Seizing the commercial value of *quantum technology*

Capgemini

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A watershed moment for quantum technology

Quantum technology is rapidly approaching an inflection point. Consistent roadmaps from IBM provide confidence in frictionless quantum computing within the current decade. At the same time, bold programs from quantum startups like QuERA and Pasqal could accelerate this timeline even further, especially when integrated with new middleware and algorithmic approaches.

While advancements across technology roadmaps are generating tremendous excitement in academic circles, industries are struggling to translate the theoretical promises of quantum computing into practical value. For companies, the challenge lies not just in mastering an extraordinarily complex technology, but also in identifying a way to use its present capabilities to create an advantage that could not otherwise be achieved using classical computers. They must also address practical considerations, including a significant talent shortage, limited budgets and resources, and the inherent challenges of adopting a new way of working.

Amid looming uncertainty and complexity, many enterprises are opting to defer quantum investments until the technology reaches maturity. While this approach may seem prudent, it will ultimately prove unwise, as postponing quantum investments does not expedite the realization of value.

In fact, the opposite is true: Delaying quantum investments today significantly prolongs the company's time-to-value. Quantum is not just software that can simply be implemented and deployed once it is ready—it represents a fundamentally new way of working. One that demands a deep understanding of the technology's capabilities to tackle challenges that companies may not have even conceived of yet, and which cannot be addressed using traditional computing methods.

We could soon see a quantum computer that can be used for commercial applications, particularly in quantum chemistry. But to unlock value, companies need to explore impact end-to-end".

As we stand on the brink of this transformative future, companies must adjust their view of quantum technology, not seeing it as the latest form of digital evolution, but as a true revolution.

PASCAL BRIER

Group Chief Innovation Officer

JULIAN VAN VELZEN

CTIO & Head of Capgemini's Quantum Lab

Last year, IBM demonstrated that quantum systems have reached utility, or the point at which they can run quantum circuits better than classical computers can simulate them. This opens the potential for quantum computers to explore new classes of problems in physics, chemistry, materials, and other fields.

"Now, the next step is to find where these problems show quantum advantage. Advantage will be achieved by industry experts using a strong software platform to map their most challenging use cases to real, advanced quantum hardware. This is exactly what we are working on with our global IBM Quantum Network. We look forward to seeing those breakthroughs soon."

JAY GAMBETTA

IBM Fellow and Vice President, IBM Quantum

Defining quantum computers within the context of the enterprise IT landscape

People often talk about quantum computing in a naïve way—defining it simply (and imprecisely) as "better computing." This leaves some with the impression that quantum computers are essentially the same as classical computers, just faster and more powerful.

But this is not accurate. Quantum computers represent a whole new class of computing power that leverages unique processing methods to operate. Quantum computers have entirely different capabilities and limitations than traditional devices, which means that they should not be thought of or used interchangeably.

For many corporate executives, understanding how quantum technology is different, what it is good at, and where it can be applied within the context of existing systems and processes is a critical first step in drawing commercial value from the technology.

As research teams and tech leaders lobby for investments in this area, they must do so from a point of business value. Increasingly, this means exploring how quantum capabilities can completely redefine workflows, opening remarkable new opportunities that simply aren't available with traditional computers.

In this case, quantum technology itself will trigger the proverbial "quantum leap forward," unlocking a dramatic transformation that will propel industries to surpass previous expectations, overcome existing limitations, and reach new levels of innovation.

> *We take an application approach to quantum. It's not about finding ways to make the technology work for its own sake, but to deliver value to the business, in the form of enhanced innovation, improved speed, and competitive advantage."*
>
> **JULIAN VAN VELZEN**
> Head of Capgemini's Quantum Lab
> *Capgemini*

The quantum tipping point: Chemistry

While quantum computing is poised to revolutionize numerous industries, particular attention is directed towards chemistry. This sector offers a distinct class of problems that are practically insurmountable with conventional hardware but are possible to address using a quantum computer.

For example, areas such as drug discovery, carbon capture, and battery technology can greatly benefit from the exponential speed up of processes enabled by enhanced computational power, as well as quantum's ability to provide explanations for complex phenomena more efficiently or effectively than classical computers.

However, the value realization of quantum computing is not entirely straightforward. Companies must determine whether these problems, albeit solvable, will yield practical value that outpaces the cost of change.

For example, if a chemicals company could find a ground state of an energy a thousand times more accurate in one-tenth of the time via quantum computing, what value does that bring to the business? If a pharmaceutical company develops quantum capabilities that would enable their research team to access entirely new chemistries, would that offer unprecedented levels of improvement compared to existing calculation pipelines?

Whether a company is applying quantum in an existing workflow or using it as a foundational element of an entirely new working model, companies need to consider if doing so would provide the organization with a small improvement or a major advantage—and the value of that advantage compared to the delivery cost. It's important to keep in mind that calculating the cost of quantum includes obvious investments in technology, as well as secondary costs related to reskilling the workforce, redefining processes, and adapting the tech stack.

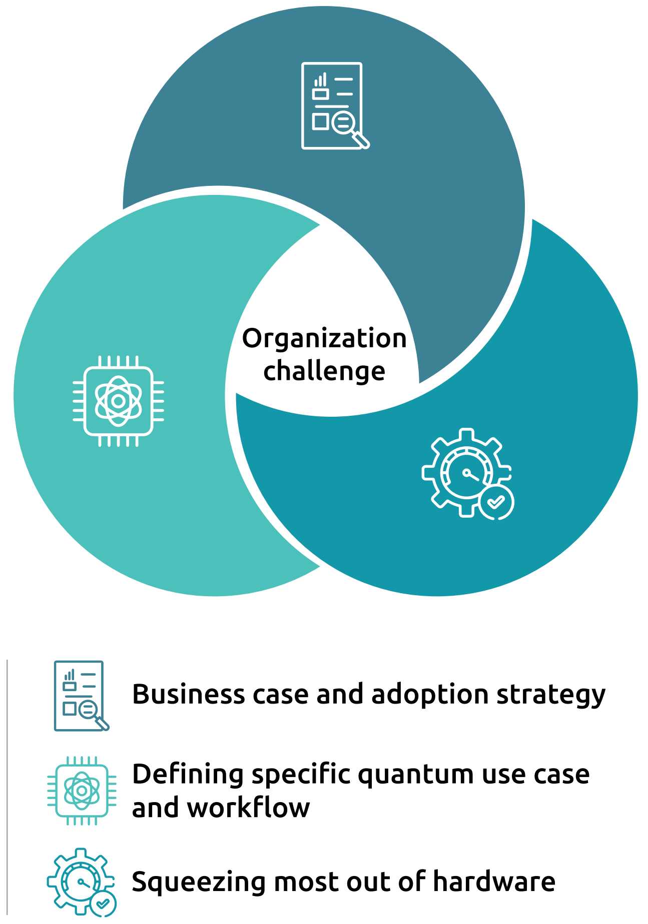
Identifying the ideal quantum use case involves more than merely applying the technology as one might with software. Rather it entails identifying a precise computational challenge within a new or existing workflow that is uniquely solvable using that technology and, in a manner, where the derived value surpasses the associated costs.

Three dimensions for achieving the quantum value

In quantum, as with any emergent technology, investment requires something of a leap of faith—not in terms of what the technology can do and the impact it will have, but in terms of when the company will begin to see a return on their investment.

A company's ability to derive commercial value from quantum—and the timeframe associated—will depend not only on the rate of technological advancements but also on the company's strategic approach, their readiness for change, and how well they utilize current capabilities to reinvent existing workflows or create new ones.

In this section we outline three distinct, but interdependent, elements that companies must embrace to harness the power of quantum technology and derive commercial value: 1. Business case development and adoption strategy; 2. Use case identification; and 3. Technology investments.



1. Establishing the quantum business case and adoption strategy

The transformative nature of quantum computing makes this technology incredibly exciting to organizations. However, it also poses a considerable challenge in formulating a business case and adoption strategy. After all, if the company doesn't yet know what avenues the technology can open, how can it evaluate the return on their investment or develop an adoption strategy and timeline?

Unlike most technology implementations, the evaluation and development phases of the quantum roadmap are often deeply interwoven. To understand the value of the technology, the company must identify a use case; but to identify a use case, companies must first explore how the technology can be used. This requires a deep understanding of the business, its challenges, and its goals, as well as a firm grasp of how the technology works and where it excels.

When it comes to quantum, R&D leaders are essentially asking the company to invest without knowing the specifics of the return. That is, on its face, a high-risk request, though perhaps not as risky as delaying investments or outright ignoring the opportunity.

Rather than denying the investment, companies should find ways to reduce the risk of a quantum investment. In the most practical terms, this means identifying a quantum partner that will focus on developing an approach and deploying the technology in a way that will deliver commercial value to the business over time, as opposed to simply exploring what the technology can do.

> *Quantum is not a plug-and-play technology. Companies need to develop their capabilities to use the technology—and they need to start now if they want to make market-disrupting moves and create an advantage.*

IFTIKHAR AHMED
Capgemini's Quantum Lab | Quantum Advisory
Capgemini Invent

Exploring the real cost of quantum

Establishing the business case for quantum tends to be less straightforward than most typical technology investments. This is because of both the so-called long-tail costs that accompany the initial hardware expenditures and the delayed return on those investments due to the nature of the technology.

For example, companies will need to move away from traditional, on-premise computing models and transition to the cloud to support quantum computing operations. They will also need to invest in specialized equipment and integrate infrastructure components to maintain the stability of quantum computers. These supplemental technology and infrastructure expenses come in addition to the multi-million-dollar hardware purchase price.

Another important consideration within the business case and adoption strategy is the human element. The demand for quantum talent at the PhD level far outpaces supply, making it extremely difficult for even the most renowned brands to recruit and retain talent. While it is possible to reskill existing R&D team members with relevant backgrounds and experience, doing so will also require an investment in time and resources from the business.

When adopting this technology, organizations must also be prepared for the very real possibility that implementing quantum computing could negatively impact productivity initially given the complexity of the technology and its impact on existing processes and workflows.

On the other side of the value equation, calculating the return on quantum investments tends to deviate from that of most other IT expenditures. This is because the computational advantages of quantum only become significant for problems that are fundamentally difficult to solve using classical hardware. This is a process that can take years to complete and, thus, years to draw value.

While this may appear daunting, we must consider that the cost and complexity of quantum computing very closely resemble some of the earliest challenges of classical computers. These devices were also prohibitively expensive, created intense disruption to existing systems and processes, and required a massive shift in skills among people. Over time, the benefits have clearly outweighed the cost—and one could argue that only those companies that have changed in tandem with technology have withstood the test of time.

When it comes to quantum computing, one potential solution to mitigate costs is leveraging cloud computing infrastructure. This approach mirrors the centralized computing model used in the 1940s mainframe era. By hosting quantum computers in data farms and offering access through cloud services, the costs can be distributed among multiple users, making quantum computing more financially feasible and accessible.

> *For many companies, it's not immediately obvious that there is a tradeoff between the cost and value of quantum. We bring together that commercial understanding of the business and the technical expertise to help companies calculate the benefit of the extra compute in real terms."*

JAMES CRUISE
Capgemini's Quantum Lab | Application Aware Algorithms
Cambridge Consultants, part of Capgemini Invent

2. Defining a specific quantum use case and workflow

The application of quantum technology in an enterprise setting is often both narrow and specific. As such, the successful execution of a use case by one company represents the art of the possible but does not necessarily offer a roadmap for other organizations, even in the same industry.

With this in mind, companies must accept that quantum use cases will only be discovered by informed exploration, usually with the help and guidance of a qualified partner. Further, the key to drawing commercial value from that use case lies in identifying clear and specific areas where quantum algorithms can outperform classical approaches or enable activities that would be otherwise impossible via traditional processes.

By way of example, here we explore three chemistry-based use cases where quantum technology shows great promise for delivering practical value.

> *With quantum computing, the question is: What can we build today that will help us create value in only a few years' time, while progressively improve the return in the following years?"*
>
> **SAM GENWAY**
> Capgemini's Quantum Lab | Quantum-centric data-driven R&D
> *Capgemini Engineering*

> *At Airbus, we are actively exploring quantum computing applications and see enormous potential that this technology can help us solve some of the most complex aerospace challenges. The range of use cases is broad and includes challenges in chemistry: For example, modelling reactions in fuel cells might accelerate solutions for hydrogen-powered aviation, a key element towards decarbonisation of aviation. But we are still in an early stage, so leveraging its unique properties will require longstanding efforts, encouraging us to draw strong ties and work in close collaboration with the quantum ecosystem."*
>
> **JASPER KRAUSER**
> Central quantum coordinator, Airbus

Use case	Challenges	Quantum capabilities
Drug discovery	Drug development is a long, complex and expensive process, with average timelines lasting more than one decade and budgets exceeding $1 billion.	• Simulate the interactions of potential drug candidates with complex biological targets, enabling companies to explore a potentially broader space of "hard-to-drug" targets. • Facilitate the exploration of chemistries that are difficult to simulate, potentially advancing research and making R&D more routine for new categories of therapeutics.
Carbon capture	For effective carbon capture, the materials used to bind with carbon dioxide molecules must possess features like adequate pore size to allow gas flow and stability and enable selective removal. These materials are extremely complex to model using traditional methods, making progress in this sector difficult and costly.	• Simulate the interaction between carbon dioxide molecules and adsorbent materials to enable the design of novel materials or optimize existing materials for more effective carbon capture.
Battery technology	Existing battery materials undergo degradation processes, leading to the release of transition metals into the electrolyte, where they catalyze unwanted reactions and lower performance. This challenge is particularly pronounced in cathode materials, which often contain heavy metal atoms and are difficult to simulate.	• Support researchers in modeling and simulating degradation processes in detail, enabling them to gain insights into the underlying mechanisms of battery degradation and develop strategies to mitigate them. • Enable more accurate simulations of battery performance, supporting the development of next-generation batteries with enhanced performance, efficiency, sustainability and durability.

It's important to note that quantum computers cannot be used in isolation. Companies must identify crucial elements within their workflows that necessitate the precision or computational power attainable solely through quantum computing, while utilizing classical hardware for other aspects due to current limitations in quantum capabilities. It also means that companies must adapt or build the surrounding tech stack and processes to enable the use case in full and, in turn, reap the benefits of quantum.

> *One of the greatest challenges in drug discovery is to predict with high enough accuracy the binding of a drug molecule to certain proteins in the body responsible for a given disease, but this is fundamental to understanding the functioning of a drug. At Algorithmiq, we have combined within our drug discovery platform, our state-of-the-art classical algorithms with the most powerful proprietary quantum algorithms to solve these complex problems in chemistry. It allows us to explore classes of drugs which are currently inaccessible to classical computation. An example of such use case concerns the optimal engineering of drug-photon interactions where the drug molecule is to be activated solely by external sources of light after being administered to the patient. This requires that both the ground and excited chemistry of the cancer drug be understood which is currently too much of a formidable task to be possible with contemporary classical computational methods."*
>
> SABRINA MANISCALCO
> CEO, Algorithmiq

3. Squeezing the most out of existing quantum hardware

The timeline around quantum maturity remains fluid. That said, most experts agree that quantum applications won't be available "out of the box" for at least the next decade. So if companies want to draw commercial value from the technology within the next three-to-five years, they will need to be creative about how to do so.

In the quantum world, being creative essentially means finding clever ways to overcome the current constraints of technology. Here we explore some of the challenges and limitations associated with quantum computers, their implications for businesses, and the steps companies can take to help mitigate these issues.

Framing problems with respect to quantum

While quantum computing presents a genuine opportunity to achieve what would be impossible on classical hardware today, the limitations of today's quantum computers require companies to prepare problems in a way that they can be processed using current capabilities.

Restructuring problems typically involves techniques such as embedding, or encoding the problem in a format that quantum computers can efficiently process, as well as using supplemental technologies like machine learning, which can help identify patterns or structures in the problem that can be exploited for quantum computation.

The integration of data-driven methodologies also plays a pivotal role in this process. By leveraging data to fill in gaps that traditional simulations cannot address explicitly, it is possible to enhance the problem-solving capabilities of quantum computers.

Error correction and noise

In traditional computing, systems are naturally error-correcting, meaning noise is automatically dealt with. This passive capability ensures the reliable performance of the system without much additional effort.

In quantum computing, however, noise correction is very much an active exercise. Any deviation in the state of a qubit, even at the smallest scale, will extend throughout the computation and must be actively managed from end to end.

To achieve reliable and efficient quantum computations, companies must identify strategies for how to reduce errors to improve the speed and accuracy of algorithms.

Quantum 101: Error suppression, mitigation and correction

Error Suppression:

Techniques directly applied to interactions with quantum hardware to either reduce the number of errors or making errors more manageable. This includes optimization of gate implementations to minimize errors and actively isolating qubits when carrying out measurements.

Error Mitigation:

Techniques implemented on the output of the quantum circuits at the algorithmic level to minimize the effect of errors that occur. Generally involves executing further circuits on the quantum hardware to infer the influence of noise.

Error Correction:

Software based detection and correction of errors during circuit execution by introducing redundancy by encoding a single logical qubit across a large number of physical qubits. Requires on the fly detection of correction to prevent errors propagating through circuit execution.

Performance: Scale, quality, and speed

In computing, we often equate speed with time, measuring how quickly calculations are processed. However, quantum computing introduces a unique challenge in that electrons can flip circuits at lightning speed, but the pace at which we can change the state of atoms lags far behind.

Consequently, quantum computing operates at a clock speed roughly a thousand times slower than that of a GPU. Since quantum chemistry typically requires long calculations, it means that traditional, classical computing tasks performed on a quantum computer will be inherently slow.

To leverage the power of quantum hardware effectively, teams must identify and utilize its strengths, rather than forcing it to mimic classical computing.

That said, even when considering the theoretical advantage of quadratic speedups for tasks where quantum computers excel, companies must recognize that the benefits of doing so may be offset or even negated by slowdowns that result from physical constraints and implementing error correction methods. Such factors may impact quality and scale.

This complex nature of quantum performance underscores the need for companies to approach quantum use cases holistically and conduct a full-scale analysis of the value of the output with respect to the total cost of operation.

Data loading

In addition to speed considerations, loading data into and out of a quantum computer presents significant challenges. Unlike classical computing, where data can be easily cloned and manipulated, it is impossible to copy a quantum state. This means that any manipulation performed on a copied piece of information also affects the original.

As such, traditional concepts like checkpointing, where data is stored for future reference, do not apply in quantum computing. Instead, each time a piece of information is needed, it must be reloaded into the quantum computer, preventing the creation of multiple copies for different computations.

This limitation underscores the importance of a "low data, high compute" approach in quantum computing. With this in mind, organizations should focus on scenarios where small amounts of data can be efficiently processed through multiple computations to achieve meaningful results. This is precisely why chemistry use cases, and materials development in particular, represent a strong quantum opportunity.

While it is critical to overcome the constraints of quantum computing in the present tense, companies must proceed with an eye for the future. This means taking an ecosystem approach so that the organization is aware of what developments are coming and that the work being done today is aligned with those advancements.

Understanding future computing is critical for unlocking the long-term benefits of quantum technology. For example, when it comes to error correction, developing a noise reduction strategy against near term hardware is generally not worth doing. This is more of a long-term capability, that acts as a bridge between the hardware and organizational value.

A partner approach to quantum computing

As an entirely new class of computing, most organizations do not have the internal expertise or capabilities to develop and launch quantum use cases. Now, especially in the early stages, it is important for companies to engage a reputable partner that can help the organization assess the viability of use cases, and define the value of activity relative to the cost and scale efforts over time.

In the near future, we anticipate the emergence of quantum computers suitable for delivering real value to commercial applications. The ecosystem is nascent and fractured, making it difficult for enterprise customers to derive value directly from the machines on offer. Addressing noise, error, and performance is not solely the responsibility of hardware manufactures - it also extends to algorithm design, infrastructure software, and applications. To facilitate the development of high-value applications by quantum researchers, we are dedicated to creating robust and user-friendly noise and error suppression techniques that can dramatically boost hardware performance. Collaborating with Capgemini enables us to deliver these capabilities to enterprise customers effectively."

MICHAEL J. BIERCUK

CEO, Q-CTRL

Drawing commercial value from quantum technology with Capgemini's Quantum Lab

To attain the quantum advantage, companies require a partner that understands the technology and how it can be applied strategically to derive business value.

Capgemini's Quantum Lab is a group of quantum experts with extensive experience across various domains and cutting-edge applied research endeavors. Our team is dually focused on pushing the boundaries of what is possible over time, while also prioritizing value creation from current capabilities.

Our approach hinges on practical utility, helping companies ground heuristic exploration in a more secure foundation and develop use cases with tangible outcomes. We strike a balance between innovation and pragmatism, channeling the potential of quantum technology into real-world applications that will deliver a true competitive advantage.

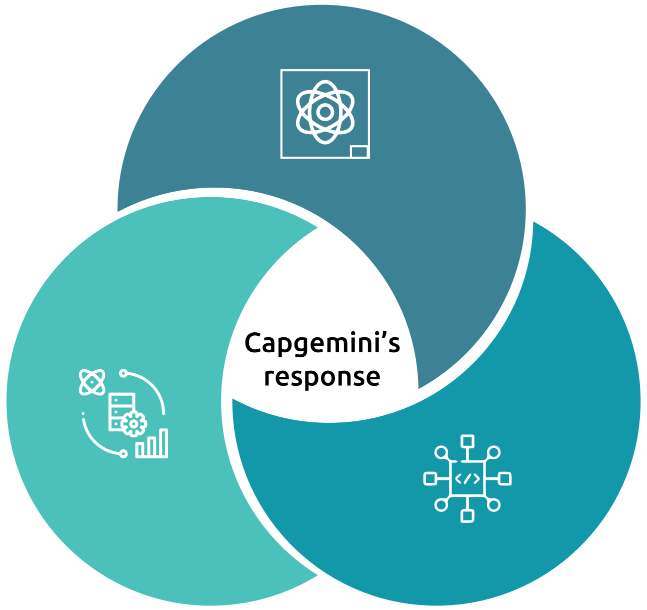
Who we are: The Quantum Lab by Capgemini

- A **holistic quantum partner**, providing true end-to-end support across strategy development, use case identification, workflow integration, iteration and value realization.
- A **robust system integrator** with established partnerships with leading players, like IBM, as well as a diverse range of startups, academics, research organizations, and tech companies, to help clients leverage collective expertise and resources for impactful innovation.
- A **multi-faceted, cross-functional team** that combines deep domain expertise and strong business acumen, ensuring companies approach quantum technology from the perspective of value creation.

A three-dimensional approach to value realization with Capgemini's Quantum Lab

Our Quantum Lab's comprehensive service offering is based on three interconnected capabilities that align with the critical dimensions companies need to harness the power of quantum technology and derive commercial value:

1	**Quantum Advisory:** Defining the business case development and adoption strategy
2	**Quantum-Centric Data-Driven R&D (QDDRD):** Identifying and executing strategic use cases
3	**Application Aware Algorithms (Triple A):** Maximizing quantum hardware investments



- Quantum advisory
- Quantum-centric data-driven R&D
- Application Aware Algorithms

Quantum Advisory: Defining the business case development and adoption strategy

Deriving a commercial value from quantum computers rests not just on technical capabilities, but an effective strategy and approach.

Our global team of quantum physicists and specialists, business strategists, industry analysts, machine learning experts, engineers and biologists integrates seamlessly within the client organization, helping companies reimagine their business in the quantum era and pinpoint the challenges only this technology can solve.

We assist companies at every stage of the journey, from defining the business case and establishing an initial use case to developing a targeted strategy to help the organization overcome specific quantum challenges and constraints. Our team of experts operate across partners and platforms, enabling companies to identify the optimal course forward and develop a longer-term strategy that aligns with an advancing landscape.

Our advisory team, in conjunction with our Quantum-Centric Data-Driven R&D solution and Application Aware Algorithms (Triple A), helps organizations bridge the gaps between an organizational problem, a quantum solution and commercial value.

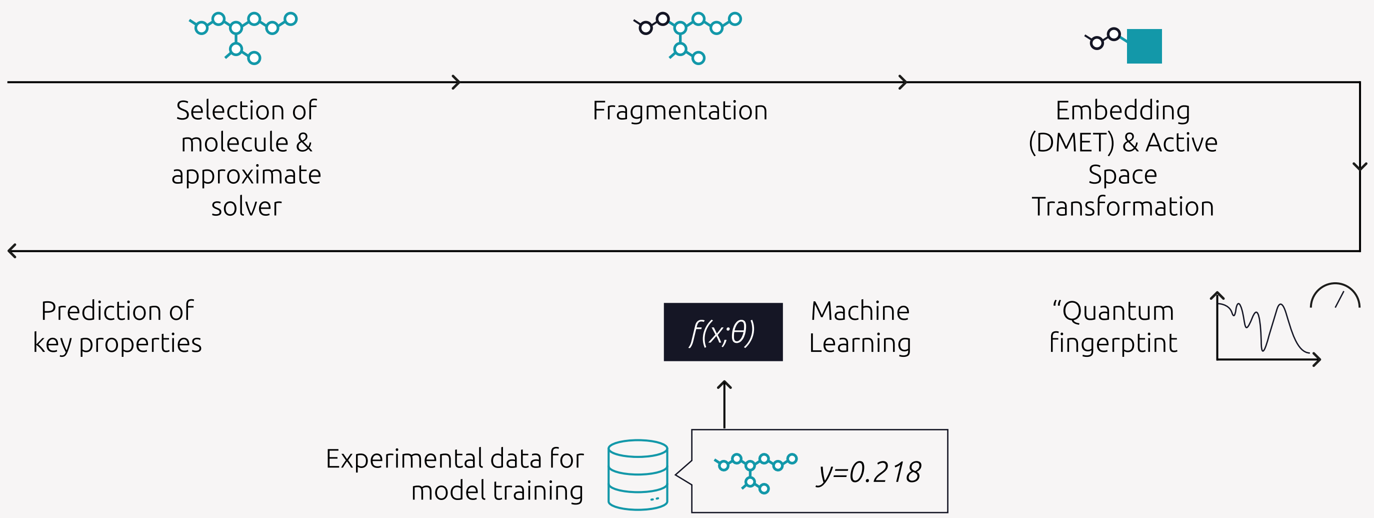
Capgemini offers the following end-to-end capabilities:

Domain knowledge insights	Deep quantum expertise	Flexibility to deliver
Broad modeling experience	Ability to scale	Broad partner ecosystem

Quantum-Centric Data-Driven R&D: Identifying and executing strategic use cases

Quantum-Centric Data-Driven R&D (#QDDRD) is an approach developed by The Capgemini Quantum Lab that is offered in conjunction with our advisory services to address the challenges associated with implementing and scaling the use of quantum technology in an industrial setting.

The QDDRD framework focuses on redesigning the research pipeline to place quantum at its core. We work with clients to develop an end-to-end computational workflow drawing on a combination of quantum technology, classical processing, and lab and simulated data to produce research results.



Our approach envisions an end-to-end workflow where quantum computing is used to probe properties and interactions within a wider machine learning pipeline which draws on all available data to make industry-relevant predictions.

Working with our advisory team, we help clients leverage the capabilities of QDDRD to tackle small problem sizes today while also preparing for future scaling of quantum hardware.

Application Aware Algorithms (Triple A): Maximizing quantum hardware investments

The perfect hardware does not yet exist—and, given that the timeline to achieve full fault tolerance is estimated at a decade or more, it is unlikely to become available soon. Rather than waiting idly, developers can mitigate this issue by rethinking algorithm design and embracing two fundamental principles:

1	Algorithms should share responsibility for error correction with hardware. This will help optimize them against hardware characteristics.
2	Algorithms should incorporate application-specific information. This will make them more robust to errors and maximize hardware performance.

By embracing these two concepts, it is possible to mitigate some of the shortcomings of existing hardware. It will also help position early adopters to draw value from quantum investments as the technology matures and realize the full commercial potential over time.

Our Application Aware Algorithms (Triple A) are designed with these principles in mind. Purpose-built for value creation, our solution helps companies develop and fine-tune algorithms and optimize limited quantum resources to enable them to unlock value sooner. Our comprehensive understanding of the entire stack, from applications to error-correcting codes, allows us to take a comprehensive approach to algorithm development, bringing the applied quantum advantage closer.

Application Aware Error Mitigation (AAEM): Error mitigation based on trained noise models

Since quantum computers require huge overhead to reduce noise, correction mechanisms need to be used in conjunction with other methods. Most often this is done by intentionally increasing noise, monitoring the results, and then extrapolating back to lower levels.

Application aware error mitigation (AAEM) is a powerful error mitigation technique that focuses on improving measurement estimations within a quantum circuit using application-specific information. By incorporating insights from the structure of the specific problem and then intentionally increasing noise, companies can accelerate problem-solving capabilities, potentially bringing the quantum advantage years closer.

AAEM, when executed in conjunction with our advisory services, also enables organizations to apply what are typically isolated estimations to a broader workflow perspective. Instead of conducting resource-intensive and time-consuming individual estimations, this tool uses the interconnectedness of the estimations both through the common application and the use of the same quantum computer to reduce the estimation overhead. By consolidating information and considering the consistent noise characteristics of the machine, companies can create a unified model of noise to enhance accuracy across multiple calculations.

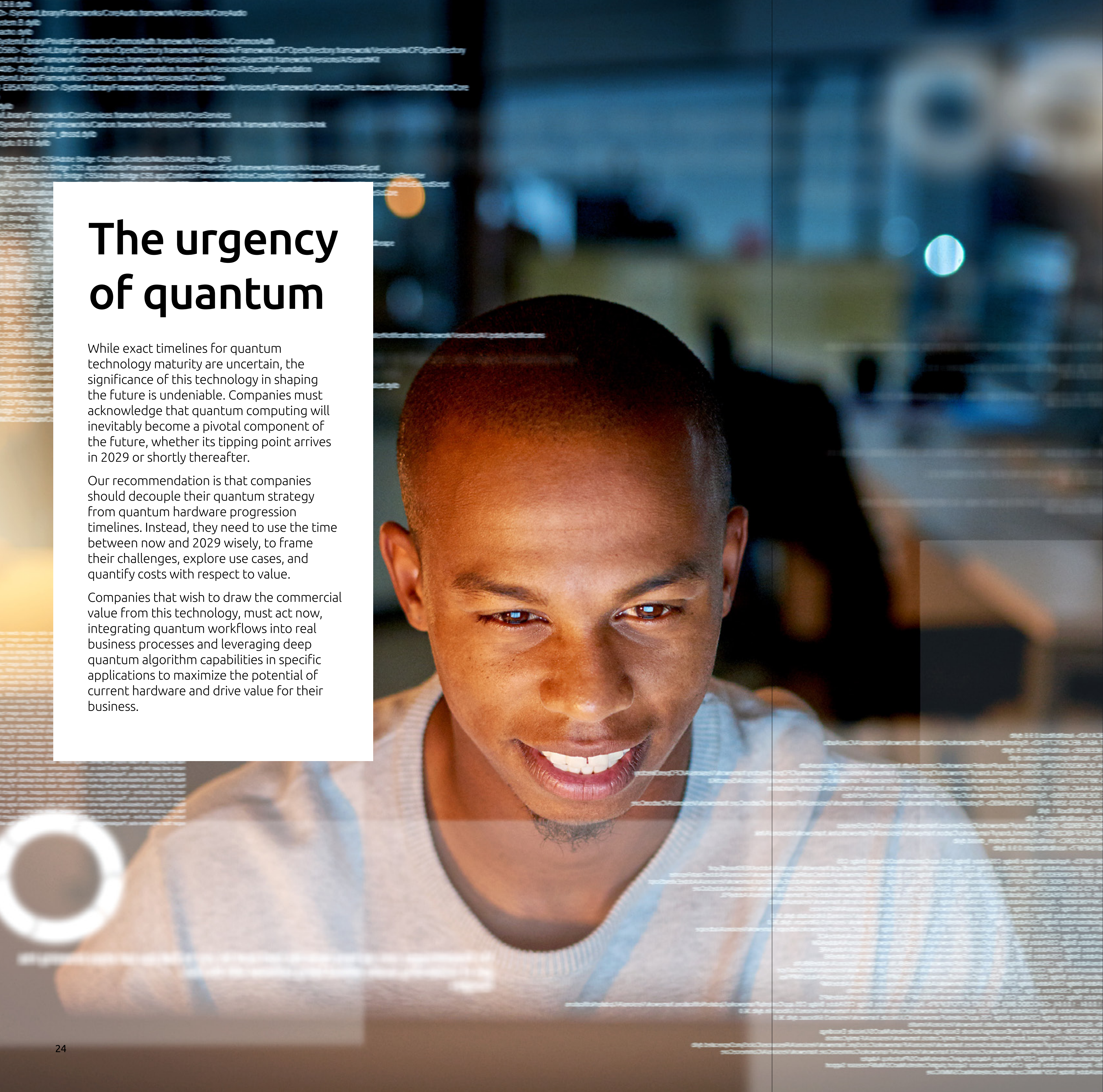
AAEM is also closely intertwined with QDDRD, helping organizations apply the newly created unified noise reduction model across relevant R&D processes, thus helping to simultaneously optimize limited quantum resources, improve the accuracy of calculations and reduce the time it takes to complete those calculations.

Recursive Amplitude Estimation (RAE): Efficient sampling for amplitude estimation

Recursive Amplitude Estimation (RAE) is a quantum computing tool that enables organizations to maximize information extraction and achieve optimal speedups from a quantum computer for problems of amplitude estimation or eigenvalue estimation through Bayesian methods.

In simpler terms, RAE identifies the point at which the level of noise outweighs the information gain from increasing the circuit depth. This strategy effectively maximizes the quantum computer's utility, essentially pushing the algorithm to its limits to reach maximum performance, while being aware of the limitations due to noise. This approach offers a nuanced balance between no speedup and theoretical maximum speedup on a perfect device, with the degree of improvement governed by the noise level of the system.

This innovative technique, in conjunction with AAEM's error mitigation capabilities, improves the efficiency of the estimation process and achieves speedups comparable to ideal quantum algorithms.



The urgency of quantum

While exact timelines for quantum technology maturity are uncertain, the significance of this technology in shaping the future is undeniable. Companies must acknowledge that quantum computing will inevitably become a pivotal component of the future, whether its tipping point arrives in 2029 or shortly thereafter.

Our recommendation is that companies should decouple their quantum strategy from quantum hardware progression timelines. Instead, they need to use the time between now and 2029 wisely, to frame their challenges, explore use cases, and quantify costs with respect to value.

Companies that wish to draw the commercial value from this technology, must act now, integrating quantum workflows into real business processes and leveraging deep quantum algorithm capabilities in specific applications to maximize the potential of current hardware and drive value for their business.

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About Capgemini

Capgemini is a global business and technology transformation partner, helping organizations to accelerate their dual transition to a digital and sustainable world, while creating tangible impact for enterprises and society. It is a responsible and diverse group of 340,000 team members in more than 50 countries. With its strong over 55-year heritage, Capgemini is trusted by its clients to unlock the value of technology to address the entire breadth of their business needs. It delivers end-to-end services and solutions leveraging strengths from strategy and design to engineering, all fueled by its market leading capabilities in AI, cloud and data, combined with its deep industry expertise and partner ecosystem. The Group reported 2023 global revenues of €22.5 billion.

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