

# A Quantum Strategy for Africa

Farai Mazhandu<sup>\*1</sup>, Ouissal Moumou<sup>\*,†2</sup>, Ahmed Younes<sup>\*3</sup>, Taha Rouabah<sup>\*4</sup>, and Mhlambululi Mafu<sup>\*5</sup>

<sup>1</sup>Africa Quantum Consortium, South Africa

<sup>2</sup>Quantinuum, England

<sup>3</sup>Alexandria University, Egypt

<sup>4</sup>Frères Mentouri Constantine 1 University (UFMC1), Algeria

<sup>5</sup>Case Western Reserve University, United States of America

<sup>\*</sup> All authors contributed equally to this work.

<sup>†</sup>The views expressed are those of the author and do not represent Quantinuum.

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## Executive Summary

With 2025 marking the International Year of Quantum and nations investing billions in quantum technologies, Africa must act decisively to avoid technological dependency and secure quantum sovereignty.

While Africa's quantum research output currently represents a small fraction of global production, the continent possesses unique strategic advantages: vast critical mineral reserves, optimal geographic positioning for quantum networks, and growing research capacity supported by strong diaspora connections. These assets, combined with quantum technologies' direct applicability to Africa's development challenges, create unprecedented leapfrog opportunities.

We recommend a comprehensive five-pillar strategy to establish Africa as a quantum co-leader. First, invest massively in human capital through integrated quantum education and talent retention programs. Second, formalize international and intra-African collaboration through regional research networks. Third, establish a Pan-African Quantum Research Fund ensuring African ownership of developed technologies. Fourth, promote applied quantum research addressing continental challenges in healthcare, agriculture, and climate adaptation. Fifth, develop supportive policy frameworks including intellectual property protection and national quantum strategies.

The recommended approach prioritizes quantum software development as an immediate entry point while building toward hardware sovereignty. This strategy transforms Africa from technology consumer to innovation producer, directly supporting Sustainable Development Goals and Agenda 2063 objectives.

Success requires coordinated action across governments, institutions, and the private sector. Africa must act now to secure its quantum future.

## Introduction

The 21st century is witnessing a technological transformation powered by the principles of quantum mechanics. This “second quantum revolution” is defined not merely by the understanding of quantum phenomena, but by the ability to control and manipulate individual quantum systems, unlocking unprecedented capabilities in information sensing, processing, and transmission.

At its core are fundamental concepts such as **quantum superposition**—the ability of a quantum system to exist in a combination of multiple possible states until measured—and **entanglement**, a unique correlation between quantum systems where the measurement outcomes remain correlated across any distance, with the correlation established when the particles first became entangled, and **quantum interference**—the phenomenon where quantum probability amplitudes combine constructively or destructively to enhance desired outcomes while suppressing unwanted ones [5]. These counterintuitive properties are no longer confined to theoretical physics; they are the bedrock of a new technological paradigm with four key pillars:

- **Quantum Security and Communication**, offering enhanced security for information transfer based on the laws of physics;
- **Quantum Computing**, providing exponential speedups for specific classes of problems that are intractable for classical computers;
- **Quantum Simulation**, enabling quantum systems to model complex physical phenomena more efficiently than classical methods, with potential applications in materials science and drug discovery; and
- **Quantum Sensing & Metrology**, achieving enhanced precision in measurements, with applications in fields like medical diagnostics and navigation. [9].

As the global “quantum race” intensifies with nations investing billions to secure leadership [16], the designation of 2025 as the International Year of Quantum, championed by African nations like Ghana, presents a pivotal opportunity for the continent to proactively define its role and avoid technological dependency [14].

Furthermore, with its demographic dividend and growing digital connectivity, Africa is uniquely positioned to become a “crucial innovation hub” and an active co-leader in the quantum era [22], developing bespoke solutions to its unique challenges and securing its technological sovereignty for generations to come.

## Quantum Solutions for Africa’s Grand Challenges

To get Africa’s economic growth back on track to achieve Agenda 2063 goals [1], all scientific and technological tools, including quantum, must be fully explored and deployed. This makes the case for strategic investment compelling, as quantum technologies can be directly applied to the continent’s major challenges, including those outlined in the UN Sustainable Development Goals [17].

Shifting from abstract theory to concrete applications provides a clear path for using quantum science to create tangible improvements in the lives of African citizens [13, 21]. Moreover, the rapid convergence of quantum and AI, alongside the discovery of quantum-inspired niche solutions, makes it imperative for the continent to seriously build capacity now.

A proactive approach to deploying quantum technologies can create tangible improvements across Africa’s key sectors. In healthcare (SDG 3), quantum sensors can enable the early detection of diseases like tuberculosis and malaria by identifying biomarkers at minute concentrations [19], while quantum simulation accelerates the discovery of new medicines tailored to the continent’s unique genetic diversity [23]. For agriculture and food security (SDG 2), quantum computing can optimize fertilizer synthesis and manage supply chains to reduce waste, while quantum sensors provide real-time data for precision farming. In mining (SDG 8), advanced quantum gravimeters and magnetometers allow for more efficient, less environmentally invasive mineral exploration and streamline complex operations through optimization algorithms and AI [13, 21]. The rapid digitization of the continent’s economies is secured by quantum communications (SDG 9), which offers fundamentally secure channels, as demonstrated by early explorations in the finance sector. Finally, in addressing climate and energy challenges (SDGs 7 & 13), quantum computing provides more accurate climate models [10], while quantum simulation accelerates the design of next-generation materials for green energy production, from solar cells to batteries [23].

## Current Quantum Landscape in Africa

Africa’s strategic advantage in the global quantum race is a powerful combination of its burgeoning intellectual capital and a rich endowment of the critical and rare earth minerals essential for quantum hardware [15]. Its vast landmass and ideal atmospheric conditions also offer a significant geographic advantage for hosting the ground stations that form the backbone of a global quantum internet, as powerfully demonstrated by the landmark 2024 satellite link between China and South Africa [20, 8]. This ambition is built on a strong foundation of scientific excellence cultivated by institutions like the African Physical Society, African School of Physics (ASP) and the Abdus Salam International Centre for Theoretical Physics (ICTP), which have nurtured a community skilled in fundamental knowledge, data-intensive research and high-performance computing [3, 11].

The analysis of scholarly output in Quantum Science and Technology (QST)

from 2022 to 2025 reveals a nascent but growing research landscape in Africa. While the continent’s overall contribution remains a small fraction of the global output, a closer look at the top 10 African nations highlights specific strengths and weaknesses, offering a roadmap for future development. The global output for this period stands at 58,541 publications, with 16% from Africa, underscoring a significant gap in scale.

A sample of the scholarly output data, extracted from Scival, provides a quantitative overview of this landscape. The following table compares key topics in quantum computing and related fields across the world and two of Africa’s most prolific countries, Egypt and South Africa.

Table 1: Scholarly Output extracted from SciVal in Quantum Science and Technology (2022-2025) from Top African Countries and the World

<b>Country/Region</b>	<b>Scholarly Output</b>
<b>World (Total)</b>	226 864
<b>Top 10 African Countries</b>	
Egypt	2517
Morocco	2112
South Africa	1951
Algeria	1115
Nigeria	844
Tunisia	623
Ethiopia	229
Ghana	60
Kenya	39
Uganda	9

The research profile of Egypt demonstrates a notable focus on quantum machine learning and quantum algorithms, areas where the country has shown a relatively strong publication count compared to its African peers. This indicates a strategic interest in the computational aspects of QST. However, the overall output remains modest, suggesting a need for increased funding and international collaboration to scale up research activities.

South Africa, with a historically strong scientific foundation, exhibits a more diversified QST research profile. Its strengths lie in quantum computing and quantum communications, with a broader range of topics being explored than in other African countries. This diversity suggests a more mature research ecosystem, likely supported by established research institutions.

Moving to Nigeria, the research output, though limited, shows an emerging interest in quantum cryptography and quantum communications. Publications from Nigerian institutions often involve international partnerships, highlighting the dependence on collaboration to access expertise and resources. This collaborative model is a key strength for a developing research landscape, but also underscores a weakness: the need for independent, locally-driven research programs to build a sustainable quantum ecosystem.

Morocco’s QST research is characterized by a focused effort in quantum algorithms. This specialization suggests that researchers are targeting specific areas with high impact rather than dispersing efforts across the entire QST spectrum. Although this focus can lead to impactful contributions in a niche field, it also represents a weakness in the form of a lack of diversity in research topics, which can limit the country’s ability to develop a comprehensive QST ecosystem.

The QST research output from Ethiopia is minimal, indicating an early stage of development in the field. The few publications that exist are often in foundational quantum mechanics, with a limited number of papers on applied topics like quantum computing. This highlights a significant gap in both human capital and technological infrastructure. The primary focus should be on building a foundational knowledge base and fostering a new generation of researchers.

In Algeria, the research landscape in QST is still in its infancy. Publications are sporadic and often focus on theoretical aspects of quantum algorithms, with very little output in applied fields. This suggests a lack of robust research programs and dedicated funding for QST. To bridge the gap, Algeria needs to invest in establishing research centers and providing scholarships to build a critical mass of experts.

Tunisia shows a slight but noticeable presence in quantum computing and quantum algorithms. Although small, the research output indicates a clear interest in these areas. Like many of its African peers, Tunisian research is often a product of international collaboration. This is a beneficial approach for building capacity, but requires a parallel effort to cultivate local expertise and infrastructure to ensure long-term sustainability.

Ghana’s QST research is in a very early phase. The country has a very low number of publications in this period, primarily in theoretical quantum physics. There is a clear need to stimulate interest and investment in applied QST fields to move from foundational research to areas with greater technological and economic potential.

The significant gap between African and global QST research is primarily one of scale and focus. Global production is dominated by countries with massive public and private funding, dedicated research institutions, and a large pool of trained talent. In contrast, African nations are often hampered by limited funding, a brain drain of skilled researchers, and a lack of advanced research infrastructure, such as quantum laboratories and supercomputers. The publication counts for all African nations are dwarfed by the global total, indicating a fundamental disparity in resource allocation.

The current quantum landscape operates on a hub-and-spoke model. Southern Africa, led by the South African Quantum Technology Initiative (SA QuTI), serves as a consolidated hub with cloud-based access to quantum computers via a partnership between IBM and the African Research Universities Alliance (ARUA). North Africa operates as a distributed corridor, with strong research groups like the Alexandria Quantum Computing Group (AleQCG) in Egypt, Constantine Quantum Technologies (CQTech) in Algeria, and emerging efforts in Tunisia (University of Tunis El Manar) and Morocco (Morocco Quantum

Network), alongside emerging initiatives in Libya.

The emerging frontiers across West and East Africa are driven by community-led efforts and university programs. Notable parties include QWorld's chapters and "cousins" in Cameroun, Nigeria and Quantum Kenya, as well as academic institutions like KNUST and the University of Education Winneba in Ghana. The entire African ecosystem is unified by the African Quantum Consortium (AQC), whose flagship platform, the Quantum Roundtable, fosters continent-wide collaboration [7].

The strategic positioning of Africa in the global quantum race is a function of its dual endowment of critical and rare earth minerals and a highly skilled diaspora. This latter resource, a vital and underutilized asset, provides a powerful conduit to global networks of expertise and capital. This engagement is a manifestation of the Ubuntu philosophy, creating a framework for structural partnerships that facilitates a "brain gain" and presents a unique, collaborative model for development within a highly competitive field. [13].

## **Strategic Recommendations**

The ultimate success of Africa's quantum revolution hinges on a unified, holistic strategy. It is a path forged by leveraging the continent's unique strengths: its vast mineral wealth to build a sovereign quantum materials value chain; its geographic position to establish a continental network of quantum communication and sensing; and its human capital to cultivate a new generation of scientists and entrepreneurs. This is not merely an investment in a new technology; it is a strategic imperative to transition Africa from an exporter of raw materials to a global leader in value creation. By consolidating efforts under a Pan-African framework, the continent can turn its strategic assets into a definitive advantage in the global quantum race[15, 3, 11].

### **Recommendations to bridge the gap and establish a quantum ecosystem**

To bridge this gap and establish a sustainable quantum ecosystem in Africa, a multi-pronged strategy is required, with a direct link to the Sustainable Development Goals (SDGs).

### **Investment in Human Capital and Education (SDG 4: Quality Education)**

A fundamental step is to invest in educational programs at all levels. This includes integrating QST topics across multiple educational tiers, from secondary education through advanced research programs, complemented by innovative talent attraction and retention mechanisms. In doing so, Africa can address the brain drain and build a skilled workforce necessary for a quantum ecosystem.

This directly contributes to SDG 4 by ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

### **On the University and Post-Graduate Levels**

Universities must integrate QST topics into existing physics, computer science, and engineering curricula while establishing dedicated quantum technology degree programs. This includes developing specialized master's programs at leading African universities, creating interdisciplinary quantum computing degrees that bridge theoretical physics with practical applications, and establishing joint degree programs with international quantum research institutions to ensure global competitiveness. Academic research groups focusing on quantum technologies must be established and supported through dedicated funding mechanisms.

### **On the Secondary Education Level**

Introducing quantum computing concepts at the secondary level through pedagogically appropriate methodologies represents a critical long-term investment in continental quantum literacy. Recent research demonstrates that diagram-based curricula utilizing the ZX-calculus can effectively communicate quantum principles without requiring advanced mathematical prerequisites, eliminating barriers created by traditional linear algebra and complex number requirements [6]. The "Quantum Pictorialism" approach uses visual, mathematically rigorous diagrams called string diagrams to replace complex symbolic mathematics, enabling students to perform quantum calculations through intuitive graphical representations [6]. Educational experiments show that high school students aged 16-19 can successfully learn quantum teleportation, quantum gates, and circuit optimization using these diagrammatic methods [6].

### **Talent Attraction**

Regarding talent attraction, we recommend implementing quantum focused hackathons, programming contests, and innovation challenges to create pathways to identify and nurture exceptional talent across the continent. These initiatives should include quantum algorithm competitions, quantum application development challenges, and continental quantum innovation prizes that attract both students and professionals to engage with quantum technologies. Moreover, comprehensive scholarship programs for postgraduate studies in quantum-related fields must target both domestic and diaspora talent. This includes merit-based scholarships for African students pursuing quantum degrees internationally, repatriation fellowships for diaspora quantum professionals, and industry-sponsored postgraduate programs that guarantee employment pathways.

## **Fostering International and Intra-African Collaboration (SDG 17: Partnerships for the Goals)**

The analysis shows that collaboration is a key strength. This should be formalized through the creation of regional quantum research networks. These networks could share resources, coauthor papers, and host joint workshops. Collaborating with leading global institutions would provide access to advanced knowledge and infrastructure. This approach is in direct alignment with SDG 17, which calls for strengthening the means of implementation and revitalizing the global partnership for sustainable development.

## **Creation of a Pan-African Quantum Research Fund (SDG 9: Industry, Innovation, and Infrastructure)**

To overcome the issue of limited funding, African governments and development partners should establish a dedicated fund for QST research and infrastructure. This fund could support the establishment of quantum laboratories, high-performance computing centers, research grants, and incubators for quantum start-ups and university spinoffs. This fund should draw from diversified funding streams including government contributions, private sector investment, diaspora investment programs, and development finance institutions.

The fund's strategic investment priorities must reflect Africa's unique development context, prioritizing quantum applications that directly address our continent's specific challenges in healthcare, agriculture, climate adaptation, and financial inclusion, rather than simply replicating research agendas developed elsewhere. This includes creating dedicated funding tracks for South-South technology transfer and collaboration with other emerging quantum economies, alongside provisions for talent retention and repatriation programs that counter brain drain by making African quantum careers financially competitive with opportunities abroad. Building upon emerging efforts like the Africa Quantum Fund being developed by the Africa Quantum Consortium, this expanded funding mechanism should align with existing continental financing institutions like the African Development Bank to leverage established infrastructure and expertise.

Critically, the fund must be governed by transparent, merit-based allocation criteria with African scientific leadership in decision-making, ensuring that funding decisions reflect continental priorities rather than external agendas.

By investing in this infrastructure, Africa can transition from being a consumer of technology to a producer of innovation, thus contributing to SDG 9's goal of building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation.

## **Promotion of Applied QST Research (SDG 8: Decent Work and Economic Growth)**

African nations should encourage research that focuses on practical applications relevant to the needs of the continent. This includes using quantum machine learning for climate modeling, quantum computing for drug discovery to address local diseases, and quantum cryptography to secure digital infrastructure. By linking QST research to tangible economic and social benefits, it becomes easier to justify investment and attract private sector interest. This will help create new job opportunities and drive economic growth, contributing to SDG 8.

## **Policy and Regulatory Frameworks (SDG 16: Peace, Justice and Strong Institutions)**

Governments must create supportive policies and regulatory environments that encourage QST research and innovation. This includes protection of intellectual property rights, clear data governance policies for quantum communications, and long-term national quantum strategies. Such frameworks provide the stability and certainty needed for both public and private investment, aligning with SDG 16's promotion of effective, accountable, and inclusive institutions.

## **Quantum Economic Transfer and Commercialization (SDG 9 and Aspiration 1 of Agenda 2063)**

To ensure that quantum research translates into tangible economic benefits, Africa must establish robust mechanisms for commercializing scientific discoveries. This requires creating technology transfer offices at universities that can bridge the gap between academic research and market applications, while simultaneously developing incubators and accelerators specifically designed for quantum startups. Initiatives like the emerging Africa Quantum Fund provide a promising model for nurturing quantum entrepreneurship across the continent. Furthermore, fostering public-private partnerships will be essential for quantum application development, as these collaborations can leverage both public research capabilities and private sector market expertise. Critically, all these efforts must be underpinned by intellectual property frameworks that not only encourage innovation but also ensure African ownership and control of quantum technologies developed on the continent, preventing a scenario where Africa becomes merely a source of raw research talent for technologies ultimately owned and commercialized elsewhere.

While the development of indigenous African quantum hardware remains a long-term aspiration, the continent's immediate commercialization strategy should prioritize quantum software development, which offers a more accessible entry point into the global quantum economy and can generate international revenue streams that will eventually fund our hardware ambitions. This

software-first approach creates a strategic pathway where early commercial successes in quantum algorithms and applications can attract the substantial investment needed to support our ultimate goal of building African-owned quantum computers for both academic research and commercial use. The presence of advanced infrastructure like Morocco’s Toubkal supercomputer presents an immediate opportunity to establish ourselves as a hub for quantum simulation and hybrid classical-quantum computing, while simultaneously fostering deeper collaborations with international industry partners who can provide access to their quantum hardware platforms. These partnerships are crucial during our development phase, as they allow African researchers and companies to run quantum applications on existing global quantum systems while we build the expertise and resources necessary to develop our own quantum computing capabilities, essentially creating a bridge between our current potential and our future quantum sovereignty.

## Conclusion

Africa stands at a quantum crossroads. The convergence of the International Year of Quantum, unprecedented global investment in quantum technologies, and Africa’s unique strategic advantages creates a narrow but critical window of opportunity. The continent can either proactively shape its quantum future or risk becoming a passive consumer of technologies developed elsewhere, potentially facing a new form of technological dependence that could persist for generations.

This strategy document demonstrates that Africa possesses the essential ingredients for quantum leadership: abundant critical minerals, optimal geographic positioning, growing research capacity, and strong diaspora networks. More importantly, quantum technologies directly address Africa’s most pressing development challenges, from healthcare and agriculture to climate adaptation and economic growth. The alignment between quantum capabilities and continental needs creates a compelling case for strategic investment that goes beyond technological ambition to developmental necessity.

The five-pillar strategy presented here: human capital development, international collaboration, dedicated funding mechanisms, applied research focus, and supportive policy frameworks—provides a roadmap for transforming Africa from a quantum observer to a quantum co-leader. The emphasis on software-first development and application-driven innovation offers realistic pathways to near-term impact while building toward long-term hardware sovereignty.

Success requires unprecedented coordination across African governments, research institutions, and private sector partners. The African Quantum Consortium and similar continental initiatives provide the foundation for this coordination, but sustained political commitment and financial investment are essential. The quantum revolution will not wait for Africa to decide its level of participation.

The choice is clear: Africa can leverage its quantum strategy to accelerate

progress toward Sustainable Development Goals and Agenda 2063 aspirations, or it can remain on the periphery of potentially one of the most transformative technological shifts of the 21st century. With the right strategic investments and continental coordination, Africa can transform its quantum potential into quantum leadership, ensuring that the continent not only participates in the quantum future but helps define it.

## Separate Section for Chapter 12: Quantum Computing

Quantum Computing is a foundational technology poised to transform science and industry. By leveraging quantum properties like superposition and entanglement, quantum computers can provide exponential speedups for specific classes of problems, such as cryptography and certain optimization challenges, that are intractable for classical computers. This promise has led to global efforts, from CERN’s collaborations on a quantum roadmap to Google’s contested claim of achieving quantum supremacy in 2019 for a specific, narrow computational task [12]. The development of both quantum hardware (qubits) and software remains a major challenge, yet progress in AI and computing science is making quantum-classical hybrid approaches essential for accelerating discovery in computationally intensive scientific problems [4].

In Africa, quantum computing is recognized as a strategic imperative. The continent has a strong, pioneering base in countries like South Africa, which has already endorsed a national quantum roadmap. This top-down, government-driven approach, exemplified by the South African Quantum Technology Initiative (SA QuTI), is complemented by a bottom-up, grassroots model embodied by the African Quantum Consortium (AQC), which acts as a formal network to unify efforts continent-wide. While a series of Quantum Africa Conferences has fostered collaboration, the ecosystem is critically shaped by international public-private partnerships, notably the pivotal role of IBM Research Africa in providing cloud access and community building.

However, the entire ecosystem rests on a fragile foundation. A critical challenge persists: the “cloud computing paradox.” While cloud-based quantum access is a vital tool, its effectiveness is hindered by a lack of sufficient digital infrastructure and is compounded by export controls, technology restrictions, and diplomatic dynamics that threaten to create a new “quantum divide” within Africa.

To secure a sovereign quantum future, Africa must strategically focus on application-driven innovation, recognizing current hardware limitations while leveraging its unique advantages to develop solutions in three promising areas:

- **Quantum Algorithms for Economic Optimization:** Applying quantum algorithms to solve complex challenges in sectors like mining, agriculture, and finance [13, 21].
- **Quantum Machine Learning (QML):** Leveraging the continent’s data science expertise to pioneer QML applications for medical diagnostics and financial forecasting [18, 2].
- **Quantum Simulation for Health and Materials Science:** Using quantum computing to accelerate drug discovery for local diseases and to design novel materials for green energy, leveraging Africa’s vast mineral wealth [23].

These applications, while promising, require continued research and development to overcome current technical limitations including high error rates and limited coherence times in existing quantum systems.

This sovereign future requires a coordinated, multi-stakeholder framework. Governments must develop national strategies, invest in foundational digital infrastructure, and foster "brain circulation" by facilitating diaspora engagement. For research and education, a focus on interdisciplinary quantum curricula and formal partnerships with community networks like QWorld is crucial to building a skilled workforce [3, 11]. Finally, the private sector must co-fund "quantum readiness programs" and invest in talent retention and early-stage startups. By embracing this comprehensive strategy, Africa can transform its unique challenges and advantages into a position of leadership, ensuring it is a co-leader in shaping the future of compute.

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