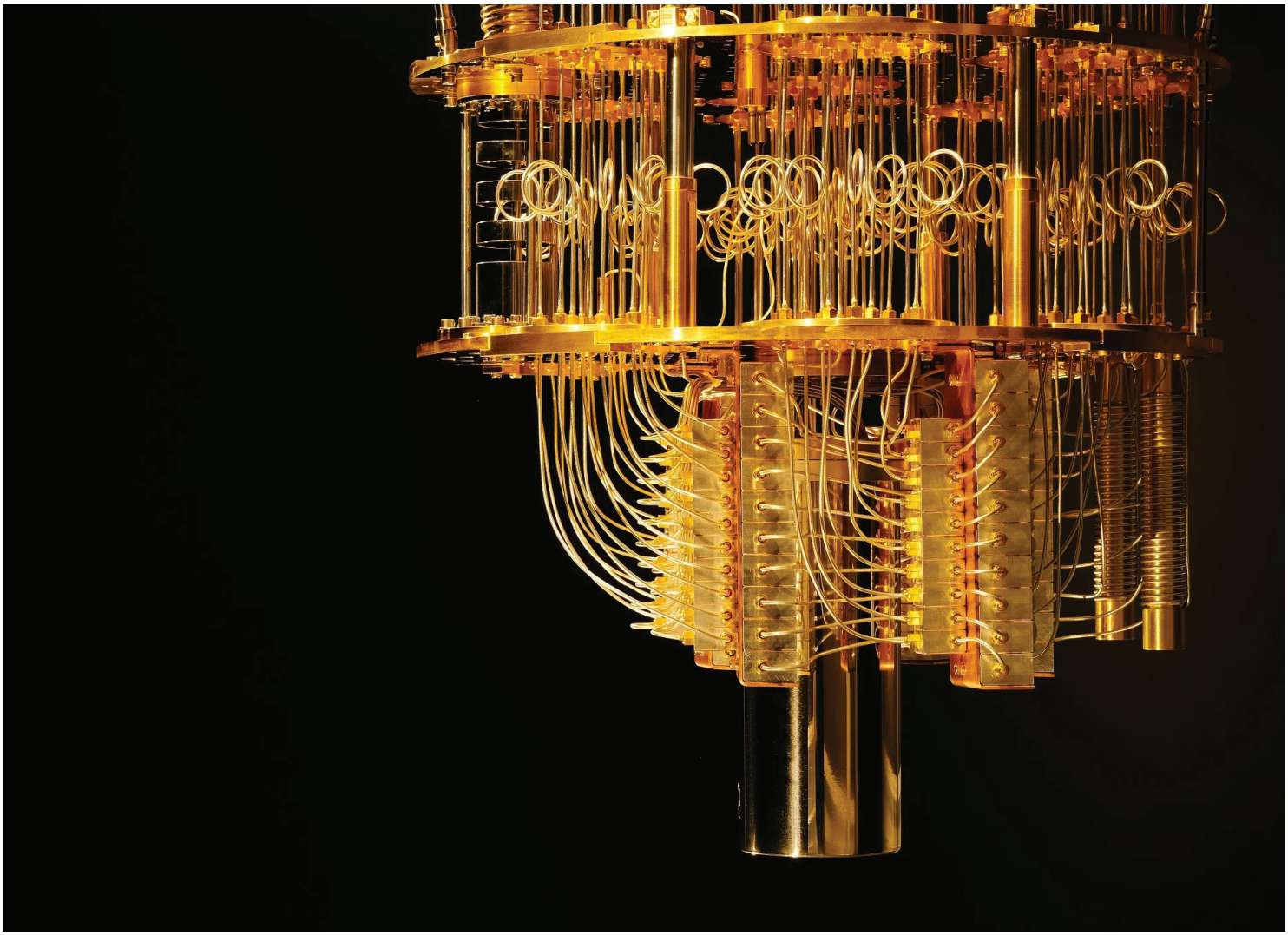
Building an Indian Quantum Industry



Building an Indian Quantum Industry

Exploit quantum computing to drive economic growth

Quantum as a strategic industry

Quantum technologies are expected to have a major impact on society and the world economy. The unique power of future quantum computers could provide solutions to major societal challenges such as energy, health, climate, and security. A quantum race has begun all over the world. Asian and Western governments are rolling out strategic plans with substantial funding.

Since the beginning of the 20th century, digital computers have been changing society. India, with its strengths in IT, has emerged as a global IT leader. It is now time for India to build capacity in quantum computing, which offers **an entirely new computation method that may solve problems that are intractable today**. As this technology progresses, there is an opportunity to bring about huge changes: next-gen battery design, corrosion analysis, automotive structural analysis, new materials design, solar conversion, catalysts, enzyme design, fraud detection, factoring, cyber forensics, ranking and partial ranking, sustainability, risk management, drug discovery and more. In essence, new industrial solutions and technologies enabled by quantum computing represent an "industry of industries" by adding value to already established industries.

Nasscom-Avasant, in their 2022 report, have predicted that India will have a $310B value industry in quantum technologies by 2030. **Capitalizing on this value requires a sound national strategy that fosters an ecosystem reflecting the unique industrial and research landscape of India that effectively deploys quantum technologies resources.** The report predicts 100X growth (or more) in India's workforce skilled on quantum technologies over the next decade. This document describes an approach for India to create a new strategic industry based on quantum computing by building an ecosystem to drive economic growth.

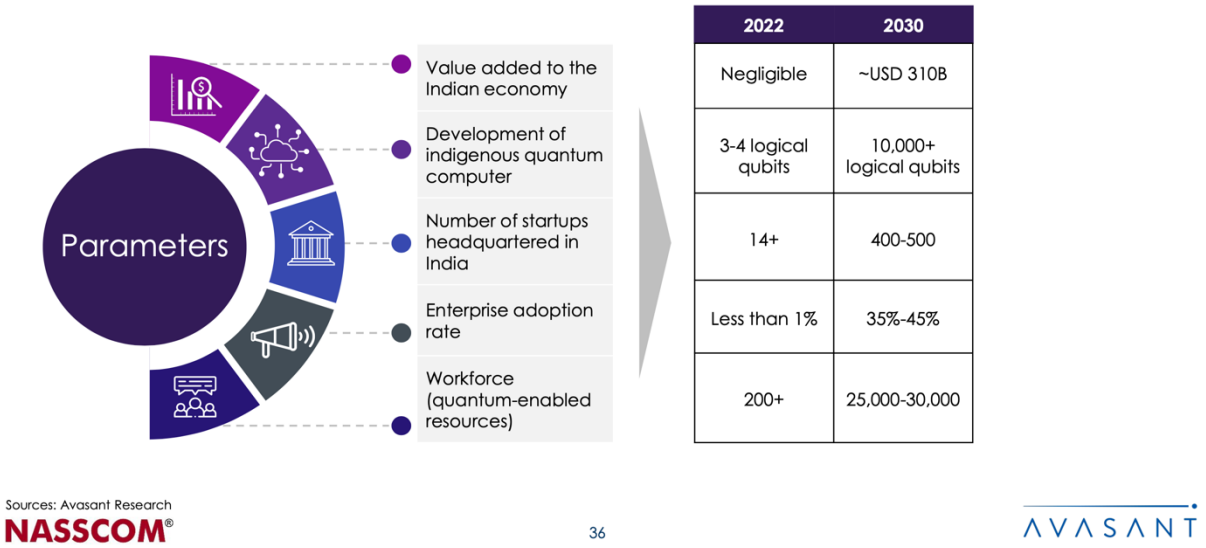


Figure 1. The figure shows the quantum technology goals for India to achieve maximum value. (Source: Nasscom-Avasant)

Building a sustainable ecosystem for a quantum industry

A quantum industry hinges on an active and vibrant ecosystem sustained by close interactions among four essential areas (Figure 2):

1. **Workforce and enablement:** A quantum computing workforce drives R&D and industry solutions to address challenging business problems. The quantum workforce is enabled by quantum computing education, including upskilling and reskilling of existing workers.
2. **Economic development and industry:** Commitment from industry to adopt quantum computing is key. It drives economic development. The pathways for industry adoption can be broken into three parts: (1) using quantum computing to improve development of new products and to enhance the efficiency of their internal processes, (2) building the quantum system components and associated technology supply chain (electronics, amplifiers, cryogenics, etc.), and (3) integrating quantum computing into the digital platform with classical and quantum data, computing, and communication.
3. **Research and development (R&D):** R&D pushes the limits of quantum computing with fundamental science and industrial research to develop algorithms, applications, and industry use cases using quantum computing as a tool. There is significant synergy of Quantum computing with classical and

high-performance computing, as we look to solving end to end problems facing industry, economies, and society. It becomes important then to consider an R&D strategy that has a roadmap to develop and leverage such synergy.

4. **Quantum computing services and infrastructure:** Quantum computing tools must be provided with a solid roadmap that establishes the path forward for continuous improvement in quantum infrastructure.

Figure 2 shows the quantum computing ecosystem characterized by these four components. Each component reinforces the others, so coordination in their development is important for success. Here, we describe in depth the mission of each component and how to make them behave like a flywheel, turning rapidly to create and sustain a strategic quantum computing industry.

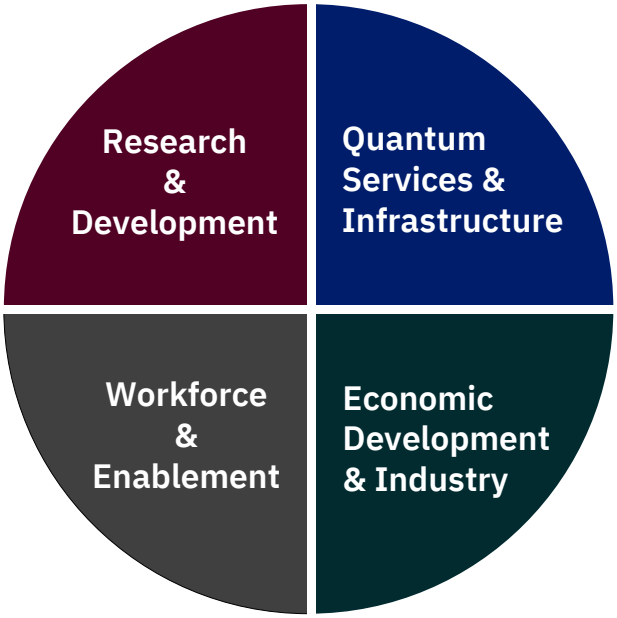


Figure 2. The four components comprising a national strategy to build a sustainable ecosystem for a quantum industry. "Research & development" includes research on new applications, software, and hardware. "Quantum services & infrastructure" bring quantum computing tools to users for the research and development of new applications and industry use cases. "Workforce & enablement" provides the education and training needed to build a workforce skilled in quantum computing, including continuous training in sync with quantum computing advances to get the most from the tools. "Economic development & industry" aims to drive the economy with quantum computing tools by setting clear business directions on what quantum computing can solve.

1. Workforce and Enablement

Workforce and enablement encompass the end-users of quantum computing and the developers. At a high level, there are three types of quantum developers:

I. **Kernel developers** that create high performance quantum circuits (analogous to assembly and CUDA optimization developers),

II. **Algorithm developers** that create primitive programs exploiting quantum and classical computing to bring computational solutions to the end users (analogous to SDK and AI framework developers), and

III. **Application and model developers** that build applications using libraries of quantum programs (analogous to application developers and data scientists).

The demand for application and model developers who are trained and skilled in quantum computing is increasing rapidly as industries adopt the technology. To meet these growing demands, there needs to be a focused program to systematically grow new generations of quantum computing users while upskilling and reskilling existing employees in non-quantum computing fields. This program should be part of a national education strategy designed for the local research and industry landscape, with continuing government support. It must address the different types of learners—self-learners, students in higher education and schools, researchers, industry practitioners—and include:

- Access to quantum computers and simulators for hands-on learning and immersive experiences.
- Educational material that is easy to consume and offers content for learners at different levels of maturity.
- Outreach activities and events to raise awareness and engage a broader community.

By 2024, India will have the largest number of software engineers in the world. Quantum computing presents a unique opportunity to shape that talent by upskilling and reskilling for new applications, and build leadership in the future of IT.

2. Economic Development & Industry

Industry transforms quantum computing innovations into products with potentially large societal and economic impact. For example, companies such as JSR, Mitsubishi Chemical and Daimler have pioneered the adoption of quantum computing in their research on efficient batteries. Financial companies such as HSBC and Goldman Sachs are investigating applications in finance, e.g., fraud detection and derivatives pricing.

A sound national quantum computing program must enable the local businesses to adopt quantum computing as a part of their industrial solutions as soon as possible to drive economic growth.

Industry must be part of R&D and the supply chain. New startups and existing organizations should be furnished with the tools needed to leverage quantum computing services to develop software solutions for industry use cases. Enabling enterprises for consulting on how to leverage quantum computing for business will further expand the ecosystem. Moreover, local manufacturing businesses can participate in the value chain and directly impact the economy by developing quantum computing hardware components. This defines the three ways of transforming industries with quantum computing:

1. Enable the adoption of quantum computing to prepare for quantum advantage,
2. Have local businesses participating in the quantum hardware components supply chain.
3. Have local businesses and new startups creating software applications that leverage quantum computing so that domain experts such as chemists, quants, etc. can find new solutions faster without needing to know quantum information science.

2.1 Enable industry to adopt quantum computing to prepare for quantum advantage

Early pioneers within key industries become a catalyst for broader change and can advance collaboration across the entire ecosystem. Preparing commercial enterprises to leverage quantum computing requires awareness, a vision and quantum computing strategy for the company, and the talent to execute it. This could lead to important

transformations in key industries like materials and chemicals, agriculture, automobile, electronics, manufacturing, financial services, and pharmaceuticals.

The goal would be to empower commercial enterprises to understand, prepare for, and adopt quantum computing to surface new approaches for solving business problems. This requires a multi-year approach focused on creating business awareness and deep technical capabilities to enable each organization to define a differentiated vision based on prioritized, feasible focus areas. As a result, the organizations must be able to build a compelling case for quantum computing in their operations, including a roadmap for adoption.

In addition, classical computing infrastructure and data needs to be prepared for the Quantum computing era. The government of India informed Parliament on August 2, 2022, that in the last four years, a total of 248 data attacks had resulted in data breaches in banks in India. Worldwide 83% of organisations have experienced more than one data breach in their lifetime according to IBM's 2022 Cost of a Data Breach Report. According to the same report, organizations in India on average reported 29,500 breaches. Organizations in India, including both government and private that hold sensitive data, need to start implementing quantum-safe cybersecurity protocols. While it may take some time for Quantum computers to reach the capability to breach today's encryption, one thing is clear: any data that falls into the wrong hands before an organisation transitions to quantum-safe protocols should be considered already lost. Also, any computer systems that will have to operate securely without major modifications over a period of years — the computer in your next car, or embedded in a satellite, for example — will need to be quantum secure well in advance of the threat.

While securing Indian data is important using quantum-safe cryptography, there is also a huge opportunity here for Indian engineers and the IT industry. India's IT industry received a tremendous boost with the opportunity to address the Y2K problem at the turn of the millennium. Now this "YQK" problem – with Q standing for Quantum – presents a similar challenge and opportunity, for Indian standards organizations, government and industry to leverage.

2.2 Local businesses participating in the quantum components supply chain

Global competition and price pressure is a common issue when developing new products. Novel approaches or products generally tend to take a long time to market

and even if they are on the market, suppliers may have limited access to potential customers. Quantum technologies present a unique opportunity to build new value and supply chains by bringing in new players and revitalizing existing participants with the prospects of a new market. The goal is to enable regional manufacturing industries to contribute to the quantum hardware components supply chains.

Building and optimizing quantum computing systems is a complex endeavor. Over the past couple of years, several quantum computing vendors have released their roadmaps for the development of such systems. Each roadmap has different levels of supporting details on how to achieve the goals set forth. What all those roadmaps have in common is that they make clear that significant innovation is needed in many components to improve size and form factor, density, thermal performance, and price, to name just a few factors. This presents multiple opportunities for business.

2.3 Local businesses participating in the quantum software opportunity

Given the inherent strong coupling of quantum and classical compute, there is an additional opportunity to link quantum computing with current high-performance computing and data platforms. Integrated with hybrid cloud technologies in serverless implementations that remove the complexity of infrastructure management and puts the focus on coding only, these services will be a game-changer for developers in different domains worldwide. Furthermore, current quantum software has many limitations for meeting the needs of the chemists, quants, and other domain experts. They need simple-to-use software applications they can use to find solutions without needing deep knowledge of quantum information science. The model developer needs to build these tools, and given India's large population of IT developers, it is natural for India to focus on becoming a leader in the quantum software application layer.

The startup ecosystem can play an accelerator role here, given their ability to invest and adapt with disruptive technologies. Startups can be enabled in via multiple mechanisms including:

- Quantum computing providers can provide access to quantum computing systems, training, mentorship, investment and collaboration
- Government can provide incubation, funding and networking support
- Academic and industry incubator programs can play a significant role in supporting early stage deep tech startups, through education, financial and other in-kind support

- Coordination across all these stakeholders can multiply the impact in terms of catalyzing and growing the startup ecosystem

3. Research and Development

Research and Development provides new capabilities by (1) finding new quantum algorithms and tools to achieve quantum advantage, and (2) applying the algorithms to real-world problems. This could lead to a discovery of key science and industry applications—for example, new methods of modeling and predicting material physics and chemistry behaviors to find more efficient batteries or materials with engineered properties; understanding new reaction pathways that may lead to better drugs, catalysts, or more energy-efficient industrial chemical synthesis; among others. These innovations benefit regional industries that adopt quantum computing as part of their workflow to drive economic development.

Such R&D efforts should have a roadmap of developing and leveraging synergy and integration across Quantum computing and Classical computing – in both forms of high-performance and standard computing. Such synergy will be relevant in multiple areas such as:

- End-to-end implementation of software that leverages classical compute for functions that are served well by classical compute – user experience, application services, data-intensive high-performance computation, for instance – and quantum compute for functions that are served well by quantum compute – complex computational problems.
- Looking to the future, quantum computing needs to scale to the form factor of quantum data centers that are leveraged at scale across many participants and organizations. This will need sustained research and development of modular data center designs that combine highly parallelizable and modular quantum computers and high-performance computers.

Continuous investment in R&D is critical to open new domains for the industries to drive the growth of the economy. This includes support for:

- Academic projects across hardware, software, and applications.
- Industry partnerships among quantum technology players to combine learnings and capabilities for technology co-development and translate research into products.

- Industry partnerships with consuming players to co-develop use cases and applications.

4. Quantum Services and Infrastructure

Quantum services and infrastructure support the activities of the ecosystem. In the early stages of the national quantum computing program, users can be provided with remote access to quantum computing services that are tuned and sized to the progress on the other three essential program areas. As adoption scales, access to quantum computing systems is a natural evolution and akin to traditional supercomputing, and will become a national asset that will drive the advancement of cutting-edge science and technology.

Summary

A successful national quantum computing strategy in India hinges on advancing four essential components in parallel: (1) workforce and enablement, (2) economic development and industry, (3) research and development, and (4) quantum services and infrastructure. This will enable the creation of a sustainable quantum ecosystem in India with a large workforce skilled in quantum computing and able to propel the country to the forefront of advanced technology. It will make it possible to accelerate the scientific method for discovery leveraging AI, quantum computing, and high-performance hybrid cloud computing to solve the bottlenecks of science and accelerate discovery and impact.