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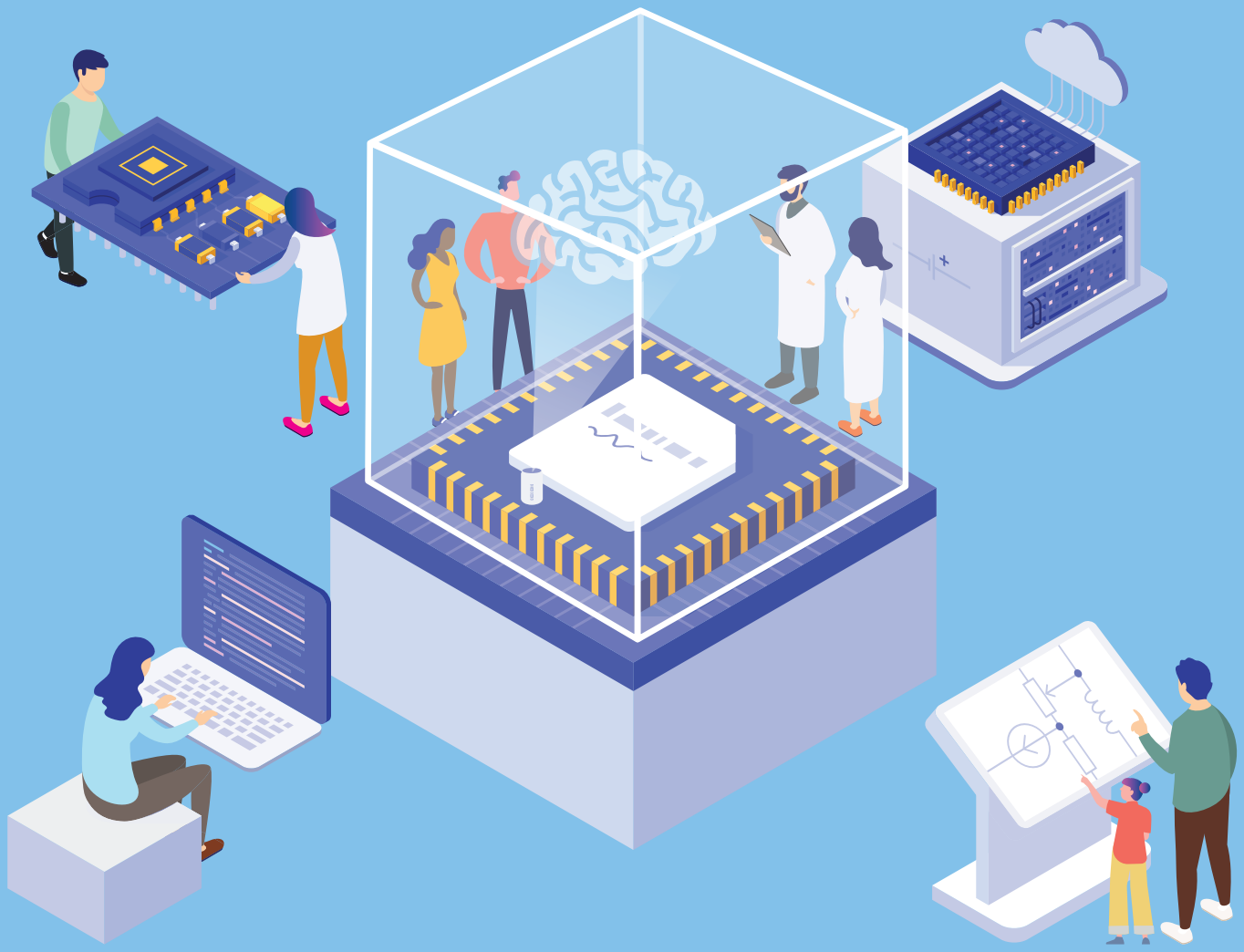


IFAP ISSUE BRIEF

Human Rights Centered Global Governance of Quantum Technologies

Advancing Information for All

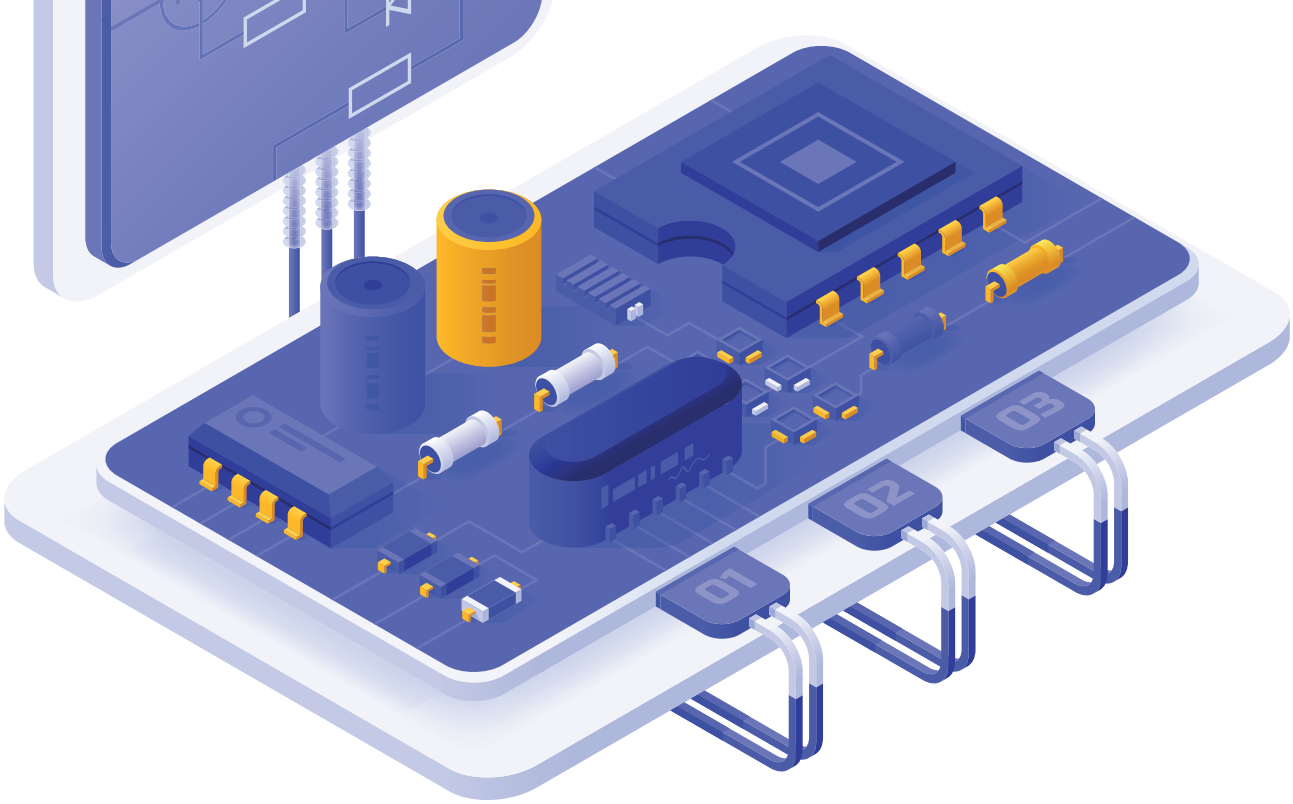
IFAP Issue Briefs Series: *Within the framework of implementing the Information For All (IFAP) Strategic Plan 2023 -2029, the IFAP Secretariat launches this foresights oriented Issue Briefs Series in order to sensitize and support Member States and other stakeholders in formulating information policies and sharing experiences and lessons learned, aimed at building inclusive, equitable and sustainable Knowledge Societies, including harnessing the opportunities offered by the frontier technologies and mitigating eventual risks.*

In the context of fast development of emerging technologies, UNESCO's Information for All Programme (IFAP) continues to empower Member States and other relevant stakeholders in developing human rights centered governance for inclusive, equitable, and sustainable knowledge societies, leveraging frontier technologies such as Quantum technology and addressing their risks."

Tawfik Jelassi, UNESCO Assistant Director-General for Communication and Information

"In recognition of the International Year of Quantum Science and Technology (IYQST), UNESCO is committed to advancing global understanding and human rights centered governance of Quantum Technologies. By fostering international collaboration and policy development, we aim to ensure that these transformative technologies contribute to inclusive, equitable, and sustainable knowledge societies."

Lidia Arthur Brito, UNESCO Assistant Director-General for Natural Sciences



Executive Summary

Quantum technologies—encompassing quantum computing, communications, sensing, and materials—represent a groundbreaking frontier with the potential to revolutionize industries such as healthcare, energy, finance, and communications. However, like all transformative innovations, they come with opportunities, challenges and implications for human rights.

Drawing lessons from the rapid advancements in artificial intelligence (AI) and the subsequent policy responses, human rights centered governance of quantum technologies is essential. In line with its Strategic Plan 2023-2029, UNESCO's **Information for All Programme (IFAP)**, jointly with partners: **European University Institute (EUI)** and **Tech and Global Affairs Innovation Hub**, Sciences Po, is presenting this Issue Brief: ***Human Rights Centered Global Governance of Quantum Technologies: Advancing Information for All***.

The Issue Brief underscores the necessity of integrating agile and anticipatory human rights centered principles into the governance of quantum technologies, to ensure that technological progress foster opportunities for protecting and promoting human rights and, therefore, does not come at the expense of fundamental freedoms and ethical considerations.

The integration of quantum technologies into AI systems introduces greater complexity, requiring stronger policy and technical frameworks that uphold human rights protections. Ensuring that these advancements do not widen existing inequalities or cause environmental harm is crucial.

The Brief expands on the "Quantum technologies and their global impact: discussion paper" published by UNESCO. The objective of this Brief is to unpack the multiple dimensions of the quantum ecosystem and broadly explore the human rights and policy implications of quantum technologies, with some key findings:

- While quantum technologies promise advancements of human rights in the areas of **encryption, privacy, and security**, they also pose risks to these very domains and related ones such as **freedom of expression and access to information**.

- Quantum innovations will reshape **security, economic growth, and science**, but without a robust **human rights-based framework**, they risk deepening inequalities and destabilizing global governance.

- The **quantum divide** is emerging as a critical issue, with disparities in access to technology, expertise, and infrastructure widening global inequalities. Unchecked, this gap could limit the benefits of quantum advancements for all.

- The **quantum gender divide** remains stark—79% of quantum companies have no female senior leaders, and only 1 in 54 quantum job applicants are women.

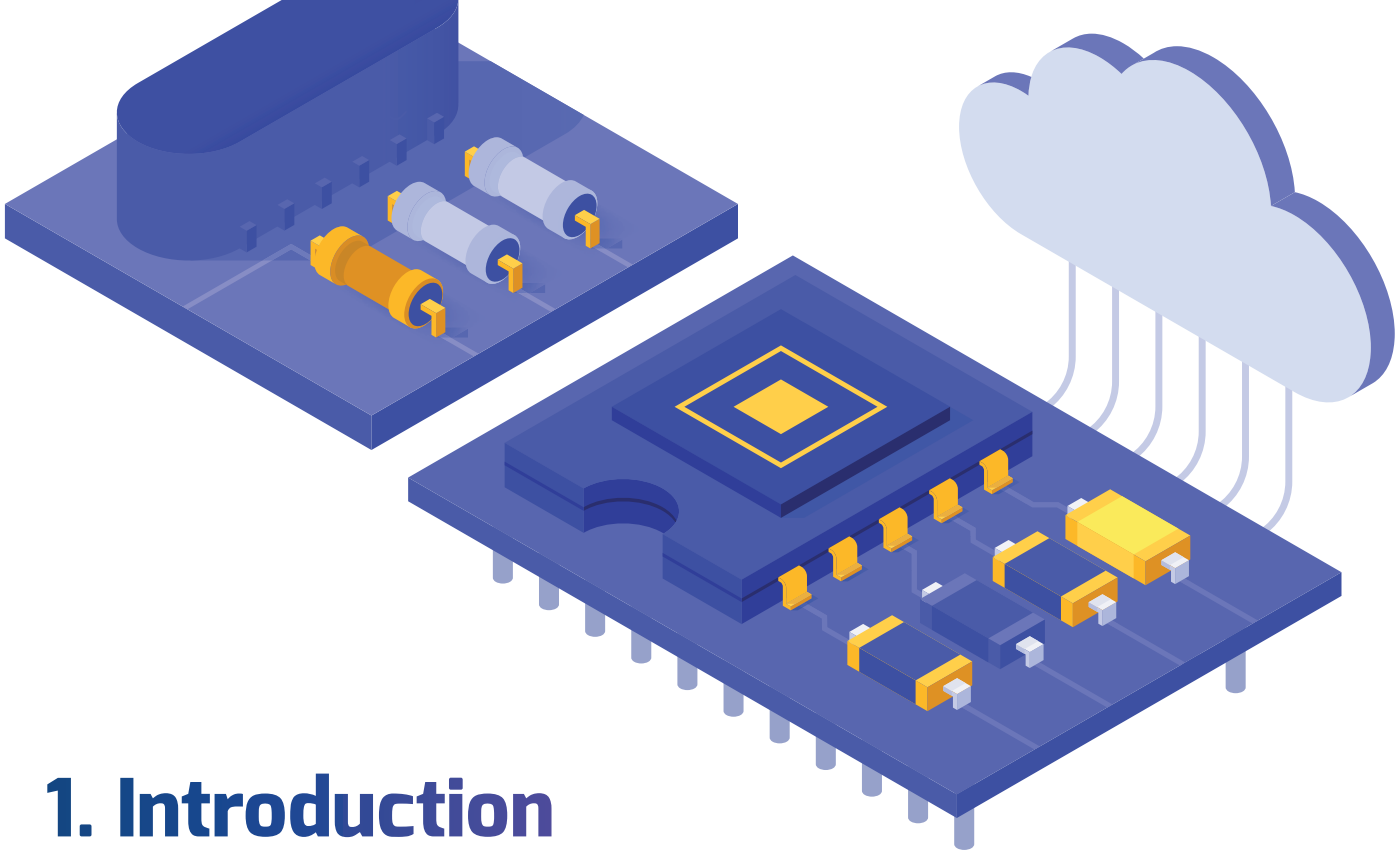
The Issue Brief provides broad recommendations and targeted actions for stakeholders, emphasizing human rights-centered governance, awareness, capacity building, and inclusivity to bridge global and gender divides. The key recommendations focus on a comprehensive governance model which must ensure a multistakeholder approach that facilitates, state duties, corporate accountability, effective remedies for human rights violations, and open standards for equitable access. Prioritizing human rights in global governance will ensure quantum innovation serves all of humanity while safeguarding fundamental freedoms.

As the lead agency for the International Year of Quantum Science and Technology (IYQ 2025), UNESCO is uniquely positioned to address these challenges in following endeavours:

- **Contribute to reducing the global divide and gender divide in the field of quantum technology** by fostering international cooperation and sharing knowledge.

- **Shape a human rights centred global governance framework of quantum technology** building on its commitment to promoting sustainable development and innovation, education, science, cultural diversity, ethics of science and technologies, equitable access to information, freedom of expression, privacy protection and linguistic diversity.

- **Build inclusive multi-stakeholder partnership of quantum technology** including for the **Quantum-AI convergence** and involve a variety of stakeholders, joint initiatives, carry out capacity-building programmes, and support knowledge-sharing platforms focused on quantum ethics, and human rights centred governance.



1. Introduction

Quantum technology is a field that leverages the fundamenta laws of quantum mechanics, particularly at the scale of atoms and subatomic particles, to develop novel applications in computing, communication, sensing, and cryptography. These technologies directly initialize, manipulate, and measure the states of quantum systems, typically using qubits as their fundamental building block (Ezraty, 2023) [1].

Despite the considerable hype surrounding the potential of quantum technology to revolutionize various sectors, in general, practical applicability for quantum technology has yet to be ready for commercial use cases and widespread deployment (Roberson et al., 2023). For example, despite massive investments, to date, quantum computing applications have yet to achieve the "quantum advantage[2]" over conventional computing. However, the field is rapidly advancing, and some niche applications are emerging; for instance, significant breakthroughs have been observed in cryptography, sensing, and communications, with more ubiquitous quantum technology applications expected to proliferate in various industries within the next decade (Bogobowicz, et al. , 2024).

Quantum phenomena have been studied for decades, but widespread use of technologies based on those phenomena are still in the early stages of development, despite the announced massive public investments and huge growth in private venture capital (WEF, 2025). Notwithstanding, while the discussions on the ethical, socioeconomic, and governance risks associated with quantum technology applications are just emerging, as expected, a global multistakeholder dialogue on building guidelines to foster international cooperation, coordination, and collaboration for human-rights based[3] global governance of quantum technology still must take concrete shape (Kop et al., 2023; WEF, 2024).

The emerging "quantum economy" suggests a future where quantum technology applications underpins global value chains, involving various sectors beyond traditional quantum domains (Mans et al,.2024). The evolution towards the quantum economy intersects with existing supply chains in critical areas such as semiconductors, nanotechnology, and cryogenics. The quantum supply chain

1 Of the Quantum Technology applications mentioned, Quantum sensing has the most progression, with multiple applications and uses already commercially available.

2 Quantum Advantage is the milestone the field of quantum computing is actively working toward, where a quantum computer can solve problems beyond the reach of -or radically faster than- the most potent non-quantum computers.

3 Universal Values, Principle One: Human Rights-Based Approach: https://unsdg.un.org/2030-agenda/universal-values/human-rights-based-approach

is currently in a nascent stage, characterized by high demand for advanced products that require extensive research and development (R&D) (Mans et al,.2024).

To fully realize the potential of the quantum economy, a multifaceted approach is necessary. This includes strategic investments from both public and private sectors, development of an inclusive skilled workforce, anticipating potential risks, and the expansion of the quantum ecosystem beyond dominant countries and largest players to avoid a quantum divide. Additionally, standardisation and consolidation are highly desired to streamline operations and ensure compatibility across the quantum supply chain (WEF, 2025).

Following these accelerated developments and acknowledging the recommendation[4] made by the 42nd session of UNESCO's General Conference, the United Nations declared 2025 as the International Year of Quantum Science and Technology (IYQ) on 7 June 2024[5], under the International Decade of Sciences for Sustainable Development (2024-2033). The International Year, of which UNESCO is the focal point, aims to raise public awareness about the importance of quantum science and its applications.

Brief background

UNESCO's Information for All Programme (IFAP) promotes inclusive and sustainable knowledge societies by addressing the challenges and divides posed by quantum technology. It seeks to inform policymakers, enhance international cooperation, and recommend strategies to harness opportunities while mitigating risks. Ensuring equitable access and establishing regulatory frameworks to protect human rights remain central to IFAP's mission. IFAP also supports the implementation of the UNESCO Recommendation on the Ethics of Artificial Intelligence (AI), encouraging global cooperation and ethical responses to frontier technologies.

Addressing emerging challenges posed by quantum technologies requires the collaboration and coordination in the development and implementation of quantum-resistant encryption methods to ensure data security across these critical sectors to prevent geopolitical tensions and digital exclusions (WEF, 2024).

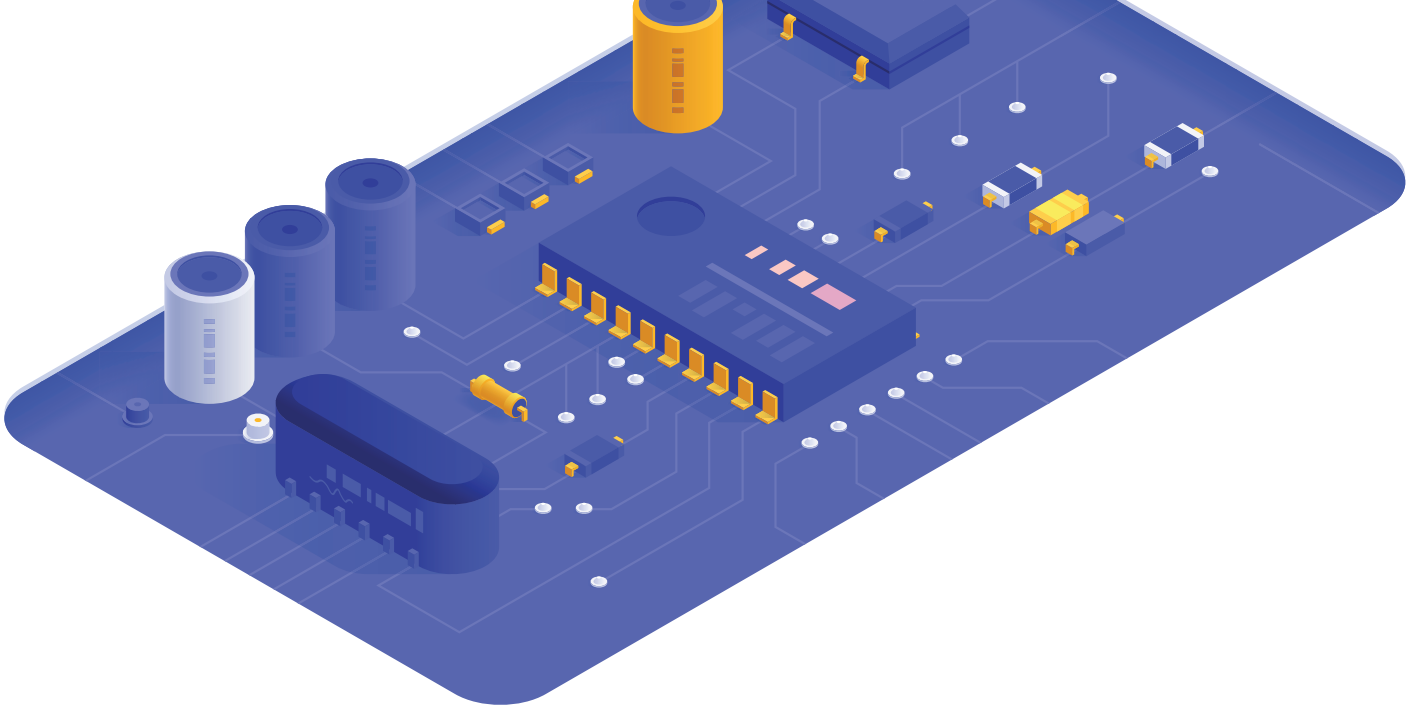
In this context, multiple stakeholders of the World Summit of the Information Society (WSIS) exchanged on quantum technology challenges, opportunities and impact. Expanding on the "Quantum technologies and their global impact: discussion paper" at the WSIS Forum 2024, IFAP, jointly with EUI, Science Po's Tech and Global Affairs Innovation Hub and Quantum Delta NL, co-organized a workshop on global governance for quantum technologies. Participants recognized the urgent need to explore the ethical, legal, social, and policy and the human rights implications of Quantum Technology. They called for interdisciplinary and collaborative research to shape inclusive, ethical, and human rights centered global governance of the emerging Quantum Economy.[6]

The Brief, aligns with the 2024 Summit of the Future outcome document on The Pact for the Future, Global Digital Compact, and Declaration on Future Generations that emphasizes the importance of science, technology and innovation and digital cooperation to potentially accelerate the realization of the aspirations of the UN across all three pillars of its work– sustainable development, peace and security, and human rights (UN, 2024).

4 UNESCO Resolution (2023): UNESCO 42 C/Resolution 23

5 Resolution adopted by the General Assembly A/RES/78/287. International Year of Quantum Science and Technology, 2025.https://documents.un.org/doc/undoc/gen/n24/175/79/pdf/n2417579.pdf

6 Pioneering Responsible Global Governance for Quantum Technologies. https://www.itu.int/net4/wsis/forum/2024/en/Agenda/Session/164



2. Mapping the Quantum Divide and Calling for Human Rights Centered Global Governance

2.1 Global Investments in Quantum Technology

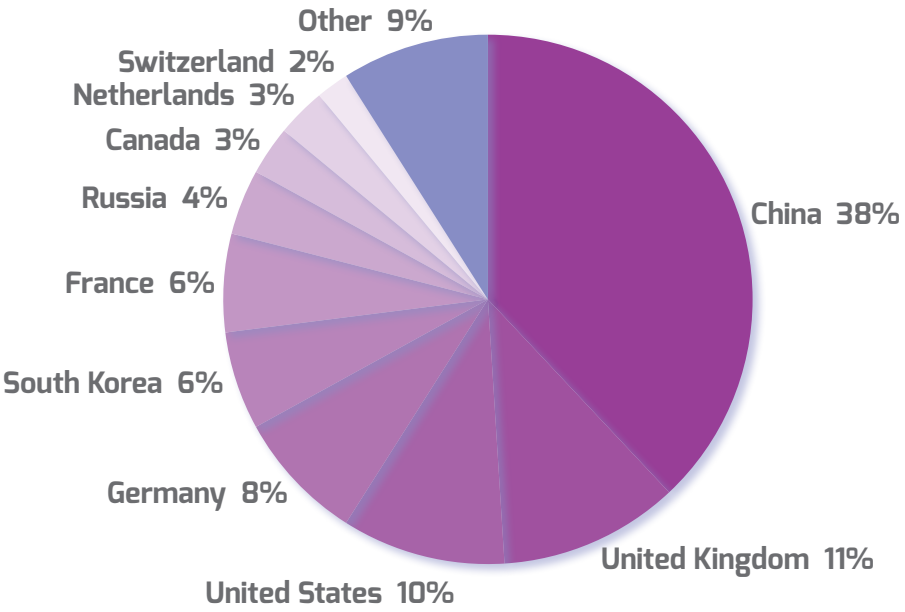
Globally, nations are adopting varied approaches to prepare for the advent of the quantum economy, with significant national quantum research and development (R&D) initiatives, strategies, and policy measures in place (QI, 2021). Most national strategies also support the establishment of national industry consortia to foster ecosystem coordination, fast-track technology transfers and accelerate the industrialisation of sovereign QT (GESDA, 2023). R&D for QT can be classified into three broad categories (WTIA, 2023): (i) National Quantum Strategy, (ii) Government-endorsed Initiatives, and (iii) International/Regional Quantum Partnerships[7].

As of 2023, announced global public investments in Quantum Technology **totaled $42 billion** (Bogobowicz, et al. , 2024). **Figure 1** shows that until 2023, the top 10 announced global public investments are mostly from Europe and North America. Notably, China leads in announced public investments, contributing $15 billion, or approximately 40% of the global total.

Driven by strategic national priorities and substantial government funding, China has positioned as a global leader in QT. China's focus includes developing a comprehensive quantum communications network and constructing the world's largest quantum research facility, underscoring its commitment to technological independence and innovation (Parker et al.,2022; CSIS,2023).

7 One of the most significant is the €1 Billion European Union (EU) Quantum Flagship which brings together government, academia, and industry stakeholders from 32 countries within and beyond the EU.

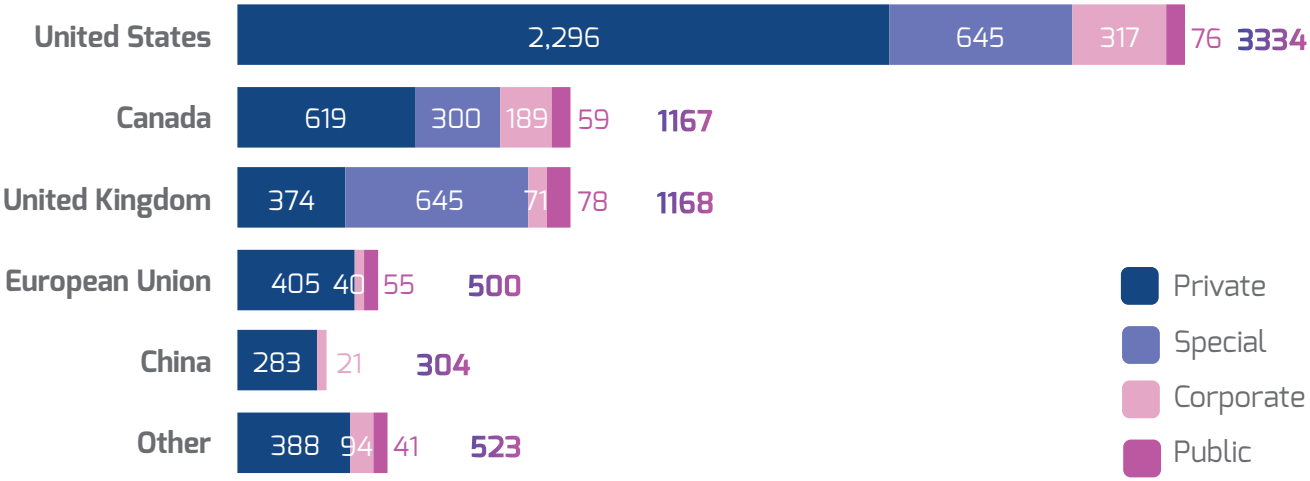
Figure 1: Top 10 Governments Actively Investing in Quantum Technology (%) (2023)



Source: Authors own adapted from World Economic Forum.

Private funding trends provide insights into the maturity and potential of Quantum Technology. Beyond the announced investments from incumbent Big Tech players that benefit from high entry barriers within the Quantum Technology ecosystem, there are also increased private venture capital and angel investor announcements in start-ups, primarily concentrated in North America, the Asia-Pacific region, and the European Union (McKinsey, 2024).

Figure 2: Total investment in Quantum Technology start-ups by location and primary investor type, 2001–22, US$ million



Source: Augmented from Bogobowicz, et al. , 2024

Figure 2 shows unbalanced investment in Quantum Technology start-ups among countries. In order to reap the promise of quantum technology in developing real-world quantum applications, effective public-private collaboration in research and development is crucial to scale the development across the global Quantum Technology venture capital.

2.2 International Research and Collaboration Initiatives

As with any other science technology and innovation ecosystem, collaboration in the Quantum Technology ecosystem across academia and industry is crucial to enhance Research and Development and innovation and facilitate the translation of research into more commercial/end user-friendly applications, including at the global level (Parker, 2023). Some ongoing examples of global research and collaboration initiatives between multiple stakeholders to enhance Quantum Technology ecosystems are:

i. Leading industry-led research and development Initiatives: IBM Q Network and Microsoft Station Q[8]
The IBM Q Network focuses on developing quantum computing technologies and applications, while Microsoft Station Q is dedicated to quantum research and innovation.

ii. Joint Research Projects (MIT - ETH Zurich)[9]
Collaborative research projects between the Massachusetts Institute of Technology (MIT) and ETH Zurich in Switzerland aim to drive advancements in quantum technologies.

iii. European Quantum Flagship Collaboration with the United States[10]
The European Quantum Flagship initiative, which involves collaboration with the United States, is a large-scale investment programme to accelerate the development of quantum technologies.

iv. Quantum Energy Initiative (QEI)[11]
The Quantum Energy Initiative (QEI), established in France and Singapore in August 2022, aims to unite global experts concerned about the resource implications of emerging Quantum Technology. Additionally, the Quantum Energy Initiative has launched a standardization working group within the Institute of Electrical and Electronics Engineers (IEEE) to develop a new standard for measuring the environmental impact of quantum computing.

v. IBM Q, University of Witwatersrand, and African Research Universities Alliance (ARUA)[12]
In 2019, IBM announced a significant expansion of its quantum computing initiatives to Africa through a new partnership with the University of the Witwatersrand in South Africa. As the first African partner on the IBM Q Network, the University of the Witwatersrand was envisioned as the primary hub for academics throughout South Africa and providing access to the 15 universities within the African Research Universities Alliance (ARUA).

The efforts to enhance international collaboration in Quantum Technology underscore the global recognition of the need to pool resources, expertise, and efforts to accelerate progress and transition to a quantum economy. However, currently most international cooperation is led by a small group of countries that dominate policy advancement, infrastructure investment, and human capital development in quantum ecosystems. This trend consolidates geopolitical power, wealth, and technological advancements, potentially creating a "quantum divide" and perpetuating global inequalities, as seen in previous technological waves (UNCTAD 2021; Ahmed et al., (2023).

8 https://news.microsoft.com/stories/stationq/
9 https://ethz.ch/en/news-and-events/eth-news/news/2014/07/beziehungspflege-zwischen-mit-und-eth.html
10 https://www.quantum.gov/competitiveness/
11 https://quantum-energy-initiative.org/
12 https://arua.org.za/first-for-africa-wits-ibm-to-expand-quantum-computing-in-africa/

2.3 Quantum Technology Workforce Development

The demand for Quantum Technology talent with advanced degrees across various applications is outpacing the available workforce. As a result, national and regional programs and strategies are being implemented worldwide to strengthen the Quantum Technology workforce. (Mateusz et al.,2022). India is leading the talent race in terms of the number of quantum-relevant graduates[13], followed by the European Union and China.

Given the time that it takes to design new curricula and develop human capital, it is highly recommended to start planning for solutions to build the quantum technician workforce now for the future, particularly in low- and middle-income countries (LMICs) to create new talent pipelines for the quantum economy (WEF 2024).

Various initiatives are being taken globally to address the challenges of skills shortage. For example, the Quantum Flagship Coordination Action and Support (QUCATS) in Europe is coordinating European quantum activities to support standardization and educate the workforce.[14]. In the United States of America, the National Quantum Initiative Act was passed in 2018 to accelerate the country's quantum research and development activities.[15].

In Africa, the African Institute for Mathematical Sciences (AIMS) has launched a Quantum Leap Africa (QLA) initiative to build the continent's capacity in quantum computing. Quantum Leap Africa aims to train the next generation of African quantum scientists and engineers, create a vibrant quantum research community, and foster collaboration with international partners[16].

The Indian Institute of Technology (IIT) Madras has established a Center for Quantum Information, Communication, and Computing to promote research and education in Quantum Technology. The Center for Quantum Information, Communication, and Computing offers courses and training programmes for students, researchers, and industry professionals to develop skills in the application of Quantum Technology[17].

In Israel, the Tel Aviv University Quantum Science and Technology Center aims to conduct and support cutting-edge research and train students at all levels in this fast-emerging field by collaborating with industrial partners on potential Quantum Technology applications and providing visibility and exposure of their activities by hosting top scientists and arranging international workshops.

In Brazil, the Brazilian National Institute for Science and Technology in Quantum Information (INCT-IQ) has launched a programme to train quantum technicians and engineers. The programme aims to develop a skilled workforce to support the growth of the quantum industry in Brazil and Latin America. The programme includes courses, workshops, and internships in Quantum Technology companies and research institutions.

There is also growing consensus from industry experts who argue that building a Quantum Technology ecosystem requires more than technical expertise in quantum physics, particularly for the transition to the quantum economy (Mishra & Nair, 2023). For instance, generalist business training such as accounting, marketing, and business development is necessary and can help existing quantum economy incumbents in the private sector identify new opportunities for using Quantum

13 "Landscape of Indian R&D in Quantum Technologies. https://www.itihaasa.com/public/pdf/Landscape_of_Indian_R_and_D_in_quantum_technolgies.pdf
14 https://qt.eu/projects/csa-projects/qucats
15 https://www.quantum.gov/about/
16 https://quantumleapafrica.org/
17 https://quantum.iitm.ac.in/wp63/

Technology for commercial activities. Scientific communication skills are also crucial to allow quantum economy engineers to interface with business development experts, product designers, and marketers—all essential to building a robust Quantum Technology ecosystem.

2.4 Gender Divide in Quantum Technology Development

The potential risks of AI in exacerbating gender inequality have been widely discussed; however, similar concerns regarding quantum technology (QT) warrant equal, if not greater, attention. At this stage of Quantum Technology development, there remains an opportunity to mitigate these risks before they become deeply embedded in the technology's infrastructure.

In parallel with AI-related concerns, it is critical to examine key issues raised in UNESCO's report Your Opinion Doesn't Matter Anyway, including:

- The responsibility of quantum technology companies in ensuring that their innovations do not contribute to technology-facilitated gender-based violence or related harms.
- The potential for quantum technology to enable gender-specific harassment, gendered disinformation, hate speech, and targeted attacks.
- The need for proactive strategies and measures by companies, governments, civil society organizations, and independent researchers to anticipate and mitigate these risks.

The rapid advancement of quantum technologies presents both opportunities and challenges for workforce development, particularly concerning gender diversity and inclusion (Beige et al.,2024). As the quantum sector expands, addressing the gender divide becomes crucial for fostering innovation and ensuring equitable participation in this transformative field.

The quantum gender divide is characterized by a significant underrepresentation of women in quantum-related roles and leadership positions. A 2023 survey by Quantum Futures, cited by the Inclusion Initiative at the London School of Economics, revealed that 79% of quantum companies lack a female senior figure, and only 1 in 54 applicants for quantum roles were women (Josten & Robinson, 2023). This stark disparity highlights the need for targeted interventions to promote gender equality in the quantum workforce.

A matter of serious concern is the limited research on the specific demographic breakdowns regarding the gender of Quantum Technology talent (Josten & Robinson, 2023; Beige et al., 2024).

In conclusion, the underrepresentation of women in quantum technology remains a fundamental challenge, impacting the field's ability to address gender-related concerns effectively. Without significant efforts to foster inclusivity, the capacity to critically engage with and mitigate gender-based risks may be severely limited. Ensuring diverse participation is essential for shaping a more equitable and inclusive future in quantum technology.

2.5 Digital Divide, Quantum Divide and Human Rights Implications

While quantum advancements can significantly enhance data processing and information accessibility, they risk deepening the digital divide. If access to quantum-powered insights and

computational capabilities remains limited to a select few—governments, corporations, or institutions—communities in situation of marginalization may face further exclusion, undermining the universal right to freedom of expression and information.

The existing digital divide can serve as a proxy for a looming quantum divide between countries with established and unestablished quantum technology programmes (WEF, 2024). Unequal access to quantum technology may exacerbate existing multidimensional inequalities (Vermeer & Mans, 2024). Globally, as mentioned above, the quantum technology talent gap poses unique risks and opportunities for developing countries. The persistent lack of diversity in the global STEM workforce is a significant issue that will most likely negatively impact the quantum economy.

Although a coordinated collaborative global R&D ecosystem is essential for the successful development and deployment of quantum technology, the current progress, as previously highlighted, is largely concentrated in a few specific countries, mirroring the deployment and development of other frontier technologies, that could exacerbate the existing "quantum divide" (Hidary & Sarkar, 2023).

Also as underlined above, the underrepresentation of women and other groups in situation of vulnerability in fields that feed directly into quantum, such as physics, engineering, and computer science, is a pressing concern (Wang et al., 2017; Diaz-Garcia, 2013). Lessons from other applications of frontier technologies reveal that the lack of diversity in the STEM pipeline and workforce will not only hinder the development of practical applications of Quantum Technology but also limit the potential widespread benefits for society (Josten & Robinson, 2023).

Privacy implications

Quantum-enhanced devices offer unprecedented sensitivity and precision, enabling advancements in various industries, including healthcare, information and communication technologies, defense, aerospace, automotive, environmental monitoring, and more (Kaltenbaek, 2021; WEF, 2024). In communications, quantum key distribution protocols are being developed to provide theoretically secure communication channels immune to networks and promise unparalleled security for sensitive data transmission (WEF, 2024).

Paradoxically, quantum computing's potential to break traditional encryption algorithms poses significant risks across potentially compromising the security of nearly all data transmitted over the Internet, in multiple sectors, including finance, healthcare, government and defense, telecommunications, journalism and human rights protection and cryptocurrencies. This vulnerability could lead to data breaches, financial fraud, compromised personal health information, threats to national security, privacy violations, and financial instability (Rosch-Grace and Straub, 2022).

In line with its mandate, UNESCO has a crucial role to play in addressing privacy and freedom of expression challenges posed by quantum technologies. With Quantum technology's potential to enhance encryption and secure communications, this would be conducive to advance freedom of expression by empowering individuals to express themselves without fear of surveillance. However, when the computational power of quantum threatens and breaks existing encryption standards and personal data protection, it could lead to undermining anonymity and limitations of free speech. UNESCO has a crucial role in advocating for human rights centered governance that harnesses the benefits of quantum technologies while protecting fundamental human rights.

2.6 The Need for Human Rights Centered Global Governance of Quantum Technology

The global nature of quantum technology development and deployment requires transnational collaboration, and coordination to ensure consistent and effective global governance, particularly in the evolving components and materials (including critical rare-earth materials) that contribute to the "quantum stack" (WEF, 2024).

However, the discourse surrounding global governance of quantum technology is still in its formative stages (Vermaas & Mans, 2024). Much of the explorations currently involve researchers, policymakers, and industry leaders primarily from North America, Europe, and Asia (including Japan, India, Indonesia and China). This skewed representation raises concerns about overlooking the perspectives and concerns of the global majority, where the impact and adoption of quantum technology may differ significantly.

As outlined in the UN Secretary-General's Global Digital Compact, which aims to establish shared principles for an open, free, and secure digital future, addressing key issues such as global supply chains, cybersecurity, knowledge transfer, and talent development is essential. These issues are particularly relevant to the emerging quantum economy.

The quantum divide needs to be addressed by putting place an anticipatory global governance mechanisms to prevent exacerbating geopolitical tensions and wealth disparities. These challenges include balancing national priorities, regional strategies, and private sector interests while addressing global technological divides. Effective cooperation is needed to establish common global norms, standards, and protocols to ensure equitable distribution of quantum economy benefits across all countries (Vermaas & Mans, 2024; WEF, 2025).

The current trend of integrating quantum technologies into AI systems introduces greater complexity. The Quantum-AI convergence presents extra global governance challenges, as nations achieving quantum supremacy may gain substantial advantages in cybersecurity and economic competitiveness, potentially reshaping global power dynamics. Moreover, existing AI governance frameworks may be inadequate to address the unique risks posed by quantum AI, necessitating updated regulation (Rosch-Grace and Straub 2022; WEF, 2024). Additionally, establishing comprehensive regulatory frameworks is crucial to safeguard human rights in the evolving technological landscape (van Dalen, 2024).

Therefore, drawing lessons from the rapid advancements in AI and the subsequent policy responses, proactive governance of quantum technologies is essential. Existing frameworks like the Universal Declaration of Human Rights (UDHR) provides a foundational framework for a rights-based governance and can offer guidance for international collaboration, and the development of guardrails.

The dual-use nature of quantum technologies, particularly their potential to enhance disruptive technologies like AI, underscores the critical need for a human rights-centered global governance framework (WEF, 2024). By grounding quantum technology governance in human rights principles, we can protect fundamental freedoms, address global inequalities, ensure ethical development and deployment, mitigate security risks, foster international cooperation, establish accountability mechanisms, and promote inclusive innovation, an approach that ultimately balances technological advancement with the protection of individual freedoms, promotes global equity, and ensures that the benefits of the quantum revolution are shared by all (van Daalen, 2024).

3. General Policy Recommendations and tailored actions for stakeholders

Quantum technologies are set to transform security, economic development, and scientific progress, but without a governance framework rooted in universal human rights, they risk deepening inequalities and threatening global stability. A human rights centered approach ensures that quantum technologies are developed and deployed in ways that uphold dignity, equity, and justice—values that transcend borders and underpin international cooperation (van Daalen, 2024).

The following general recommendations and tailored actions offer actionable guidance and steps for stakeholders join forces in shaping human rights centered global governance and inclusive development of Quantum Technology.

3.1 Infrastructure Investments for Quantum Technology

Infrastructure investments for Quantum Technology play a crucial role in advancing the field and fostering innovation and collaboration. To effectively allocate resources for infrastructure development in the Quantum Technology sector, the following are recommended:

- Ensure that **infrastructure investments** such as reliable electricity, computing power, meaningful connectivity and other prerequisites for Quantum Technology are not limited to the Global North but also extend to the Global South, by addressing existing infrastructure divides.

- Leverage **public-private partnerships** to develop a quantum-specific tech stack that integrates various tools for testing, measuring, and analyzing quantum elements is essential. This tech stack should provide a robust solution for researchers and developers to explore next-generation quantum materials, sensors, and qubits efficiently.

- Foster the development of **a robust quantum ecosystem** by supporting startups, entrepreneurs, and small and medium-sized enterprises (SMEs) working in the Quantum Technology space. This could involve providing financial incentives, access to research facilities, and mentorship programmes to accelerate the growth of quantum startups and promote entrepreneurship in the field.

3.2 Awareness Raising and Policy Considerations

Awareness-raising initiatives and policy considerations are vital for ensuring the inclusive development of Quantum Technology. We propose the following strategies to achieve this:

- Raise awareness about Quantum Technology and encourage debate on establishing **legal and ethical frameworks based on human rights** at global and national levels. These frameworks should put controls in place to harness opportunities, address identified risks and incentivize sustainable innovation.

- **Promote human rights centered policy considerations and awareness-raising and research initiatives** focused on Quantum Technology. This could include incorporating ethical and human rights considerations into academic curricula and research into the specific areas of quantum technology's implications in **freedom of expression, access to information and privacy**. It's also important to organize **public awareness campaigns** and community discussions to empower global Majority stakeholders in participating in inclusive research and innovation decision-making.

- Advocate for the **establishment of multistakeholder platforms** when necessary and continue to integrate Quantum Technology discussions into the existing fora such as **WSIS Forum**, **Internet Governance Forum (IGF), European Dialogue on Internet Governance (EuroDig) as well as AI related fora,** with representation from diverse regions and sectors. These platforms could serve as inclusive spaces for dialogue, knowledge exchange, and collaborative problem-solving, helping to bridge the gap between different stakeholders.

3.3 Capacity Building for Human Rights Centered Quantum Technology Governance

By embracing a collaborative, inclusive and human rights centered approach to Quantum Technology governance, stakeholders can navigate the complex ethical and human rights challenges posed by Quantum Technology and pave the way for a future where Quantum Technology contributes to a more equitable, sustainable, and prosperous world for generations to come, the following are recommended:

- The lack of representation in the Quantum Technology ecosystem limits talent and innovation. To address this, it's vital to **collect gender-disaggregated** data, audit hiring practices, and raise awareness on diversity and inclusion. **Addressing the quantum gender divide** requires a multifaceted approach, including education, recruitment, workplace policies, and cultural change, enabling the sector to harness diverse perspectives for more innovative advancements.

- **Dedicated higher education programmes** focusing on Quantum Technology can increase the number of qualified and diverse workers. Initiatives like DiviQ[18], which provides mentorship, scholarships, and professional opportunities to underrepresented groups, can also help foster a more inclusive environment. By **promoting diversity and inclusion**, the quantum industry can attract the full range of talent, bring new perspectives to the field, and enhance broader economic and social equality.

3.4 Recommendations for UNESCO

To ensure the human rights centered and equitable governance of Quantum Technology and harness its transformative potential for sustainable development, the following are recommended for UNESCO:

- **Contribute to reducing the global divide and gender divide in the field of Quantum Technology**. UNESCO should play a leading role in fostering international cooperation and sharing knowledge on Quantum Technology. UNESCO should contribute to reducing the divide between North and South and the gender divide, leveraging its ongoing efforts and the expertise and resources of UNESCO, including through its various Programme Sectors and intergovernmental bodies such as the Information for All Programme.

- **Shape a Human Rights-Centered Global Governance Framework for Quantum Technology.** Leveraging its expertise in education, science, cultural diversity, and ethical technology governance, UNESCO is uniquely positioned to shape an inclusive quantum future. Building on its commitment to sustainable development and innovation, UNESCO should promote participatory models, centralized knowledge hubs, and operational tools like readiness assessments to guide informed decision-making.

- **Build inclusive multi-stakeholder partnership of Quantum Technology**. UNESCO should foster diverse partnerships to advance science, technology, and innovation for sustainable development. This includes engaging multiple stakeholders, joining initiatives, conducting capacity-building programs, and supporting knowledge-sharing on quantum ethics and human rights-centered governance. Additionally, UNESCO should leverage its global networks like UNITWIN and collaborate with UN-led processes to address the implications of quantum technology.

18 https://www.diviq.org/

3.5 Tailored Actions for Targeted Stakeholders

Building on the general recommendations for Capacity Building for human rights centered Quantum Technology Governance, Table 1 summarizes the tailored actions for key stakeholders as follows:

Table 1: Tailored Actions for Targeted Stakeholders

Targeted Stakeholders	Tailored Actions
Governments and Policymakers	▶ Governments and policymakers should develop an enabling policy environment to support the human rights centered Quantum Technology governance framework by creating adaptive regulatory frameworks, fully aligned with international human rights law, that balance innovation with ethical, safety, and security safeguards while incentivizing private sector investment in quantum infrastructure, as well multistakeholder cooperation and dialogue ▶ Countries with established quantum strategies must ensure inclusive stakeholder engagement and promote global collaboration by supporting research facilities and innovation hubs in both developed and developing regions.
Private sector	▶ Leading quantum firms should drive public enrichment by sharing resources, fostering joint ventures, and accelerating commercialization. Establishing incubators, accelerators, and initiatives for underrepresented groups will nurture startups and expand access to Quantum Technology. ▶ Collaborate in an inclusive manner to contribute to a sustainable comprehensive innovation ecosystem that engages with academia, government, and civil society to co-develop environmentally friendly Quantum Technology solutions.
Technical Community and Academia	▶ Develop quantum-specific tech stacks and tools for research and development to support standardized tools and platforms for testing and analyzing Quantum Technology, including through collaborations to enhance the accessibility of quantum tools, knowledge transfers, and problem-solving through establishing international consortia and working groups focused on Quantum Technology development. ▶ Contribute to ethical and human rights-centered governance for Quantum Technology by providing expert input, collaborating with policymakers, and engaging the public. Develop courses on human rights aspects, integrate interdisciplinary perspectives, and support capacity-building, mentorship, scholarships, and fellowships for underrepresented groups.
Civil Society	▶ Engage in human rights-centered governance by co-creating Quantum Technology solutions that reflect diverse perspectives. Participate in transnational forums and multistakeholder groups focused on ethics and governance, advocate for human rights and inclusive policies, and support initiatives that bridge the digital divide and ensure equitable access to Quantum Technology. ▶ Raise awareness about the ethical and societal implications of Quantum Technology through public education campaigns and collaborations with media to ensure accurate and balanced coverage of Quantum Technology topics.

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Acknowledgments
Acknowledgments are extended to **Dr Pieter Vermaas** from the Delft University of Technology/Quantum Delta NL; **Ms Mariekie Hood** from the Geneva Science and Diplomacy Anticipator (GESDA)**; Mr Pierre Noro** from Sciences Po's Tech and Global Affairs Innovation Hub; **Mr Jaco Du Toit**, Chief of Section, Universal Access to Information, Communication and Information Sector of UNESCO; **Mr Davide Storti**, Programme Specialist, Section of Digital Policies and Digital Transformation, Communication and Information Sector of UNESCO; **Dr Amal Kasry**, Chief of Section, Basic Science, Research Innovation and Engineering, Natural Sciences Sector of UNESCO; **Ms Danielle Cliché**, Chief of Section, Policies and Strategies for Gender Equality of UNESCO and **Ms Sinéad Andrews**, Senior Programme Specialist, Section of Policies and Strategies for Gender Equality of UNESCO, who generously provided their valuable input and expertise.

UNESCO Information for All Programme (IFAP) thanks the financial support of Scientific and Technical Documentation Press (STDP) of China on the IFAP Issue Briefs Series.

科学技术文献出版社
SCIENTIFIC AND TECHNICAL DOCUMENTATION PRESS

Published in 2025 by the United Nations Educational, Scientific and Cultural Organization,
7, place de Fontenoy, 75352 Paris 07 SP, France

IFAP-2024/IssueBrief.1/QT Rev.

Jointly with European University Institute (EUI) and
Tech and Global Affairs Innovation Hub, Sciences Po.