Centre's commitment to leveraging emerging technologies and promoting collaboration across different sectors to innovate and test new approaches within the Fourth Industrial Revolution. In addition, the importance of establishing a community to shape the governance of quantum technologies and aligning KSA's efforts with the project's goals was emphasized.

Insights into the Quantum Economy and the role of the Quantum Economy Blueprint in supporting regions and countries to develop their quantum technology initiatives were discussed. The workshop covered the benefits, risks, and potential impact of the quantum economy, identified key stakeholders, and explored KSA's potential role as a pilot country. The discussions focused on the governance structure, anticipated benefits and challenges, and strategies for addressing these challenges.

The convening of stakeholders marked a step towards future collaboration that is deemed essential for advancing quantum technologies in Saudi Arabia, aiming to significantly contribute to the nation's innovation and development in this field.

2 Summary of Roundtable Discussions



2.1 The Quantum Economy Project Overview

Disparities in access to existing technologies have already created a digital divide: 2.9 billion people are still offline and do not benefit from the digital economy.

The growing global quantum divide between countries that have established quantum technology programs and those that have not will lead to significant imbalances in core areas such as cybersecurity, defense, technology, healthcare, finance, manufacturing, and more. Unequal access to quantum technology has negative geopolitical implications, putting countries with less developed quantum programs at risk of falling further behind.

The project aims to create a national platform for government, business and academic institutions to understand the potential of quantum technologies and prepare for their introduction to the KSA economy.

The project is expected to align with the WEF's Quantum Economy Blueprint Network, which advocates for a crucial global, synergistic collaboration between academia, industry, and government. This approach aims to boost national quantum initiatives, enhancing prosperity, and security.

2.2 Main Objectives

This Quantum Economy project will focus on creating a roadmap that spans government, industry, and academia. Its aim is to support the relevant stakeholders in developing a national strategy that would enable the development and commercialization of relevant Quantum Technologies and applications. The main objectives include:

- Fostering inclusive and equitable access
- Enabling responsible development and governance
- Accelerating innovation and collaboration
- Driving economic growth and sustainable development
- Strengthening the efforts in developing real-world quantum applications
- Co-developing tools for managing the transition to a secure quantum economy

2.3 The Kick-off Workshop of the Quantum Economy

To address challenges and opportunities of quantum technologies, the BoD of the C4IR KSA recently approved initiating this project to create a national platform for government, business and academic institutions to understand the potential of quantum technologies and prepare for their introduction to the KSA economy.

To achieve the goal of the project, which is creating a national platform to understand the potential of quantum technologies and prepare for their introduction to the KSA economy, the Centre for the Fourth Industrial Revolution hosted the first workshop of the quantum economy.

2.3.1 Agenda

The workshop was held on February 6, 2024. Below is an overview of the agenda.

Agenda of the inaugural Quantum Economy Workshop		
09:30 – 10:00	Arrival and welcome coffee	
10:00 – 10:10	Opening remarks	*Dr. Basma AlBuhairan, Managing Director, C4IR KSA*
10:10 – 10:20	Project overview & Workshop objectives	*Dr. Adnan AlSaati, Advisor, C4IR KSA*
10:20 – 10:40	Quantum Economy Network	*Arunima Sarkar, Thematic Lead, Quantum Technologies, World Economic Forum*
10:40 – 10:50	Coffee Break	
10:50 – 12:05	Session 1— Defining and articulating the goals, scope, and potential impact of the quantum economy project. (Discussion)	*Moderator: Dr. Saad Alowayyed, General Manager, Quantum Technologies and Advanced Computing Institute, KACST*
12:05 – 13:00	Lunch & Prayer Break	
13:00 – 14:20	Session 2— KSA's Participation as a Pilot Country in the Quantum Economy Blueprint (Discussion)	*Moderator: Dr. Muhamad Felemban, Director, Interdisciplinary Research Center Intelligent Secure Systems, KFUPM*
14:20 – 14:30	Recap & Next Steps	*Dr. Adnan AlSaati, Advisor, C4IR KSA*
14:30 – 15:00	Networking and side discussions	

2.3.2 Session 1

The national opportunities that quantum technologies and applications present

The emergence of quantum technologies presents a monumental opportunity for nations to leapfrog existing limitations and unlock transformative advancements across various sectors. In the workshop, three key areas were discussed, highlighting the potential benefits of quantum technologies. These areas include artificial intelligence (AI), sensing, and healthcare advancements, offering a groundbreaking path for such a leapfrog across diverse sectors. For additional details, see Appendix A.1.

The national risks and constraints that quantum technologies and applications present

Quantum technologies raise a number of risks, including cybersecurity threats, such as the decryption of secure data, and reliance on a few vendors. This necessitates the development of local talent and domestic quantum encryption schemes to mitigate national risks and maintain technological security. For additional details, see Appendix A.2.

The factors that would greatly drive the impact of the quantum economy in Saudi Arabia

Saudi Arabia's quantum economy can be significantly driven by industry applications in manufacturing, particularly focusing on leveraging quantum computing for sustainability and "metaverse-style" integration, along with strategic alignment of financial activities with quantum technology's strengths in optimization and risk analysis. For additional details, see Appendix A.3.

The current activities in quantum technologies that are shaping the landscape of quantum technology, its applications, and its governance in Saudi Arabia

The current activities shaping the quantum landscape, including awareness programs, open innovation, global collaborations, workforce development, and research in hardware, software, and applications, as well as access to supercomputing resources and exploration of national strategy, are presented and discussed in detail in Appendix A.4.

The key stakeholders of the quantum economy project in Saudi Arabia

While acknowledging the uncertainties surrounding the broader application of quantum computing, it is important to seize the opportunities presented by other quantum technologies. Efforts should be made to bridge the gap between research and innovation by establishing a Center of Excellence. This recognizes the crucial role of startups in fostering the ecosystem and highlights the importance of monetizing their intellectual property. For additional details, see Appendix A.5.

2.3.3 Session 2

The possible quantum technologies and applications in which Saudi Arabia can participate as a pilot country within the network

Saudi Arabia has the opportunity to lead as a pilot country within the network, exploring a wide range of possibilities in quantum technologies and applications. These possibilities span from language models to healthcare, oil & gas, and beyond. Quantum technologies promise breakthroughs in machine learning, disease detection, optimization, material separation, and new product development across various sectors within the country, see Appendix A.6.

The national risks and constraints that quantum technologies and applications present

By leveraging the World Economic Forum's network and blueprint framework, stakeholders in Saudi Arabia can align their efforts through a localized version that integrates existing initiatives into a unified, region-specific roadmap. This roadmap will guide the nation's journey in quantum technology. For additional details, see Appendix A.7.

The benefits that Saudi Arabia could gain from participating in this project

Participating in the 'Quantum Economy' project presents Saudi Arabia with a unique opportunity to encourage national collaboration, spearhead regional advancements, and ensure future sovereignty by domestically developing critical quantum technologies. For additional details, see Appendix A.8.

The Governance Structure to be Established in Saudi Arabia for Effective Project Oversight

For effective project oversight, a Center of Excellence is envisioned, featuring expert-driven governance and segmented hubs for specific domains. This approach includes a hybrid structure that involves committees, the central government, and the Research Development Innovation Authority (RDIA), with governance adapting as the project matures. For additional details, see Appendix A.9.

The major foreseeable challenges for the project, and ways to address them to ensure the project's success

Despite facing challenges such as awareness, potential technology fragmentation, talent and supply chain hurdles, and the need for a robust ecosystem, the quantum project aims to overcome these through collaboration, national-level focus, open innovation, and infrastructure development. For additional details, see Appendix A.10.

The Expected Role of Start-Up Companies in the Pilot and Strategies to Encourage Their Participation

The pilot project should aim to engage venture capitalists, thereby boosting awareness of quantum technology within the investment community and supporting deep-tech startups. These startups are crucial for driving application-driven innovation. For additional details, see Appendix A.11.

3 Moving Forward

This workshop marks the beginning of a set of a series workshop in quantum technologies and its associated economy. To ensure the continued success of this initiative, we kindly request your assistance with the following:

- Completing the Quantum Workshop Survey: Your feedback is crucial in shaping the next workshop and informing the development of our national quantum economy blueprint components. Please access the survey from here https://www.surveymonkey.com/r/GB5QQJ9.
- Sharing the survey with interested individuals: We encourage you to share the survey link with colleagues and individuals knowledgeable in quantum technologies. Their participation will enrich future workshops and contribute to the blueprint's success.

The second workshop is planned is to be held on 26 April 2024, and your valuable feedback will be essential in helping us shape it.

4 Appendices

4.1 Appendix A: Summary of Workshop Discussions

Appendix A.1

I. Quantum AI

The demand for processing and analyzing vast amounts of data is increasing rapidly, pushing traditional data centers and computational resources to their limits. This creates a significant challenge for the advancement of AI technologies, especially when it comes to training models with hundreds of millions of parameters, due to the high costs and extensive time requirements. Quantum AI provides a ground breaking solution by leveraging quantum computing's capabilities for computations at an unprecedented scale and speed. This advancement can significantly reduce the time and cost associated with training complex AI models, offering a path to overcome current computational limitations. Investing in quantum AI technology enables a leap forward in AI innovation, facilitating progress in various sectors and driving economic diversification through the adoption of cutting-edge advancements.

II. Quantum Sensing

Traditional sensors are limited by their sensitivity to the environment, which restricts their performance, accuracy, timing, and speed. This limitation poses a challenge in various applications where precise and rapid sensing capabilities are crucial. Quantum sensing offers a revolutionary approach by exploiting the inherent extreme sensitivity of quantum systems to their environment. This technology promises to deliver superior performance compared to traditional sensors, providing enhanced accuracy, timing, and speed. The introduction of quantum sensors paves the way for new products and applications, opening up numerous opportunities across different fields.

III. Health Care:

Quantum technology is set to revolutionize healthcare by enhancing disease detection and accelerating drug discovery. Quantum sensing enables more accurate and earlier disease diagnosis, while quantum computing facilitates the simulation and analysis of complex molecular interactions, leading to the discovery of new drugs more efficiently. This quantum leap promises to improve patient care and treatment outcomes significantly, by offering more precise diagnoses and faster development of effective medications.

Appendix A.2

I. Cybersecurity

Quantum technology introduces significant cybersecurity risks alongside its advancements. Firstly, the advent of quantum computing threatens classical cryptography schemes by potentially allowing the decryption of currently secure data. This risk necessitates immediate action to encrypt sensitive data with post-quantum cryptography schemes, especially for data whose sensitivity extends beyond the arrival of practical quantum computing capabilities. The second risk involves the concentration of quantum technology providers, creating a dependency on a limited number of vendors. This dependency poses a national security threat, as it limits control over and access to these critical technologies. Mitigating these risks requires developing local capabilities and adopting secure cryptographic standards that can withstand quantum computing threats.

II. Lack of Talent and Workforce

The introduction of quantum technology underscores the critical need for developing local expertise, particularly in quantum communication, sensing, and computation. The emphasis is on training a native talent pool to ensure Saudi Arabia's cybersecurity is robust and self-reliant. This approach is essential for safeguarding against the potential vulnerabilities quantum computing presents to traditional cybersecurity methods. By nurturing home-grown talent in both conventional and quantum cybersecurity fields, the country can better prepare for the disruptive impact of quantum technologies on data protection. Additionally, fostering the development of quantum encryption schemes domestically is highlighted as a strategic move. It not only strengthens national security but also reduces financial dependence on foreign intellectual property, potentially saving significant national expenses. This dual focus on defines and the creation of proprietary quantum technologies is crucial for maintaining a competitive and secure technological advances.

Appendix A.3

I. Industry Applications

The potential of quantum technology to drive progress in the manufacturing sector is substantial, though its adoption is challenged by the need to identify applications that match the sector's specific demands and the difficulty in formulating business and financial justifications for its investment. Quantum computing's unique algorithms and potential have not been fully exploited due to a lack of practical application and understanding. This highlights the necessity for an optimized approach to transform external environments and unlock its benefits across various sectors. By applying quantum computing to innovative areas such as 'metaverse-style' applications, there is an opportunity to revolutionize how manufacturing, supply chains, and customers interact, encouraging a shift towards a government-supported, quantum-enabled business ecosystem that transcends traditional industry limits. Furthermore, quantum

II.Financial Applications

In the financial sector, quantum technology's exploration highlights significant potential for impacting the economy. This sector, facing optimization challenges like portfolio management and risk analysis, is well-suited to the strengths of quantum computing. Bridging the gap between specific industry problems and quantum capabilities is crucial. Despite issues with error correction and stability in current quantum computers, there's room for near-term value. Aligning the financial industry's challenges with quantum solutions is key to effective harnessing of this technology. Addressing this alignment could lead to quantum advancements, positioning the sector as a leader in integrating quantum computing into economic activities. Focusing strategically on matching financial sector needs with quantum computing's unique advantages promises transformative benefits.

computing's rapid data processing capabilities could significantly advance sustainability and emissions reduction efforts in industries, enhancing AI and ML applications for more efficient exploration and drilling processes, thereby accelerating environmental and operational improvements.

Appendix A.4

I. SAMA

Creating Awareness: The central bank conducted a comprehensive training session for its staff on quantum computing. This session encompassed both the cybersecurity aspects and the potential negative implications of quantum technology, alongside the positive applications such as simulations.

Open Innovation and Commercialization: The central bank has proactively identified potential PoCs to explore the application of quantum technology, especially in areas where classical computers fall short. These PoCs mainly focus on simulations and solving complex problems that are currently intractable.

Global Collaboration: The central bank has engaged in significant collaboration with global organizations. It has participated in the development of a paper on quantum security in partnership with the World Economic Forum and the Financial Conduct Authority.

II. King Fahd University of Petroleum and Minerals

Workforce Development: KFUPM has launched two quantum computing programs: one at the undergraduate level and a Professional Master's in Quantum Computing. These programs have been operational for almost three years, with two batches of graduates already contributing to the quantum economy.

Innovation and Research: KFUPM is at the forefront of quantum technology research through its dedicated in-house group, covering everything from hardware and physics to software and practical applications. The university has further enhanced its quantum research capabilities by setting up a specialized laboratory focused on quantum physics and superconducting qubits, key to advancing quantum computing hardware. Additionally, a significant partnership with Saudi Aramco has resulted in a shared professor program, aimed at strengthening local research in areas such as quantum communication, sensing, and security.

III. King Abdullah University of science and Technology

Access to Hardware: A top-ranking supercomputer is available at KAUST, which can be very useful for emulating quantum computing and boosting research and education in quantum algorithms. This supercomputer is available for non-profit collaborations within the Kingdom, in efforts to explore and develop quantum computing solutions.

IV. Ministry of Communications Information & Technology:

National Strategy Preparation: MCIT is exploring a national quantum technology strategy, requiring significant effort, stakeholder involvement, and complex governance. Identifying the right governance structure such as establishing committee, authority, or program is key for management. Workshops are crucial for consolidating efforts and emphasizing integration across quantum sensing, communication, and computing, essential for advancing Saudi Arabia's quantum technology position.

Appendix A.5

I. Role and importance of startups

Start-ups play a critical role in fostering an innovation-supportive ecosystem, essential in sectors on the cusp of technological breakthroughs. By pioneering new methodologies, these start-ups are setting the groundwork for future advancements, including in emerging or unproven areas. Recognizing the potential commercial value of these innovations is key to progress. It fuels awareness, engagement, and the development of essential components required for significant achievements

Furthermore, The significance of monetizing intellectual property cannot be overstated, particularly within the context of start-ups. These ventures extend beyond mere product development and sales, embodying a collective intellectual endeavour that culminates in the creation of substantial intellectual assets such as patents and scholarly articles. The strategic gathering and subsequent capitalization of these assets from an early phase in their growth trajectory stand as a critical advantage. Such assets, tangible in nature, can be effectively leveraged to demonstrate potential financial gains to investors, thereby highlighting the dual role of intellectual property as both a strategic and fiscal asset within the start-ups domain. This approach not only aligns with but also amplifies the call for heightened awareness regarding the pivotal role of intellectual property, underscoring its value and potential for monetization as integral to the start-ups ecosystem's evolution.

II. Lack of Quantum Tech Start-ups in Saudi Arabia

Despite the uncertainties surrounding quantum computing, including its yet-to-be-defined quantum advantage, the projected timeline for progress, and the challenges start-ups face in generating returns before being surpassed by classical computers, there are opportunities in other quantum technologies, such as quantum communication and security that are already being utilized. Furthermore, there is significant potential within the Saudi Arabian start-ups ecosystem to capitalize on these quantum advancements, with increasing interest and promising concepts emerging in the local market.

I. The Critical Role of Research Centres

In order to localize Quantum Technologies and create a lighthouse for quantum startups in Saudi Arabia, and to bridge the gap between research and innovation with use cases for quantum technologies, KACST is progressing towards establishing a Centre of Excellence for Quantum Technologies

Appendix A.6

I. Quantum ML Applications

In the advancement of quantum technology, leveraging small quantum computers for machine learning, specifically in training language models, presents a notable opportunity for breakthroughs. Developing energy-efficient algorithms could revolutionize current practices, drawing significant support and incentives from government sectors. This approach hinges on optimizing neural network components to efficiently process data, enhancing output accuracy while minimizing energy consumption and hardware dependency. By adopting nature-inspired computational methods, we can address geopolitical tensions over hardware acquisition, offering a pathway to sustainable and accessible quantum computing advancements. This strategic focus promises to accelerate the integration and impact of quantum technologies in practical applications.

II. Petrochemicals and Supply Chain Applications

In petrochemicals and Supply chain, three key quantum initiatives are transformative. Quantum sensing addresses longstanding challenges in the field with unprecedented problem-solving capabilities. Quantum computing revolutionizes the sector's reliance on AI for operational optimization, enhancing efficiency and reducing costs by adjusting decades-old parameters and practices. Quantum simulations play a crucial role in developing new products, representing a substantial opportunity with ongoing exploration of applicable use cases. These quantum applications collectively hold the potential to profoundly impact the future of the petrochemicals manufacturing industry.

III. Oil and Gas Applications

Addressing the profound implications quantum technologies hold for the oil and gas sector, it's pivotal to highlight their role in optimization and material separation. Quantum sensing, as well, emerges as a critical area with a significant percentage of applicable use cases, particularly in upstream operations within this industry.

IV. Health Care Applications

Quantum optics, in conjunction with AI, significantly advances disease detection and diagnostics, especially for various types of cancer. By employing advanced lasers and specific bandwidths of wavelength, this technology enables a level of analysis surpassing traditional methods. This integration allows for the processing and interpretation of complex data, leading to early detection and more accurate diagnostics. Such advancements represent a substantial improvement in medical science, offering the potential for earlier interventions and enhanced patient outcomes in cancer care.

V. RDIA Quantum Technologies and Applications Portfolio

The RDIA has identified multiple quantum technologies and applications relevant to Saudi Arabia in the recent call for proposals, encompassing both use cases and technologies for producing quantum effects in devices. They include quantum annealing machines, superconducting qubits, quantum entangled light sensors, optical lattice clocks, distributed quantum sensing, topological quantum materials, spintronic materials, photonic materials, condensed matter physics, cryogenic engineering, quantum error correction theory, standardization of quantum computers, atomic interferometers, quantum key distribution, continuous variable quantum systems, energy conversion materials, and the development of building assembly lines at the nanoscale. These areas highlight the breadth of quantum technology's potential impact and the opportunities for innovation.

Appendix A.7

I. Leveraging WEF's Expertise for National Roadmap Development

The World Economic Forum (WEF) facilitates the piloting of frameworks by leveraging its vast quantum network of policy and application experts. This process involves testing these frameworks in regional or national contexts by local and regional entities. The key benefits include access to the WEF's extensive expertise and a detailed blueprint outlining steps, modules, and building blocks for developing a national roadmap. This roadmap begins with conducting a self-assessment and SWOT analysis, considering national priorities. The blueprint serves as a foundational guide for discussions on roadmap development. Furthermore, the WEF can facilitate engagements with experts from its network to provide additional insights. If there's interest, policymakers involved in similar initiatives can also share their experiences and successful strategies. This collaborative approach aims to support nations in creating effective roadmaps tailored to their specific needs and priorities.

II. Localized Version of The Blueprint

A feasible approach to aligning various stakeholders in KSA with the Quantum Economy Blueprint Network pilot could involve creating a localized version of the blueprint. This version would integrate with and harmonize existing initiatives and ideas within the country. The aim would be to consolidate these efforts into a single, cohesive blueprint, which would then be developed into a detailed roadmap. This roadmap would outline the necessary activities across different regions of the country to advance towards the envisioned quantum future. The initial step in this process should be a comprehensive reconciliation exercise, evaluating what has already been accomplished and determining what aligns with Saudi Arabia's unique context and objectives. Ultimately, this would result in a unified, localized blueprint tailored to the Kingdom, guiding its strategic quantum technology endeavours.

Appendix A.8

I. Leveraging Collaboration for Innovation and Development

Participating in this project offers KSA the unique advantage of rallying various sectors around a shared technological vision, fostering unity and collaboration even beyond the project's immediate scope. The initiative has sparked widespread interest, laying the groundwork for discussions on a range of future technological endeavours. The project also prompts a broader dialogue on computing technologies, particularly on enhancing machine learning (ML) and simulations for material or drug design and discovery through quantum advancements. This aligns with existing objectives in ML and discovery and design, suggesting that immediate efforts could focus on leveraging conventional computing resources to the fullest. Additionally, this initiative encourages the formation of alliances and working groups dedicated to addressing challenges where quantum computing could later introduce significant improvements in energy efficiency and processing speed. These discussions and collaborations are valuable side benefits, setting the stage for Saudi Arabia to seamlessly integrate quantum technologies when they become more viable, following the trajectory of Moore's law for quantum devices.

II. Leading the Regional Quantum Leap

Saudi Arabia's prominent position in the region, characterized by its vast size and advanced infrastructure, presents a significant opportunity to lead in quantum technologies development. By aligning goals and targets with global standards and creating focused points for development, Saudi Arabia can spearhead the creation of a regional quantum technologies ecosystem. The proposal involves forming a body to adopt a global blueprint, engaging all relevant stakeholders, including RDIA, and setting specific, achievable goals. This collaborative effort would involve partners from across the region, working collectively towards well-defined objectives. The strategy would encompass developing a comprehensive roadmap and strategy, aiming to localize the quantum technologies ecosystem within Saudi Arabia. Given the country's scale and infrastructural capabilities, it is uniquely positioned to achieve this ambition, leading the way in regional quantum technologies advancements.

III. Securing National Quantum Sovereignty

Participating in the quantum Economy project is crucial for Saudi Arabia, mainly for enhancing national security through the localization of quantum computing and cryptography technologies. This approach is vital, not just due to global export controls but as a strategic imperative for national sovereignty. Developing domestic quantum capabilities is essential for securing the nation against emerging cyber threats, making Saudi Arabia a forerunner in the field of quantum security.

Appendix A.9

I. Center of Excellence

Initiating a centre of Excellence could be the foundational step for Saudi Arabia quantum technology initiatives, marking the beginning of a comprehensive platform dedicated to fostering innovation, problem-solving, and collaboration in both quantum and conventional computing. By assembling a select group of experts from different sectors within a focused incubation environment, this central hub is positioned to translate theoretical concepts into flagship projects, demonstrating a clear transition from ideas to tangible outcomes. Addressing concerns that the initiative may become too dispersed, it emphasizes the need for a precise, expert-driven governance model to provide support and direction, thus ensuring innovation is fostered within a manageable scope. This strategy is aimed at facilitating the creation of a flagship project, critical for generating momentum and increasing interest in quantum technology across Saudi Arabia, leveraging the concentrated efforts of a group deeply invested in the centre's success.

II. Leap Hybrid Governance Structure for the Center of Excellence

To oversee the project effectively within KSA, a hybrid governance structure incorporating various approaches is essential. Central to this structure is the establishment of a centre of excellence, serving as a pivotal hub to unite experts and leverage resources across KSA and its partners. This could include a committee dedicated to managing governance in relation to specific sectors, central government involvement, and mechanisms to promote and incentivize contributions from various stakeholders, including integrating RDIA for funding and directional support. The governance model proposed acknowledges the need for innovation in governance practices, recognizing that establishing a fixed structure from the outset may be less effective. Instead, an interim structure, adaptable and based on the most readily available resources and partnerships, is proposed to swiftly achieve common objectives and facilitate early progress. This flexible, phased approach to governance, evolving with the project's maturity, allows for continuous learning and adjustment.

III. Structure of the Center of Excellence

Upon finalizing the overarching strategy, a foundation for a Center of Excellence could be established. This center could be segmented into various hubs, each dedicated to a specific domain, such as hardware, cybersecurity, among others. These hubs would encompass representatives from government sectors, industry, academia, and other relevant entities, facilitating a collaborative environment aimed at achieving their respective objectives. Concurrently, attention must be devoted to essential parallel domains, notably human capital development and overarching governance mechanisms, which are critical for the comprehensive support of the entire program.

Appendix A.10

I. Quantum Technologies and Applications Awareness

Understanding the full potential of quantum technology presents a significant challenge, particularly in distinguishing its fundamental physics from the excitement around its computing capabilities. The World Economic Forum (WEF), in collaboration with governments, has played a pivotal role in addressing this challenge by developing national strategies that enhance awareness among key decision-makers within businesses and governments. This is crucial for clarifying the aims, potential applications, and practical implications of quantum technology, moving beyond the hype to focus on real-world impacts. The WEF's efforts include a section in their blueprint titled 'Creating Awareness,' aimed at prioritizing quantum technology in both academic and industrial sectors, and highlighting the importance of cybersecurity awareness due to its direct relevance to quantum technology's impact. The objective is to facilitate a comprehensive understanding among scientists, industry experts, the wider public, and particularly those in positions to make informed decisions about the implications of quantum technology for their operations and the nation as a whole.

II. Fragmented Approaches in Quantum Technologies

In the Kingdom, a particular challenge lies in the importation of hardware, which highlights broader logistical and supply chain issues that are crucial to address. The fragility of quantum sector supply chains is a global concern, with only a few countries boasting self-sufficient quantum technology chains. Adopting open innovation strategies, such as leveraging technologies like Qiskit to create hardware-agnostic abstraction layers, could be pivotal. This approach enables quantum algorithms to run on various platforms, fostering flexibility and broader application. Additionally, the concept of a supervisory system for quantum technologies presents an untapped opportunity. Despite the availability of open-source projects like Qiskit, effectively scaling this idea remains unexplored. Addressing these challenges by fostering a supportive ecosystem and leveraging open innovation can significantly contribute to overcoming the obstacles of talent attraction and retention, as well as the logistical hurdles of hardware importation, paving the way for a more robust quantum sector.

III. Fragmented Approaches in Quantum Technologies

One potential challenge is the fragmentation among the underlying technologies in quantum computing, as not all quantum computers are created equal. There's a notable diversity in the types of technologies currently being explored, which contrasts sharply with the strategies of countries that have developed national-level quantum initiatives. These countries often concentrate their resources and efforts on one or two technologies, adopting a more unified approach. This fragmentation could pose a challenge, as it may dilute focus and resources, potentially hindering the ability to achieve significant advancements in any single technological approach.

IV. Robust Quantum Ecosystem

It's evident that no single quantum technology has emerged as the clear leader. In the early stages, many practitioners assess the most promising technologies, typically adopting an open architecture approach, which is crucial for providing flexibility to explore various technologies. Another challenge to consider is that the quantum computer alone does not confer a significant advantage. The full benefits of quantum computing can only be realized with a robust ecosystem and supporting infrastructure.

Appendix A.11

I. Application Driven Innovation

A key strategy for supporting start-ups in the quantum field involves direct engagement with venture capitalists (VCs). The goal is to elevate their awareness of quantum technologies, turning these concepts into trending topics within the investment community. Unlike government funding, which predominantly supports basic research with a focus on discovery rather than application, private funding from VCs can drive application-driven innovation. Additionally, they can foster discussions that might influence regulations and encourage the development of dedicated programs within the private sector.

II. Deep-Tech Start-ups

Start-ups innovating with new business models, creating tangible products, and leveraging emerging technologies are classified as deep tech companies. Initiatives at KAUST, in collaboration with MCIT and with support from entities like Garage and KAUST itself, are pivotal in fostering an ecosystem that encourages the growth of these companies. Quantum-related start-ups, in particular, represent the core of deep tech due to their complexity and the specialized support they require.

4.2 Appendix B: Resources and links

- "Quantum Economy" https://www.weforum.org/communities/gfc-on-quantum-economy/
- "Quantum Economy Network" https://www.weforum.org/communities/gfc-on-quantum-economy/
- "Quantum Economy Blueprint" https://www.weforum.org/publications/quantum-economy-blueprint/
- "Quantum Computing Governance Principles" https://www.weforum.org/publications/quantum-computing-governance-principles/
- "Centre for the Fourth Industrial Revolution KSA" https://c4ir.sa/

5 Acknowledgement

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