Asia-Pacific Economic Cooperation

Strengthening Collaboration on Standardisation for Quantum Technologies in the APEC Region

Final Report and Roadmap

Acknowledgements

This Final Report was prepared by a Standards Australia project team led by Ms Alexandra Dunn-Delvaen, Strategic and International Officer; Mr Alistair Tegart, Standards Advisor – Quantum Technologies; Mr Jamal Waqar, Head of Research, Experience, Data and Analytics; Ms Shannen Brown, Research and Analytics Manager; Ms Helena Spahn, Research Analyst; Ms Adneya Wadetiwar, Research Analyst; Mr David Choi, Research Analyst; Mr Michael Waldron, Business Analyst; and Ms Kacey Graham, Voice of the Customer Manager at Standards Australia.

The team thanks Dr Cathy Foley, Chair of QT-001 Quantum Technologies, the Australian Committee participating in IEC/ISO JTC 3 Quantum Technologies, and Mr Michael Egan, Director of Quantum at KPMG Australia and QT-001 Member, for their contributions to this Final Report.

Standards Australia extends our sincere appreciation to the Asia Pacific Economic Cooperation (APEC) Subcommittee on Standards and Conformance (SCSC) Secretariat for their assistance and on-going support for the Project. We thank the Secretariat for enthusiastically promoting the importance of the Project and the project activities to the APEC SCSC, the broader APEC community and their stakeholders.

We would also like to take this opportunity to thank the APEC Sub Committee on Standards and Conformance (APEC SCSC) project co-sponsors, who have generously provided their time, thoughts and contributions to the Strengthening Collaboration on Standardisation for Quantum Technologies project. The Project co-sponsors included the following APEC member economies: Canada, the People's Republic of China, Malaysia, the Philippines, and the United States.

The Project benefited from considerable assistance from APEC SCSC members and representatives from the private and public sector across the Asia Pacific that provided input into the Project Survey and attended the *Strengthening Collaboration on Standardisation for Quantum Technologies* Workshop. Significant contributions were provided including on policies, guidelines, frameworks and strategies that APEC economies and the private sector have put in place or are developing to support the development and adoption of quantum technologies, as well as on quantum standards that have been developed or are in development domestically and internationally.

Financial support from the Australian Government Department of Foreign Affairs and Trade under the APEC Support Program is gratefully acknowledged and appreciated.

This Final Report does not reflect the views of Standards Australia, Dr Cathy Foley, Mr Michael Egan, the Australian Government or APEC. Neither Standards Australia nor any person acting on its behalf is responsible for any errors, omissions in, or the correctness of the information contained in this document. The Final Report is not presented as standards or innovation policy per se, but with a view to inform and stimulate wider consideration of the current and future role of standards in supporting quantum collaboration in the APEC region.

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Abbreviations and Acronyms

APEC	Asia-Pacific Economic Cooperation
APEC SCSC	Asia-Pacific Economic Cooperation Sub-Committee on Standards and Conformance
ASEAN	Association of Southeast Asian Nations
ETSI	European Telecommunications Standards Institute
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers Standards Association
ISO	International Organisation for Standardisation
ITU	International Telecommunication Union
JTC	Joint Technical Committee
NIST	National Institute of Standards and Technology
PPPs	Public-Private Partnerships
PQC	Post-Quantum Cryptography
QKD	Quantum Key Distribution
QRNGs	Quantum Random Number Generators
SDN	Software-Defined Networking
SOM	Senior Officials' Meeting
SRL	Standardisation Readiness Levels
TRL	Technology Readiness Levels

Executive Summary

Quantum technologies are rapidly emerging as a transformative force across the economy. As global investment and strategic interest intensifies, the Asia-Pacific region faces both significant opportunities and challenges in harnessing these technologies for inclusive and secure economic growth.

This report presents key findings of the APEC project titled *Strengthening Collaboration on Standardisation for Quantum Technologies*, delivered by Standards Australia with support from the Australian Government Department of Foreign Affairs and Trade (DFAT). The project aims to support regional collaboration on quantum technologies by identifying shared priorities, promoting international standards, and building capacity across APEC economies.

Key project activities include:

- **An APEC-wide survey** on the standards and policy landscape for quantum technologies in the APEC region, conducted from May-July 2025.
- **A Discussion Paper** on the challenges and opportunities to developing and deploying quantum technologies and how international standards can reduce potential barriers, published in July 2025.
- **A two-day hybrid workshop** bringing together stakeholders from across APEC member economies to advance regional dialogue on quantum standardisation and identify shared priorities for collaboration. The workshop was hosted as part of the APEC Senior Officials' Meeting 3 (SOM 3) in the Republic of Korea in July 2025.
- **This Final Report and Collaborative Roadmap** based on findings from the survey, discussion paper and hybrid workshop. The roadmap was first drafted during the workshop, with the aim of stimulating collaboration in support of quantum standards development activities in the region. This roadmap has been developed in an iterative manner with input from project participants via online collaboration tools following the workshop, and further refined at a post-workshop webinar in September 2025.

Findings from the project outputs highlight:

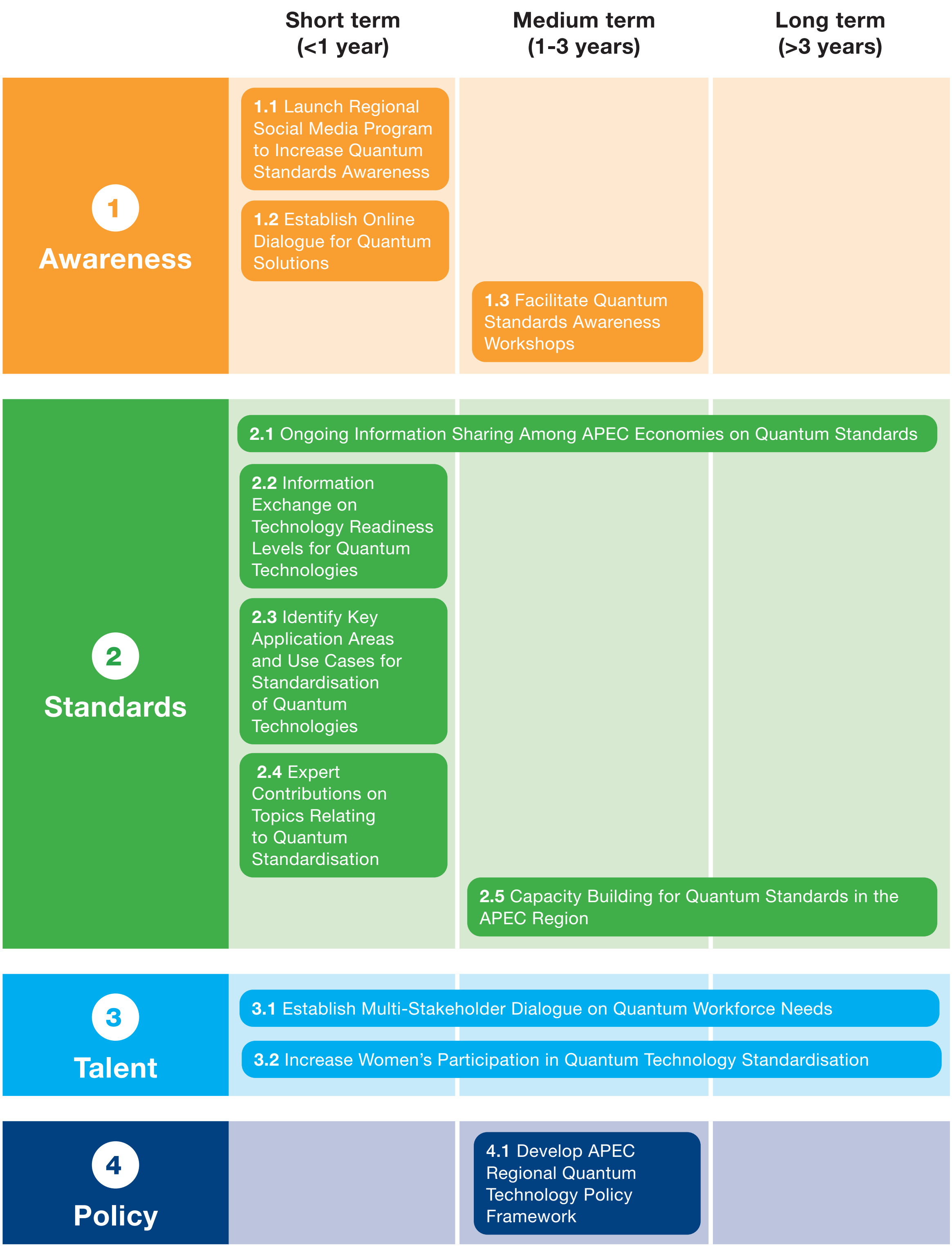
- **Diverse levels of quantum readiness across APEC economies.** Some economies are leading the quantum revolution with national strategies and investment in local quantum industries, while others are in the early stages of research and exploration.
- **Critical barriers** to quantum development and deployment, including high costs, limited access to skilled talent, regulatory uncertainty, and fragmented infrastructure are hindering progress across the region.
- **Opportunities for regional collaboration**, particularly in standardisation, workforce development, and knowledge exchange have the potential to minimise the technology divide and provide pathways to accelerate the adoption of quantum technologies in the APEC region.

To address the key challenges and opportunities identified, this report provides recommendations in the form of a practical roadmap structured around four priority areas:

1. **Standards Awareness**
2. **Standards Development**
3. **Talent Development**
4. **Policy Coordination**

The initiatives outlined in each of these priority areas are designed to leverage the diverse capabilities of APEC economies and provide meaningful pathways for participation and collaboration on quantum technologies. Collectively, APEC economies have the opportunity to advance quantum readiness, strengthen regional resilience and drive economic growth across the region.

Quantum Roadmap at a glance



1. What are Quantum Technologies?

Quantum technologies refer to a suite of advanced technologies that harness the principles of quantum mechanics. These principles are the foundational laws of physics that govern the behaviour of matter and energy at the atomic and subatomic scale.[1] Although quantum technologies can be traced back to the early 20th century, the 21st century has been characterised by rapid advancements in both theory and real-world applications across a range of scientific, technical and commercial disciplines.[2]

Quantum technologies exploit the unique properties of quantum mechanics to enable new capabilities that are beyond the reach of classical systems, and are focused on using these effects in emerging applications, such as:

- **Quantum computing**: Leverages properties of superposition and entanglement to perform calculations exponentially faster than traditional computers. While classical computers can only address problems one step at a time, quantum computers explore countless possibilities in parallel.
- **Quantum sensing**: Applies principles of quantum mechanics to achieve ultra-precise measurements of physical properties such as time, electrical and magnetic fields, for a wide range of applications such as position, navigation and timing, as well as identifying chemical signals.
- **Quantum communication**: Leverages the properties of entanglement to harness ultra-secure protocols such as Quantum Key Distribution (QKD), enabling highly secure communication channels within and between quantum computers.[3]

According to McKinsey & Company, by 2040 the total global revenue for quantum technologies could reach **$198 billion USD**[4]. Quantum technology is already becoming increasingly accessible through cloud-based platforms. Companies such as Amazon, Google, IBM and SpinQ offer quantum-as-a-service model allowing organisations to experiment with quantum algorithms and explore potential applications without substantial upfront investment.[5] It is expected that in the next 5 years organisations from the finance, pharmaceuticals and logistics sectors will adopt quantum technologies for specific applications and efficiencies.

1 "Quantum Technology," Sydney Quantum Academy, accessed June 20, 2025, https://sydneyquantum.org/discover/quantum-technology/.

2 "A brief History of Quantum," The University of Melbourne, accessed October 22, 2025, https://pursuit.unimelb.edu.au/articles/a-brief-history-of-quantum.

3 Henry Semenenko et al., Quantum Communication 101 (NASA, 2024), https://www.nasa.gov/wp-content/uploads/2024/07/quantum-communication-101-final.pdf?emrc=b0a13c.

4 Henning Soller et al., The Year of Quantum: From concept to reality in 2025 (McKinsey & Company, 2025), https://www.mckinsey.com/capabilities/tech-and-ai/our-insights/the-year-of-quantum-from-concept-to-reality-in-2025.

5 Jacob Roundy, "What is quantum as a service? Definition and top providers," *Informa TechTarget,* April 7, 2025, https://www.techtarget.com/searchcio/definition/quantum-as-a-service.

Table 1 – Examples of Quantum Applications and Use Cases Across Industries

Industry	Applications and Use Cases	Example
Pharmaceuticals	Quantum computing could revolutionise the pharmaceutical industry by accelerating lifesaving drug development.	Pfizer and IBM are working together to integrate generative AI and quantum computing to help make clinical trials faster and more efficient.[6]
Enhancements in AI	Quantum technology can handle the computational challenges of training advanced AI models, processing certain computations exponentially faster than the world's fastest classical computers.[7]	Google's Sycamore processor performed a specific computation in 200 seconds that would take a supercomputer at least 10,000 years.[8]
Finance	Quantum algorithms can be used to find optimisations for risk analysis, portfolios and fraud detection.	JP Morgan Chase, an American multinational investment bank and financial services company, established a quantum engineering team and are developing quantum algorithm systems for AI, financial optimisation and cryptography.[9]
Supply Chain and Logistics	Quantum technologies can be used for route optimisation, network design and predictive maintenance.	Volkswagen have used quantum algorithms to optimise taxi routes in Beijing, using the D-Wave 2000Q™ quantum computer.[10]
Healthcare	Quantum sensors could advance early disease detection, including cancer, infectious diseases and neurological disorders like Alzheimer's disease.[11]	Researchers are developing quantum sensors that can detect the earliest signs of biomarkers associated with cancer.[12]

6 Quantum News, "Quantum Computing Revolutionising Pharma: Speeding Drug Design and Accelerating Clinical Studies," *The Quantum Zeitgeist*, June 3, 2024, https://quantumzeitgeist.com/quantum-computing-revolutionising-pharma-speeding-drug-design-and-accelerating-clinical-studies/.

7 Marin Ivezic, "Google's Sycamore Achieves Quantum Supremacy," Post Quantum, October 26, 2019, https://postquantum.com/industry-news/google-sycamore/.

8 Ivezic, "Google's Sycamore Achieves Quantum Supremacy." *Post Quantum*, October 26,2019, Google's Sycamore Achieves Quantum Supremacy.

9 James Dargan, *"11 Global Banks Probing The Wonderful World of Quantum Technologies," The Quantum Insider,* May 28, 2024, https://thequantuminsider.com/2021/06/23/11-global-banks-probing-the-wonderful-world-of-quantum-technologies/.

10 How Volkswagen is Using Practical Quantum Computing to Explore Traffic Optimization and More," D-Wave Quantum, accessed September 30 15, 2025, https://www.dwavequantum.com/media/bbximewp/dwave_vw_case_study_v8.pdf.

11 Quantum Sensors: The Future of Early Disease Detection," Toxigon Infinite, last modified September 30, 2025, Sensing a cure: quantum technology takes aim at neurodegenerative disease | Pritzker School of Molecular Engineering | The University of Chicago., https://toxigon.com/quantum-sensors-for-early-disease-detection.

12 Soheil Sadr et al., "Revolutionizing Cancer Detection: Harnessing Quantum Dots and Graphene-Based Nanobiosensors for Lung and Breast Cancer Diagnosis," BioNanoScience 15, no. 111 (2024), https://doi.org/10.1007/s12668-024-01639-y.

2. Quantum Technologies in the APEC Economies

2.1 Quantum Technology Developments Across APEC Economies

As advancements in quantum technologies unfold and the global race for quantum leadership accelerates, many APEC economies are aligning public initiatives, private investment, research contributions and standardisation efforts to build robust quantum ecosystems and capitalise on the strategic advantages of early investment. This section provides an overview of the current quantum landscape in APEC, with a focus on government priorities, industry and investment activities, and the research and academic landscape.

2.1.1 APEC Government Priorities

Governments across the APEC region are actively shaping the development of quantum technologies through national strategies and policies. As of November 2025, 17 out of 21 APEC economies have announced a national quantum strategy, roadmap or initiative.[13] While national priorities and resources vary across the region, most strategies share common goals including boosting economic competitiveness, enhancing national security and positioning economies at the forefront of global technological leadership.[14] These recent developments reflect a sustained governmental commitment to quantum technologies, and an effort to create the stability and assurance needed to accelerate innovation and attract industry investment.[15]

In addition to the positive opportunities for efficient use of resources, new discoveries and economic growth, safeguarding digital infrastructure and trade systems from emerging technological risks is increasingly recognised as a key component of economic resilience across the APEC region.[16] Quantum technologies, while offering significant innovation potential, also present challenges to the integrity of digital communications and secure transactions. In particular, the potential for quantum computing to break common encryption methods poses risks to financial systems, cross-border trade, and digital supply chains.

To strengthen economic and digital resilience, several APEC economies are proactively adopting post-quantum cryptography (PQC) and quantum key distribution (QKD) to ensure continuity of secure data exchange and protect the integrity of digital infrastructure. These initiatives demonstrate a shared commitment to maintaining trusted digital environments that underpin regional commerce and innovation.

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13 Insights taken from the APEC Discussion Paper: Strengthening Collaboration on Standardisation for Quantum Technologies.

14 "National Quantum Strategy," Australian Government: Department of Industry, Science and Resources, published May 3, 2023, https://www.industry.gov.au/publications/national-quantum-strategy; Secretariat of Science, Technology and Innovation Policy, Cabinet Office, *Strategy of Quantum Future Industry Development – Summary* (Government of Japan: Cabinet Office, 2023), https://www8.cao.go.jp/cstp/english/strategy_r08.pdf; "National Quantum Strategy," United States Government, accessed June 26, 2025, https://www.quantum.gov/strategy/.

15 Nathan K Langford and Simon J Devitt, *Quantum Technologies and Standardisation Globally and in Australia* (Standards Australia, 2025), accessed October 17, 2025 , https://www.standards.org.au/documents/quantum-technologies-and-standardisation-globally-and-in-australia.

16 Scott Buchholz et al., "The realist's guide to quantum technology and national security," *Deloitte*, February 6, 2020, https://www.deloitte.com/us/en/insights/industry/government-public-sector-services/the-impact-of-quantum-technology-on-national-security.html.

Examples include:

- **Australia**: The Australian Cyber Security Centre (ACSC) and Australian Signals Directorate (ASD) are preparing for a full transition to quantum-resistant cryptography by 2030 to safeguard digital government and economic systems and have implemented controls in their Information Security Manual specifically to address this issue.[17, 18]
- **Canada**: The Government of Canada is collaborating with Shared Services Canada (SSC) and the Treasury Board of Canada Secretariat (TBS) to update policy and guidance for the national transition to PQC, supporting secure digital operations.[19]
- **Republic of Korea**: *The Quantum Strategy Vision 2035* includes measures to expand security compliance and verification for quantum communication systems, supporting the reliability of digital networks.[20]
- **Singapore**: In February 2024, the Monetary Authority of Singapore issued an *Advisory on Addressing the Cybersecurity Risks Associated with Quantum*, encouraging financial institutions to plan for resilience against quantum-era threats.[21]
- **United States**: In 2024, the U.S. Department of Commerce's National Institute of Standards and Technology (NIST) finalised three post-quantum encryption standards to protect data and digital transactions across the economy.[22]

These coordinated actions highlight how quantum security is increasingly viewed through the lens of economic and regulatory preparedness, ensuring that the region's digital infrastructure remains secure and resilient as technologies evolve.

2.1.2 Industry and Investment Activities in the APEC Region

Growing global investment in quantum technologies underscores its shift from a theoretical concept to commercial readiness. In early 2025, over $1.82 billion USD globally was invested in quantum technologies.[23] While the total value of quantum investment across the APEC region remains difficult to quantify, recent funding rounds in the region highlight its growing prominence in the global quantum landscape.

In early 2025, several companies based in APEC economies raised funding to support the development and scaling of quantum technologies. Most notably IonQ, headquartered in the United States, secured over $370 million USD to advance its

17 Post Quantum Government Initiatives by Country and Region," GSMA, accessed June 20, 2025, https://www.gsma.com/newsroom/post-quantum-government-initiatives-by-country-and-region/.

18 Information security manual: September 2025 changes, Australian Government: Australian Signals Directorate (Australian Government: Australian Signals Directorate, 2025), https://www.cyber.gov.au/sites/default/files/2025-09/ISM%20September%202025%20changes%20%28September%202025%29.pdf.

19 *Roadmap for the migration to postquantum cryptography for the Government of Canada* (ITSM.40.001), Government of Canada: Communications Security Establishment Canada (Government of Canada: Communications Security Establishment Canada, 2025), https://www.cyber.gc.ca/sites/default/files/itsm.40.001-migration-post-quantum-cryptography-government-canada-e.pdf.

20 Republic of Korea Government: Ministry of Science and ICT, *Korea's National Quantum Strategy* (Republic of Korea Government: Ministry of Science and ICT, 2023), https://quantuminkorea.org/wp-content/uploads/2024/06/Koreas-National-Quantum-Strategy-2023_c.pdf.

21 ADVISORY ON ADDRESSING THE CYBERSECURITY RISKS ASSOCIATED WITH QUANTUM", Monetary Authority of Singapore, (Monetary Authority of Singapore, 2024), https://www.mas.gov.sg/-/media/mas-media library/regulation/circulars/trpd/mas-quantum-advisory/mas-quantum-advisory.pdf.

22 NIST Releases First 3 Finalized Post-Quantum Encryption Standards," NIST, Published August 13, 2024, https://www.nist.gov/news-events/news/2024/08/nist-releases-first-3-finalized-post-quantum-encryption-standards.

23 Matt Swayne, "Q1 2025 Quantum Technology Investment: What's Driving the Surge in Quantum Investment?" *The Quantum Insider,* May 27, 2025, https://thequantuminsider.com/2025/05/27/q1-2025-quantum-technology-investment-whats-driving-the-surge-in-quantum-investment/.

mission of building and deploying quantum computers.[24] Another US headquartered company, PsiQuantum Pty Ltd, received $312.5 million USD in equity and loans to build the world's first commercial-scale quantum computer in Brisbane, Australia.[25] The investment will also enable the establishment of a regional quantum hub, the creation of PhD positions and advancement of research collaborations.[26] D-Wave Systems, originally founded in Canada and now operating out of California, has also attracted $150 million USD to support its technical development and business.[27] Other notable investments across the region include Quantum Brilliance based in Australia, which raised $20 million USD, while OptQC, a Japanese company, secured $4.4 million USD earlier this year to support the development of photonic quantum computers.[28]

At present, the biggest investments in quantum technologies have been directed to economies with advanced quantum ecosystems such as the United States, Japan and Canada. While emerging quantum economies share a common ambition to build their own quantum capabilities, inclusive growth will depend on coordinated investment in talent, infrastructure, and cross-border collaboration.

2.1.3 Research and Academic Landscape in the APEC Region

A strong academic and research base is a critical enabler of national quantum capabilities. In many leading economies, quantum ecosystems have been underpinned by the outputs of universities and publicly funded research institutions. The academic sector plays a central role in the development of quantum technologies, with many of the most important discoveries in quantum computing originating in university laboratories.[29]

China has emerged as a major leader in quantum research, publishing over 27,000 quantum technology papers between 1990-2021. Australia has published over 4,000 papers during the same period. Singapore and Chinese Taipei are growing their quantum capabilities through government funded programs and partnerships, publishing 2,399 and 2,116 academic papers respectively.[30] These global research efforts not only highlight the competitive landscape of quantum technologies but also lay the foundation for advancements in scientific discovery, workforce development, and social impact.

Scientific discovery: Universities and research institutes aim to push the boundaries of quantum science, often leading to ground-breaking theoretical research. For example, famous algorithms like Shor's (used for decryption) and Grover's (used to search data

24 IonQ, "IonQ Raises Over $372 Million Via At-the-Market Equity Offering Program," *IonQ*, March 10, 2025, https://ionq.com/news/ionq-raises-over-usd372-million-via-at-the-market-equity-offering-program.

25 *Private Equity Media*, "$940m in government funding for quantum computing," Private Equity Media, April 30, 2024, https://www.privateequitymedia.com.au/news/investment-activity/940m-in-government-funding-for-quantum-computing/

26 "PsiQuantum," Queensland Government: Queensland Treasury, last modified July 19, 2024, https://www.treasury.qld.gov.au/investment/investment-growth-stories/psiquantum/.

27 *D-Wave Quantum*, "D-Wave Announces Successful Completion of $150 Million At-the-Market Equity Offering," D-Wave Quantum, January 23, 2025, https://www.dwavequantum.com/company/newsroom/press-release/d-wave-announces-successful-completion-of-150-million-at-the-market-equity-offering/

28 Quantum Brilliance, "Quantum Brilliance Raises USD $20 Million in Series A Funding Round," *Quantum Brilliance,* January 15, 2025, https://quantumbrilliance.com/press-release/quantum-brilliance-raises-usd-20-million-in-series-a-funding-round; OptQC, "We are pleased to announce that we have raised a total of 650 million yen in funding," *OptQC*, January 23, 2025, https://www.optqc.com/en/news/news/press-fundraising-announcement20250123.

29 National Quantum Information Science Research Centers, NQISRC, U.S. Department of Energy: Office of Science, https://nqisrc.org/.

30 *Policy and R&D trends of quantum technology in the leading countries of the Asia and Pacific Regions,* (Japan Science and Technology Agency), March 2023, https://spap.jst.go.jp/investigation/downloads/2022_rr_01_en.pdf; Susan Hill, "Quantum Technology Advancements in Asia-Pacific: A Regional Powerhouse Emerges," *Martin Cid Magazine*, January 20, 2025, https://www.martincid.com/technology/quantum-technology-advancements-in-asia-pacific-a-regional-powerhouse-emerges/.

faster) were created by researchers. These contributions guide how quantum computers are built and defines its capabilities, setting the stage for practical applications.[31]

Workforce development: Universities are critical to training the future workforce of quantum scientists and engineers.[32] As the quantum industry evolves, there is growing demand from both government and industry for a highly skilled workforce. University-led programs, including quantum bootcamps, scholarships, and exchange programs, are central to meeting this demand. Equally important are Vocational Education and Training (VET) programs, which equip technicians with hands-on skills like operating quantum hardware and calibration.[33] These programs empower technicians with practical know-how, improving their job prospects and driving quantum innovation.[34]

Social impact: Academic research also seeks to address global challenges through the development of quantum technologies. Universities are actively exploring real-world applications in areas such as precision medicine and climate monitoring. This includes quantum-enhanced drug discovery, secure communication networks and high-sensitivity environmental sensing, demonstrating a strong focus on delivering public value and societal benefit.[35]

The importance of collaboration

Collaboration is essential to advancing quantum technology in the APEC region. Universities work closely with governments, industries and other academic institutions to share expertise, resources, and infrastructure. Public-Private Partnerships (PPPs), global academic networks, and industry-academia partnerships are prevalent collaborative arrangements in the academic sector. Several companies have collaborated with universities to develop quantum software, test hardware and train talent. In 2023, IBM announced a 10-year, $100 million USD partnership with the University of Tokyo and the University of Chicago to develop a quantum-centric supercomputer, marking a new era of high-performance computing and underscoring the importance of cross-border collaboration in the region.

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31 Marie, "Decoding the Power of Quantum Algorithms: A Deep Dive into Shor's and Grover's Methods," Science & Tech Powered by AI, April 28, 2025, https://www.xevlive.com/2025/04/28/decoding-the-power-of-quantum-algorithms-a-deep-dive-into-shors-and-grovers-methods/.

32 Sophia Chen, "The Future is Quantum: Universities look to train engineers for emerging industry," Nature, November 13, 2023, https://www.nature.com/articles/d41586-023-03511-7.

33 The Role of Australia's VET Sector in the Era of Industry 4.0," Insources, accessed June 25, 2025, https://insources.com.au/qms/the-role-of-australias-vet-sector-in-the-era-of-industry-4-0/.

34 U.S. Senate Committee on Commerce, Science, & Transportation, "Cantwell, Young, Durbin, Daines Introduce National Quantum Initiative Reauthorization Act," *U.S. Senate Committee on Commerce, Science, & Transportation*, December 3, 2024, https://www.commerce.senate.gov/2024/12/cantwell-young-durbin-daines-introduce-national-quantum-initiative-reauthorization-act; Franziska Greinert et al., "Advancing quantum technology workforce: industry insights into qualification and training needs," *EPJ Quantum Technology* 11, no.82 (2024), https://doi.org/10.1140/epjqt/s40507-024-00294-2.

35 Global Times, "Research breakthrough in China's quantum direct communication marks potential transition from theory to real-life implication," *Global Times*, February 23, 2025, https://www.globaltimes.cn/page/202502/1328916.shtml; Betty Zou, "U of T researchers develop new approach using quantum computers to accelerate drug discovery," *University of Toronto: Temetry Faculty of Medicine,* January 22, 2025, https://temertymedicine.utoronto.ca/news/u-t-researchers-develop-new-approach-using-quantum-computers-accelerate-drug-discovery; Matt Swayne, "Quantum Sensor Measures Data Securely Over 50 Kilometers Without Entanglement," *The Quantum Insider*, January 2, 2025, https://thequantuminsider.com/2025/01/02/quantum-sensor-measures-data-securely-over-50-kilometers-without-entanglement/.

2.2 Quantum Collaboration Involving APEC Economies

APEC member economies are actively engaged in advancing quantum technologies through a range of strategic partnerships, academic exchanges, and international conferences, despite varied levels of technological advancement. Through these collaborations and strong industry-academic ties, APEC economies are positioning themselves at the forefront of transformative advancements in quantum science and technology.[36] This section provides a high-level overview of existing collaboration initiatives involving APEC economies both in the region and beyond.

Australia:

In Australia, companies like Quantum Brilliance - a German-Australian quantum computing provider, have led collaborative efforts with the Royal Melbourne Institute of Technology (RMIT) and La Trobe University, focusing on pioneering diamond-based quantum computers.[37] Quantum Brilliance has also established offices in Singapore and Japan, signalling potential future collaborations in the region.[38]

Canada:

Canada is collaborating with France, the United States, and the United Kingdom to advance quantum research and development, announcing over $52 million for funding 107 quantum science projects.[39]

Malaysia:

The Malaysian Institute of Microelectronic Systems (MIMOS) collaborates with SDT Inc, a quantum computing company headquartered in Republic of Korea.[40] The ASEAN Quantum Summit, a key regional initiative aimed at establishing collaboration and advancing quantum innovation across South East Asia, will also be held in Malaysia in 2025.[41]

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36 "Quantum Technology Roadmap," PCIEERD, accessed June 20, 2025, https://pcieerd.dost.gov.ph/images/pdf/2021/roadmaps/sectoral_roadmaps_division/etdd/Quantum-Technology-RD-Roadmap.pdf; "One Quantum Philippines," One Quantum Philippines, accessed June 23, 2025, https://www.onequantum.ph/; "The European Quantum Communication Infrastructure (EuroQCI) Initiative," European Commission, accessed June 21, 2025, https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci.

37 Johannes Kostka and Michael Quin, "New hub to make diamond-based quantum computers," RMIT University, published April 21, 2022, https://www.rmit.edu.au/news/all-news/2022/apr/diamond-quantum-computing-hub.

38 "Germany Awards Contract to Quantum Brilliance and ParityQC to Build World's First Mobile Quantum Computer by 2025," Quantum Brilliance, published September 18, 2024, https://quantumbrilliance.com/press-release/germany-awards-contract-to-quantum-brilliance-and-parityqc; "Quantum Brilliance Partners with STFC Hartree Centre to Make Quantum Tech More Scalable," Quantum Brilliance, published November 1, 2023, https://quantumbrilliance.com/press-release/quantum-brilliance-partners-with-stfc-hartree-centre-to-make-quantum-tech-more-scalable; "Quantum Brilliance establish a subsidiary in Japan," Quantum Brilliance, accessed June 25, 2025, https://quantumbrilliance.com/press-release/quantum-brilliance-establish-a-subsidiary-in-japan-en.

39 Cierra Choucair, "Canada Invests over $52 Million in 107 Quantum Research Projects in Computing, Communications, and Beyond," The Quantum Insider, January 21, 2025, https://thequantuminsider.com/2025/01/21/canada-invests-over-52-million-in-107-quantum-research-projects-in-computing-communications-and-beyond/; "£6.5m boost for innovative quantum projects in UK and Canada," UKRI, published January 27, 2025, https://www.ukri.org/news/6-5m-boost-for-innovative-quantum-projects-in-uk-and-canada/.

40 Cierra Choucair, "Malaysia's First Quantum Computing Centre Launched Through SDT Inc. and MIMOS Partnership," *The Quantum Insider,* November 13, 2024, https://thequantuminsider.com/2024/11/13/malaysias-first-quantum-computing-centre-launched-through-sdt-inc-and-mimos-partnership/; "Thailand's First International Quantum Conference Hosted by PSU," PSU: Faculty of Science, published December 2, 2024, https://www.sci.psu.ac.th/en/news/2024/12/sqst2024-opening-ceremony-en/.

41 World Quantum Day, "The Southeast Asia World Quantum Day Initiatives," *World Quantum Day*, June 18, 2025, https://worldquantumday.org/news/the-southeast-asia-world-quantum-day-initiatives.

New Zealand:

New Zealand's Quantum Technologies Aotearoa program, led by the Te Whai Ao – Dodd-Walls Centre, collaborates with partners from the United States, Republic of Korea, Japan, Singapore, and Australia. The program aims to strengthen global connectivity and build domestic capability in a rapidly evolving sector shaped by the principles of quantum physics.[42]

The Philippines:

In 2025 the Philippines held its inaugural national quantum conference, QISTCon.ph 2025. The conference was established with the aim of developing a responsible regional quantum ecosystem, and featured discussions on technical advancements, real-world applications, educational initiatives, and policy discussions for quantum technologies.[43]

Thailand:

Thailand hosted the SEA Quantathon 2025, a regional quantum computing hackathon held in Bangkok. This event sought to encourage collaboration among Southeast Asian nations and promote innovation in quantum computing applications that provide positive social benefits. The Quantathon formed part of the SEA Quantum Network's pilot initiatives, which include the ASEAN Quantum Summit 2025 in Malaysia and QISTCon.ph 2025 in the Philippines.[44]

United States:

The United States has formed collaborative alliances with European nations, including Switzerland and the Netherlands, to drive innovation and cooperation in quantum information science and technology.[45]

Southeast Asia Quantum Industry Association (SEAQIA):

The Southeast Asia Quantum Industry Association has been established to support quantum stakeholders in the region and to nurture the development of quantum technologies in Southeast Asia. The association's objectives include increasing awareness about quantum technologies, promoting best practices, and coordinating access to infrastructure.[46]

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42 Catalyst: Strategic – a quantum technologies research platform," New Zealand Government: Ministry of Business Innovation and Employment, accessed September 29, 2025, https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/catalyst-fund/funded-projects/catalyst-strategic-quantum-technologies-research-platform.

43 QISTCon.PH 2025," Quantum Information, Science, and Technology, Conference in the Philippines, accessed October 27, 2025, https://www.qistcon.ph/.

44 SEA Quantathon," International Year of Quantum Science and Technology, accessed October 27, 2025, https://quantum2025.org/iyq-event/sea-quantathon/.

45 "National Quantum Initiative," United States Government, accessed June 26, 2025, https://www.quantum.gov/; "Joint Statement of the United States of America and the Netherlands on Cooperation in Quantum Information Science and Technology," U.S. Department of State, published February 16, 2023, https://2021-2025.state.gov/joint-statement-of-the-united-states-of-america-and-the-netherlands-on-cooperation-in-quantum-information-science-and-technology/; "The United States and Switzerland Sign Joint Statement to Strengthen Collaboration on Quantum," United States Government: National Quantum Initiative, published October 19, 2022, https://www.quantum.gov/the-united-states-and-switzerland-sign-joint-statement-to-strengthen-collaboration-on-quantum/.

46 SEAQIA: Southeast Asia Quantum Industry (SEAQIA)",Association, Southeast Asia Quantum Industry Association, accessed October 17, 2025, Southeast Asia Quantum Industry Association (SEAQIA) https://www.quantumassociation.asia/.

2.3 Challenges and Opportunities for Quantum Technologies in the APEC Region

To understand the challenges and opportunities for developing and scaling quantum technologies across the APEC region, Standards Australia, with support from the APEC Sub-Committee on Standards and Conformance (SCSC) Secretariat, undertook an APEC-wide survey on *Strengthening Collaboration on Standardisation for Quantum Technologies* (hereafter referred to as the APEC Quantum Survey).[47] With over 43 participant responses across a range of APEC member economies, this section provides an analysis of these survey responses to two key questions:

1. What challenges are limiting the ability to develop and scale quantum technologies in the future?
2. What are the opportunities to support the development and adoption of quantum technologies?

These survey findings are supported by insights gathered during a two-day hybrid workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies* (APEC Quantum Workshop) hosted by Standards Australia in July, 2025.

An in-depth review of relevant literature, policy documents, and reports was also conducted to provide additional context and highlight further areas for regional collaboration and action.

2.3.1 Barriers to Developing and Scaling Quantum in the APEC Region

The World Economic Forum's *Quantum Economy Blueprint (2024)* outlines several challenges associated with the development and adoption of quantum technologies. One of the most prominent challenges is the emergence of a global 'quantum divide', where certain economies risk falling behind due to limited access to quantum technologies. This disparity not only has the potential to deepen regional inequalities but also introduces significant security vulnerabilities. Economies with less advanced quantum capabilities may be ill-equipped to protect against quantum-enabled cyber threats, thereby placing their national security at risk.

Insights from the APEC Quantum Workshop and APEC Quantum Survey suggest that many economies remain in the early, exploratory stages of quantum development and are uncertain about best practices for quantum development. When asked about the main challenges limiting the future development and scaling of quantum technologies in the APEC region at scale (where multiple answers were allowable), several key themes emerged.[48]

The most frequently cited challenge amongst participants was the high cost and technical complexity of quantum technologies (77%). This was followed by concerns about limited understanding of quantum technologies and their potentials (60%), lack of access to standards, frameworks, or guidance for quantum development (51%), shortage of skilled quantum professionals (44%), and data availability and quality issues for quantum system development (40%). Other notable challenges included resistance to adoption by stakeholders or institutions (35%), and ethical and security concerns (30%).

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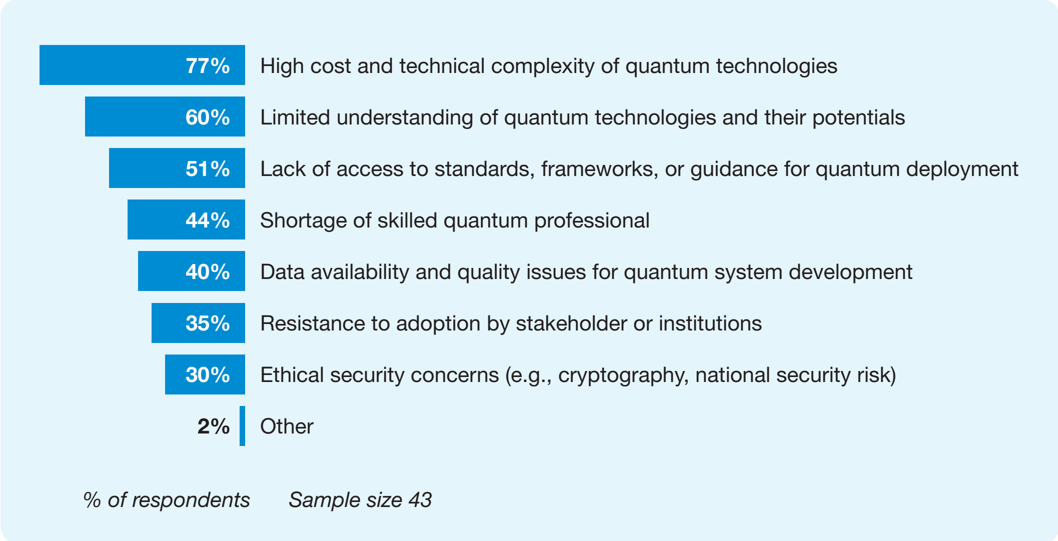
47 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologies* - APEC Survey (external survey, publicly unavailable, June 2025).

48 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologie*s - APEC Survey (external survey, publicly unavailable, September 2025).

Figure 1 - Challenges Limiting the Development and Scaling of Quantum Technologies in APEC



Source: Strengthening Collaboration on Quantum Technologies - APEC Quantum Survey, 2025

High Cost and Technical Complexity of Quantum Technologies

As quantum technologies advance toward real-world deployment, economies across the APEC region are grappling with the practical challenges of implementation. Among these, the transition to post-quantum cryptography stands out as a critical priority for securing digital infrastructure against future quantum threats. However, this transition is not without significant hurdles. One of the major challenges identified in the transition to post-quantum cryptography is the high cost of implementation, particularly due to the technical complexity of quantum-resistant hardware. This concern was validated through the quantum survey conducted across APEC economies, where 77% flagged cost and complexity as significant barriers. For instance, stakeholders from Papua New Guinea highlighted that with an infrastructure deficit, the hardware required is both expensive and technically demanding to deploy.[49] Similarly, stakeholders from Singapore emphasised that the implementation costs for quantum technologies are substantial, and there is a pressing need to analyse viable business models to ensure effective and sustainable implementation.[50]

A recent Quantum Technology Monitor report shows that private investment in quantum technologies dropped by 27% in 2023, mirroring a broader decline in venture capital across all startup categories, which fell by 38% compared to previous years.[51] This environment has left even well-funded startups facing limited financial runway and uncertainty around future private funding rounds. As a result, public funding has become increasingly important to fill the gap. Cost-consciousness remains essential, especially given the long development timelines in quantum, which continues to exist in a hybrid state of traditional research and early commercial scaling. Managing the cost equation

49 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies*.
50 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*
51 McKinsey Digital, Quantum Technology Monitor (McKinsey & Company, 2024), https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/steady%20progress%20in%20approaching%20the%20quantum%20advantage/quantum-technology-monitor-april-2024.pdf.

is therefore a critical priority, one that must be addressed even before workforce and infrastructure considerations can be fully developed.[52]

Limited Understanding of Quantum Technologies and their Potential

APEC member economies demonstrate varying degrees of quantum understanding, ranging from foundational awareness to active deployment. Both the survey and workshop revealed that a limited understanding of quantum technologies and their potential impacts is seen as a significant barrier, with 60% of survey respondents highlighting this as an impediment to the development and adoption of quantum technologies. These findings are consistent with insights from the *Quantum Readiness 2025* report by QuEra, which emphasised the need for more affordable access and expanded quantum education programs to accelerate quantum awareness and adoption across the globe.[53]

To strengthen understanding and knowledge on quantum technologies in the APEC region, there is a need to prioritise collaboration and capacity-building initiatives that empower member economies to participate in the quantum future.[54] Establishing shared platforms for investment, talent development, and infrastructure planning will be essential to avoid long-term dependencies and ensure that quantum innovation contributes to the region's digital sovereignty, economic resilience, and global competitiveness.

Participation in international standard-setting bodies, such as IEC/ISO JTC 3, the Joint Technical Committee on Quantum Technologies, is one avenue through which APEC member economies can raise awareness about standards within their economies and ensure their national interests are represented. While several APEC economies are already involved in IEC/ISO JTC 3, particular attention should be given to supporting contributions from developing economies, which are often under-represented in international standards forums.

> *"Raise awareness of the use of technical standards as a contributor to the development of quantum technology in our economy."*[55] – Survey Respondent from Peru, APEC Quantum Survey

The concept of Standardisation Readiness Levels (SRLs) was a key tool introduced during the APEC Quantum Workshop, and has the potential to support awareness and understanding about quantum standardisation efforts. Standardisation readiness levels identify the maturity of technologies against of a range of technological, industrial, and market factors to prioritise new standards development projects. For quantum technologies, SRLs can help identify current gaps and opportunities for future standards development work and provide an understanding of areas where standardisation efforts would have the greatest impact. This common framework would thereby enable APEC economies to align funding priorities and engage more effectively in international standardisation efforts. Work to develop an SRL framework for quantum technologies is likely to progress under IEC/ISO JTC 3.

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52 Standards Australia, Strengthening Collaboration on Standardisation for Quantum Technologies - APEC Survey (external survey, publicly unavailable, September 2025).

53 Quera, Survey Report: Quantum Readiness (Quera, 2025), https://cdn.prod.website-files.com/643b94c382e84463a9e52264/679026cb4e2b6e7fa8ec2882_QuEra%20Quantum%20Readiness%20survey%20Jan%2025.pdf.

54 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

55 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologies* - APEC Survey (external survey, publicly unavailable, September 2025).

Regulatory Barriers: Lack of Access to Standards, Frameworks and Guidance

As quantum technologies rapidly evolve, APEC economies are grappling with regulatory uncertainty, driven by the absence of foundational standards and benchmarking frameworks. This challenge was clearly articulated during the APEC Quantum workshop, where participants emphasised the need for common quantum terminology and vocabulary to ensure a shared understanding.[56] Establishing foundational standards and shared principles are an important step towards reaching alignment on policies and ensuring interoperability across borders.[57]

Concerns about the regulatory environment for quantum technologies are further reflected in the APEC Quantum Survey, where 51% of respondents reported the lack of access to standards, frameworks, or guidance as a major barrier to the future development and scaling of quantum technologies. The absence of foundational tools has the potential to hinder innovation efforts and the efficient deployment of quantum technologies, particularly for fast evolving technologies like Quantum Key Distribution (QKD). Without standardised frameworks and robust testing environments, researchers and developers face barriers in scaling quantum prototypes into practical, secure systems. This gap has the potential to significantly hinder progress and increases the risk of fragmented development.

While economies are developing their own approaches to quantum governance, they share a common challenge in balancing the promotion of innovation with the need to address security concerns. This has led to the rise of hybrid governance models that aim to manage both priorities effectively.[58] However, businesses may encounter significant barriers when entering regional markets due to incompatible infrastructure, divergent standards, and regulatory uncertainty. These issues weaken the potential for a unified APEC quantum ecosystem and limit opportunities for cross-border collaboration and investment.

Workshop participants from economies including Papua New Guinea, the Philippines, and Thailand highlighted fragmented approaches to quantum governance and regulation as a major impediment to regional integration.[59] A lack of congruence between national frameworks not only slows down the pace of innovation but also risks creating isolated pockets of development that are unable to benefit from shared knowledge, resources, and market access.

Private companies, in particular, face difficulties in making strategic investments as each economy operates within its own unique regulatory ecosystem. This lack of harmonisation increases the cost and complexity of scaling solutions across borders, discouraging private sector participation and slowing the growth of a cohesive regional quantum industry. With each economy operating its own framework, businesses may face increased complexity and risk when considering cross-border investments. A more coordinated and inclusive approach is needed to unlock the full potential of quantum technologies across the region, as reflected in the workshop quotes below:

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56 NIST, Standardization Readiness and its Application (NIST, 2024), https://share.ansi.org/Shared%20Documents/Standards%20Activities/Standards-Drive%20Public-Private%20Partnership%20for%20CETs/AI%20&%20ML%20Brainstorming%20Session_17July2024/Presentations/Session1_Standards%20Readiness%20Levels_NIST%20Allocca.pdf.

57 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

58 Insights taken from the APEC Workshop on Strengthening Collaboration on Standardisation for Quantum Technologies.

59 Insights taken from the APEC Workshop on Strengthening Collaboration on Standardisation for Quantum Technologies.

> *"The lack of unified effort like the European Quantum Communication Infrastructure (EuroQCI),[60] is a weakness in the APEC region"*[61]
>
> *"Interoperability standards will allow economies to collaborate effectively and avoid fragmentation."*[62]

Relatedly, companies across the APEC region are pursuing different approaches to developing quantum technologies, ranging from superconducting qubits to techniques involving suspended electrons manipulated by lasers at room temperature.[63] This diversity reflects the experimental nature of the field but also highlights the limited consensus on the most suitable technical pathway. As a result, efforts to harmonise or align these approaches remain uncertain, and in some cases, standardisation is viewed as a potential impediment to innovation.

Unlike other fields where both the technology and market are mature, many quantum technologies are still evolving. The pursuit of divergent technical approaches across economies and organisations presents challenges for harmonisation and standardisation. Without alignment, there is a risk of fragmented ecosystems in which differing technical pathways are incompatible. This has the potential to impede collaboration, slow technological progress, and reduce market access. Standardisation is therefore critical to enable interoperability, facilitate trade, and support the coordinated regional development of quantum technologies. International standards provide agile and fit-for-purpose frameworks that support the responsible development and implementation of quantum technologies. As consensus-based instruments, they establish globally recognised benchmarks that promote harmonisation and interoperability across markets, enabling greater innovation, investment, and cross-border collaboration. In the context of quantum technologies, standards play a critical role in establishing trust, security, and reliability in complex systems, allowing governments, industry, and research institutions to develop, regulate, and adopt quantum technologies in a safe, coordinated, and transparent manner.

Talent Shortage: Limited Access to Quantum-Ready Skilled Workforce

The APEC region is at the forefront of technological innovation. However, its progress in quantum technologies is constrained by a significant skills gap. Findings from the APEC Quantum Survey indicate that 44% of respondents view the shortage of qualified quantum professionals as a major barrier to the development and deployment of quantum technologies.[64]

> *"Concerning the Philippines, the top challenge among the choices is the lack of professionals. Without professionals, further innovation, advising, and expert-based decision-making cannot be done in full confidence and at the right time. The lack of professionals also hinders the government in purchasing facilities since the scarcity of professionals means fewer people to consume and/or operate them."*[65]
>
> — Survey Respondent from the Philippines, APEC Quantum Survey

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60 European Commission, "European Quantum Communication Infrastructure- EuroQCI", accessed on October 23, 2025, European Quantum Communication Infrastructure - EuroQCI | Shaping Europe's digital future

61 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

62 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

63 Niko Mohr et al., "Five lessons from AI on closing quantum's talent gap—before it's too late," McKinsey & Company, December 1, 2022, https://www.mckinsey.com/capabilities/tech-and-ai/our-insights/five-lessons-from-ai-on-closing-quantums-talent-gap-before-its-too-late.

64 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologies* - APEC Survey (external survey, publicly unavailable, September 2025).

65 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologies* - APEC Survey (external survey, publicly unavailable, September 2025).

Numerous workshop stakeholders also highlighted quantum education and talent acquisition as significant ongoing challenges, with a shortage of local experts across APEC economies impacting the development and advancement of quantum technologies. The talent shortage is particularly felt by quantum start-up companies, who require skilled people to improve and expand their operations.[66] These organisations often face intense competition for a limited talent pool of quantum experts and technical specialists, making recruitment and retention a significant challenge. An article published by global consulting firm, McKinsey & Company, suggests that organisations building out their quantum teams will be particularly in need of quantum hardware engineers, quantum software engineers, and quantum translators.[67] Without a strong pipeline of skilled professionals, companies operating in the APEC region risk falling behind in a rapidly evolving global quantum landscape.

Addressing the talent gap will require strategic investment in education, international collaboration, and capacity-building initiatives that build local expertise and create an environment that enables innovation and sustainable growth. Activities highlighted by participants from both the APEC Quantum Survey and APEC Quantum Workshop include technical capacity building, academic exchanges, and workshops with quantum stakeholders. Further opportunities for talent development are elaborated upon in Section 2.3.2 of this report and in the roadmap in Section 3.

Investment Gaps: Uneven Funding Slows Quantum Technology Advancement

Quantum technologies are poised to revolutionise a wide range of industries, including defence, mining, healthcare, finance and logistics, yet development across the APEC region is being hindered by significant investment gaps. While some economies in the region have surged ahead with substantial government funding and national quantum initiatives, many other APEC economies face uneven access to funding from both the private sector and government.[68] This disparity not only slows regional innovation, but also risks creating long-term dependencies on dominant players, potentially undermining economic sovereignty and technological competitiveness.

> *"Without significant government funding or industry partnerships, local R&D efforts may struggle to keep pace with global advancements. This capital barrier, coupled with the steep learning curve of quantum mechanics and engineering, limits Malaysia's ability to establish a strong foundation for quantum innovation, which could eventually hinder our digital sovereignty and economic competitiveness in high-value sectors like cybersecurity, finance, and advanced manufacturing"*[69]
>
> — Survey Respondent from Malaysia, APEC Quantum Survey

The limited presence of major quantum computing companies within APEC also discourages investments and reduces opportunities for local partnerships and innovation. Stakeholders from APEC developing economies noted that companies are less inclined to invest in their markets compared to developed ones, further widening the gap in quantum readiness.[70] To strengthen quantum capabilities in the APEC region, there is a need to prioritise collaboration, inclusive funding strategies, and

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66 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

67 McKinsey, "Closing the quantum workforce gap: Lesson from AI", accessed on September 20, 2025, [Closing the quantum workforce gap: Lessons from AI | McKinsey]

68 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

69 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologies* - APEC Survey (external survey, publicly unavailable, September 2025).

70 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

capacity-building initiatives that empower member economies to participate in the quantum future.[71] Establishing shared platforms for investment, talent development, and infrastructure planning will be essential to avoid long-term dependencies and ensure that quantum innovation contributes to the region's digital sovereignty, economic resilience, and global competitiveness.

Security Risks Associated with Quantum Technologies

As quantum technologies are deployed across APEC economies, concerns around their ethical and security implications are becoming increasingly prominent. According to global technology company Thales, 73% of organisations recognise the future threat of quantum computing, yet only 39% have defined a quantum related security strategy.[72] Innovations such as quantum key distribution and quantum sensors offer transformative capabilities, but they also introduce new vulnerabilities.[73]

Around 30% of APEC Quantum Survey respondents raised concerns about the ethical and security risks associated with deploying quantum technologies. Compounding these risks is the lack of mature, quantum-specific security protocols and standards. Unlike classical cybersecurity frameworks, quantum systems require entirely new approaches to threat mitigation, ones that are still in development. The threat of "harvest now, decrypt later" attacks was highlighted as a particular concern during the workshop.[74] In such scenarios, encrypted data is collected today with the intention of being decrypted in future using quantum computing powers capable of breaking current public key encryption methods. These emerging threats highlight the critical need for APEC economies to invest in robust quantum cybersecurity frameworks and ethical safeguards. Without coordinated action, the region risks falling behind in securing quantum infrastructure, leaving both public and private sectors exposed to potential breaches

Supply Chain Challenges for Quantum Technologies

The development and deployment of quantum systems such as quantum computers, sensors, and secure communication networks depend on highly specialised components, many of which are sourced from a limited number of global suppliers. Without coordinated regional strategies and investment in domestic capabilities, these bottlenecks risk slowing innovation and deepening technological dependencies on dominant players outside the region.

Supply chain management remains a critical challenge for the quantum technology sector across the APEC region, particularly due to the reliance on highly specialised components, limited regional manufacturing capabilities, and the need for secure and resilient cross-border logistics.

Single sourcing in the quantum technology supply chain was identified as a critical risk during the APEC Quantum Workshop.[75] With few suppliers in key quantum and hardware sectors, the supply chain is highly vulnerable to disruptions.[76] In workshop

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71 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

72 Thales, " Post Quantum Cryptography" accessed on September 25, 2025, PowerPoint Presentation

73 Adrien Green et al., "Quantum Key Distribution for Critical Infrastructures: Towards Cyber-Physical Security for Hydropower and Dams," *Sensors* 23, 9818 (2023): 1-24, https://pmc.ncbi.nlm.nih.gov/articles/PMC10748243/pdf/sensors-23-09818.pdf.

74 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

75 Insights taken from the APEC *Workshop on Strengthening Collaboration on Standardisation for Quantum Technologies.*

76 Insights taken from the *APEC Workshop on Strengthening Collaboration on Standardisation for Quantum Technologies.*

discussions, emphasis was placed on the importance of establishing long-term partnerships and improving supply chain visibility, which remains an ongoing process.[77] Establishing reliable and diversified supplier networks is critically needed to help mitigate potential supply chain risks and to support the development of resilient and secure quantum supply chains in the region.

Workshop participants also highlighted the role of knowledge sharing initiatives across the APEC region in strengthening supply chains, which could allow economies to specialise in different aspects of quantum development and leverage each other's comparative strengths.[78] Current benchmarking efforts in quantum technology must extend beyond qubits to include algorithms, quantum processing units (QPUs), components, and hardware-specific use cases. Developing comprehensive standards in these areas will improve transparency and comparability across platforms, build trust among stakeholders, and empower early adopters to influence the structure and direction of the global quantum supply chain.

2.3.2 Opportunities for Quantum Collaboration in the APEC Region

Building a resilient quantum ecosystem is essential for realising the transformative potential of quantum technologies. Progress in this field does not occur in isolation, it depends on the dynamic interplay of collaboration, shared infrastructure, and coherent policy frameworks. The quantum ecosystem encompasses a network of organisations, researchers, investors, governments, and other stakeholders working collectively to translate quantum research into real-world applications and driving innovation, workforce growth, infrastructure development, and commercial outcomes that underpin the broader economic and social value of the quantum industry.[79]

As emphasised during the APEC Quantum Workshop, the Asia-Pacific region is uniquely positioned to take a leading role in the development and deployment of quantum technologies. Its strengths in semiconductor and software engineering, combined with open hardware platforms and active participation in international standardisation bodies, create fertile ground for quantum innovation.[80] Findings from the APEC Quantum Workshop, APEC Quantum Survey, and Discussion Paper highlight several opportunities for enhanced regional collaboration on standardisation for quantum technologies, which will be elaborated on in the following section.

Lead the Development of Quantum Standards, Benchmarks and Frameworks

Quantum technologies are increasingly regarded as one of the defining innovations of the 21st century. According to research conducted by the University of Cambridge, this Quantum Revolution is not only expected to reshape science, technology, and commerce, but also demand legal and ethical frameworks to address its societal and geopolitical implications.[81] Against this backdrop, the development of robust and forward-looking standards takes on particular significance.

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77 MOODY's, "Safeguarding the quantum computing supply chain," Moody's, July 3, 2025, https://www.moodys.com/web/en/us/kyc/resources/insights/safeguarding-the-quantum-computing-supply-chain.html.

78 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

79 Cathy Foley, "What does building a quantum ecosystem look like?", InnovationAus.com, September 20, 2024, https://www.innovationaus.com/what-does-building-a-quantum-ecosystem-look-like/.

80 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

81 Virginia D'Auria and Mark Teller, "What are the priorities and the points to be addressed by a legal framework for quantum technologies?" Research Directions: Quantum Technologies 1, no.9 (2023), https://www.cambridge.org/core/services/aop-cambridge-core/content/view/E77592D14EC3E136B3797B907F2068F2/S2752944423000037a.pdf

Standards are widely recognised as a long-term investment and a strategic enabler focused on long-term value. As one participant from the APEC Quantum Workshop noted:

> *"Once we have standards for quantum technology, it's a big opportunity in the future, and these standards will be used in research and for applications. ISO and IEC start with the discussions now, and in the future, we will have standards which we are going to follow worldwide."*[82]

Standardisation in quantum technology benchmarking represents a strategic gap and opportunity. Despite broad consensus on its importance, no shared benchmarking framework currently exists.[83] This is particularly evident for quantum computing, where qubit benchmarking is essential for comparing performance across platforms such as semiconductors, diamond lattices, and photonics. At present, performance claims remain unverifiable due to the absence of agreed standards.

Benchmarks are also needed for quantum algorithms, processing units (QPUs), components, and hardware use-cases.[84] The lack of benchmarking standards in these areas makes it difficult to evaluate their potential benefits and applications and prioritise research efforts. Establishing comprehensive benchmarking and performance standards would enable companies to focus their efforts on high-impact areas while relying on shared frameworks to ensure consistency, reliability, and efficiency. There is great value in predefined standards that provide transparent and credible metrics.[85]

A compelling example of the impact of standards can be seen in quantum sensing. As with many new technologies, transitioning from research to large-scale manufacturing often presents significant challenges. Standards can help address these obstacles by providing technical clarity and consistent definitions on quantum sensing, while also supporting industry development, trade, and operational efficiency. In this way, standards are both a foundation for technical precision and a catalyst for industrial growth.[86]

Standards play an equally important role in ensuring inclusivity. Bringing stakeholders from different sectors, economies, and disciplines into the standards development process ensures that standards truly reflect the diversity of needs across the APEC region. From this angle, standardisation is more than a technical exercise. it is a strategic tool that can accelerate quantum readiness, support sustainable growth, and position participants as leaders in defining the future of the industry:

> *"Each stage in the technology life cycle is supported by standards, from terminology that builds community and guides measurement priorities, to benchmarks that manage hype and educate users, to interoperability standards that let innovations fit into larger systems."*[87]

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82 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

83 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

84 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum* Technologies.

85 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum* Technologies.

86 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum* Technologies.

87 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum* Technologies.

Establish Collaboration Initiatives Across APEC Economies

Collaboration is increasingly recognised as a foundational enabler in the development and deployment of quantum technologies. As highlighted during the workshop, collaboration is not only a facilitator of technical progress but also a strategic mechanism for aligning efforts across economies, disciplines, and sectors. Stakeholders across the region outlined multiple opportunities for collaboration on standardisation activities and other initiatives extending beyond standards.[88]

Existing standards development activities under IEC/ISO JTC 3, Quantum Technologies, are a concrete and effective example of how collaboration on standardisation can work in practice. Through formal liaisons and information-sharing arrangements with other standards development organisations and technical committees, IEC/ISO JTC 3 can coordinate efforts across related technical domains and avoid duplication. Liaison committees to IEC/ISO JTC 3 span areas such as artificial intelligence, nanotechnologies, and telecommunications, all of which are directly relevant to the development of quantum technologies. In this sense, liaisons function not just as points of contact, but as strategic mechanisms to integrate expertise, align standards, and accelerate the development and implementation of standards.

Collaborative talent development programs, such as the APEC Scientist Exchange Initiative, should be considered as a practical step towards building trust and technical knowledge sharing, with the added benefit of establishing mutual understanding.[89] Advancing technical expertise must go beyond general education to ensure that quantum education is accessible and targeted towards building a skilled talent pool.[90] By working together to expand quantum knowledge, APEC economies can carve out areas of strength while contributing to a more resilient and inclusive regional quantum ecosystem. Greater knowledge sharing across the APEC region can strengthen quantum-related supply chains, support the growth of interconnected sectors, and enable economies to specialise in different areas of quantum technology based on their comparative advantages.[91]

Ensuring standards systems are agile, responsive, and flexible is critical as new technologies continue to emerge. Collaboration between government, industry, and academia has demonstrated tangible benefits in the development of quantum standards. Coordinated efforts can produce reference specifications that guide implementation, while the incorporation of emerging technologies, such as post-quantum (PQC), can ensure these standards remain relevant and effective. Overall, strong stakeholder collaboration can support the growth of an agile and practical quantum ecosystem.[92]

Create a Regional Quantum Technology Framework

The creation of a regional quantum framework has the potential to strengthen coordination and alignment across member economies. A flexible and transparent framework that maps existing standards, national quantum policies and strategies would help identify opportunities for collaboration, promote shared objectives, and signal

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88 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum* Technologies.

89 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

90 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

91 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

92 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

sustained commitment from governments and industry regarding the importance of quantum.

Shared frameworks also have the ability to create opportunities for industry, academia, and the public sector to contribute to collective outcomes. For example, they can facilitate industry engagement by identifying specific technologies, use cases, or areas for industry leaders to contribute their expertise. By extension, active industry involvement in joint quantum initiatives can support commercialisation of quantum solutions and accelerate digital transformation across the region. Similarly, participation from universities and academic institutions can help promote talent development and innovation through collaborative research and training programs, thereby expanding the pool of skilled quantum professionals throughout the region.

Several APEC economies, including Japan, Singapore, the Republic of Korea, and Canada have developed national quantum strategies or roadmaps in recent years. These strategies and roadmaps outline initiatives to support quantum advancements across a range of areas including research, workforce, and standardisation. Building on these national efforts, a regional framework would help ensure APEC economies remain at the forefront of quantum innovation by providing a coordinated approach that connects existing strategies, ensuring that investments and policy directions are complementary rather than duplicative. Such alignment would enhance interoperability, promote the adoption of harmonised standards, and support the efficient exchange of knowledge and resources across the region.

Australia's *National Quantum Strategy* is one example of how quantum opportunities can be realised at a domestic level. The strategy provides a long-term vision for Australia's quantum industry structured around five central themes as shown in Figure 2 below:

Figure 2 - Australia's National Quantum Strategy (2023)[93]

A skilled and growing quantum workforce

Thriving research, development, investment in and use of quantum technologies

Secured access to essential quantum infrastructure and materials

Standards and frameworks that safeguard national interests

A trusted, ethical, and inclusive quantum ecosystem

Source: Australian Government, Department of Industry, Science and Resources, National Quantum Strategy (2023)

Importantly, the strategy outlines a roadmap for advancing near-term quantum applications that are approaching commercial readiness, such as quantum sensors, while also positioning Australia to capitalise on longer-term opportunities like quantum

93 Australian Government: Department of Industry, Science and Resources, National Quantum Strategy (Commonwealth of Australia, 2023), https://www.industry.gov.au/sites/default/files/2023-05/national-quantum-strategy.pdf.

computing. International technology standards are recognised as a key enabler of trust, consistency, and economic growth within Australia's quantum ecosystem. To this end, the strategy affirms Australia's commitment to maintaining an active presence in international quantum standards setting bodies and working closely with industry to strengthen participation in standards development.[94] The actions and priorities outlined in national strategies, including Australia's, offer valuable insights that could inform the development of a regional quantum policy framework for APEC.

Prioritise Education and Upskilling

Education and talent development emerged as one of the most pressing opportunities identified during the workshop.[95] The long-term success of quantum technologies will depend not only on breakthroughs in science and engineering, but equally on the ability to cultivate a skilled workforce. As noted in Section 2.3.1, nearly half of the APEC Quantum Survey respondents (44%) view the shortage of qualified quantum professionals as a major barrier to the development and deployment of quantum technologies.[96]

Building capacity across the APEC region requires concerted investments in education and training to ensure that talent development keeps pace with rapid technological advances. Cross-border training initiatives, pilot projects, and local degree programs were identified during the workshop as valuable mechanisms to provide hands-on experience and build a sustainable pipeline of skilled workers. Workshop participants also emphasised the role of public engagement, suggesting that awareness campaigns, social media initiatives, and clear policy signals, such as white papers or media announcements, would encourage broader participation.[97] The development of quantum use cases for standardisation across multiple sectors was further seen as a means of increasing understanding and encouraging adoption, ensuring that the benefits of quantum extend beyond specialist communities.

Capacity building should be strongly supported by structured programs and practical test beds. Crossover initiatives such as training, talent development, and upskilling programs tailored to different audiences are all mechanisms that can help build technical capacity. For example, universities may take the lead on talent development, while industry partners drive domain-specific upskilling. Workshop participants also proposed the establishment of test-bed projects across APEC economies, such as extending a quantum key distribution (QKD) network from Singapore to Malaysia and onwards to Thailand, to combine hands-on learning with regional collaboration.[98]

Highlight Regional Quantum Use Cases

The three domains of quantum technologies (computing, communications, and sensing) are already creating opportunities across the APEC region. In the Philippines, quantum computing is being explored for climate modelling and disaster risk forecasting, improving agricultural planning and emergency response. In Peru, quantum-inspired simulations in environmental science are being used to model biodiversity and ecosystem dynamics, leveraging educational investments to expand research and training opportunities. Globally, atomic clocks and quantum sensors can improve the

94 Australian Government: Department of Industry, Science and Resources, National Quantum Strategy.
95 Australian Government: Department of Industry, Science and Resources, National Quantum Strategy.
96 Standards Australia, *Strengthening Collaboration on Standardisation for Quantum Technologies* - APEC Survey (external survey, publicly unavailable, September 2025).
97 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*
98 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

accuracy of fundamental physics tests, international unit measurements, and secure communication systems.[99]

Many workshop participants, from a broad range of APEC economies, identified the high priority of quantum technologies in advancing cybersecurity, specifically quantum key distribution and post quantum cryptography (PQC). Quantum key distribution (QKD) provides protection against both classical and quantum-enabled attacks, while quantum random number generators (QRNGs) deliver truly random outputs, enhancing cybersecurity across government and industry applications. Post-quantum cryptography was seen as essential for securing digital infrastructure across the region, even in economies not currently engaged in quantum computing development.

These use cases reveal the broad application of quantum technologies with benefits cutting across a range of sectors from agriculture, environment and weather disaster to telecommunications and cybersecurity, signifying the vast opportunities presented by quantum technologies. In both the APEC Quantum Survey and Workshop, there was a clear demand for regional use cases that demonstrate the tangible impacts of quantum technologies. The identification and development of use cases from across APEC economies would help improve understanding of quantum technology applications and serve as an informative resource for future standards development activities, policy decisions and funding priorities.

99 Insights taken from the APEC Workshop on *Strengthening Collaboration on Standardisation for Quantum Technologies.*

3. Quantum Collaboration Roadmap

As part of the APEC Quantum workshop, a draft roadmap was established to stimulate collaboration in support of quantum standards development activities in the region and internationally. This roadmap has been developed collaboratively and iteratively with input from project participants during the workshop, via online collaboration tools, and further refined at a post-workshop webinar in September 2025. The roadmap covers a range of initiatives spanning standardisation awareness, standards development, talent, and policy, and is designed to provide equitable support across varying economies and collaborative participation over an extended timeframe. Activities described in the roadmap are initial project concepts for the consideration of the APEC Sub-Committee on Standards and Conformance (APEC SCSC) and participating economies to further develop and progress through scoping and funding.

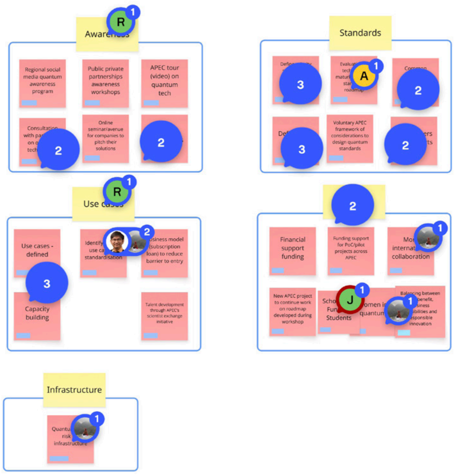
Roadmap Stage 1

Collaborative Session During Workshop in Republic of Korea

Roadmap Stage 2

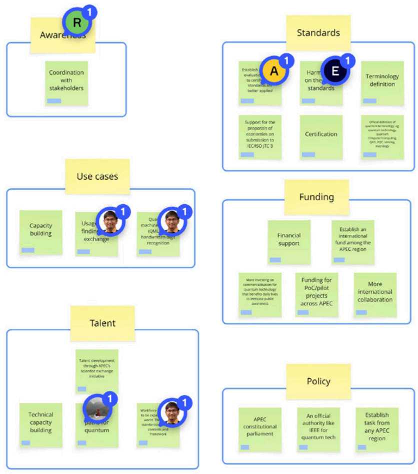
Online Interactive Version

Short term (<1 year)



Medium term (1-3 year)

Long term (>3 year)



In Stage 2, the roadmap was converted to an online format using the Miro platform. Workshop participants were invited to review the roadmap, provide feedback, add ideas, and expand on existing ones.

This stage received active input from participants across a diverse range of APEC economies.

Roadmap Stage 3

Post-Workshop Webinar Session

<table>
<tr><th></th><th>Short term (<1 year)</th><th>Medium term (1-3 years)</th><th>Long term (>3 years)</th></tr>
<tr><td rowspan="3">1. Awareness</td><td colspan="3">Coordination of discussion with variety of stakeholders (industry, government, academia, etc)</td></tr>
<tr><td>Regional social media quantum awareness program</td><td></td><td></td></tr>
<tr><td>Online seminar/ avenue for companies to pitch their solutions</td><td></td><td></td></tr>
<tr><td rowspan="6">2. Standards</td><td colspan="3">Forum for the proposals of economies on submission to IEC/ISO JTC 3</td></tr>
<tr><td>Evaluation of technology maturity level for standards roadmap</td><td></td><td></td></tr>
<tr><td>Define priority sub-areas of quantum and sector of application</td><td></td><td></td></tr>
<tr><td>Whitepapers from experts</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Technical capacity building in quantum standards</td></tr>
<tr><td></td><td>Continue information sharing within APEC member economies</td><td></td></tr>
<tr><td rowspan="2">3. Use cases</td><td colspan="3">Use case discovery, definition and exchange</td></tr>
<tr><td colspan="3">Identify priority use cases for standardisation</td></tr>
<tr><td rowspan="2">4. Talent</td><td colspan="2">Women in quantum</td><td></td></tr>
<tr><td></td><td>Workshop with quantum stakeholders in each country</td><td></td></tr>
<tr><td rowspan="2">5. Policy</td><td colspan="3">New APEC project to continue work on roadmap developed during workshop, including presentations of economy's landscape/markets/industries that may benefit from quantum technologies</td></tr>
<tr><td></td><td>Having a regional framework in terms of vision, missions, policies/strategies among the APEC economies</td><td></td></tr>
</table>

Roadmap Stage 4

Finalised Version

	Short term (<1 year)	Medium term (1-3 years)	Long term (>3 years)
1 Awareness	**1.1** Launch Regional Social Media Program to Increase Quantum Standards Awareness **1.2** Establish Online Dialogue for Quantum Solutions	**1.3** Facilitate Quantum Standards Awareness Workshops	
2 Standards	**2.1** Ongoing Information Sharing Among APEC Economies on Quantum Standards		
	2.2 Information Exchange on Technology Readiness Levels for Quantum Technologies **2.3** Identify Key Application Areas and Use Cases for Standardisation of Quantum Technologies **2.4** Expert Contributions on Topics Relating to Quantum Standardisation	**2.5** Capacity Building for Quantum Standards in the APEC Region	
3 Talent	**3.1** Establish Multi-Stakeholder Dialogue on Quantum Workforce Needs		
	3.2 Increase Women's Participation in Quantum Technology Standardisation		
4 Policy		**4.1** Develop APEC Regional Quantum Technology Policy Framework	

3.1 Expanded Overview of Finalised Quantum Collaboration

The following section provides a detailed overview for each of the roadmap initiatives, categorised under four key thematic areas:

1. Standards Awareness
2. Standards Development
3. Talent Development
4. Policy Coordination

1. Standards Awareness

1.1 Launch Social Media Program to Increase Quantum Standards Awareness

Objective:

To promote public understanding and awareness of quantum technology standards across APEC economies, supporting their adoption, development, and implementation.

Detailed Description:

This initiative will raise awareness about the importance of quantum technology standards by leveraging targeted communication strategies and social media outreach. Activities within the scope of this initiative include:

- **Establishment of dedicated steering committee** to lead activities
- **Development of educational resources** such as explainer videos, webinars, infographics, and interactive tools tailored to different levels of technological literacy.
- **Campaigns showcasing real-world examples** of how quantum standards ensure trust and interoperability in quantum systems.
- **Content tailored to local contexts** for maximum engagement and relevance.
- **Collaboration with media partners**, standards bodies, and educational institutions across the region.
- **Monitoring and evaluation** of engagement levels to refine communication strategies over time.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Government agencies and regulators
- Industry associations and consortia
- Research institutes, universities, and academic institutions
- General public and broader community

Target Audience:

- General public
- Educational institutions and students
- Government officials and policymakers

Anticipated Benefits:

- Increased community, public and private sector understanding of quantum standards, particularly those developed by IEC/ISO JTC 3.
- Enhanced awareness of the role of standards in enabling interoperability and trust in quantum systems.
- Greater visibility of quantum technology developments across APEC economies.
- Stronger engagement from industry, academia, policy makers and the public.
- Support for harmonisation and adoption of international standards through clear and accessible communication.

2025–2026: Development and launch of social media campaign, creation of educational resources, initial dissemination.

2026 onward: Continued refinement of content, expansion of regional participation, and increased collaboration with partners.

1. Standards Awareness – continued

1.2 Establish Online Dialogue for Quantum Solutions

Objective:

To create an online or in-person dialogue where quantum technology stakeholders can identify and address issues and needs, pitch solutions, show use cases, and connect with potential clients, investors, and stakeholders across APEC economies.

Detailed Description:

This initiative will support the growth of the regional quantum ecosystem by providing greater visibility and networking opportunities for startups and technology providers. The platform will:

- **Enable quantum stakeholders to present their solutions** through pitches, demonstrations, and case studies.
- **Facilitate virtual networking events.**
- **Connect innovators with investors,** incubators, research institutions, and potential clients across the region.
- **Highlight regional success stories** to stimulate investment and drive innovation.

Potential Entities Involved:

- National standards bodies (NSBs)
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Venture capital firms, investors, and tech incubators
- Research institutes, universities, and academic institutions

Target Audience:

- Industry stakeholders and end-users
- Investors and venture capital firms
- Government agencies and policymakers
- Startups and entrepreneurs
- Research and academic institutions

Anticipated Benefits:

- Accelerated commercialisation of quantum technologies.
- Increased visibility and market access for startups across APEC.
- Stronger collaboration between innovators, industry, and end-users.
- Expanded investment opportunities and reduced barriers to scaling quantum solutions.
- Greater regional coherence in fostering a competitive quantum ecosystem.

2025–2026: Platform design and development, pilot phase with selected startups and industry partners.

2026 onward: Regular pitching events, expanded participation, integration with broader APEC initiatives.

1. Standards Awareness – continued

1.3 Facilitate Quantum Standards Awareness Workshops

Objective:

To increase understanding and awareness of quantum technology standards and related topics across APEC economies by engaging key stakeholders through workshops and networking events.

Potential Entities Involved:

- National standards bodies (NSBs)
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Research institutes, universities, and academic institutions

Detailed Description:

Building on the success of the Strengthening Collaboration on Standardisation for Quantum Technologies workshop held in July 2025, this initiative responds to strong demand from participants for further workshops focused on various aspects of quantum standardisation. Proposed activities include:

- **Workshops** on the development, adoption and deployment of quantum technology standards across the APEC region.
- **Thematic sessions** on key topics such as post-quantum cryptography, quantum computing, and quantum sensing.
- **Interactive sessions** involving stakeholders from industry, government, academia, and standards bodies to strengthen collaboration.
- **Networking opportunities** to grow regional partnerships and accelerate knowledge exchange.
- **Shared learning** on standards development and implementation, tailored to different levels of technical expertise.

Target Audience:

- Industry stakeholders and technology developers
- Standards development organizations
- Academic and research communities
- Government and regulatory bodies

Anticipated Benefits:

- Increased awareness and understanding of quantum standards across diverse stakeholder groups.
- Stronger networks and stakeholder engagement in quantum standardisation within the APEC region.
- Improved knowledge sharing on emerging standards and implementation practices.
- Greater alignment on regional standards priorities and enhanced participation in international standards development.

2026 onward: Series of workshops across APEC economies, comprising virtual and in-person formats where possible.

2. Standards Development

2.1 Ongoing Information Sharing Among APEC Economies on Quantum Standards

Objective:

To establish a sustainable mechanism for regular exchange of information, best practices, and updates on quantum standards among APEC member economies, supporting regional alignment and interoperability in quantum technologies and use cases.

Detailed Description:

This initiative aims to create a collaborative platform for APEC economies to share information on quantum standards activities, including national strategies, technical committees, emerging standards, and stakeholder engagement. The initiative may consist of:

- **Regular and ad hoc virtual meetings** hosted by rotating member economies to discuss quantum standards proposals and recent developments in quantum standards.
- **Circulation of draft proposals** for comments by APEC members, supporting early socialisation and regional awareness.
- **Annual summary reports** compiling key developments, challenges, and opportunities in quantum standards across APEC economies.
- **Mapping exercises** to identify overlaps, gaps, and opportunities for quantum standards prioritisation and harmonisation.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Venture capital firms, investors, and tech incubators
- Research institutes, universities, and academic institutions

Target Audience:

- Standards professionals and policymakers in APEC economies
- Quantum technology developers and researchers
- Industry representatives seeking clarity on standards pathways
- Regulators and government officials involved in technology governance

Anticipated Benefits:

- Improved visibility and coordination of quantum standards efforts across APEC
- Reduced duplication and fragmentation in standards development
- Enhanced regional capacity to contribute to international standards
- Stronger public-private collaboration in shaping quantum standards
- Support for interoperability and trust in emerging quantum technologies

2026: Initiation, stakeholder engagement, first roundtable and initial standards mapping exercise

2027 onward: Continuation of roundtables, annual reporting, and expanded participation

2. Standards Development – continued

2.2 Information Exchange on Technology Readiness Levels for Quantum Technologies

Objective:

To facilitate consistent understanding, application, and communication of Technology Readiness Levels (TRLs) for quantum by promoting information exchange and sharing of best practices across APEC economies.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- Industry associations and consortia
- Research institutes, universities, and academic institutions

Detailed Description:

This initiative will support the development of a shared knowledge base and dialogue around TRLs for quantum technologies. While TRLs are commonly referenced in research, innovation, and commercialisation contexts, their interpretation and application can vary significantly across economies and sectors.

The initiative will include the following activities:

- **Comparative analysis of quantum TRL frameworks** used by APEC economies, identifying similarities, differences, and sector-specific adaptations.
- **Development of a reference guide** summarising TRL definitions, use cases, and mapping across economies.
- **Workshops and webinars** to raise awareness about applying TRLs in government programs, industry, and standards development.

Target Audience:

- Policymakers and program managers in innovation and technology development
- Standards professionals and technical experts
- Researchers and technology developers
- Industry stakeholders involved in commercialisation and product development

Anticipated Benefits:

- Greater clarity and consistency in the use of TRLs across APEC
- Improved communication and collaboration on quantum technology development and assessment
- Enhanced ability to benchmark and align innovation programs
- Support for standards development and regulatory policy for emerging technologies

2026: Launch stakeholder engagement and initial data collection on TRLs

2027: Comparative analysis and development of reference guide, hosting of first workshop

2027 onward: Ongoing workshops and webinars, periodic review and updating of reference guide and expanded collaboration efforts

2. Standards Development – continued

2.3 Identify Key Application Areas and Use Cases for Standardisation of Quantum Technologies

Objective:

To identify and prioritise key application areas and use cases within quantum technologies where standardisation would help drive development, deployment and scalability.

Detailed Description:

The need for standards is critical to ensure compatibility, trust, and efficient development of quantum technologies. This initiative will focus on identifying specific application domains where standardisation efforts can have the greatest positive impact.

Activities that form part of this initiative include:

- **Standards mapping** to identify gaps and opportunities for quantum standards development and adoption
- **Landscape analysis** of quantum technology applications across APEC economies, including computing, communications, sensing, and cryptography.
- **Stakeholder consultations** with industry, academia, and government to gather insights on current challenges and opportunities for standardisation.
- **Technical workshops** to explore application-specific requirements and potential standardisation pathways.
- **Development of a prioritisation framework** to assess application areas based on criteria such as maturity, cross-border relevance, market potential, and risk.
- **Publication of a roadmap report** outlining recommended application areas for standardisation, including short-, medium-, and long-term priorities.
- **Coordination with international standards bodies** to align findings with ongoing efforts and avoid duplication.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Government agencies and regulators
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Research institutes, universities, and academic institutions

Target Audience:

- Standards developers and policymakers
- Quantum technology researchers and engineers
- Industry stakeholders seeking clarity on standards pathways
- Regulators and government officials involved in technology governance

Anticipated Benefits:

- Clear identification of high-impact areas for quantum standards development
- Improved coordination and resource allocation for standards efforts
- Enhanced interoperability and trust in quantum technologies
- Support for regional and international collaboration on quantum innovation

2026: Project initiation, stakeholder mapping, and landscape analysis

Consultations and technical workshops

2027: Development of prioritisation framework and draft roadmap for standardisation activities

2028: Final publication and dissemination of standardisation roadmap

2. Standards Development – continued

2.4 Expert Contributions on Topics Relating to Quantum Standardisation

Objective:

To facilitate expert-led contributions that inform, guide, and accelerate the development of quantum standards across APEC economies by leveraging technical expertise and insights.

Detailed Description:

This initiative seeks to harness the knowledge of subject matter experts in quantum technologies to support standards development efforts within APEC. Contributions will focus on emerging technical topics, strategic priorities, and cross-cutting issues relevant to quantum standardisation.

Activities that form part of this initiative include:

- **Call for expert papers or briefs** on priority topics such as quantum-safe cryptography, quantum networking protocols, benchmarking quantum processors, and quantum metrology.
- **Formation of an expert advisory group** to provide ongoing input and review of quantum standardisation activities within APEC and globally.
- **Technical webinars and panel discussion**s featuring invited experts to share insights and encourage dialogue among stakeholders.
- **Compilation and circulation of expert contributions** to support standards bodies and policymakers.
- **Coordination with international standards organisations and other relevant bodies** to ensure alignment and relevance of expert input.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Industry associations and consortia
- Government agencies and regulators
- Technology companies, quantum startups, and SMEs
- Research institutes, universities, and academic institutions

Target Audience:

- Standards developers and technical committees
- Policymakers and regulators
- Quantum technology developers and researchers
- Industry stakeholders seeking guidance on standards pathways

Anticipated Benefits:

- Access to high-quality, expert insights on quantum standardisation
- Enhanced technical depth and relevance of APEC standards initiatives
- Strengthened regional capacity to contribute to international standards
- Improved coordination and knowledge sharing across economies

2026: Launch of expert call and formation of advisory group, collection and review of expert contributions

2027: Webinars and compilation of expert contribution

2028 onward: Continued engagement and coordination on standards development activities

2. Standards Development – continued

2.5 Capacity Building for Quantum Standards in the APEC Region

Objective:

To strengthen the capacity of APEC economies to understand, adopt, contribute to and develop quantum technology standards by providing targeted training, resources, and collaborative opportunities aligned with international best practices.

Detailed Description:

Many APEC economies face challenges in accessing the expertise, infrastructure, and institutional knowledge required to effectively engage in quantum standards development and implementation.

This initiative will support capacity building through a series of coordinated activities designed to:

- **Deliver targeted training workshops** on quantum standards fundamentals, international standards development processes and emerging areas of standardisation for quantum technologies.
- **Develop a training toolkit,** including presentations, case studies, and practical exercises, that can be adapted for use by standards bodies, government agencies, and academic institutions across APEC.
- **Facilitate knowledge exchanges** between economies with advanced quantum standards programs and those seeking to build capacity. For example, through mentoring, study visits, or virtual exchanges.
- **Coordinate with international standards organisations** to ensure alignment and relevance of training content and to encourage participation of APEC member economies in international standards development fora.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Government agencies and regulators
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Research institutes, universities, and academic institutions

Target Audience:

- Standards professionals and technical experts in APEC economies
- Policymakers and regulators involved in emerging technologies
- Researchers and developers in quantum technology fields
- Industry representatives seeking to align with standards

Anticipated Benefits:

- Increased regional capacity to engage in quantum standards development
- Improved understanding and adoption of international quantum standards
- Strengthened collaboration and knowledge sharing across APEC
- Support for innovation, interoperability, and market access in quantum technologies

Expected Impact:

This initiative will empower APEC economies to actively participate in and benefit from quantum standards development. By building foundational knowledge and practical skills, it will support regional innovation, reduce technical barriers to trade, and enhance APEC's collective influence and contributions to global quantum standards.

2026: Needs assessment and development of training materials, delivery of initial workshops

2027: Knowledge exchanges and capacity building activities

2028 onward: Expansion of training offerings and ongoing coordination with international standards organisations

3. Talent

3.1 Establish Multi-Stakeholder Dialogue on Quantum Workforce Needs

Objective:

To establish ongoing engagement between industry, government, and academic stakeholders to identify quantum technology workforce needs, skills gaps, and opportunities for workforce development across the APEC region.

Detailed Description:

A diverse and skilled quantum workforce is essential to support the development and adoption of quantum standards. This initiative proposes the establishment of a structured forum for multi-stakeholder dialogue on quantum workforce needs. The initiative will support:

- **Identification of industry training requirements** and emerging skills gaps.
- **Development of educational materials** on quantum technologies, aligned with industry needs.
- **Promotion of internship, mentorship, and training opportunities** across APEC economies.
- **Engagement with universities, industry, and government** in co-designing workforce strategies.
- **Engagement with national standards bodies** to promote industry participation in standards development activities.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Government agencies and regulators
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Research institutes, universities, and academic institutions
- General public and broader community

Target Audience:

- Government officials from APEC member economies
- Quantum workforce professionals and trainees
- Industry stakeholders
- University students and graduates in STEM fields
- APEC Digital Economy Steering Group (DESG)

Anticipated Benefits:

- Stronger collaboration across industry, academia, and government.
- Better alignment of workforce skills with evolving industry requirements.
- Strengthened regional talent pipeline in quantum-related fields.
- Increased awareness of quantum careers and workforce pathways.
- Enhanced support for future standards development through technical expertise.

2026: Establishment of dialogue forum, initial needs assessment and identification of skills gaps.

2027: Development of educational materials, identification and promotion of internship and training opportunities.

2027 onwards: Integration of workforce development activities and educational materials into member economy initiatives.

3. Talent – continued

3.2 Increase Women's Participation in Quantum Technology Standardisation

Objective:

To increase women's participation and leadership in quantum technology standardisation processes across APEC economies through targeted initiatives and partnerships.

Detailed Description:

Recognising that diversity drives innovation, this initiative seeks to ensure that standards development processes are inclusive and reflective of all stakeholder needs, particularly women. The initiative will include the following activities:

- **Establishing partnerships with relevant organisations** to create pathways for women's engagement in quantum standardisation activities.
- **Creating networking opportunities** for women working in quantum-related fields across APEC economies.
- **Offering training programs, internships, and scholarships** to encourage women to participate in quantum technology standards.
- **Promoting visibility** of female role models and leaders in quantum technologies and standards development.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Government agencies and regulators
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Venture capital firms, investors, and tech incubators
- Research institutes, universities, and academic institutions
- General public and broader community

Target Audience:

- Women in STEM fields across APEC economies
- Early-career female professionals in the quantum workforce
- University students and recent graduates
- Standards development organisations and NSBs

Anticipated Benefits:

- Broader diversity of perspectives in standards development processes.
- Improved innovation and creativity through inclusive participation.
- Stronger networks and role models for women in STEM and standards.
- A more inclusive and representative quantum technology community across APEC.

2026: Identify and engage with relevant organisations (eg: Women in STEM networks), develop training framework

2027: Initiate pilot training programs, organise networking events

2028 onwards: Scale up training programs, expand partnerships and offerings

4. Policy

4.1 Develop APEC Regional Quantum Technology Policy Framework

Objective:

To explore the development of a flexible regional framework that supports coordination and strategic alignment on quantum technology policies and strategies across APEC economies.

Detailed Description:

A regional quantum technology framework for APEC has the potential to strengthen collaboration, drive innovation, and enhance the region's competitive advantage with regards to quantum technologies. Beyond standardisation, the framework would also consider opportunities for APEC economies to align on national quantum policies, strategies and economic objectives, underpinned by common principles.

This initiative will consist of the following activities:

- **Mapping existing national quantum strategies, policies, and initiatives** across APEC economies.
- **Identifying areas for coordination**, knowledge sharing, and strategic alignment.
- **Developing shared framework** for regional alignment on quantum technologies.
- **Establishing working groups** to initiate roadmap activities based on shared priorities.

Potential Entities Involved:

- APEC Sub-Committee on Standards and Conformance (SCSC) and related APEC forums
- National standards bodies (NSBs)
- International standards organisations (e.g. ISO, IEC)
- Government agencies and regulators
- Industry associations and consortia
- Technology companies, quantum startups, and SMEs
- Research institutes, universities, and academic institutions

Target Audience:

- Government agencies
- NSBs
- Industry associations and technology companies
- Academic research institutions and policy institutes
- APEC SCSC
- International standards organisations (e.g., ISO, IEC)

Anticipated Benefits:

- Greater regional coherence and strategic alignment
- Reduced duplication of effort across economies
- Stronger foundations for cross-border collaboration
- Shared guidance to inform future initiatives and investments

2026: Initial mapping and consultation

2027: Identification of areas for coordination, draft framework development

2028 - ongoing: Publication of framework, establishment of working groups, ongoing engagement with key stakeholders

Conclusion

Quantum technologies have transitioned from theoretical research to practical application across a range of sectors. However, APEC member economies display varying levels of quantum readiness and capability. While some economies have established comprehensive national quantum strategies supported by substantial public investment, other member economies are at earlier stages of exploration and development. Without a coordinated regional approach to quantum technologies there is a risk that incompatible quantum ecosystems will emerge, thus inhibiting trade, limiting collaboration, and reducing collective regional competitiveness.

This Project has reviewed and analysed existing trends, surveyed APEC member economies, informed workshop participants and collaboratively identified opportunities for future activities. The Final Report has provided a detailed examination of the quantum technology landscape, identifying critical barriers and opportunities, and outlining practical initiatives to support regional standards alignment and collaboration on quantum technologies.

Findings presented in this report highlight the important role of international standards in providing a valuable framework to address challenges and promote interoperability. International standards establish globally recognised technical specifications, promote harmonisation across jurisdictions, facilitate market access, and provide the foundation for responsible technology development and deployment. In the quantum domain, standards are particularly critical for interoperability, building supply chain capability, ensuring security, enabling performance benchmarking, and creating confidence in emerging technologies. Active participation in international standards development organisations, particularly IEC/ISO JTC 3, presents a critical opportunity for APEC economies to shape the technical and policy frameworks that will govern quantum technologies globally.

Strengthening technical capacity, facilitating knowledge transfer, and establishing mechanisms for coordinated engagement will be essential to ensuring equitable participation and influence. The roadmap initiatives identified in this report, such as participation in international standardisation activities, workshops and knowledge sharing events represent practical avenues to strengthen regional capabilities and global influence. These initiatives seek to accommodate the diverse strenghts and priorities of APEC member economies while providing meaningful pathways for participation and action.

The Project team encourages the APEC SCSC to review and endorse a program of activities based on the roadmap, and APEC member economies to consider leadership and participation in individual activities.

This Report establishes a foundation for future collaboration in the development of quantum standardisation and capabilities. Together, APEC economies have the ability to collectively secure the economic and social benefits of quantum technologies, strengthen regional resilience, and contribute to a globally harmonised quantum ecosystem.

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Appendix

Appendix A: Risks and Mitigation Strategies for Roadmap Initiatives

Effective risk management and mitigation strategies should be considered prior to and throughout the implementation of roadmap initiatives. The initiatives outlined in this report operate across diverse economies, sectors, and stakeholder groups, making the proactive identification and mitigation of risks essential to ensuring their impact and success. Potential risks are listed in Table 2 below, along with suggested mitigation strategies. It is important to note that this list is non-exhaustive, and that further risks may be identified throughout the implementation of the roadmap initiatives.

Table 2 - General Risks and Mitigation Strategies for APEC Quantum Roadmap Initiatives

Risk Category	Description	Applicable Initiatives	Potential Impact	Mitigation Strategies
Low Stakeholder Engagement	Limited participation or sustained involvement from key stakeholder groups such as standards bodies, government agencies and academia.	1.1 1.3 2.1 2.3 3.1 4.1	Reduced diversity of input, weaker collaboration, and slower progress.	Conduct thorough stakeholder mapping; maintain regular communication; tailor engagement strategies to each stakeholder group; highlight benefits of participation.
Awareness and Communication Challenges	Difficulty communicating complex quantum concepts to non-specialist audiences, leading to low understanding or interest.	1.1 1.3	Reduced public engagement and limited awareness of the importance of standards.	Develop audience-specific communication materials; use clear, visual formats; collaborate with media and educational partners to enhance accessibility.
Resource and Funding Constraints	Limited financial or human resources to sustain initiatives over the medium to long term.	All initiatives	Incomplete implementation or delayed delivery.	Seek co-funding or in-kind support from partners; prioritise high-impact activities; integrate initiatives with existing APEC programs.
Coordination Across Economies	Varying levels of readiness, infrastructure, and national priorities among APEC economies.	2.1 2.5 3.1 4.1	Uneven participation and fragmented outcomes.	Adopt a phased approach; tailor activities to local contexts.
Data and Information Gaps	Insufficient or inconsistent data on standards, TRLs, or workforce needs across economies.	2.1 2.2 3.1	Incomplete analysis resulting in reduced decision-making abilities.	Conduct baseline surveys; promote information sharing; establish a data repository.

Table 2 continued

Risk Category	Description	Applicable Initiatives	Potential Impact	Mitigation Strategies
Expert Availability and Knowledge Retention	Limited pool of subject matter experts available to contribute to technical and training activities.	2.4 2.5	Reduced technical quality of outputs and limited depth of standardisation and training activities.	Establish expert advisory groups; offer recognition or publication opportunities; partner with universities and industry leaders.
Gender and Inclusion Barriers	Underrepresentation of women and minority groups in quantum and standards development.	3.2	Reduced diversity of perspectives and innovation potential.	Partner with women-in-STEM networks; provide targeted opportunities; monitor participation metrics.
Technological Evolution and Obsolescence	Advancements in quantum technologies outpacing existing materials, training, or policies.	2.2 2.5 4.1	Reduced relevance of outputs and credibility of initiatives.	Conduct regular reviews; maintain continuous engagement with experts.
Logistical and Event Delivery Challenges	Difficulties organising multi-economy events due to factors such as time zones, travel costs, or coordination issues.	1.3 2.1 2.5 3.1	Delays, low attendance, and reduced engagement.	Leverage hybrid or virtual delivery options; plan early and align with existing APEC meetings or events.
Policy Misalignment or Overlap	Differences in national strategies or overlapping initiatives creating duplication of effort.	2.3 4.1	Conflicting priorities and inefficiencies.	Maintain regular coordination through APEC forums, such as APEC SCSC; map related activities; encourage transparency and complementarity with national programs.