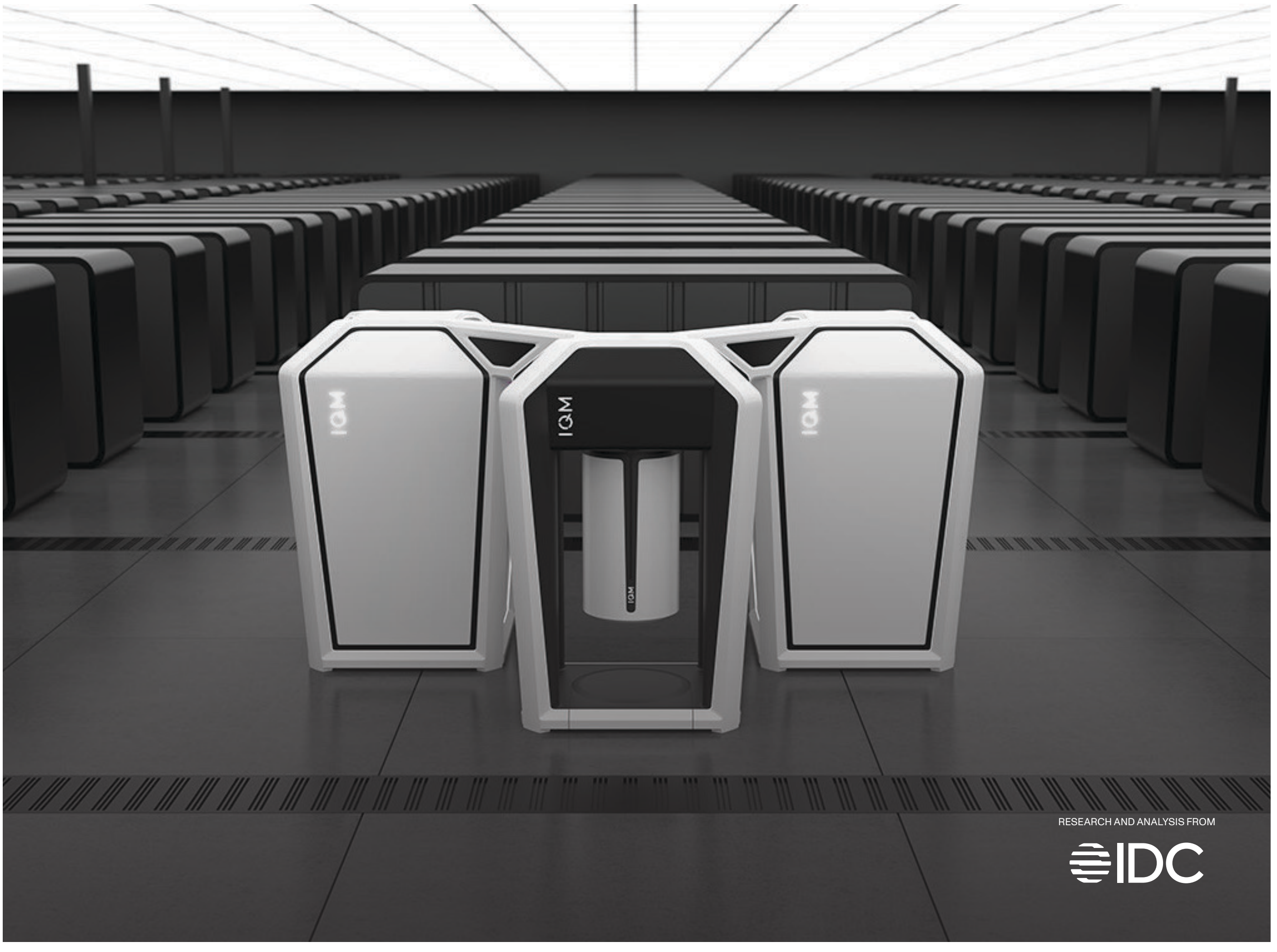
NOVEMBER 2021

Untangling the HPC Innovation Dilemma Through Quantum Computing



Executive Summary

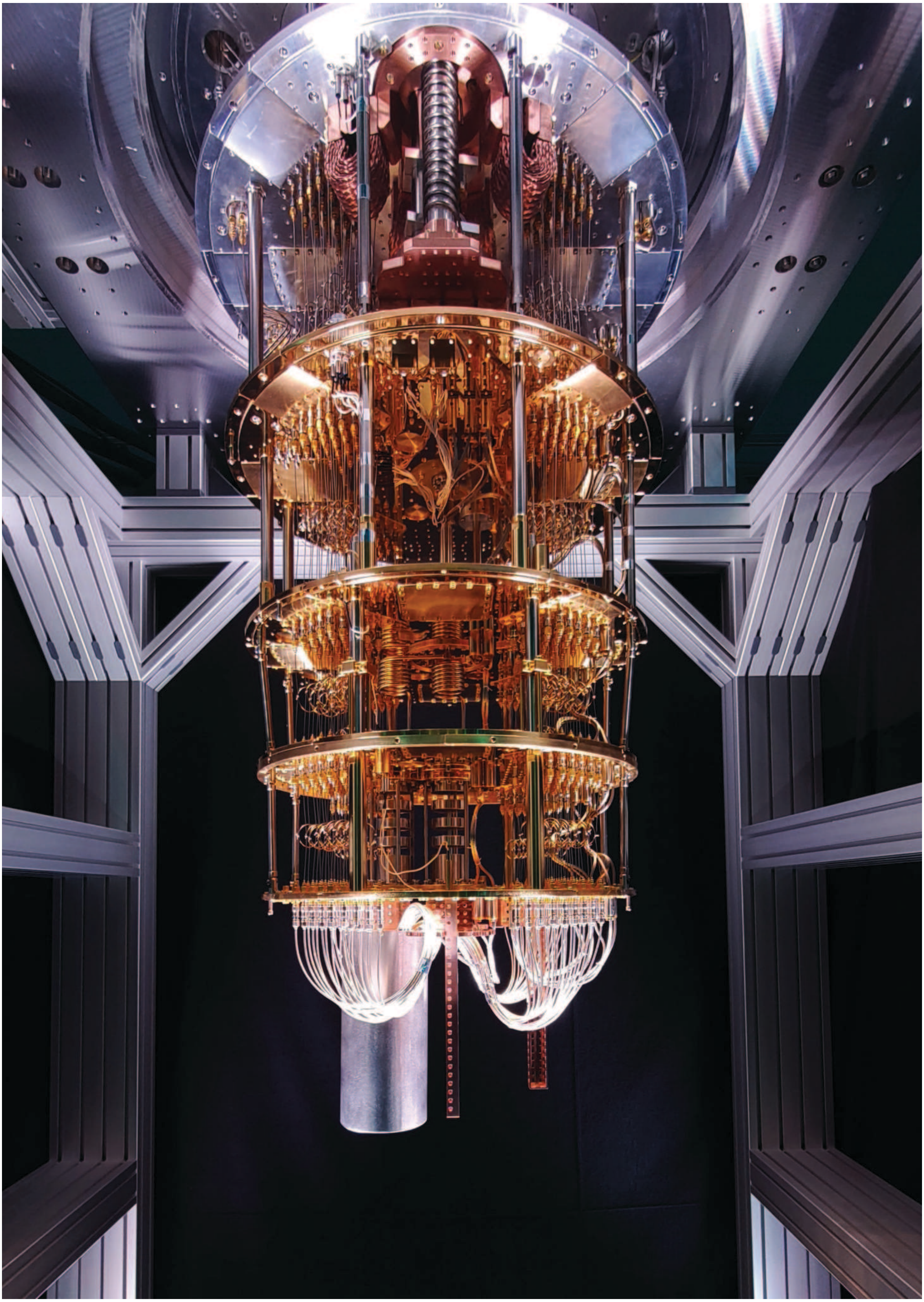
This IDC White Paper, sponsored by IQM, is one of the first studies conducted with high-performance computing (HPC) centres to understand their challenges and readiness for quantum computing. Quantum computing is one of the most promising solutions to address the "innovation dilemma" that HPC centres are facing.

The paper also provides an overview of the journey that HPC centres must embark on to successfully adopt quantum computing. The paper is broadly based on data from the IQM and Atos — State of Quantum Computing in HPC Research Survey conducted by IDC Europe in August 2021 (see the "Methodology" section at the end of the paper for further details).

AT A GLANCE

KEY STATS

- Staying ahead of the competition is a top priority for **52%** of HPC centres worldwide.
- **27%** of HPC global centres are already experimenting with quantum computing.
- **49%** of HPC centres plan to adopt quantum computing technologies for the first time by 2023.



Key Takeaways

- **HPC centres** play a pivotal role in addressing our most challenging problems, but they are now in an **"innovation dilemma"** — facing increasing pressure to radically innovate their infrastructure but without a new paradigm to take them to the next level.

- **Quantum computing** could be the answer to this innovation dilemma. Even though quantum computing is still far from being commercially mature, quantum computing providers are on the right trajectory to build quantum computers that can overtake classical high-performance computers in performing certain tasks (**"quantum advantage"**).

- While only 27% of HPC centres worldwide are already experimenting with quantum computing, adoption of the technology will dramatically accelerate **in the next two years**. By 2023, **76%** of HPC centres worldwide will be using the technology — the majority with an **on-premises infrastructure**.

- Quantum computing is not a short-term bet but a **long-term strategic move** requiring HPC centres to make a full **cultural transformation**. IDC suggests that HPC centres put in place a **three-step road map** for successful quantum computing adoption, including:

  1. *Gap analysis and quantum solution identification (immediate)*
  2. *Quantum solution design and integration (midterm)*
  3. *Quantum computing use case development and implementation (long term)*

ILLUSTRATION OF IQM QUANTUM COMPUTERS IN A SUPERCOMPUTING FACILITY

HPC Centres: Innovation Strategies at a Crossroads

HPC centres help science and business leaders to tackle our toughest problems. These range from weather forecasting to drug discovery, molecular dynamics, physical simulations, natural disasters and artificial intelligence.

For example, the Oak Ridge National Laboratory Summit is used to enable new material discoveries, for nuclear burning simulations of the stars or for deep learning in cancer research . Forschungszentrum Juelich's JUWELS supercomputer is used to study how the human brain's 100 billion neurons exchange information by creating virtual maps and performing simulations[1]. In 2020, the use of high-performance computers in genome decoding of SARS-CoV-2 and protein analysis laid the foundations for COVID-19 vaccine development. The upcoming high-performance computer Leonardo, to be housed in Bologna, Italy, will be instrumental in the continued fight against COVID-19[2].

Because of the economic impact across almost every industry, the benefits for society are enormous. In healthcare, for example, the image analysis of tissues to identify anomalous features can result in better patient diagnosis and treatment success rates, and an overall reduction in the cost of healthcare for governments. By unlocking more detailed weather forecasts, meteorologists can more accurately predict natural disasters. It is estimated that by the end of its six-year lifespan, the Cray XC40 installed at the UK Met Office back in 2016 will have returned £2 billion in socioeconomic benefits[3].

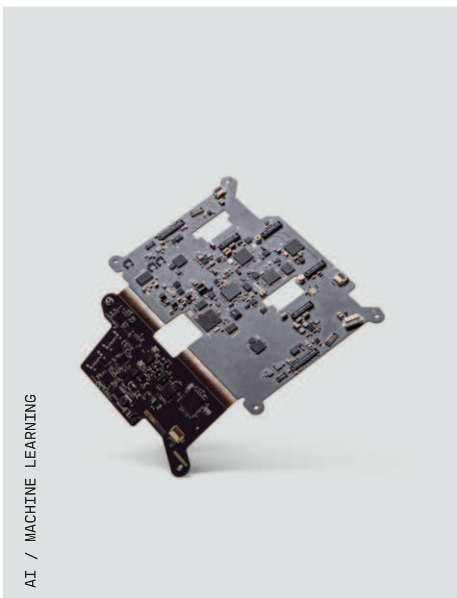
High-performance computers have a critical role in the defence and security of governments around the world, and due to the ripple effects on the economy and society they are an indispensable element of national competitiveness.

[1] https://www.fz-juelich.de/portal/EN/Press/_webstories/juwels/artikel.html?nn=2297240
[2] https://www.cineca.it/en/hot-topics/Leonardo-announce
[3] https://www.metoffice.gov.uk/about-us/what/technology/supercomputer


ENERGY / SUSTAINABILITY


500 ml
Ringer-acetat
Fresenius Kabi
MEDICAL INDUSTRY


CONSTRUCTION


AI / MACHINE LEARNING


FINANCE

HPC CENTRES' INNOVATION ACCELERATION OVER TIME: INCREASING INFRASTRUCTURE COMPLEXITY

Today's modern HPC systems are the result of a long history of technology innovation. While the first large-scale computer was built out of military necessity during World War II, it was only in 1964 that the term high-performance computer started to appear with the Control Data Corporation (CDC) 6600 system. With performance of up to 3 megaflops, it was able to model global circulation to advance atmospheric science.

Remarkable progress in process and memory was made in the 1970s. Cray-1 was one of the first high-performance computers to use vector processing at a chip level as well as transistor memory. Fast-forward to 1982 and the Cray X-MP pioneered the use of multiprocessing.

Technology advances continued with the Connection Machine CM-1. This was the first parallel high-performance computer designed for artificial intelligence (AI) problems and pattern recognition, capable of 59 gigaflops at peak performance. The machine paved the way for novel multiprocessor architectures as well as the use of commodity processors in HPC.

Today's high-performance computers consist of a multitude of nodes and interconnects linked together through a high-speed network. The exponential growth of Big Data through the extended use of AI and machine learning (ML) is driving architectural diversification. Combining CPUs with GPUs and application-specific accelerators is a common practice. Meanwhile, cloud computing has been added to the mix. IDC data shows that the growing compute for public cloud IaaS market globally reached $3.7 billion in 2020 and is expected to increase 33% over a five-year period to reach $15.7 billion.

While on-premises HPC will remain the de facto architectural type, many HPC centres appreciate the advantages offered by HPC as a service. One of the benefits of the cloud is that it provides access to on-demand HPC resources to a wider scientific community that can run HPC experiments flexibly at a relatively accessible cost. Cloud also enables researchers to test early scientific theories or experiments relatively quickly at a lower financial risk, avoiding committing large resources to unviable new research streams.

HPC centres understand that cloud is an element of an HPC architecture that meshes off the shelf elements with custom-built infrastructure components. The result is an increasingly complex HPC system infrastructure.

NEED TO ENSURE COMPETITIVENESS AND INCREASE PERFORMANCE IS DRIVING HPC CENTRES' PRIORITIES

The pursuit of scientific research breakthroughs to yield economic or societal benefits underscores the essential role of an HPC centre in supporting competitiveness. This will not change in the short term. Figure 1 shows that by 2023, over half of HPC centres around the world will seek to gain competitive advantage over their peers and boost research efforts through international collaboration. A third will strategically look to accelerate R&D cycles.

For 63.3% of EMEA-based HPC centres, expanding international collaboration is the main priority (above the global average). Conversely, in Asia/Pacific (57.7%) and North America (54.2%), staying ahead of the competition is the number 1 priority. When looking at the results by type of respondent, which include the top 500 HPC centres as well as HPC centres housed in academic and research institutions, 58% of the top 500 HPC centres globally highlighted the need to remain ahead of their peers.

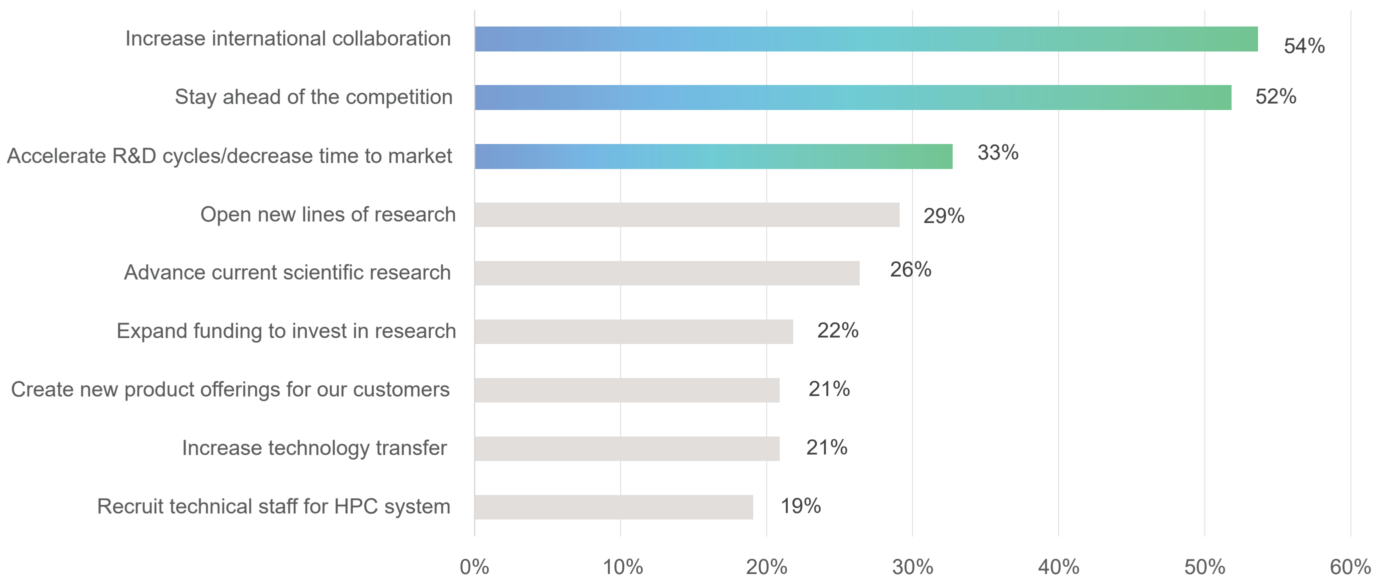


FIGURE 1. HPC CENTRES' STRATEGIC PRIORITIES

Survey question: What are your organisation's strategic priorities over the next two years?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

Technology is a tool to deliver on HPC centres' business priorities. HPC systems' purchasing decisions are made primarily in the boardroom (see Figure 2), followed by the IT department, in alignment with HPC centres' strategic objectives. Purchasing decisions are also multifaceted.

When selecting an HPC solution, HPC centres look beyond the HPC systems' specifications, such as hardware performance, to include the assessment of their own IT skills as well as the flexibility of the contract terms (see Figure 2).

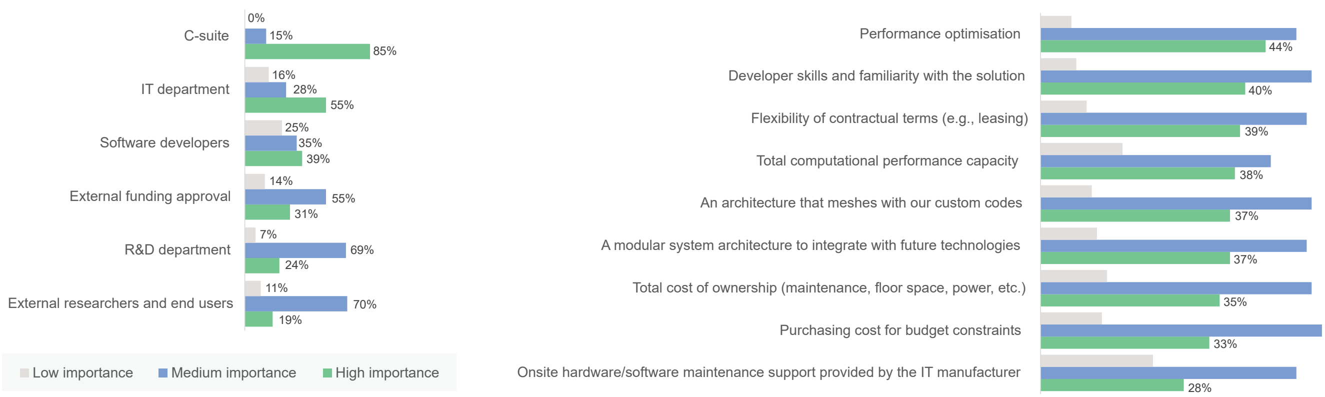


FIGURE 2. TOP INFLUENCERS IN HPC PURCHASING DECISIONS, TOP FACTORS INFLUENCING HPC PURCHASE

Survey question: Who influences the purchasing decisions for HPC hardware? How important are the following factors to your organisation when purchasing an HPC infrastructure solution?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

COMPUTATIONAL SPEED, SUSTAINABILITY, AND CAPEX ARE HPC CENTRES' MAIN CHALLENGES

To sustain competitiveness, HPC centres need to enhance their innovation capabilities to improve computing power. But innovation does not come without challenges. HPC centres must pursue computational prowess while addressing the increasing amount of energy those systems require to run as well as the significant financial investments to purchase and maintain such a complex infrastructure. Figure 3 shows that the main challenges faced by HPC centres revolve around long time to output, sustainability and energy efficiency, and high capex required.

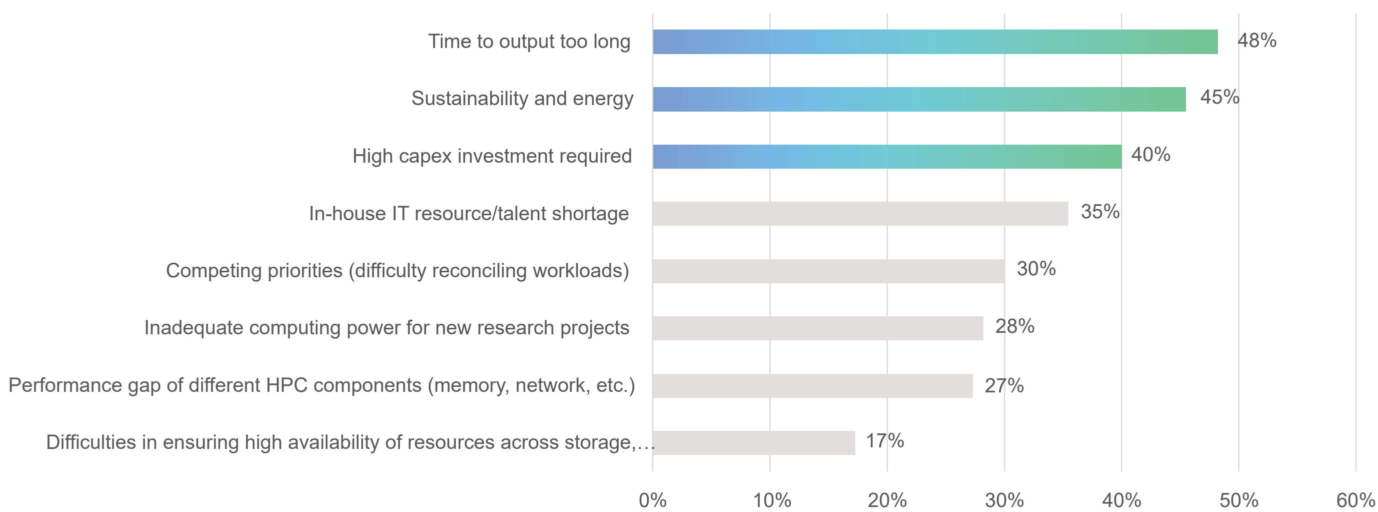


FIGURE 3. HPC CENTRES' TECHNOLOGY CHALLENGES

Survey question: What are your organisation's top HPC-related technology challenges?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

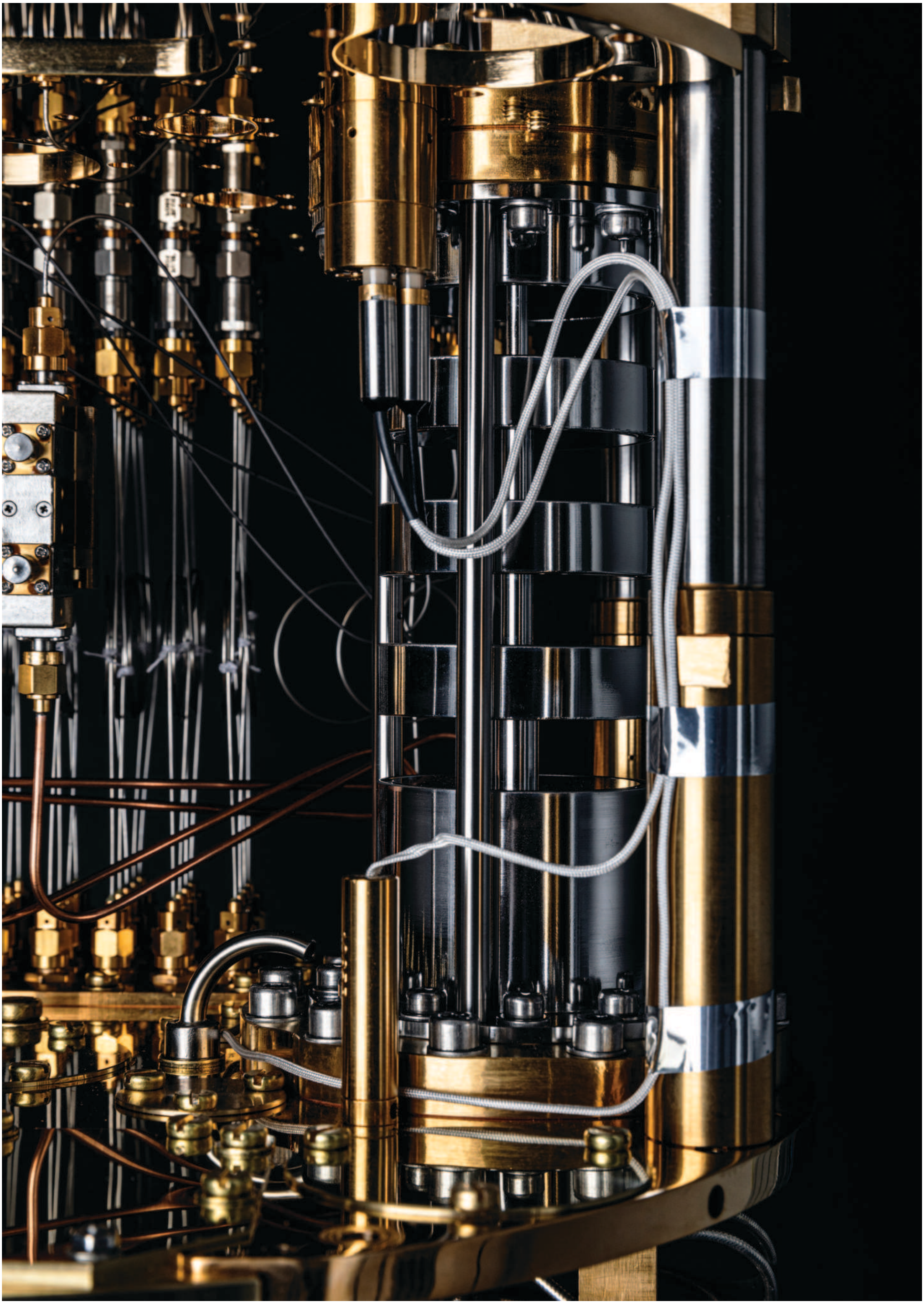
- **Time to output.** The exponential rise of Big Data has brought new processing challenges for memory systems, bandwidth and latency. The emergence of more powerful systems with heterogeneous computing such as GPU, ASIC and field programmable gate array (FPGA) acceleration is pushing the limits of what is technologically possible. For many HPC centres, however, processing speed is still insufficient to meet their research needs and tackle their business challenges.

- **Sustainability and energy.** HPC infrastructures require an enormous amount of energy to process the data. Fugaku, today's most powerful high-performance computer (at the Riken Centre for computational science in Japan) has a peak performance of 537 petaflops and consumes nearly 30 megawatts of power — the equivalent of a small town[4]. The level of energy consumed by a system impacts the total cost of ownership (TCO). IDC research shows that digital leaders with advanced views on sustainability and energy efficiency tend to go through faster hardware renewal cycles and therefore deploy younger infrastructure to advance their sustainability goals.

- **Capital investment.** The cost of purchasing and installing hardware is very high for HPC centres. Besides the computing infrastructure, they also need to invest in the software and the facility that houses the HPC. Also, HPC systems now have a shorter lifetime before becoming obsolete. The rapid advances in HPC technology across the supply chain translate into a three-year period of usability for most. Once the performance and capabilities of the hardware no longer serve the research and business objectives, the HPC centre will need to secure and inject more capital to meet its strategic objectives. IDC has seen a rise in flexible payment options, such as leasing and consumption models. The most digitally advanced organisations take full advantage of these elastic financial options to access the latest hardware options without impacting their cash flow.

These highlighted trends illustrate how HPC centres need to constantly perform a balancing act between achieving their strategic goals while minimising technological, sustainability and economic shortcomings.

[4] https://www.top500.org/lists/top500/2021/06/highs/



Quantum Computing: The Way Forward to Empowered HPC Capabilities

SOLUTIONS TO OVERCOME HPC CENTRES' CHALLENGES

HPC centres find themselves facing an "innovation dilemma" — greater pressure to radically innovate their infrastructure but without a new paradigm to take them to the next level.

Meanwhile, without setting any limits on what is possible, HPC hardware researchers are investigating alternative ways to increase processing power to make high-performance computers work with sufficient energy at a not too prohibitive cost. Figure 4 shows that memory-driven computing, FPGAs, chiplet-based computing and quantum computing are among the most important emerging technologies over the next five years for HPC centres globally.

Memory-driven computing, cited by 21.8% of HPC centres around the world as the number 1 emerging technology, is a novel approach to HPC classical architectures. Unlike conventional computers, which move the data ingested to the processors, memory-driven computing gives all processors access to a single shared pool of memory. The data is transmitted through photons. As memory-driven computing is specifically designed for the big data era, it could reduce the time needed to process massive data sets, making it possible to scale data processing in many fields such as genomics and medical imaging that have big data requirements. In addition, by allocating the right processor to individual tasks, it could bring performance and efficiency enhancements.

FPGAs were cited by 17.2% of HPC centres as the most important emerging technology. Today's FPGAs are integrated circuits with programmable interconnects. They offer major performance potential and can act as HPC hardware accelerators to boost computing power. FPGAs enable organisations to process data in real time and are well suited for deep learning applications that require low latency.

Another emerging architectural approach is chiplet-based computing, which was cited by 17.2% of HPC centres. Historically the design of CPUs has followed a monolithic approach. A chiplet contains some of the specialised function blocks that are part of the monolithic CPU. Due to the modularity of chiplet design, there are more options to select and combine individual components.

Quantum computing was cited as the number 1 emerging technology by 13.6% of HPC centres worldwide. Despite memory-based, FPGA and chiplet-based technologies promising incremental performance improvements, quantum computing represents a new paradigm that could revolutionise the way computers work and lead to a huge leap forward in processing power.

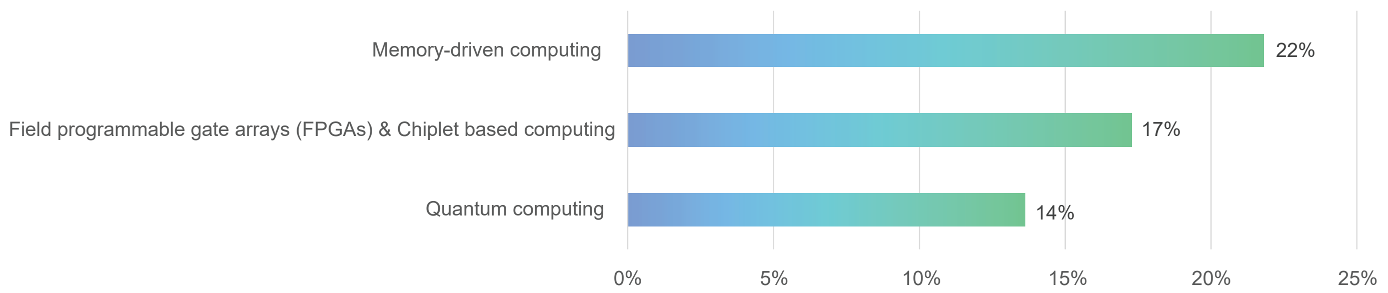


FIGURE 3. THREE MOST IMPORTANT EMERGING HPC TECHNOLOGIES BY 2026

Survey question: What are the most important emerging technologies for HPC centres in the next five years?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

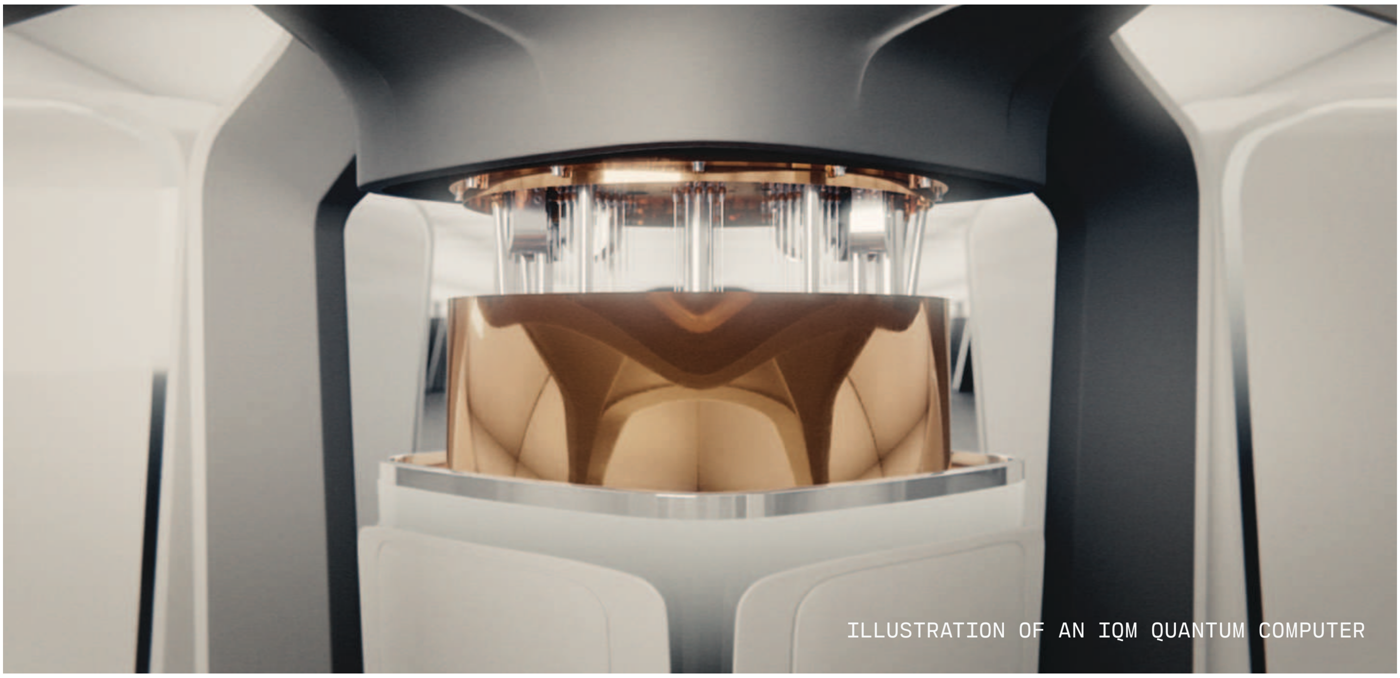


ILLUSTRATION OF AN IQM QUANTUM COMPUTER

QUANTUM: THE NEXT COMPUTING REVOLUTION

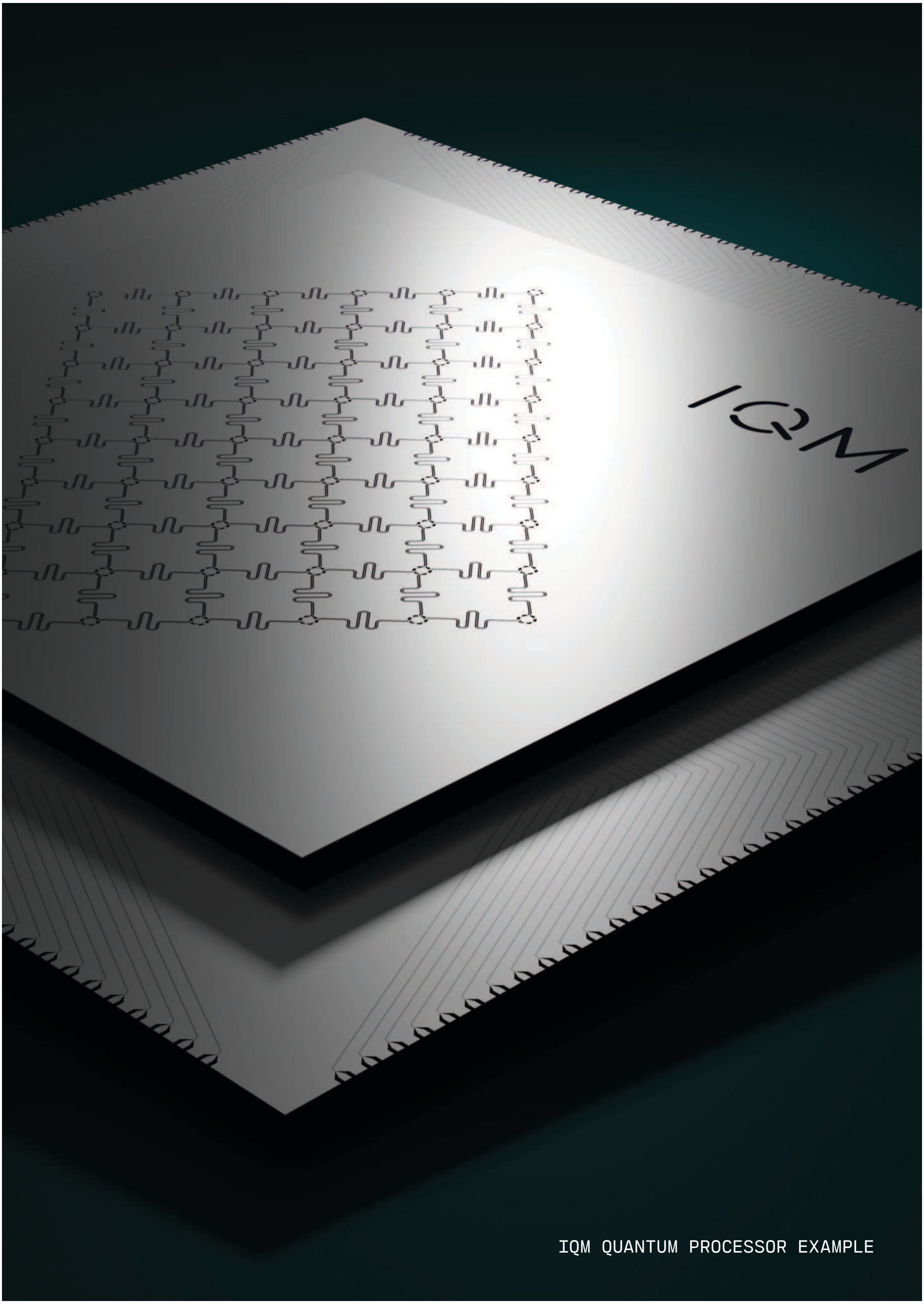
Unlike classical computing, which performs computations in a sequential way, quantum computing exploits quantum mechanics such as superposition and entanglement to manipulate enormous combinations of states at once for computations and to process information on a large scale. Put simply, while classical bits can be just in one state (either 0 or 1) at a time, qubits can represent multiple states (or, better, 0, 1 or a coherent superposition of both) at the same time. While two classical bits can be in only four possible states (00, 01, 10 or 11) at a time, two qubits can represent all of them at the same time. Therefore, by adding qubits to a quantum computing system, its power grows exponentially.

Even though the first quantum computers were accessible to the public in 2019, quantum computing is still a few years from commercial maturity. However, as the stability and quality of qubits continue to advance, quantum computing providers are on the right trajectory to build quantum computers that can overcome classical high-performance computers in performing certain sets of tasks (so-called quantum advantage). Some areas where quantum computers might have an edge over classical HPC systems are simulation of physical systems and optimisation and acceleration of AI and ML workloads.

Quantum computing is expected to tackle more complex computational challenges, achieving time to outputs that are either unobtainable or not obtainable within a reasonable timeframe with the most powerful classical high-performance computers.

From an energy efficiency standpoint, due to the exponential power of qubits, quantum computers potentially require less floor space and less electricity, provided that advancements in the cooling system are also obtained.
From a capital investment perspective, quantum computing can bring a twofold advantage. Firstly, in terms of hardware lifespan. HPC centres still don't have a forward-looking technology that can really disrupt the sector. Quantum computers could solve the innovation pressure resulting from the short lifetime of classical infrastructures and the rapid incremental advances in HPC technology that force HPC centres to frequently renew the infrastructure. Secondly, in terms of return on investment (ROI). The disruptive power of quantum technology to significantly accelerate scientific discoveries and open new research and business landscapes should reach such a magnitude to offset the initial investment.

Therefore, quantum computing is expected to tackle more complex computational challenges, increasing the speed of resolution of some of the hardest computational problems HPC centres face and creating brand new research streams. All this, and probably sustainably too. Quantum computing can therefore not only become one of the next HPC technologies, but also a completely new computational paradigm that resolves HPC centres' innovation dilemma.



IQM QUANTUM PROCESSOR EXAMPLE

HPC Centres and Quantum Computing: How’s the Journey Going?

Quantum computing can boost HPC capabilities and open completely new research scenarios in a wide range of problems that classical computers have been unable to solve. This provides an enormous opportunity for HPC centres, which can leverage the technology to both expand the knowledge of the functioning of quantum processes and address business issues that can revolutionise entire industries, from banking to pharma.

Some HPC centres have already started to embrace the potential power of quantum. The Fraunhofer Institute in Germany, for example, is using 27-qubits quantum hardware for optimisation and machine learning[5]. Others, such as the Italian National Institute of Nuclear Physics, have started exploring how quantum capabilities on the cloud can support scientific innovation in physics[6].

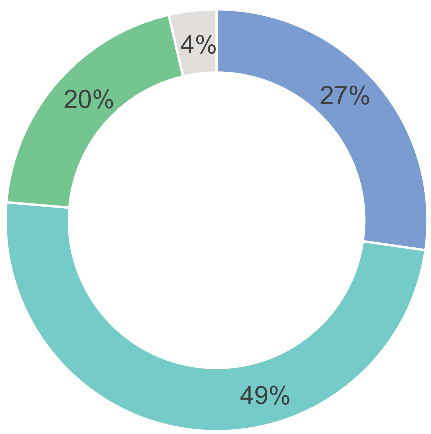
Quantum computing is still years away from its technological maturity and quantum systems will still need to scale to thousands or even millions of qubits to have a significant impact on real-life use cases. However, HPC centres can play a crucial role in those initial development stages and over the next few years can start to experiment with the technology, collaborate with quantum vendors and become proactive players in the big changes taking place.

It’s different this time — quantum computing will not only require a new technology, but a change of paradigm in the way problems are formulated and solved. A forward-looking strategy is needed, and a wait-and-see approach will not pay off.

[5] https://research.ibm.com/blog/fraunhofer-quantum-system-one
[6] https://home.infn.it/en/press-release/press-release-2021/4496-l-istituto-nazionale-di-fisica-nucleare-ed-amazon-web-services-lavorano-insieme-per-accelerare-la-ricerca-nel-quantum-computing-2

HPC CENTRES WILL ACCELERATE QUANTUM COMPUTING ADOPTION OVER THE NEXT TWO YEARS

HPC centres seem to have already understood the huge potential of quantum computing. While only one in four HPC centres worldwide has already officially adopted the technology to conduct internal pilot projects or even to develop business use cases, a high number will start using it over the next couple of years (see Figure 5). At the end of 2023 more than three in four HPC centres worldwide will have already kicked off their quantum computing journey. A fifth of HPC centres will still wait until the next two to five years, while only a minority will not take part in this quantum computing transition.



- Using - we are running internal pilot projects and/or developing business use cases
- Not using but plan to adopt in the next two years
- Not using but plan to adopt in the next two to five years
- Not using and no plans to adopt in the next five years

FIGURE 5. HPC CENTRES' LEVEL OF ADOPTION OF QUANTUM COMPUTING, 2021

Survey question: Which of the following statements best describe your organisation's level of adoption of quantum computing technologies?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

From a deployment perspective, cloud-based approaches to quantum computing are still the preferential route for most HPC centres (70%), whereas on-premises/cloud mixed solutions are adopted by only 23% of HPC centres (see Figure 6). The dominant use of quantum computing as a service clearly reflects the exploratory phase in which some HPC centres are currently involved. However, this trend is set to reverse in five years. By 2026, 76% of HPC centres worldwide will have adopted an on-premises/cloud mixed approach to quantum computing, while only 21% will still rely exclusively on cloud-based solutions.

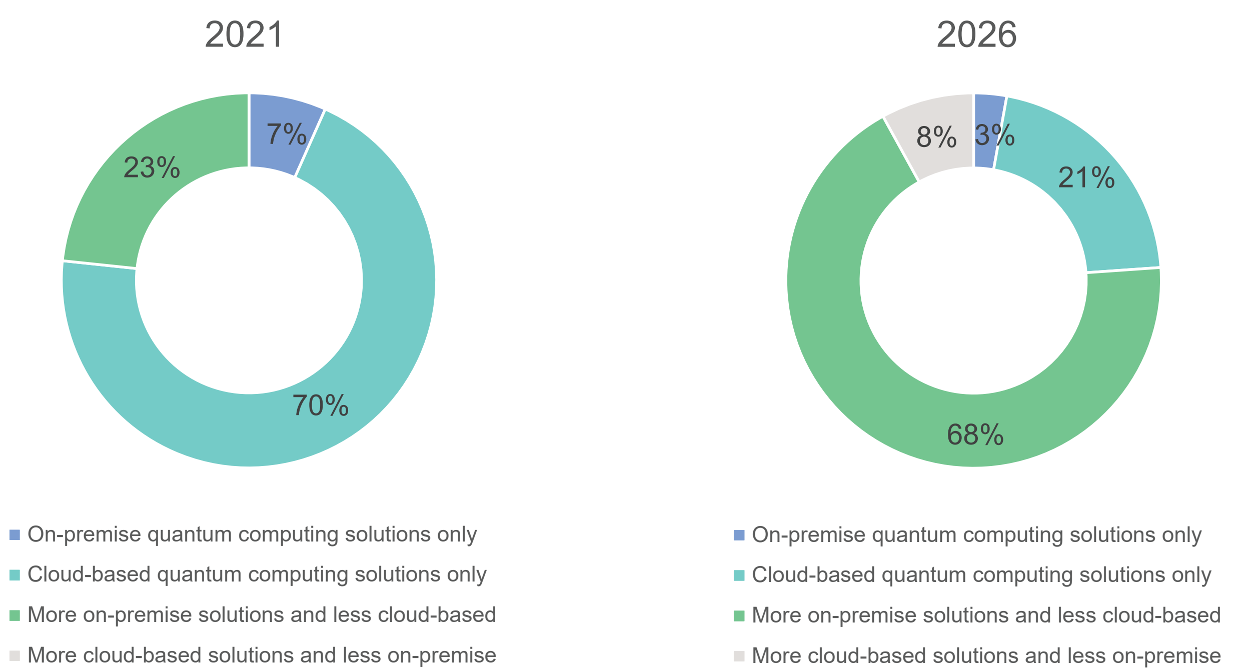


FIGURE 6. HPC CENTRES' CURRENT (2021) AND EXPECTED (2026) QUANTUM COMPUTING DEPLOYMENT MODELS

Survey question: Which of the following deployment models for quantum computing technologies is your organisation currently using and planning to use in five years from now?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 30 — 2021; n = 106 — 2026)

This is testament to HPC centres' role in balancing both external and internal computing resources. HPC centres can now access quantum computing on the cloud, mostly free of charge or with a minimum pay-per-use fee. However, while quantum computing as a service has many advantages, it also comes with some limitations due to the lack of control over the quantum hardware that an onsite installation provides.

Having an on-premises quantum machine has the added benefit for an HPC centre to customise the hardware to meet the requirements of specific problems and use cases, integrate the quantum capabilities into the classical HPC systems in place and access the quantum manufacturer expertise to get accustomed with the evolving technology and collaborate to advance its development.

HPC centres are therefore going to take quantum computing even more seriously. However, quantum computing is not — and will never be — simply a new technological component to be integrated in the existing infrastructure. Quantum computing is not only about the technology, but about the novel resources, approach and mindset to solve new types of problems.

QUANTUM COMPUTING: A LONG-TERM STRATEGIC MOVE REQUIRING CULTURAL TRANSFORMATION

While quantum computing is set to outperform classical computers on a range of problems that are intractable or difficult to solve for them, it will not substitute traditional high-performance computers, which will remain a core component of the HPC infrastructure. It's clear then how quantum computing should be seen not only as a way to improve computing performance but also to open new research scenarios and address business issues that have always plagued organisations around the world.

The huge strategic impact of quantum computing is already recognised by almost half (48%) of HPC centres worldwide that plan to leverage the technology at an early stage to build a sustainable competitive advantage (see Figure 7). The interest in and need to start deploying quantum computing is also confirmed by the increasing demand from both investors and external users. There is no doubt that quantum computing is now at the top of the agenda for HPC centres worldwide to push innovation and address the "innovation dilemma" they have been struggling with for a long time.

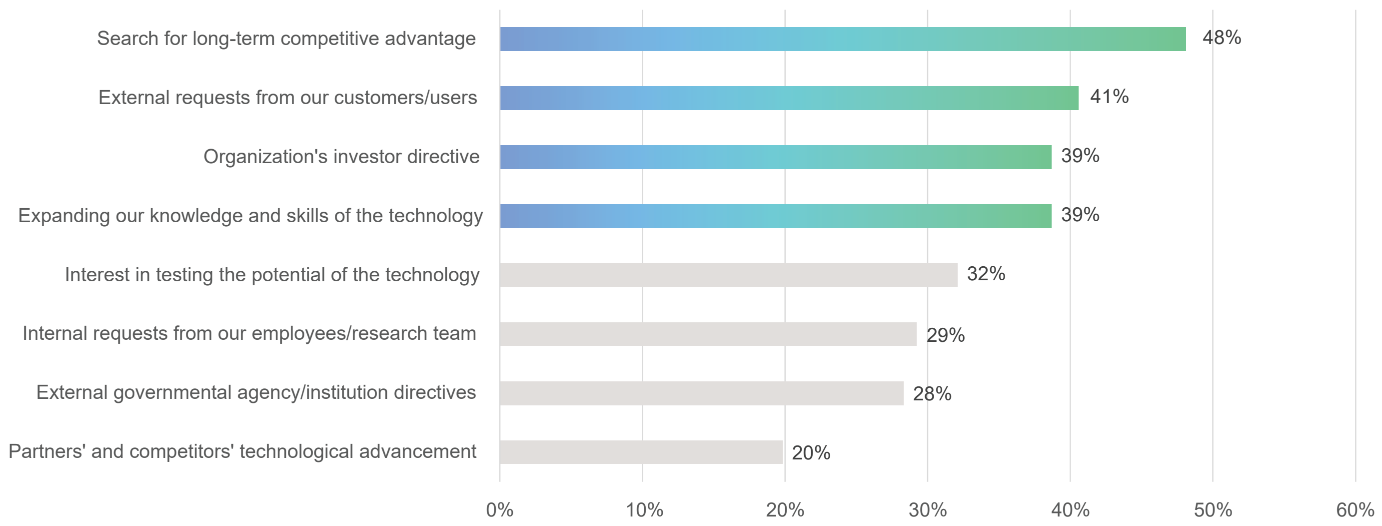


FIGURE 7. HPC CENTRES' DRIVERS FOR THE ADOPTION OF QUANTUM COMPUTING

Survey question: What are the main drivers for the adoption of quantum computing technologies in your organisation?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 106)

However, the innovation boost that quantum computing promises will not be quick and clean. The technology is still in its infancy and it will be years before we have scalable, error-free universal quantum computers. Even though HPC centres will be able to focus on customised problem-specific quantum solutions, significant research and business impact are still some way off.

In addition, quantum represents not only a new technology but also a new paradigm requiring a wide range of skills to deal with completely different hardware, completely different programming languages and applications, and a completely different way to formulate real-life problems and analyse the results.

The potential implications of the technology are evident from the barriers to quantum computing that HPC centres highlight (see Figure 8). The first concern is represented by the regulatory, legal and security risks that quantum computing can bring. The implementation, management and maintenance of quantum computing systems is still not regulated and potential cybersecurity threats connected to it have not been fully identified yet (implications for GDPR, for example). As with other emerging technologies before it, proper technical and regulatory rules will have to harmonise the development of quantum computing in the coming years.

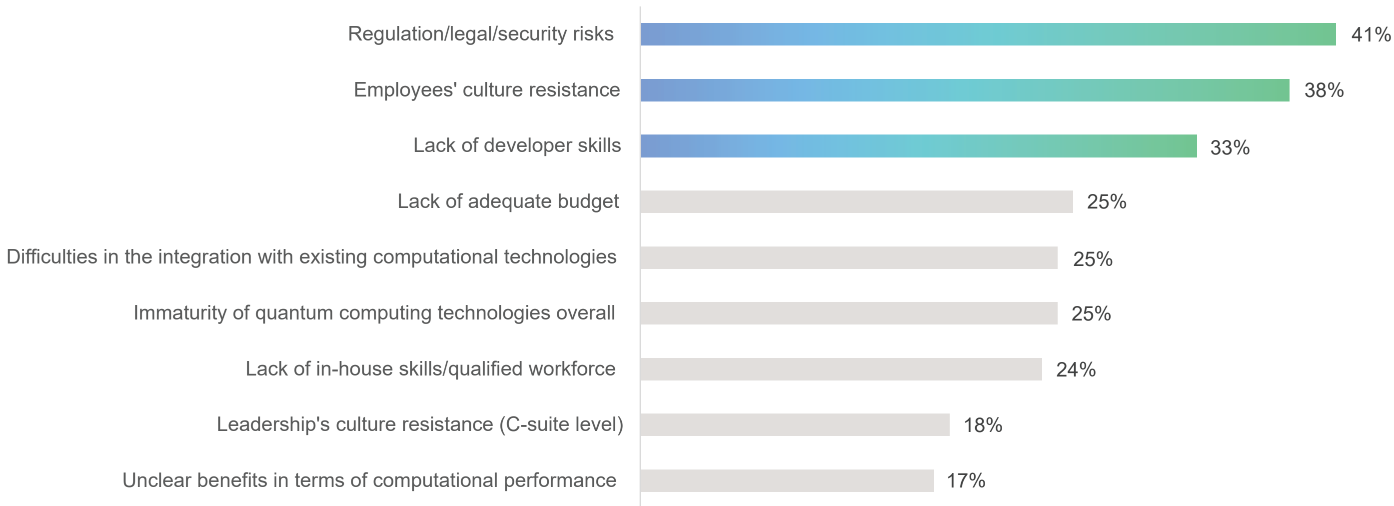


FIGURE 8. HPC CENTRES' BARRIERS TO THE ADOPTION OF QUANTUM COMPUTING

Survey question: What barriers (if any) are hampering quantum computing technology adoption in your organisation?

Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021 (n = 110)

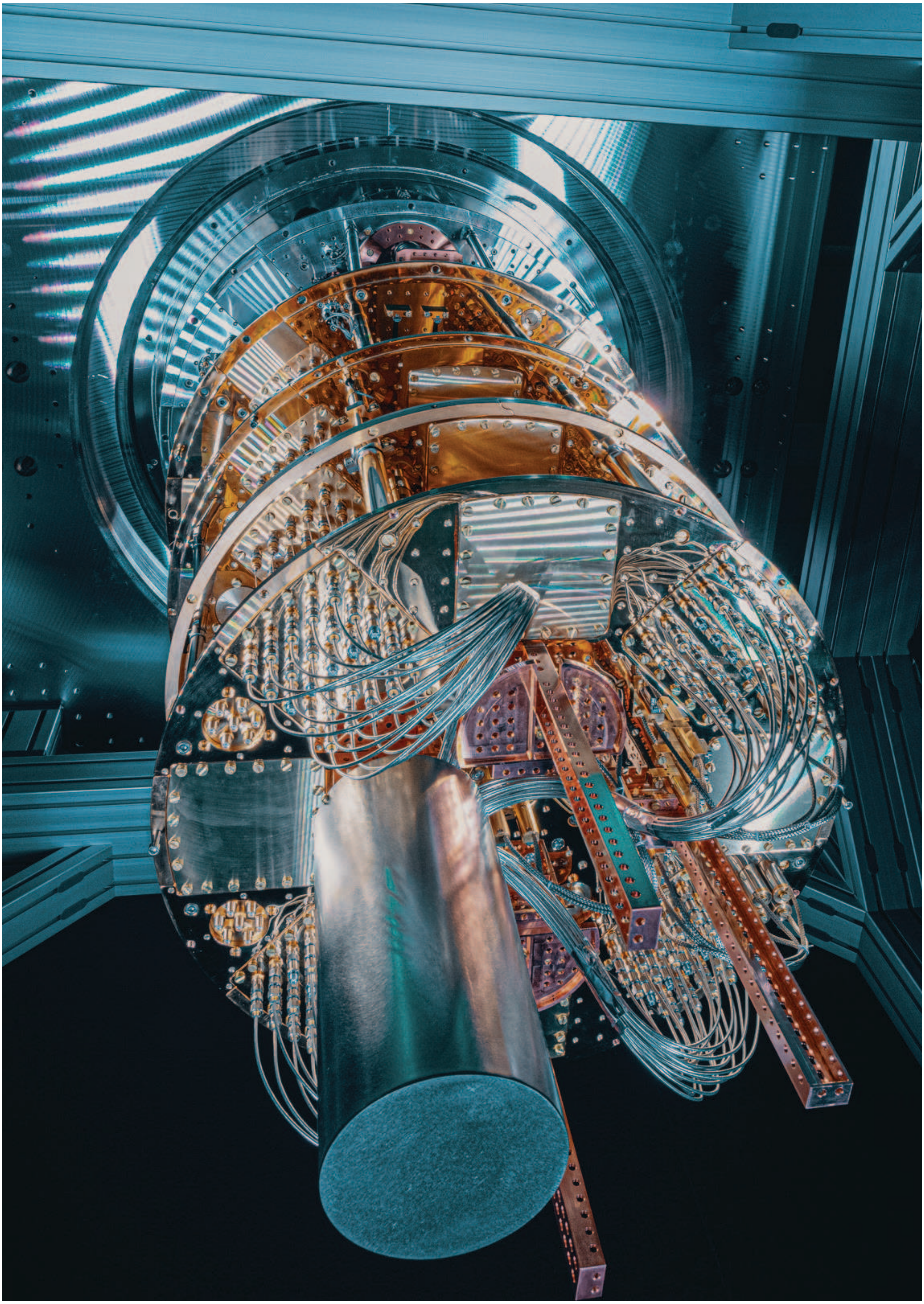
HPC centres face a number of challenges in the next few years, highlighting the significant changes they will have to make to turn quantum computing into reality. Internal resistance and skills development will now more than ever require a radical cultural and organisational transformation to address. It's also clear that, given their strategic relevance, specific plans to tackle them should be put in place right away.

Creating a Quantum Computing Adoption Road Map for HPC Centres

The quantum paradigm has all the requirements to be the next big thing in high-performance computing, due to its huge potential to resolve longstanding research and business problems and address the innovation dilemma.

However, we want to make it clear that it will take years for quantum technology to scale and for a universal quantum computer that can tackle a range of currently insoluble problems. Moreover, quantum will not be a high-performance computing "panacea" and will not replace classical high-performance computers for many of the tasks they're already able to do. Quantum computers will not substitute traditional HPC infrastructure, but will be integrated with it to offer advanced computational power when specific problems need to be addressed.

However, HPC centres cannot take a wait-and-see approach to quantum computing, which should be considered a long-term strategic move and not simply a tactical decision. HPC centres should already start their quantum computing journey and put in place a forward-looking and structured road map to achieve the full integration of the technology into their infrastructure. This will not only be a technical exercise but will require a full business, organisational and cultural transition.



A THREE-STEP APPROACH TO FULLY EXPLOIT QUANTUM POTENTIAL

The complexity and innovative reach of quantum computing require a strategy of gradual adoption over time. On one hand, this enables the proactive participation of HPC centres in the development and implementation of quantum computing, contributing to the experimentation and advancement of the technology over the years. On the other hand, it enables the development of the necessary quantum competencies and skills through training, acquisition and collaboration with the quantum computing provider.

This strategy needs to be implemented by HPC centres through a three-step journey that can be started right away (see Figure 9). Each step corresponds to different levels of HPC centre quantum computing skills and quantum computing maturity. While quantum computing maturity will depend on the current technological level provided by the quantum computing provider, quantum computing skills maturity will largely rely on the specific capabilities of the HPC centre to acquire and accelerate its competencies.

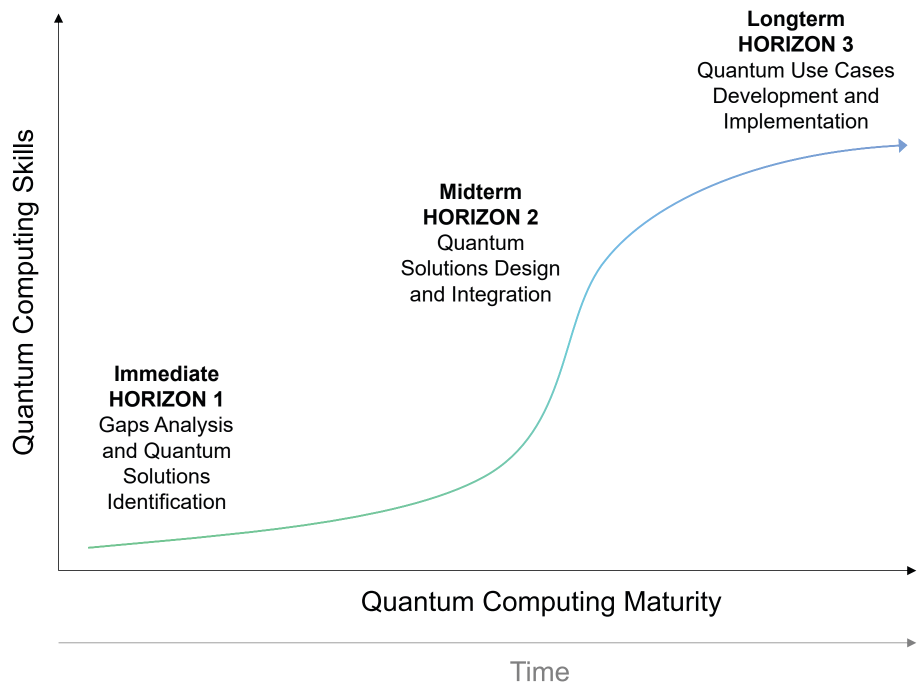


FIGURE 9. HPC CENTRES' THREE-STEP ROAD MAP FOR THE ADOPTION OF QUANTUM COMPUTING

Source: IDC European Quantum Computing Launchpad, 2021

HORIZON 1 (IMMEDIATE): GAP ANALYSIS AND QUANTUM SOLUTION IDENTIFICATION

As a first and immediate step, HPC centres should identify the problems that they are not able to fully address with their current classical infrastructure. This should focus on the potential performance improvements for problems that HPC centres are already addressing and new computational challenges beyond what is already currently possible. While universal quantum computers are still a long way down the track, the focus on specific problems will facilitate the achievement of a significant computational impact over a much shorter time frame.

This first step should already involve collaboration with the quantum computing provider, which can support the definition of the problems and help their “translation” into quantum-tractable objectives. The final output of this first phase should be the definition of the main scope of the quantum solution that will be developed to address the specific key problems that have been identified.

This phase will also be a first and crucial occasion to start the familiarisation of internal research scientists and IT developers with the quantum computing approach, features and technical challenges.

HORIZON 2 (MIDTERM): QUANTUM SOLUTION DESIGN AND INTEGRATION

Once the final objectives are clear, the quantum computing solution should then be designed, developed and integrated with the existing classical HPC infrastructure adopting state-of-the-art technology. The quantum solution will require a high degree of customisation to be able to focus on the specific problems identified. For this reason, the solution should be mainly based on an on-premises approach that can be integrated with a proper selection of cloud applications to address more standard functionalities.

A crucial role will be played in this phase by the collaboration between the HPC centre and the quantum computing provider. The high level of customisation required and the need to smoothly interact with the existing infrastructure can only be addressed through continuous interaction between the two actors. The degree of participation of the HPC centre in this phase should be calibrated based on its effective quantum design capabilities at this stage, but in the most advanced scenarios could also take the form of a real co-design approach with the quantum computing provider.

In this phase, research scientists and IT developers will have the chance to actively collaborate in the design of the quantum solution and the HPC centre will be able to further expand the internal participation to the innovation process.

HORIZON 3 (LONG TERM): QUANTUM COMPUTING USE CASE DEVELOPMENT AND IMPLEMENTATION

In the final phase, the quantum computing solution has already been integrated with the existing infrastructure and the HPC research team can eventually develop and experiment with the use cases that best fit the solution deployed. The objective now is the achievement of quantum advantage, namely the development of pilots to address specific real-life problems and outperform purely classical HPC systems. Collaboration with the quantum computing provider will still be important here, from scientific support to the technical upgrade of the solution based on the latest advancements of the technology. However, it will also be crucial at this stage to develop a wide quantum ecosystem including academia, research centres and end-user companies to co-develop, implement and test real-life use cases.

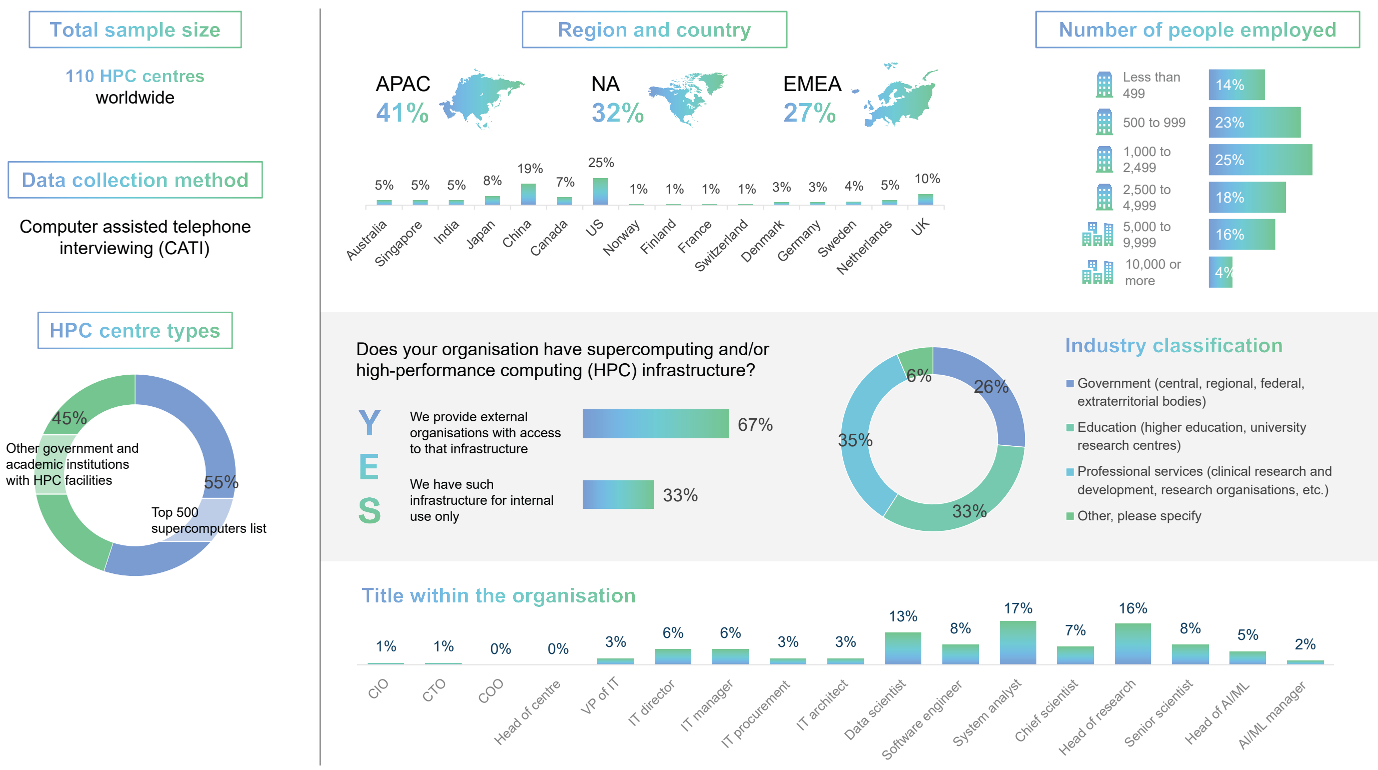
The achievement of quantum advantage should be the long-term destination of the entire HPC centre's quantum computing journey. This will enable HPC centres to build a sustainable competitive advantage and pave the way for the future development of a universal quantum computer.

In this phase, HPC centre competencies and skills will be taken to the next level, thanks to the continuous work on both the technical and business aspects of the use cases. This final step will also be the occasion to involve the whole organisation in the quantum-based innovation process and complete the cultural transformation that will be pivotal to achieve a real scientific and business impact.

Survey Methodology and Demographic

This IDC White Paper is based on the IQM and Atos — State of Quantum Computing in HPC Research Survey conducted by IDC Europe in August 2021. The survey seeks to understand HPC centres' business and technology challenges worldwide as well as the attitudes towards quantum computing adoption over the short term:

- 110 HPC centres worldwide completed the questionnaire through computer-assisted telephone interviews (CATI).
- From a regional standpoint, 41% of HPC centres were in the Asia/Pacific region, 32% in North America and 27% in EMEA.
- In terms of size of HPC centres, over two-thirds have 1,000 employees or more. Of these, 25% have 1,000–2,499 employees, 18% have 2,500–4,999 employees, 16% have 5,000–9,999 employees and 4% have 10,000 employees or more.
- Of the total 110 sample, 67% use the HPC infrastructure internally and 33% provide external organisations with access to their own HPC infrastructure.
- Looking at vertical composition, 26% of HPC centres are part of a governmental body, 33% operate in academia and 35% perform professional services activities such as research or clinical research.
- 39% of survey respondents are director level and above (e.g., VP or C-suite).



Source: IQM and Atos — State of Quantum Computing in HPC Research by IDC Europe, August 2021

Message from the sponsor

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IQM is the Pan-European category leader in building quantum computers.

IQM delivers on-premises quantum computers for supercomputing centers and research laboratories and provides complete access to its hardware. For industrial customers, IQM delivers quantum advantage through a unique application-specific co-design approach. IQM is building Finland's first commercial 54-qubit quantum computer with VTT, and an IQM-led consortium is building Germany's quantum computing system that will be integrated into an HPC supercomputer to create an accelerator for future scientific research. IQM is also part of Atos Scaler program.

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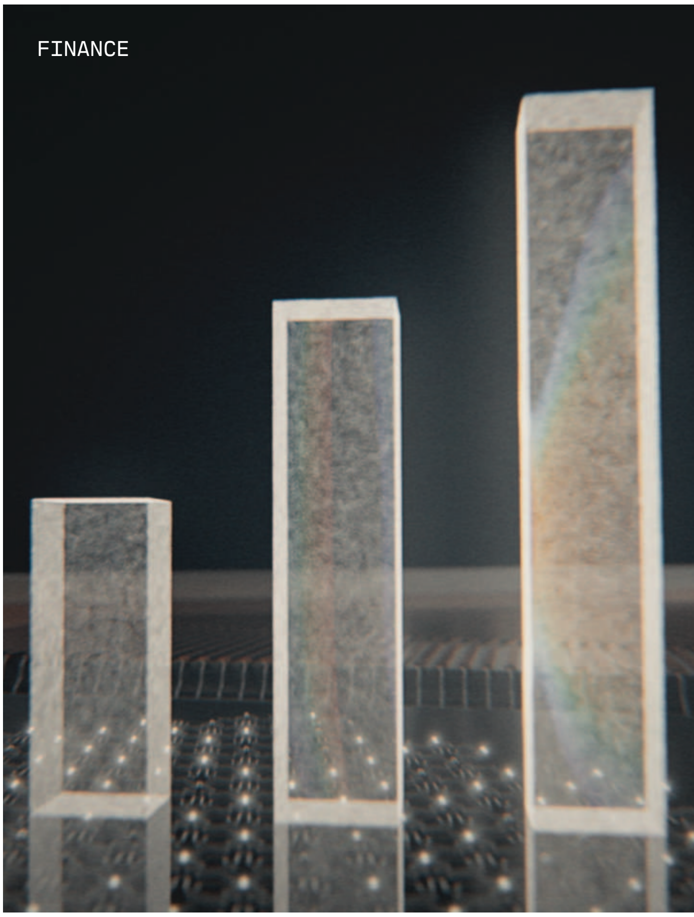

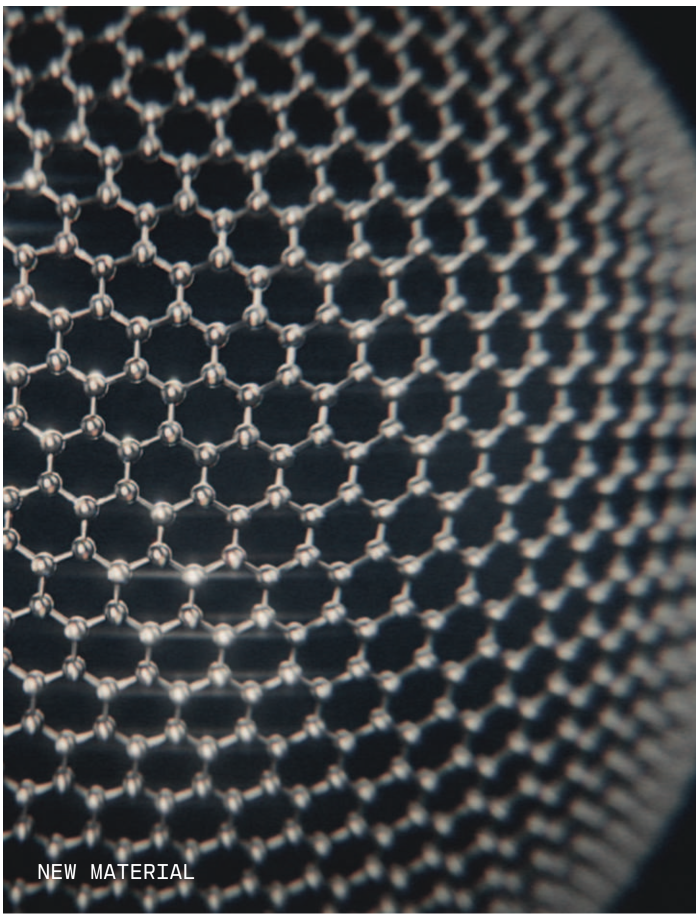

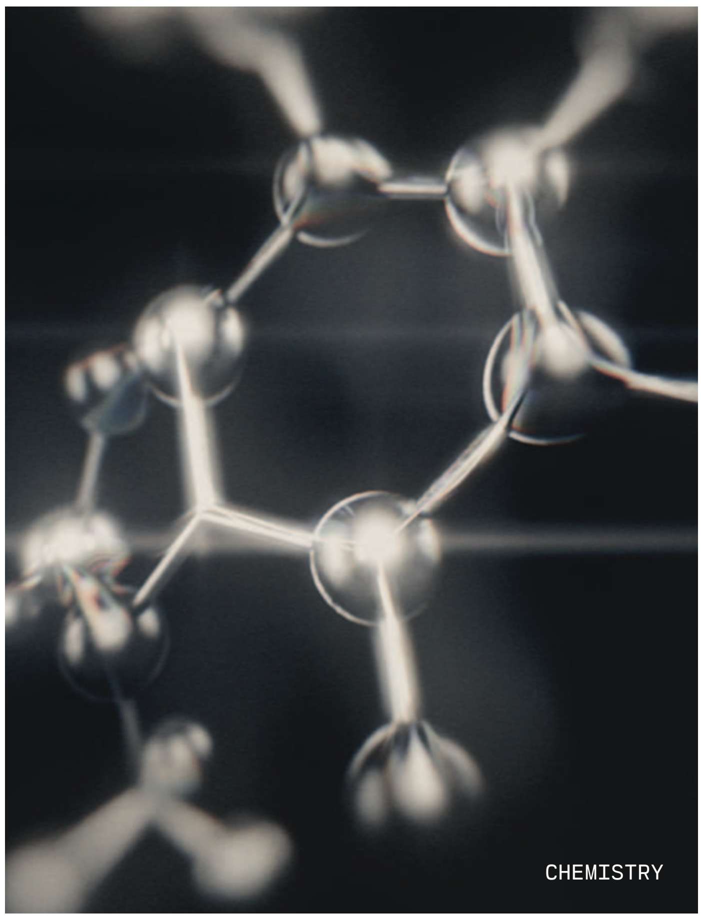

IMAGES:
APPLICATION-SPECIFIC CO-DESIGN APPROACH

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