
# Brief on Strengthening Quantum Applications Ecosystem in India

Redefining what's possible with quantum technology

An Ardent Co. submission

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# Background

**The Department of Science & Technology (DST)**, which operates under the Ministry of Science & Technology, will be responsible for implementing **the National Mission for Quantum Technologies and Applications (NM-QTA)** between 2023-24 and 2030-31.

The mission involves a cost **of ₹ 6,003.65 crore** for the mentioned period. The goal of this initiative is to initiate, cultivate, and expand scientific and industrial research and development, and create a dynamic and inventive environment for Quantum Technology.

The following are the watershed moments depicting the trajectory of growth and development of Quantum Technology and Applications in India.

- **The Department of Science & Technology** launched a program named **Quantum-Enabled Science & Technology (QuEST)** in 2018, with a commitment to invest Rs. 80 crores over the next three years to expedite research.

- **The Finance Minister of India** announced the **National Mission for Quantum Technologies and Applications (NM-QTA)** in the 2020 Budget speech with a total allocation of **₹8000 crore** over five years to strengthen the quantum industry in the country.

- Additionally, in October 2021, the government inaugurated C-DOT's **Quantum Communication Lab** and unveiled a **Quantum Key Distribution (QKD)** solution that was developed indigenously. **The Ministry of Electronics and Information Technology (MeitY) partnered with Amazon Web Services (AWS)** to create the **Quantum Computing Applications Lab**, aimed at facilitating quantum computing-based research and development and promoting scientific advancements.

# Economic and social manifestations globally

## The United States

Quantum information technology has demonstrated its proficiency in tackling complex problems where classical computers may be capable of verifying a solution but struggle to identify the exact answer from among billions of potential solutions.

Given that public sector officials encounter such demanding challenges on a regular basis, quantum information technology is starting to offer genuine potential not only for solving problems but also for enhancing people's quality of life.

For instance, **Groovenauts**, a company based in Japan, employed machine learning powered by quantum computing to enhance the optimization of garbage collection routes in Tokyo. According to their pilot study, the use of quantum technology resulted in a substantial increase in efficiency and even demonstrated the potential for a nearly 60% decrease in carbon emissions.

In 2022, the US Federal investment in quantum technology accounted for less than 9% of the total quantum information technology market, despite nearly doubling the figure from two years ago. Furthermore, the industry as a whole is expanding at a **much quicker rate of 30.2% CAGR.** At this pace, by the time the market reaches an estimated worth of US$44 billion in 2028, direct public spending will be even less significant.

## China

China initiated its research and development (R&D) efforts in quantum technology in 2008, and as of 2022, the country can claim several impressive achievements in this field. These include the development of the world's first quantum satellite, the establishment of a quantum communication line between Beijing and Shanghai, and ownership of two of the world's swiftest quantum computers. China has clearly emerged as one of the frontrunners in the space, largely owing to the government's active financial assistance.  In 2022, the Chinese government allocated **$15.3 billion** in public funds for quantum computing investments, **which is more than double the amount invested by EU governments ($7.2 billion) and eight times the amount pledged by the United States ($1.9 billion).**

# Economic and social manifestations in India

It is interesting to note that with the introduction of this mission, India will become the seventh country to establish a specialised quantum mission, following the United States, Austria, Finland, France, Canada, and China.

The initiative will accelerate QT led economic growth and make India one of the leading nations in the development of Quantum Technologies & Applications (QTA) in the following areas:

- Healthcare and diagnostics
- Defence
- Space and energy
- Data security

In other words, it will work towards indigenously building quantum-based computers which are far more powerful and are able to solve the most complex problems in a highly secure manner.

According to NASSCOM, India's plan suggests that the country will make significant progress in quantum infrastructure within the next five years, with the government playing a major role in its development.

The Indian government has planned to invest Rs. 8,000 crore (equivalent to US$1.2 billion) in quantum information and meteorology, quantum applications and materials, and quantum communications over the next five years. NASSCOM predicts that this investment will lead to a **45% increase in adoption of quantum technology** in industries such as manufacturing, high-tech, banking, and defence.

The quantum ecosystem in India is expanding rapidly with approximately 10-15 government agencies, 20-30 service providers, 15-20 startups, and 40-50 academic institutions currently involved in this field.

The Indian government's serious efforts to catch up with China and the US in the field of quantum technologies could lead to the adoption of such technologies contributing around **US$280 billion to US$310 billion to the Indian economy by 2030**.

The proposed initiative is in line with the national objectives such as **Digital India, Make in India, Skill India, Stand-up India, Start-up India, Self-reliant India, and the Sustainable Development Goals (SDG)**.

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# Emerging trends

Prominent technology companies like Google, Microsoft, and IBM have established specialised programs focused on quantum computing and its potential applications. In a similar vein, several Indian startups, such **as QNu Labs, BosonQ, and Qulabs.ai**, are making notable contributions to the development of quantum-based applications related to cryptography, computing, and cybersecurity.

Additionally**, Tata Consultancy Services, HCL Technologies, Infosys, Tech Mahindra, Zensar, Mphasis, and Coforge**, along with some other companies are developing use cases and proof of concepts for clients using quantum technologies.

A couple of years ago, **Horizon Quantum Computing**, a company that is dedicated to creating software tools for quantum computers, secured additional funding in an extension of its initial funding round. The funding was led by **Sequoia Capital India**. Sequoia Capital India is a well-respected investor in the tech industry, and their involvement in this funding round is a strong vote of confidence in Horizon Quantum Computing's potential.

Similarly, in 2020, an Indian start-up **QNu Labs** raised funding from reputable venture capital firms like **Wavemaker Partners** and **Sequoia India**.

More importantly, India aims to develop a **50-qubit quantum computer by 2026**, while smaller quantum devices such as simulators and sensors are expected to be developed much earlier. Domain experts believe that India has the potential to become an appealing hub for quantum research and development, software creation, and manufacturing of components and equipment.

# Leveraging quantum technology

**Quandela,** a quantum technology startup based in France, specialises in offering comprehensive quantum solutions leveraging single-photon technology. Their portfolio encompasses a wide array of advanced products, including photon sources, detectors, and quantum processors. They also design and provide tailored quantum computing systems for both industrial and scientific purposes.

Their services encompass the **development of highly efficient single photon sources, the creation of cutting-edge quantum computer algorithms, and the provision of cloud-based quantum computing solutions**. Their innovative solutions contribute to enabling improved communication systems, enhanced sensing capabilities, and progress in the field of quantum computing.

**QLM**, a startup based in the United Kingdom, has successfully showcased **a gas sensor that utilises photon quantum statistics to detect methane emissions**. This innovative sensor has the potential to replace the existing manual sniffer tests employed in the oil and gas industry to identify leaks of this potent greenhouse gas. By harnessing the principles of quantum mechanics, QLM's gas sensor offers a more advanced and efficient solution for detecting methane emissions during oil and gas exploration activities.

In 2021**, Atomionics**, a startup focused on quantum technology and based in Singapore, announced the successful acquisition of $2.5 million in seed funding for the purpose of commencing its operations.

The company is in the process of developing a compact **atomic interferometer capable of measuring gravity with greater accuracy compared to current commercially available gravimeters**. This advanced technology holds the potential to unveil valuable insights about subsurface structures. By detecting and analysing gravity variations, the portable atomic interferometer could potentially identify infrastructure elements like pipes and tunnels, as well as uncover natural resources such as oil, gas, and mineral deposits. The ultimate objective of the team is to create **a mobile instrument that enables continuous surveying capabilities.**

Similarly, **Qulabs**, an early pioneer in the field of quantum computing startups in India, was established in 2017. The company's primary objective is to offer a diverse range of services encompassing quantum machine learning, quantum communication, quantum computations, quantum algorithms, simulations, and more. By bringing together a multidisciplinary team of research scientists and engineers from esteemed institutions such as IITs, ISI, and IISc, Qulabs is actively advancing the frontiers of quantum research within India.

In addition to its core activities, the startup has launched **QuAcademy**, a platform dedicated to training, development, and the practical implementation of novel quantum technologies. Through QuAcademy, Qulabs aims to foster expertise and facilitate the translation of emerging quantum technologies into real-world applications.

Another instance is that of **Qnami**, a startup originating from Switzerland, is actively involved in the development of quantum sensing solutions for various applications, including healthcare. In the **healthcare sector**, Qnami specifically focuses on harnessing quantum technology to achieve high-resolution imaging and diagnostics.

By capitalising on the unique properties of quantum systems, Qnami aims to enable more precise and detailed imaging of biological samples, such as cells and tissues. This technological advancement has the potential to revolutionise imaging techniques by significantly improving sensitivity and spatial resolution.

Qnami's quantum-based sensors have the **capacity to revolutionise existing imaging modalities, like magnetic resonance imaging (MRI), by enhancing their sensitivity and resolution**. Additionally, these solutions have the potential to facilitate the creation of innovative imaging techniques that can offer valuable insights into cellular structures, biomolecular interactions, and disease processes at the atomic and subatomic levels.

Overall, Qnami is committed to leveraging quantum sensing technology to advance imaging capabilities, improve diagnostics, and contribute to the development of more effective and targeted healthcare solutions. Their primary objective is to leverage the power of quantum systems to enable **early detection and diagnosis of diseases, promote personalized medicine, and drive advancements in the healthcare field**.

# How could venture capitalists contribute to the future of quantum technology?

Venture capitalists play a crucial role in assisting businesses through various means, such as injecting capital, offering valuable analytical insights, managing financial resources, and finalising investment deals. Their involvement allows entrepreneurs to transform their concepts into fully operational businesses, benefiting from the support and guidance provided by venture capitalists along the way. Thus, here are a few ways how venture capital firms could contribute to the domain of quantum technology.

- **Investment and Funding:** Venture capital firms can provide financial support to quantum technology startups through investments, funding rounds, or partnerships. This capital infusion enables startups to accelerate their research, development, and commercialization efforts.

- **Strategic Partnerships:** Venture capital firms can form strategic partnerships with quantum technology startups, leveraging their resources, expertise, and market reach. This collaboration can facilitate technology transfer, joint development projects, and access to Venture capitalist firms' extensive network of industry partners and customers.

- **Industry Expertise and Guidance:** With its extensive experience in the telecommunications and technology sectors, corporate venture capital firms like **Motorola, Qualcomm, Infosys & Wipro** can offer valuable industry insights, guidance, and mentorship to quantum technology startups. This expertise can help startups navigate challenges, refine their business strategies, and align their technology development with market needs.

- **Market Access:** Corporate venture capital firms can help quantum technology startups gain market access and commercialise their products by leveraging corporate venture capital firms' distribution channels, customer base, and brand recognition. This support can significantly enhance startups' visibility, credibility, and market reach.

- **Technology Collaboration:** Venture capital firms can collaborate with quantum technology startups on specific technological advancements or applications. By combining Motorola, Qualcomm, Infosys & Wipro's existing technology capabilities with the novel quantum technologies developed by startups, new solutions and products can be created, expanding the scope and impact of quantum technology.

- **Research and Development Support:** Quantum technology is a rapidly evolving field with ongoing research and development efforts. Venture capital firms can provide support by sponsoring research projects, collaborating with academic institutions, or establishing innovation centres focused on quantum technology. This support can accelerate advancements in the field and foster collaboration between researchers and industry experts.

- **Intellectual Property and Patent Support:** Venture capital firms can assist startups in navigating intellectual property (IP) matters and patent strategies. This support can help startups protect their innovative technologies, establish a strong IP portfolio, and defend against potential infringements.

- **Ecosystem Development:** Prominent venture capital firms can actively contribute to the development of the quantum technology ecosystem by supporting incubators, accelerators, and industry associations. This involvement can foster collaboration, knowledge sharing, and the overall growth of the quantum technology community.

# Building a regulatory framework for quantum technology and applications

A regulatory framework would play a crucial role in the field of quantum technology by offering stakeholders clarity, protection, and safety. It would establish clear boundaries, safeguards intellectual property rights, and ensures the secure utilization of quantum technology. Moreover, the framework would encourage innovation, attract more investment, and facilitate international collaboration. It would also address ethical and societal concerns, promoting responsible and transparent development and utilization of quantum technology.

Ultimately, a well-designed regulatory framework creates a nurturing environment for progress in quantum technology, while also safeguarding interests and maximizing societal benefits. In the following section, we are going to have a look at how other countries are preparing to gain an edge in the world of quantum technology while enlisting a few measures that India as an emerging player in the space could adopt to grow at a faster pace.

## European Union

It is essential to remember that the Quantum Technology and Applications are still its nascent stage. Therefore, across the world, countries have been trying to infuse large sums of capital in the research and development of QTAs. Europe is no different.

In 2018, EU initiated **Quantum Technologies Flagship** in an attempt to bring together research-oriented institutions, industry and public funders – leading to consolidation and expansion of scientific leadership and excellence in the gamut of Quantum Technology. The flagship has a budget of €1 billion.

Since June 2019, the **EuroQCI Declaration** has been signed by all 27 EU Member States, indicating their collective commitment to collaborate with the European Commission and receive support from the European Space Agency in order to establish a comprehensive quantum communication infrastructure (EuroQCI) that spans across the entire European Union.

As part of the **European High Performance Computing Joint Undertaking (EuroHPC JU)**, the European Commission is currently planning to construct cutting-edge pilot quantum computers by 2023. These quantum computers will serve as accelerators that are interconnected with the supercomputers of the Joint Undertaking, creating hybrid machines that combine the strengths of both quantum and classical computing technologies.

In October 2022, the EuroHPC JU announced the selection of six locations across the European Union to host the initial European quantum computers. These quantum computers will be seamlessly integrated into EuroHPC supercomputers and will exclusively utilize state-of-the-art European technology. The chosen sites are located in **Czechia, Germany, Spain, France, Italy, and Poland**. The project is funded with a total of €100 million, with 50% provided by the EU and the remaining 50% contributed by 17 participating countries of the EuroHPC JU.

## The United States

In 2018, the **National Quantum Initiative Act** was passed by the U.S. Congress with the goal of expediting quantum research and development within the country. This legislation allocated funding for quantum research, established dedicated research centers, and facilitated collaboration among government, academia, and industry.

Additionally, the U.S. government initiated the **National Quantum Initiative Program**, which specifically focuses on advancing research in quantum information science and technology. The program aims to provide support for the progress of quantum computers, quantum communication systems, and quantum sensors.

To further encourage collaboration and innovation in the field of quantum research, **the U.S. Department of Energy (DOE)** established the **Quantum Information Science Centers**. These centers serve as platforms for fostering collaboration among national laboratories, universities, and industry players in quantum research.

The U.S. government has demonstrated ongoing commitment to supporting quantum technology through various agencies, including the **National Science Foundation (NSF)** and the **Defense Advanced Research Projects Agency (DARPA**). These agencies offer financial support for quantum research and development initiatives, as well as actively promote initiatives geared towards advancing the field of quantum technologies.

## China

China in its 14th five-year plan asserted the significance of Quantum Technology by stressing on it as the substratum to its continuing growth and development across different walks of life. Under this, the Chinese government introduced two education reforms named **'Education Modernisation 2035 Plan'** and the **'Implementation Plan for Accelerating Education Modernisation.'**

China has implemented two legislative initiatives with the objective of equipping its population for a future centered around quantum technologies. These initiatives are backed by a significant financial investment of approximately **$150-200 billion annually**, which accounts for about **4% of China's GDP**. Additionally, as a complementary measure, the Chinese government has been **encouraging the repatriation of students** who have studied at prestigious Western universities since 2008.

In addition to the efforts in public education, Chinese quantum companies such as **Origin Quantum**, **CIQTEK**, and **Alibaba** have taken the initiative to establish their own in-house quantum education programs. These companies actively engage with universities, including at the primary school level, fostering curiosity and interest in quantum technologies among students.

# Considerations for building a national policy framework for quantum technology ecosystem

While India has taken great strides in the field of Quantum Technology in a short span of time, a lot still needs to be figured out. Therefore, here is a list of measures that India could take to match up to the pace of relatively faster growing countries in the domain.

- **Definition and Scope:** Clearly delineate the boundaries and scope of Quantum Technology within the regulatory framework.

- **Support for Research and Development:** Promote and provide assistance for research and development activities in Quantum Technology through funding programs, collaborations, and partnerships with academic institutions, research organizations, and industry. All the frontrunning countries in the sphere of Quantum Technology have placed this measure at the core of their strategy.

- **Protection of Intellectual Property Rights (IPR):** Establish mechanisms to safeguard and manage IPR associated with Quantum Technology innovations, such as patents, copyrights, and trade secrets, to encourage investment and foster innovation.

- **Data Protection and Privacy:** Address privacy concerns and data protection issues specific to Quantum Technology, particularly in applications involving sensitive information or personal data. Ensure compliance with relevant data protection laws and regulations.

- **Facilitating Commercialization:** Foster an enabling environment for Quantum Technology startups and industry by streamlining regulations, providing access to funding opportunities, and offering support for market entry and commercialization endeavors.

- **Standards and Certification:** Develop standards and certification processes for devices, systems, and applications to ensure safety, interoperability, and reliability. This may encompass performance standards, security protocols, and quality assurance procedures.

- **Funding and Investment:** Establish funding mechanisms, grants, and venture capital support dedicated to startups and projects, fostering innovation and entrepreneurship in the field.

- **International Collaboration:** Encourage collaboration and partnerships with international organizations, institutions, and governments to leverage global expertise, exchange best practices, and participate in international Quantum Technology research and development initiatives.

- **Ethical Considerations:** Address the ethical implications and potential societal impact of QT, including discussions on fairness, accessibility, transparency, and risk assessment. Develop guidelines or principles to ensure responsible and ethical use of QT technologies.

- **Regulatory Oversight and Compliance:** Establish a regulatory authority or framework to oversee compliance with the regulatory guidelines, monitor advancements in QT, and adopt regulations as necessary to keep pace with technological developments.

# Additional recommendations

The following is **the list of recommendations** in order to facilitate growth of Quantum Technologies and Applications in India. The same has been categorised under three heads: commercial ecosystem development, scientific and industrial research and development and quantum technology-led economic growth.

### Commercial ecosystem development

According to NASSCOM, **the government is the primary supporter of quantum initiatives in India**, as about 92% of the 100 quantum projects initiated in the country are sponsored by the government. Therefore, the government must attempt to attract more private players. There is also **a critical requirement for creating a pool of skilled individuals** who can contribute to the quantum-applications ecosystem and drive the innovation and commercial growth of the sector. However, it's important to note that government is already undertaking projects in this direction, including propagating relevant courses in higher education setups.

### Scientific industrial research and development

- **A comprehensive roadmap:** To ensure efficient and effective development of quantum technology in India, a comprehensive strategy must be established over the next 10-15 years, focusing on key areas that provide economic and strategic benefits.

- **Identification of significant players in the space:** Adequate attention must be given to those who can contribute to the development of quantum technology.

- **A well-defined regulatory framework**: A coherent regulatory framework must be established to define the legitimate use of quantum computing.

- **Centres of Excellence:** The Indian government should also prioritise establishing centres of excellence dedicated to quantum science and technology within academic institutions and government research institutes to strengthen the domestic quantum technology workforce and create crucial intellectual property infrastructure.

## Quantum technology-led economic growth

- **State-Centre Partnership:** The central and state governments should collaborate to establish quantum innovation hubs and a conducive fiscal and legal environment to foster innovation and attract international firms while involving local talent.

- **Collaboration with private players:** The involvement of startups and Big Tech corporations is essential in converting research into real-world applications.

- **Multilateral engagements:** International cooperation with allies such as the US, Australia, Canada, UK, Quad, and BRICS should be pursued to build a successful quantum ecosystem.

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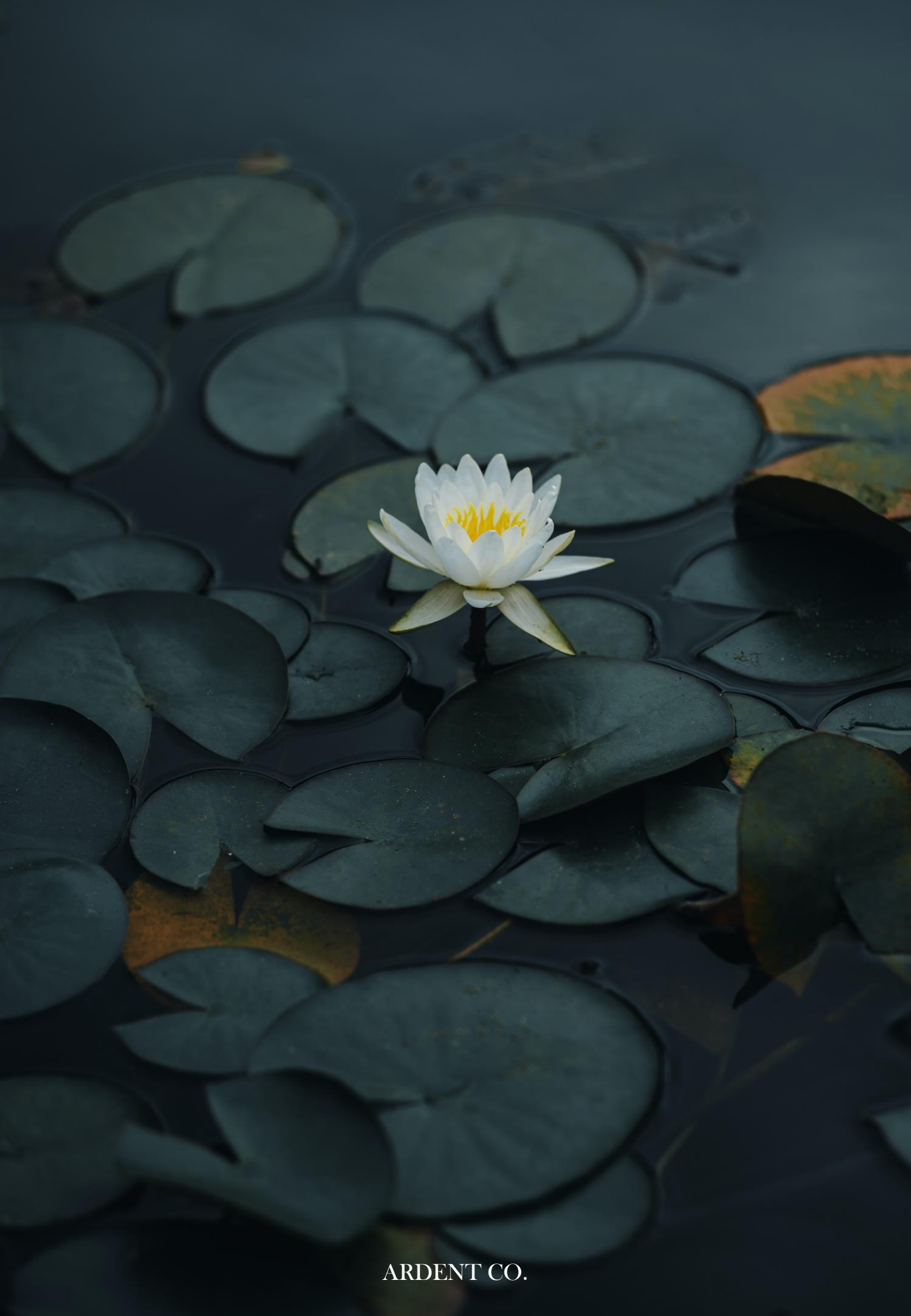
# Bottom Line

India is making significant strides in the field of quantum technology and has committed significant resources to accelerate research and development and create a vibrant & innovative ecosystem. The country has launched programs such as **Quantum-Enabled Science and Technology (QuEST)** and **the National Mission for Quantum Technologies and Applications (NM-QTA)** with a total outlay of ₹8000 crore over five years. The Indian government has also initiated the **development of quantum communication labs** and unveiled indigenously developed **quantum key distribution (QKD) solutions**.

The focus must be on developing an overarching strategy for the next 10-15 years to ensure that the efforts put in are concentrated in key areas that provide both economic and strategic benefits. Furthermore, India plans to develop a quantum computer with about 50 qubits by 2026 and is expected to become an attractive destination for quantum R&D, software development, and component and equipment manufacturing. The adoption of quantum technologies in **India could potentially add US$280 to US$310 billion of value to the Indian economy by 2030**.



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