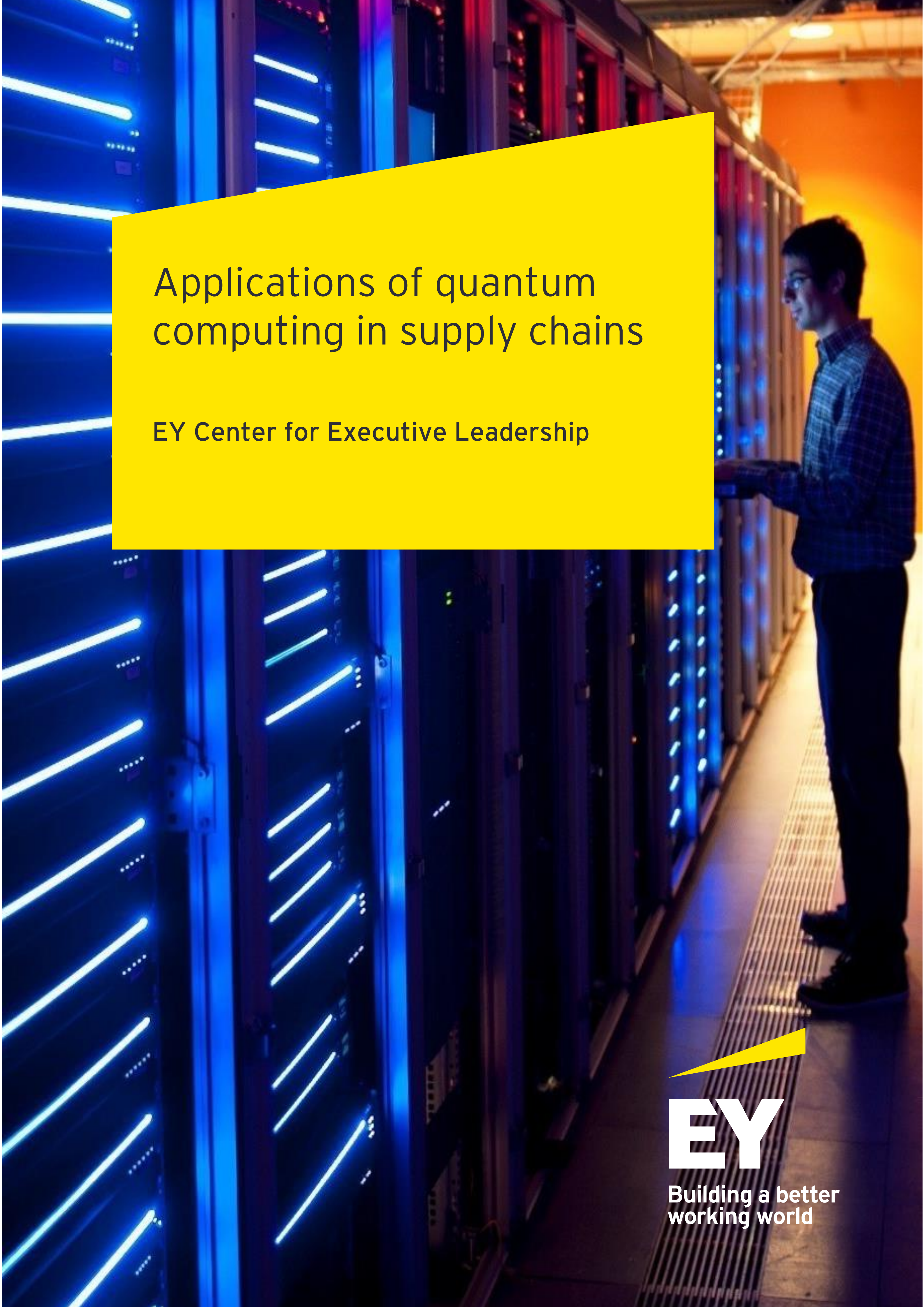
Applications of quantum computing in supply chains

EY Center for Executive Leadership



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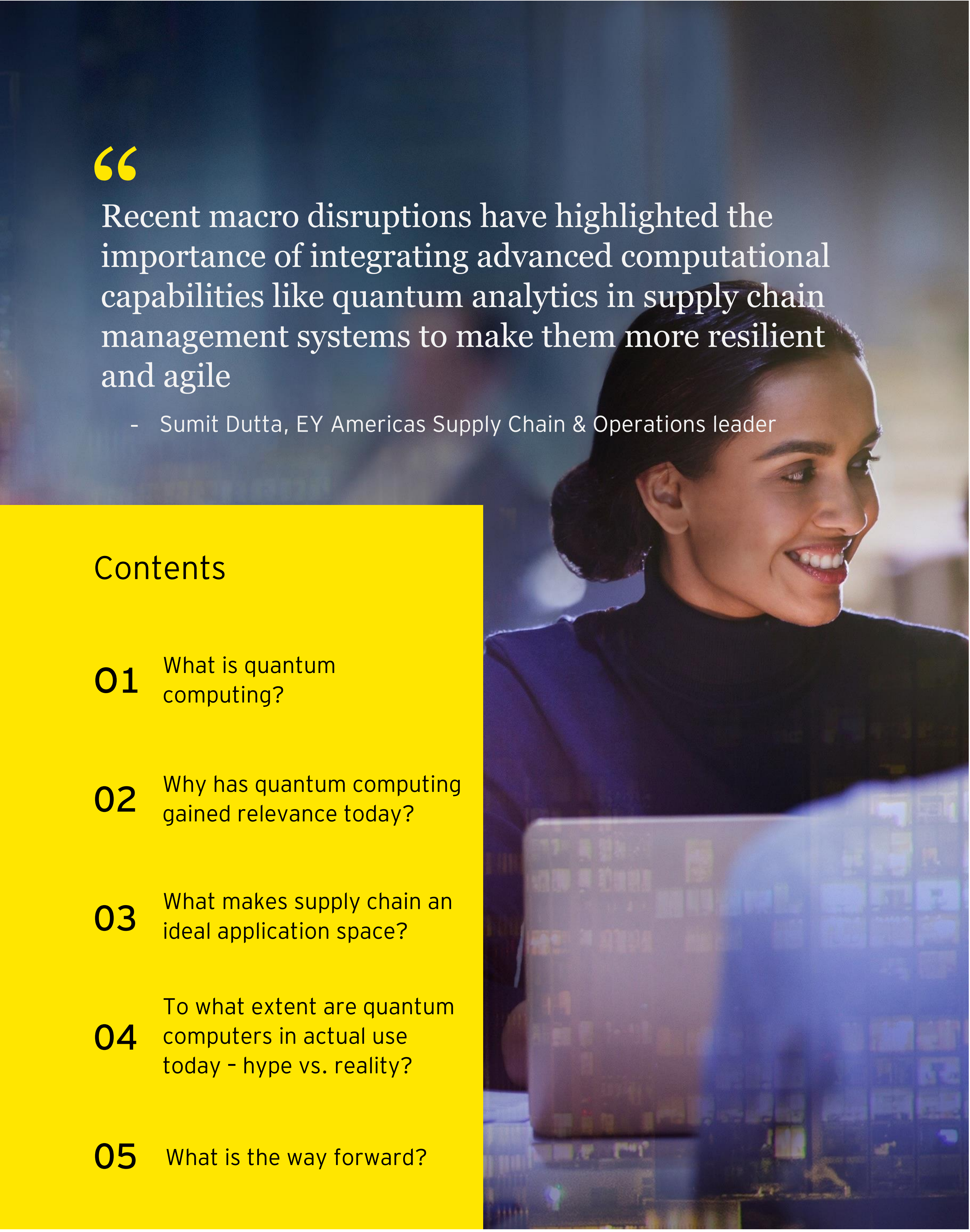

> Recent macro disruptions have highlighted the importance of integrating advanced computational capabilities like quantum analytics in supply chain management systems to make them more resilient and agile
>
> \- Sumit Dutta, EY Americas Supply Chain & Operations leader

Contents

In brief

- Unlike classical computers, quantum computers build a multi-dimensional landscape where a larger data set can be examined simultaneously, thus, resulting in exponential improvement in speed and accuracy of the analysis.
- Rising number of interconnected nodes in supply chains make it an ideal application area. Network design optimization, supplier management, predictive maintenance, and route optimization are some of the most prominent use cases in supply chain.
- Lack of talent and commercial application knowledge are the key hurdles in realizing the potential of quantum computers to solve industry-relevant problems in the near-term.

What is quantum computing?

In simplest terms, quantum computing uses the properties of quantum physics in combination with information technology to solve complex problems. Quantum computing uses qubits, which can represent a 0 or 1, or both at the same time, in contract to classical computing where bits are used, i.e., a 0 or a 1.

Use of qubits allows firms to have properties such as superposition (ability to be in multiple states simultaneously), entanglement (property that allows two qubits to be "linked" together beyond what is possible in classical systems: whenever we affect one of the entangled qubits, the other one will be immediately affected as well, regardless of the distance between them - this phenomenon is being researched for its uses in communication protocols), and interference (a by-product of superposition that allows to bias measurement of a qubit toward a desired state or set of states) — enabling them to assess multiple variables at the same time. These features of quantum computing help increase the speed and accuracy of data analysis exponentially.

The theoretical quantum computing advantage

	Classical computing	Quantum computing
Cryptography **RSA 2048 prime number factor encryption**	1 billion years	~100 seconds
Chemistry **Ferredoxin simulation**	Intractable	~300 seconds
Materials Science **thermoelectric materials discovery and optimization**	15 years	15 months
Financial Services **risk assessment for large portfolios**	Overnight or Days	Real-time or Hours

Organizations are exploring the "art of the possible" with quantum. It is not simply a question of how much faster a quantum computer is than classical. It is the broad landscape of how we rethink our approach to asking for answers from a computational platform that we never before would have thought to ask.

Why has quantum computing gained relevance today?

Development of the vendor community that is focused on driving commercialization within the quantum computing space has gained traction over the last few years and is expected to continue development at a much faster pace in the coming years.

Many leading technology companies have started building on their quantum computing solution suite. For instance, firms with a mature quantum computing capabilities were seen developing scalable, full stack quantum computing solutions, while many others have started exploring the possibilities within QC commercialization and can be considered as a promising emerging player.

There has also been an uptick in private funding within the quantum computing start-up ecosystem. According to recent CrunchBase publication, in 2021, VC-backed quantum start-ups witnessed more than 70% increase in investment compared to 2020, bringing the total investment to over $800 million in 2021. With the rising commercialization opportunities across multiple sectors, investor interest is expected to increase further over the next five years.

What makes supply chain an ideal application space?

Today, we see a growing appetite to address the concerns surrounding Post Quantum Encryption/Cryptography (PQE/PQC) to protect global supply chains from future attacks.

Problems involving multiple variables and constraints constitute a large part of activities across every function of the supply chain, such as warehouse and distribution facility bottlenecks, materials sourcing, unloading and loading, plant/machinery maintenance, route optimization, and scheduling. Additionally, the rising number of interconnected nodes and complexities in supply chains make it an interesting field of application for quantum computing.

Case in point

Ports across the US are facing increased levels of congestion, which is threatening to increase cargo lead times and costs for importers. This makes it imperative for ports to optimize their cargo handling operations using advanced systems like quantum-powered AI engines. Port of LA has very recently started using a quantum application for one of its terminals to expedite delivery and increase the amount of cargo that can be handled. Using a digital twin of the port operations, the system enabled a large set of simulation runs - testing out optimization schemes against a wide range of terminal conditions such as truck appointment methods, queuing variations, traffic patterns, the number of trucks in the terminal, and the number of no shows.

Leveraging the unique features of quantum computing, firms can simulate complex interactions by linking different supply chain variables, that are likely working in silos, to get entangled with each other, allowing the user to observe all of them by changing just one of them.

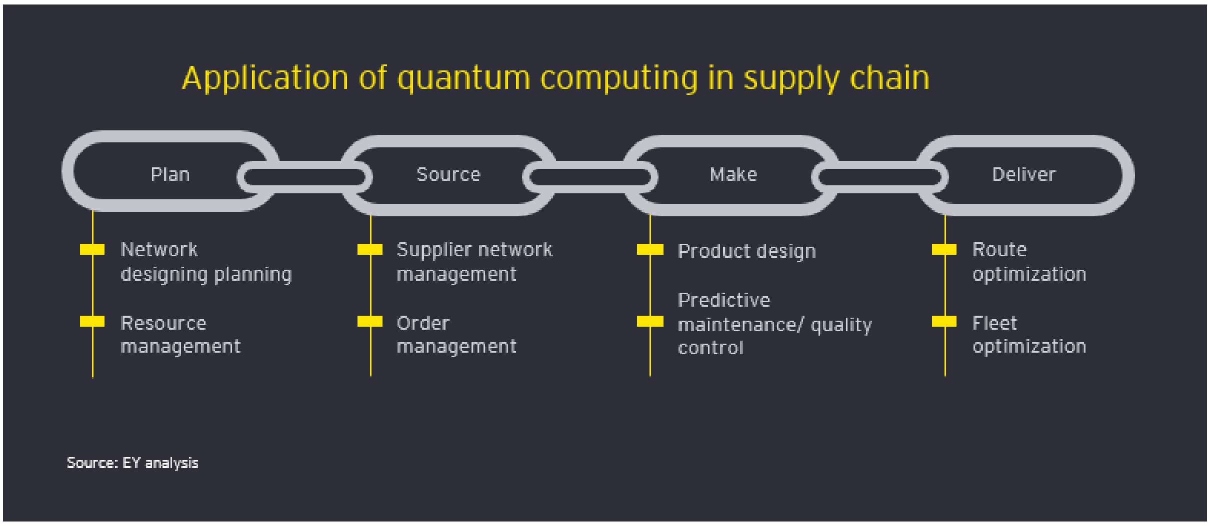

Fig.1: Quantum computing applications across supply chain functions

1. Plan:
   - **Network design planning:** Using advanced systems powered by quantum analytics, firms can optimize the identification of the ideal locations, count, and characteristics of assets including, warehouses, stores and distribution centers.
   - **Resource management:** Firms can run multiple simulations of their everyday operations to assess utilization rate of resources and optimize the usage, while minimizing carbon footprint.

Case in point

One of the largest steel manufacturers in the world is testing quantum computing to develop an optimal schedule for the intermediate products used during the steel manufacturing process. This was one of the biggest logistical challenges faced by the company (due to the number of variables involved), but also represented an area with potential for significant gains in efficiency and reduction in operating costs.

2. Source:
   - **Supplier network management:** Can centralize a highly scattered and unstructured supplier network to optimize material acquisition process and communication.
   - **Order management:** Can forecast and manage fluctuations in order volume.

Case in point

A Germany headquartered multi-national automobile manufacturer is exploring the use of quantum computing to find more efficient ways to purchase large number of components that go into its vehicles. The company has started using the quantum computing system to determine which components should be purchased from which supplier at what time to ensure the lowest cost while maintaining production schedules (e.g., one supplier might be able to deliver components faster, while another may deliver similar parts at a lower cost – the machine will help determine the most optimal selections from the available choices).

3. Make:
   - **Product design:** Quantum computing has the potential to significantly change the way products are designed by bringing in increased levels of precision and accuracy. Quantum computing can enable calculations of noise, vibrations and system loads for individual components — thereby optimizing the product design process of each component, which reduces the cumulative impact of safety margins of each component, allowing manufacturers to lower costs without sacrificing the performance of the system.
   - **Predictive maintenance/quality control:** Can improve time-series data analysis, particularly by combining machine learning with quantum computing, to drive accurate and early detection of potential events or errors.

Case in point

A leading industrial company recently decided to integrate quantum algorithms into digital twin simulation workflows, as part of its broader Industry 4.0 efforts focused on increasing data collection, analytics, and simulation across its plants. The company hopes to see the initial results of the quantum and quantum-inspired algorithms in one of its facilities by end of this year, which could eventually scale across its other facilities in the future.

4. Deliver:
   - **Route optimization**: Can determine the simplest path with shortest distance, lowest cost, minimal environmental impact, and lower effort.
   - **Fleet optimization**: Can access the optimal fleet size and maximize the productivity rate of existing fleet.

Case in point

A leading global beverage distributor utilized quantum-inspired architecture to enhance daily routing computation and optimize its deliveries servicing approximately 700,000 vending machines. The firm was also able to initiate its operations ~45 minutes earlier each day, post the quantum architecture upgrade.

To what extent are quantum computers in actual use today – hype vs. reality?

Digital maturity is still in its nascent stages in many industries, making practical application of QC even more difficult. According to the EY Global Reinventing the supply chain for an autonomous future, most companies are moving from a linear supply chain but only ~25% consider themselves digitally networked and/or autonomous. Firms across multiple industries have initiated extensive R&D to better understand the potential applications within different functions and quickest way to bring it into practical use.

Case in point

A South Korea headquartered multinational automotive manufacturer announced a partnership with a quantum computing company to develop algorithms to study lithium compounds and their chemical reactions involved in battery chemistry. The two companies have initiated this pilot collaboration and are laying the foundation to create better quality batteries by more precisely simulating and controlling their chemical reactions. The two companies are also in the initial stages of exploring the application of quantum computing to enable vehicles in recognizing real-world objects even more efficiently.

Various governments are also undertaking initiatives to support innovations in quantum computing. Few governments that announced the most significant fundings for quantum computing and analytics include China, the US, France, Japan, UK, India, and Germany.

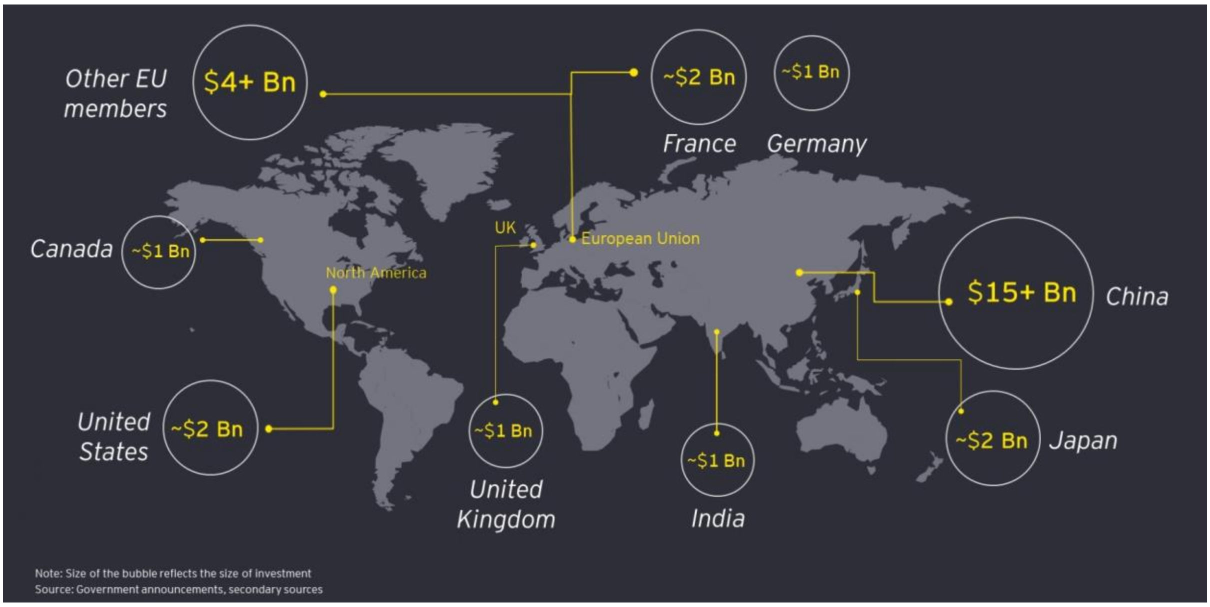

Fig.2: Announced government fund allocation for quantum computing R&D as of March 2022

From a sectoral and functional perspective, financial services, health care and pharmaceutical, energy and chemicals, supply chain, and manufacturing are likely to be the areas with strongest potential to benefit from quantum computing implementation. However, it may still be a long way for firms to completely unlock the potential of quantum computing to gain high-value benefits at a large scale.

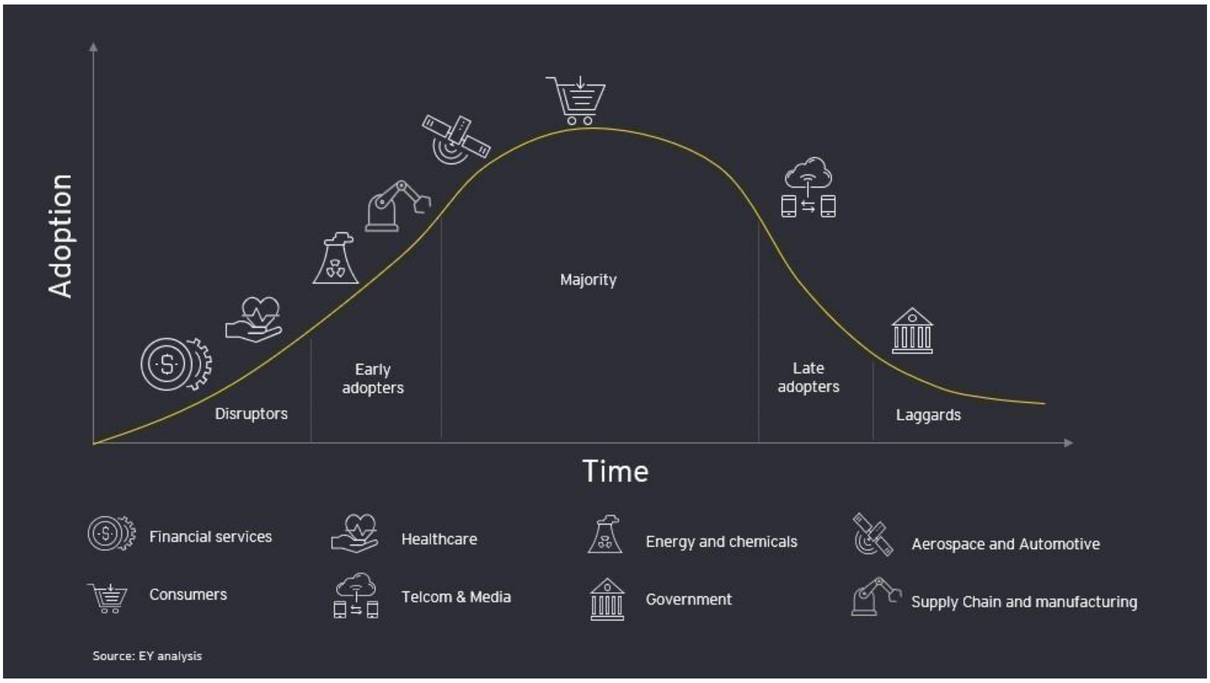

Fig.3: Quantum computing adoption across sectors

In the recent times, use of hybrid quantum computing approach that allows firms to combine quantum computing capabilities with classical computing, GPUs, and others, has gained traction. Since commercial application of quantum computing is still in its growing stages, using such hybrid approaches helps industry players in mitigating the current limitations that quantum computers have (high error rates, etc.), until quantum technologies mature.

While many firms see benefit in using 'Universal Quantum Computing' solutions (the form of quantum computing that can handle optimization tasks along with others), rising focus of industry players on targeted problem solving and optimization of complex functions through use of advanced technology is building more opportunities for Adiabatic Quantum Computing, that refers to the form of quantum computing that uses quantum annealers to solve complex optimization tasks (supply chain optimization, portfolio management, etc.), and is quite powerful but not fit for wider application.

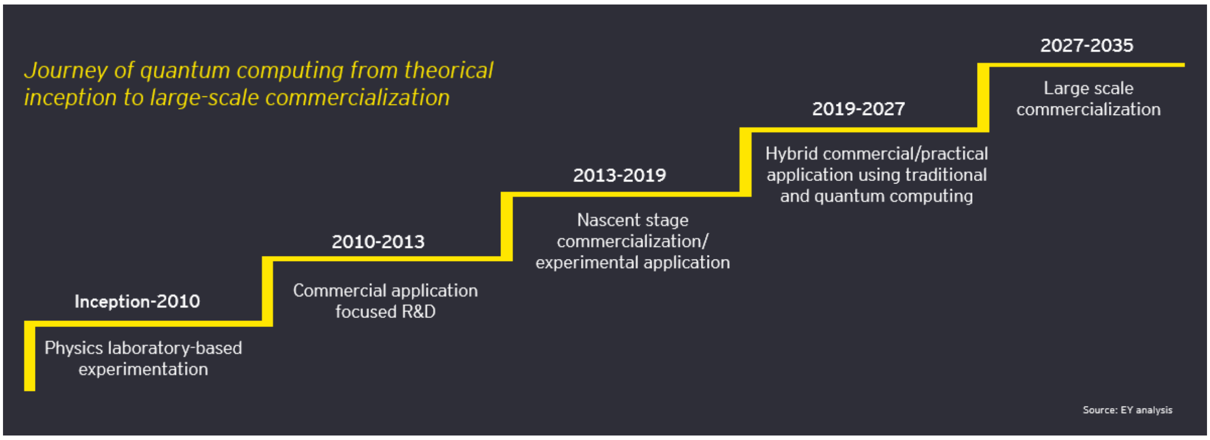

Fig.4: Quantum computing maturity timeline

What is the way forward?

While companies are keen to utilize QC in real-time, there is still a significant lack of readiness. Following a structured approach can be useful in formulating a roadmap to integrate QC in different functional areas and leverage its full potential.

1	Identify internal gaps acting as implementation barriers
2	Shortlist areas ideal for QC application
3	Assess the level of change readiness based current capability landscape
4	Build a strong partner network via third-party collaborations

1. Identify internal gaps acting as implementation barriers:

As the first step, firms that are keen on QC integration must identify challenges restricting wide-spread adoption. Currently the most acknowledged challenges include:

- **Significant knowledge gap:** Information availability around quantum computing and its practical application to drive commercialization across most industries is still very low.
- **Inappropriate approach selection:** Getting the technology to work is a specific challenge but understanding how to approach designing what questions to ask and how is also incredibly challenging and specific.
- **Lack of talent:** There is a significant talent gap related to quantum technology making it difficult for firms to build strong talent pool to fast-track its deployment.

2. Shortlist areas ideal for QC application

Post gap identification, firms need to shortlist functional areas where implementation of QC could be the most impactful. Two parameters considered useful in improving accuracy of the target selection process include:

- **Investment required:** Measuring the investment required and potential ROI could help estimate the value opportunity for the enterprise.
- **Ease of implementation:** Studying the complexity of process and number of nodes involved at the target area could help in assessing the effort/ resources require.

3. Assess the level of change readiness

Once the firm picks the pilot area for QC integration, it should evaluate the current capabilities of the firm that will be required for rapid and effective transformation.

For instance,

- **Talent/skill mapping:** Assessing whether the current talent pool is equipped to manage the upgraded QC-powered requirements, equipment, and systems.
  If not, upskill the existing workforce to make them quantum ready and/or hire data scientists and other talent with required QC knowledge.
- **Digital maturity:** Evaluate to what extent is the current internal ecosystem utilizing advanced technologies (such as AI, ML, Blockchain, cloud, AR, VR) and how strongly are the operations digitally networked. If the technology utilization is low, then first improve on that to build a foundation for QC integration.

4. Build a strong partner network

Vendor network around quantum computing is growing steadily across all domains, i.e., research, experimentation, and application. Firms must try to integrate solutions from different providers to establish a cohesive end-to-end deployment model to support QC integration in the existing network.

Having a custom or multi-provider vendor collaboration approach would help maintain the progress momentum and allow firms to integrate QC faster, while ensuring adherence to ever-increasing compliance requirements.

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