Business impacts

Learning objectives

By the end of this module, you should be able to:

- Recognize the benefits of exploring quantum computing now.
- Identify the industries and applications where quantum computing shows promise.

Potential quantum industry applications

Classical supercomputers struggle to solve problems with many variables interacting in complicated ways, like modeling molecular behavior. These classical limitations pose barriers to progress for a wide range of industries, and impede important research in physics, chemistry, materials science, and more.

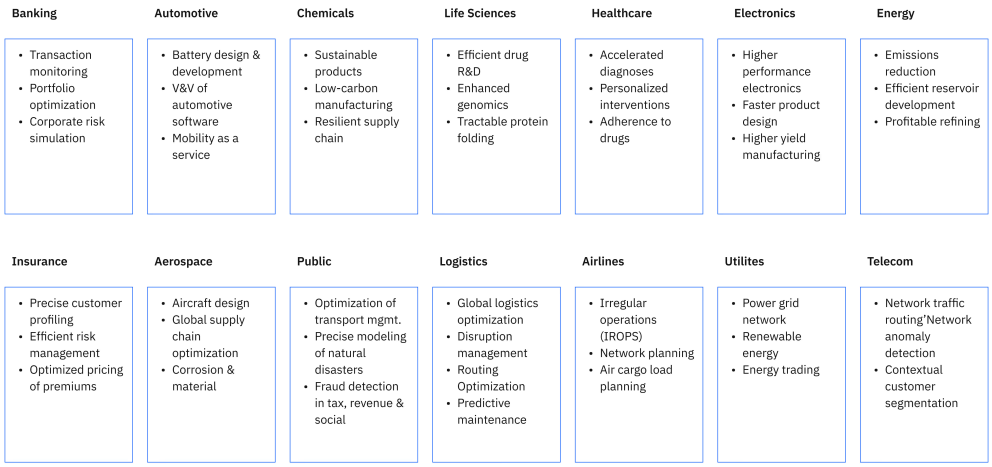
To understand how a molecule will behave, scientists often have to synthesize it and experiment with it in the real world. To see how a slight tweak would impact its behavior, they usually need to synthesize the new version and run their experiment all over again. This is an expensive and time-consuming process. It hampers the development of stronger, lighter materials for aerospace engineering, constrains the evolution of semiconductors, and hinders advancements in medical science. Quantum could help us push past barriers of complexity.

We expect quantum to have the biggest impact in areas like machine learning, the simulation of natural systems, and the creation of useful new materials.

IBM is exploring industries where quantum computing is expected to show opportunity. The image below lists several use cases for a variety of

industries, and the following sections of this lesson describe how some of our partners are exploring some of these use cases.

Quantum use cases by industry



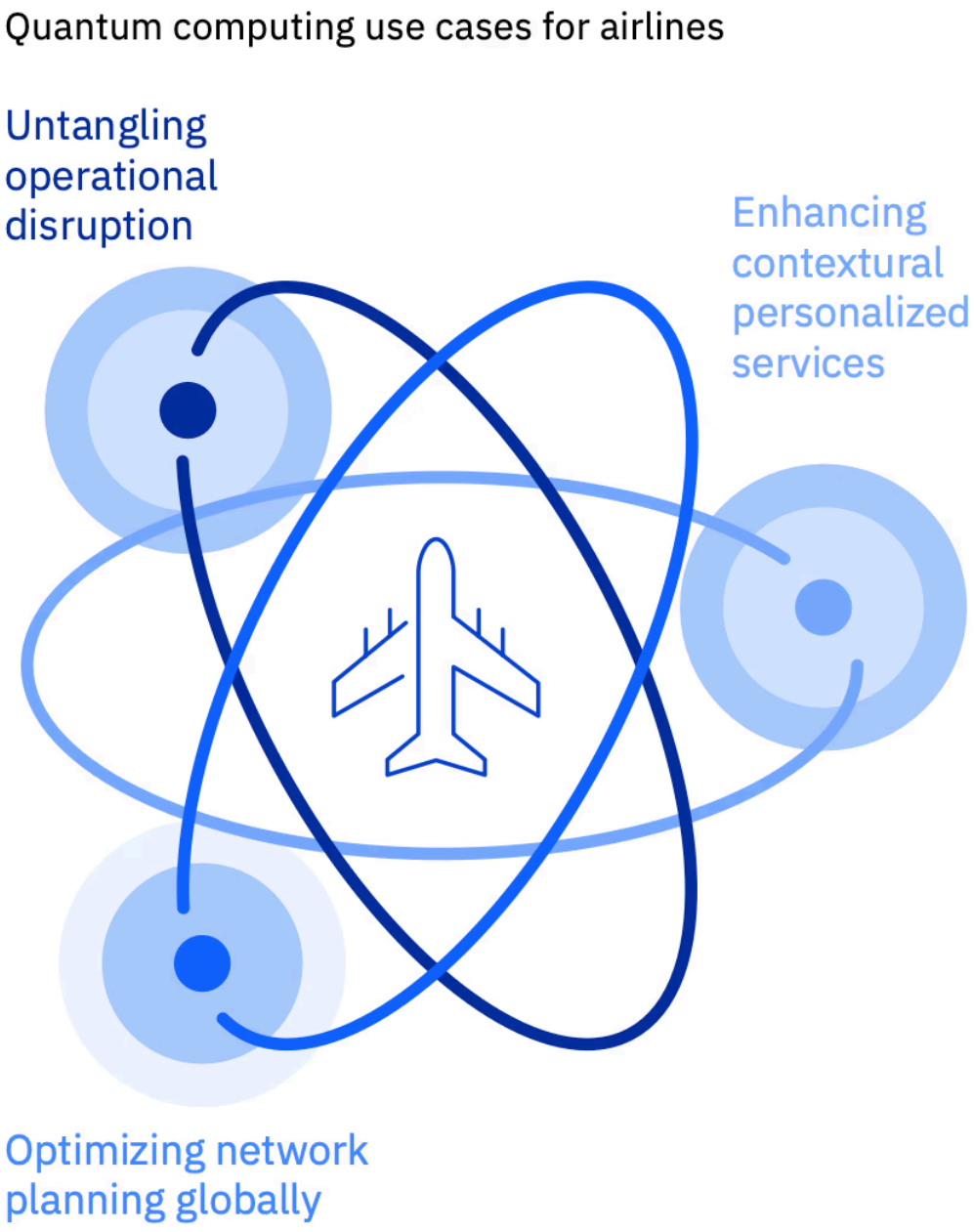
Distribution & logistics

When you think of supercomputers, you might think of national labs. But did you know that one of the biggest supercomputers is operated by Walmart? As an article by McKinsey points out, travel, transport, and logistics show promise for quantum computing.

Many of the largest computing systems are dedicated to solving optimization and AI problems in the airline, logistics, retail and consumer products industries. Large and complex optimization and scenario simulation problems arise in network planning, routing, scheduling, pricing, cargo loading, and disruption management. Providing memorable customer experiences by serving individualized content and making timely and relevant recommendations is powered by evolving AI models. However, the problem of complexity usually scales exponentially with the problem size.

NC State, in collaboration with Delta Air Lines, investigated the application of quantum technology to airline gate-scheduling optimization
. Potential use cases for airlines include more efficient disruption

management simulation, airline network planning, and optimization of air cargo loads.



For the logistics industry, which is facing significant acceleration in online commerce, quantum computers may be capable of supporting global routing optimization and frequent re-optimization to create profitable multimodal transportation and last mile delivery services. Quantum computing may help simulate the impacts of logistics disruptions with better accuracy and support sustainable logistics processes, such as container shipping optimization.

Integrated classical–quantum solutions may improve customer profiling and relevant next best action recommendations for retail and consumer products industries. Continuous new product innovation is a key factor

for these industries, and quantum computing could play a critical role in the development and testing of new products. Streamlining the supply chain through optimization may better support companies' efforts to navigate complexity and manage a balance between inventory shortage and surplus.

Quantum computers provide a tool to look at these problems in a different way. Scientists continue to experiment with better algorithms to apply to these problems. In anticipation of commercial quantum computing, leading companies are identifying and testing use cases that generate in-house quantum capabilities. The more effectively designed a use case is, the more likely it will be to deliver business value. Take, for example, the use case of untangling operational disruption in airline schedules and staffing. This use case shows promise because it has the potential to offer a disruptive solution for a core business problem in the future; there is an existing, though sub-optimal, classical alternative; and quantum algorithms have already been shown to be effective in choosing the best scenarios in Monte Carlo simulations used in banking and finance. Strategic use cases such as this one attend to near-term technical feasibility; consider the potential for quantum computing technology to outperform classical alternatives; and assess the projected business impact, as determined by market outcomes, competitive consequences, and financial impact. For some key business problems, even a slight advantage can have significant impact.

Check this out

Review these resources to learn more quantum computing use cases in retail & consumer products, as well as travel & transportation industries.

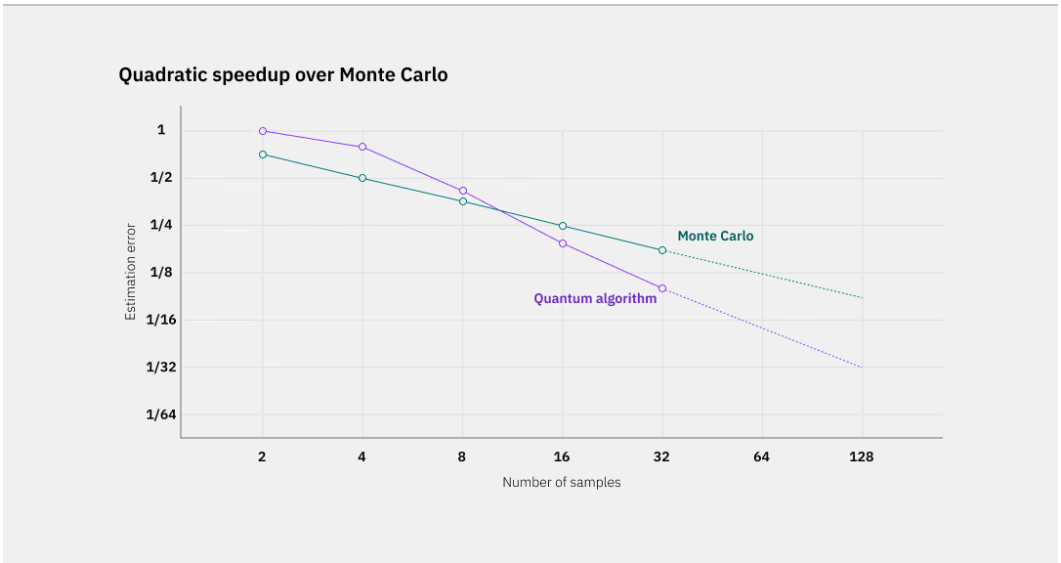
- Read the IBM report on exploring quantum use cases for airlines: "Exploring Quantum Computing Use Cases for Airlines."
- Read the IBM Institute for Business Value report on quantum logistics: "Exploring Quantum Computing Use Cases for Logistics."

Financial services

Banking, financial markets, and insurance firms are about managing risk. Wall Street behemoths such as JPMorgan Chase and Goldman Sachs hope quantum computing can give them an edge in the odds, allowing them to better manage threats and opportunities related to their portfolios. Quantum computers could also help financial pros improve on

their Monte Carlo simulations, mathematical models that predict possible outcomes of complicated decision trees to maximize profit. Other areas of quantum experimentation include fraud detection, anti-money laundering, credit scoring, precise customer profiling, more efficient risk management, and optimization of pricing models.

IBM researchers developed a quantum algorithm that outperforms the traditional approach of Monte Carlo sampling. In a Monte Carlo simulation, the computer takes many random samples from a given probability distribution to see which outcome is most likely. Reducing the error on the predicted outcome of the Monte Carlo simulation by a factor of $1/X$ requires X^2 more traditional samples, but only X more quantum samples. You can view the impact of this statement in two ways: (1) you can get to a fixed confidence level faster with a quantum computer, or (2) for fixed time, a quantum computer can give you more confidence in your answer than a classical Monte Carlo solution would.



According to the
"Getting Your Financial Institution Ready for the Quantum Computing Revolution"
report by the IBM Institute for Business Value, financial institutions explore quantum computing to dramatically speed up immensely complicated calculations and improve accuracy. To this end, IBM researchers have created a quantum finance simulator for option pricing. Using software tools and quantum algorithms developed by IBM to price options that scale better than traditional methods, members of the IBM Quantum Network experiment with finance and quantum computing.

JPMorgan Chase partnered IBM Quantum to
predict the price of financial options and to improve fraud detection and

creditworthiness determination.

PayPal partnered with IBM to figure out how to use quantum computing for fraud detection, credit-risk operations, and overall security posture.

HSBC is working with IBM to accelerate quantum computing readiness. HSBC is planning to explore the use of quantum computing for pricing and portfolio optimization, to advance its net zero goals, and to mitigate risks and fraudulent activities. To learn more, check out this article: "HSBC Working with IBM to Accelerate Quantum Computing Readiness."

Check this out

- Explore quantum computing use cases for financial services by reading this report from the IBM Institute for Business Value: "Exploring Quantum Computing Use Cases for Financial Services."
- For an overview of the technical methods of quantum computing applicable to finance, please see this paper by the IBM Quantum team published in *IEEE Transactions of Quantum Engineering*: "Quantum Computing for Finance: State-of-the-Art and Future Prospects."

Healthcare and life sciences

There are a variety of computationally intensive problems in this sector, fueled by an explosion of real-world and genomic data that conventional computing cannot adequately address.

In healthcare, quantum computing may help address complex challenges in diagnostics, personalized medicine, and insurance pricing.

In life sciences, quantum computing may advance the discovery of new drugs and protein structures.

The central role of the three-dimensional (3D) protein structure in drug discovery has been studied for many years. The prediction of the 3D structure from a primary sequence of amino acids is known as the protein folding problem. IBM researchers demonstrated how quantum computing can be used to tackle this problem.

Cleveland Clinic is partnering with IBM with the mission of fundamentally advancing the pace of discovery in healthcare and life sciences through the use of high-performance computing on the hybrid cloud, artificial intelligence (AI), and quantum computing technologies. Learn more by

reading
"Cleveland Clinic and IBM Unveil Landmark 10-Year Partnership to Accelerate Discovery in Healthcare and Life Sciences."

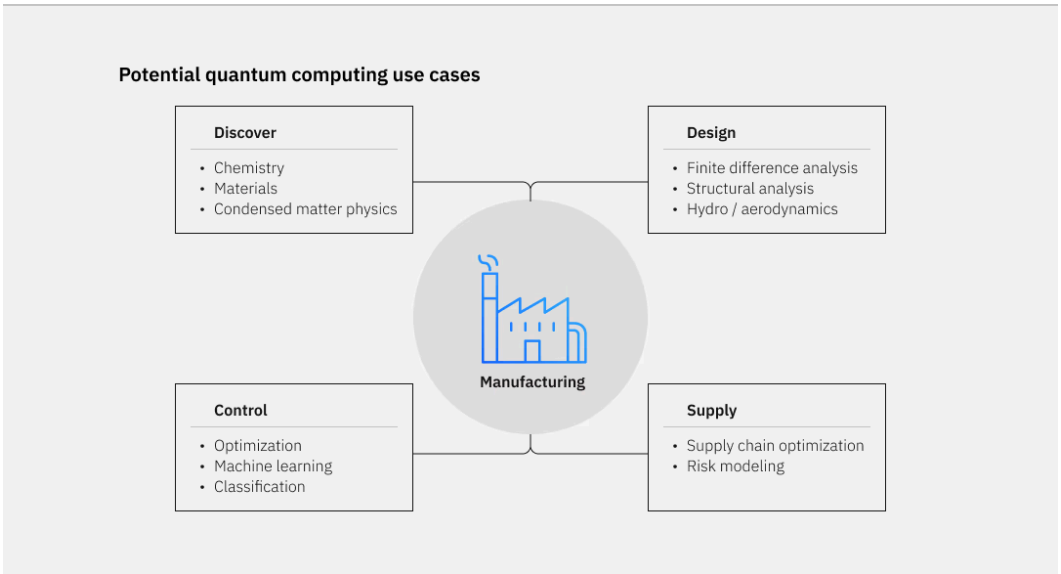
Amgen, in partnership with IBM Quantum, explored quantum machine learning for population health modeling based on electronic health records. Learn more by reading
"Quantum Kernels for Real-World Predictions Based on Electronic Health Records."

Check this out

- Explore quantum computing use cases for healthcare in this report from the IBM Institute for Business Value:
  "Exploring Quantum Computing Use Cases for Healthcare.".
- Explore quantum computing use cases for life sciences by reading the insights from the IBM Institute for Business Value:
  "Exploring Quantum Computing Use Cases for Life Sciences."

Industrial discrete manufacturing

Manufacturing may become an early beneficiary of quantum computing. Use cases in chemistry and materials as well as optimization applications in production planning, fabrication, logistics and supply chain, as well as machine learning for quality control, for example, are all potential areas where quantum computing may have an impact. This graphic depicts the categorization of potential quantum computing use cases in manufacturing.



Many companies are exploring potential quantum computing applications in aerospace, automotive, and electronics manufacturing.

Quantum applications in aerospace and defense include flight route optimization, computational fluid dynamics, and material development.

The automotive industry could potentially benefit from quantum computing in a variety of areas such as new battery design and development, software verification and validation, factory automation, quality control, and advanced driver assistance. Daimler Mercedes-Benz, used quantum computing for optimizing transportation logistics and chemistry of vehicle batteries. Ben Boeser, innovation director for the company's North American R&D unit, says that developing and perfecting more energy-dense battery technologies could "unlock a billion-dollar opportunity." Simulating all the various molecular properties and behaviors is beyond the current computing power of even today's supercomputers. Quantum computing offers a potential way to speed up the simulation process. Boeser notes that "the multiyear process of testing and validating new battery technology could translate into missed opportunities in the market if this work is delayed," which is why Daimler Mercedez-Benz worked with IBM Quantum to harness the power of quantum for battery research as the technology advances.

In electronics, quantum computing could improve manufacturing throughput with complex, dynamic fab scheduling; optimize product performance, such as chip performance, power, and area; and even accelerate the commercialization of advanced materials with larger, more accurate molecular simulations. JSR is partnering with IBM Quantum to explore how quantum computing can advance semiconductor chip

research, namely in the development and manufacture of photoresists. Learn more about this partnership and the opportunities for potential quantum applications in chemicals and materials simulations in this video.

Check this out

- Read the IBM Institute for Business Value report on how quantum computing may help the electronics industry in materials development, product design, and smarter manufacturing: "Exploring Quantum Computing Use Cases for Electronics."
- Daimler-Benz is exploring how quantum computing can advance the development of new materials for batteries, improve automotive manufacturing techniques, and enhance product experience.

Industrial process manufacturing

"We know in our bones that there are huge global challenges that we will tackle in the foreseeable future. When quantum computing scales to become utterly disruptive, we'll be ready," says Dr. Vijay Swarup, Vice President of Research and Development at ExxonMobil. Working

together, ExxonMobil and IBM recently demonstrated advancements in using quantum computers to accurately calculate thermodynamic observables, demonstrating how quantum can be the next-generation tool for chemists and chemical engineers developing advanced energy solutions. The use cases for ExxonMobil don't stop there, as they strive to solve complex energy challenges. See how ExxonMobil uses quantum computers to ship cleaner fuels.

IBM is working with Mitsubishi Chemical, an IBM Quantum Network Partner through the IBM Quantum Keio Hub, on a variety of potential quantum applications. Their 2019 publication, "Computational Investigations of the Lithium Superoxide Dimer Rearrangement on Noisy Quantum Devices," could be fundamental for future battery development. An *EE Times* article, "Battery Research Advances Quantum Computing Capabilities," provides more information on this research, which was quickly followed by two other research papers — one on "Applications of Quantum Computing for Investigations of Electronic Transitions in Phenylsulfonyl-Carbazole TADF Emitters" and one on "Quantum-Classical Computational Molecular Design of Deuterated High-Efficiency OLED Emitters."

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Check this out

Review the resources listed here to learn more about how IBM Quantum computers are impacting these industries.

- Read the IBM report on "Exploring Quantum Use Cases for Chemicals and Petroleum."
- See client case study: ExxonMobil is harnessing quantum computing to develop more accurate chemistry simulation techniques in energy technologies and solutions.
- Read this McKinsey report on the potential they see in the chemicals and petroleum sector: "The Next Big Thing? Quantum Computing's Potential Impact on Chemicals."
- Read how IBM and partners are accelerating the discovery of new ways to mitigate climate change.

Utilities

"Utilities play a critical role in helping industries, companies, and consumers achieve net-zero targets," says Gregor Pillen, General Manager IBM DACH. "However, realizing that requires sophisticated technologies to help utilities better predict and optimize the grid to meet demand, as well as increase the use of clean, renewable energy. Quantum computing offers the computing capabilities to help utilities navigate this new, more sustainable future."

As part of its decarbonization efforts, E.ON has partnered with IBM to explore the potential of quantum computing to optimize the world's increasingly decentralized energy infrastructure. "You plug in your electric car to charge the battery, and you might have a solar panel that powers your house and car. But can you sell that excess energy to your neighbors down the road? Why do you have to get energy from thousands of kilometers away that was made in the power plant burning gas?" asks Corey O'Meara, E.ON digital technology quantum computing lead (see "IBM Panel Highlights Quantum Role in Sustainability"). Quantum computing algorithms could hold the key to managing the complexity that results when additional assets are plugged into the grid.

The potential for quantum computing to aid in the discovery of new materials designed to improve the generation, transfer, and storage of energy is one reason why bp is allying with IBM Quantum to achieve its net-zero goals.

Woodside Energy, an IBM partner, is experimenting with new algorithms to reduce the overhead of data transfers between classical and quantum systems, making it possible to apply quantum kernels to streaming data.

In the telecommunications industry, quantum computing shows potential to deliver solutions for network traffic routing and workload balancing, GHG/energy consumption, and contextual customer segmentation. Vodafone is partnering with IBM Quantum to help validate and progress potential quantum use cases in telecommunications

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Check this out

– Read this McKinsey report on how quantum computing could accelerate the development of climate technologies to transform the fight against climate change: "Quantum Computing Might Just Save the Planet."

Key takeaways

Quantum computing is expected to have a strong impact in the Chemicals & Petroleum, Distribution & Logistics, Financial Services, Healthcare & Life Sciences, and Manufacturing sectors.

Example applications for quantum computing include:

– Simulating quantum dynamics to advance materials discovery

– Managing risks and opportunities related to financial portfolios

– Discovering new drugs and protein structures

– Optimizing decentralized energy systems

Quantum computing can help to solve applications which involve

– Simulating nature

– Artificial intelligence

– Optimization

Business leaders should prepare for this new technology by evaluating readiness now. This can be done by identifying a quantum computing champion, evaluating which areas of their business might be impacted by quantum computing, developing the right skill sets, and experimenting