A quantum leap in finance

How to boost Europe's quantum technology industry

European Investment Bank

European Commission

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Published by the European Investment Bank.

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Printed on FSC® Paper.

pdf: QH-05-22-374-EN-N ISBN 978-92-861-5404-1 doi: 10.2867/297484

Contents

Foreword

by Teresa Czerwińska

European Investment Bank Vice-President

Digital technologies are the single most important driver of innovation, competitiveness and growth. Yesterday's emerging technologies — supercomputing, artificial intelligence and big data — are already transforming businesses, public services and societies. However, they cannot yet solve all problems, such as simulating the complex structures of proteins, or the efficient electrical grids needed for a green transition. This is where quantum technologies come in. They promise to give us the computational power to do all that, and more.

Quantum technologies can speed up the twin transition to a green and digital economy in Europe and safeguard the European Union's strategic autonomy. New quantum computing capabilities tackle strategically important problems for Europe's core industries that will ensure their long-term competitiveness. Quantum computing could become a driving force for decarbonisation through the design of advanced fuels, batteries and biodegradable materials that also reduce our dependence on petrochemicals. It is no longer a question of whether quantum computers will transform our existing cybersecurity systems, but of when, adding urgency to Europe's quantum ambitions.

Given the enormous potential of quantum technologies, Europe must take all the necessary steps to propel itself to the forefront of this strategically important sector. One key challenge is to bridge the financing gaps that many promising quantum companies face by providing and mobilising targeted investment.

I am confident that this need can be successfully addressed by a smart combination of dedicated financial instruments and policy programmes that bridge the knowledge gaps between quantum startups, investors, and potential customers.

This study is the first step. It highlights concrete industrial and commercial applications across a broad range of sectors (pharmaceuticals, automotive, renewable energy, and finance) to inspire action from the companies that stand to benefit from them. It encourages Europe's world-leading research institutions and scientists to embrace a more commercial approach to technology transfer. Finally, it calls upon European investors to learn about this exciting technology and do more to fund fledgling quantum startups.

The European Investment Bank Group stands ready to support innovative companies and foster an environment that accelerates the adoption of their groundbreaking solutions to make Europe greener, healthier and more resilient.

Foreword

by Roberto Viola

European Commission, Director-General, Communications Networks, Content and Technology

I am grateful to the European Investment Bank, and in particular its Innovation and Digital Finance Advisory division, for its excellent cooperation in the preparation of this important study.

Over the past decades, Europe has nurtured research breakthroughs in quantum technologies and been the home of many Nobel laureates — with the most recent winners in 2022.

Today, European research excellence in quantum is flourishing, in no small part thanks to continuous EU investment in this field, from the first large-scale quantum research programme launched in 1999, all way through to the 2018 €1 billion Quantum Technologies Flagship initiative. This excellence puts Europe in a good position to benefit from the enormous economic and strategic potential of quantum. From tracking future pandemics or designing new materials and new drugs, modelling extreme weather patterns and contributing to disaster relief, enhancing the ability to detect movement below ground and under water, to other functionalities that may not even have been imagined yet, the prospect of quantum technologies helping to solve some of the major challenges of our time cannot be underestimated.

We are proud of the EU-based researchers who are helping to make this potential a reality, and of the increasing number of European companies specialising in quantum. Yet, while 25% of all quantum companies worldwide are located in the European Union, many of Europe’s quantum companies report difficulties in accessing the finance they need to scale up and flourish. Some targeted initiatives to boost Europe’s quantum industry are underway, but further efforts are needed, as currently only 5% of global funding for quantum is directed to Europe.

This study is therefore very timely, as it seeks to analyse this financing challenge and suggest possible solutions. It makes a clear case for how quantum will transform a large number of industrial fields and traces the likely evolution of the quantum technologies market in the European Union in the coming years. It considers the barriers European quantum companies face to accessing the investments they need, especially from the private sector, compared to competitors from other world regions. Last, but not least, it outlines ways in which policymakers might remedy this and support Europe’s quantum ecosystem in this crucial stage of its growth.

At the European Commission, we see quantum as essential to the European Union’s strategic and economic future in today’s complex geopolitical situation, which makes digital sovereignty more and more important. Quantum is placed prominently in our Digital Decade strategy, and we have set an ambitious target of Europe being at the cutting edge of quantum technologies by 2030. At the same time, it is clear that only by aligning and consolidating our activities, and by working together at the national and EU level, can we ensure that Europe’s leading position in quantum research is the foundation for a world-leading European quantum ecosystem.

I am pleased to see that the European Investment Bank is joining us in this endeavour by underlining the vital importance of quantum technologies as a strategic sector for the European economy and showing that it is ready to support these technologies. I hope that this study will serve as the basis for a fruitful dialogue between European policymakers about our next steps.

"Those who are not shocked when they first come across quantum theory cannot possibly have understood it."

Niels Bohr, Danish Nobel Prize laureate in Physics, 1922

"The atoms or elementary particles themselves are not real; they form a world of potentialities or possibilities rather than one of things or facts."

Werner Heisenberg, German physicist and a pioneer of quantum mechanics

About this study

This paper is based on extensive research carried out by the Innovation and Digital Finance Advisory division of the European Investment Bank Group, in close collaboration with the European Commission's Directorate-General for Communications Networks, Content and Technology (DG Connect), under the joint InnovFin Advisory programme. McKinsey & Company provided consulting support.

Our objective is to describe the overall European quantum industry and its position in the global quantum technology landscape. We have analysed the current status and trends of the technology globally and in Europe to gain an insight into how to best support the development and deployment of this key enabling technology in Europe. Finally, we recommend a mix of policy and financing measures to accelerate the journey from academic knowledge to large-scale commercial success to propel Europe into the position of world leader in quantum technology.

The report includes three sections:

1. **The state of play:** We describe the key segments of the quantum technology market (quantum communication, quantum computing and simulation, and quantum sensing) and illustrate their practical applications for leading European industries.
2. **Why investment in quantum technologies is lagging behind in Europe:** We describe investment trends in the global quantum technology market and identify the strengths and bottlenecks explaining why the European Union is behind.
3. **How the European Investment Bank and the European Commission can support quantum companies:** Based on the findings, we propose new dedicated financial instruments and policy programmes to make it easier for quantum companies in Europe to find investors, commercial partners and a supportive environment.

Study approach

The research builds on previous and current activities performed by the EIB Group and the European Commission to evaluate initiatives to improve access to finance in a broad range of innovative sectors, including artificial intelligence and blockchain, high performance computing, space and research, and technology organisations.

Analysis was based on desk research and in-depth interviews and workshops with more than 15 quantum technology startups and ten investors.

Preface

Quantum technologies offer a vision of a healthier, more sustainable and resilient Europe. They will one day enable disruptive innovations that could transform our societies, economies and almost all industries. This report aims to answer the key questions about the future of quantum technologies: **What** can we expect from ground-breaking innovations? **Why** should we already begin to boost investment into the nascent European quantum industry? **How** can we speed up the development of the industry in Europe?

What is quantum technology?

Quantum technology employs the **principles of quantum physics** to make computing faster, measurements more accurate and communications more secure.

Most quantum technology models are based on quantum bits, or qubits. They are similar to binary bits in classical computing but have additional properties due to three key quantum mechanical principles: **superposition, entanglement** and **decoherence**.

Quantum superposition means that any two quantum states[1] can be added together to form a new quantum state. While a binary bit can have either the value 0 or 1, a qubit can have the values of 0,1 and a superposition of 0 and 1. Because of this, a qubit can be programmed to hold almost twice as much information. This will enable quantum computers to one day perform certain useful calculations much faster than any supercomputer.

Entangled qubits exist in a single quantum state. If the state of one qubit is changed, the other one will instantly change in a predictable way even over very long distances. This property has many uses, for example to link up quantum computers, make measurements or secure communications.

Quantum decoherence is the loss of information when a quantum system interacts with the environment. Quantum technologies cannot give exact, mathematically accurate results without correcting for decoherence errors and other noise.

[1] In quantum mechanics, what is usually described as subatomic particles (electrons and photons, for example) is instead defined as a mathematical probability that we will detect the thing we are describing when we make a measurement. The sum of all possible measurements (the probability distribution) is referred to as the **quantum state**.

Why invest in quantum technology?

We may not yet know what the quantum future will look like, but we can glimpse its promise for a healthy, sustainable and resilient Europe. Quantum technologies[2] will one day solve problems that have eluded even our most powerful classical computers. From chemicals and life sciences to finance and renewable energy, quantum technologies could speed up the development of ground-breaking new products or improve existing ways we do things.

"Meeting the goal of net-zero emissions […] won't be possible without huge advances in climate technology that aren't achievable today. Even the most powerful supercomputers available now are not able to solve some of these problems. Quantum computing could be a game changer in those areas."

McKinsey, 19 May 2022

Quantum technologies could accelerate the transition towards a greener and more sustainable economy[3]

The European Union aims to become the first carbon-neutral continent by 2050. An ambitious goal — but one that must be reached if the world is to avoid the catastrophic consequences of a temperature increase of more than 1.5°C.[4]

Quantum computing could enable the technological breakthroughs needed to **decarbonise industrial production and energy generation at scale**. Use cases range from improving electric batteries for vehicles and curbing emissions from energy-intensive industrial processes to improving solar power technology, bringing down the cost of hydrogen production and discovering new, greener fertilisers to cut methane emissions in agriculture.

"There is a 50-50 chance of average global temperature reaching 1.5 degrees Celsius above pre-industrial levels in the next five years, and the likelihood is increasing with time."

World Meteorological Organization report published 9 May 2022

Quantum technologies could transform healthcare

The coronavirus pandemic reminded us that our healthcare systems are fragile and that the existing drug discovery process is expensive, inefficient and slow. It took unprecedented global coordination and resources to swiftly develop life-saving mRNA vaccines. We hoped they could vanquish cancer, AIDS or malaria next, but we may have to wait a while longer.

What if we could test the therapeutic value of complex molecules faster, more cheaply and more accurately? **The greater computational power of quantum computing could make elusive cures a reality**, speed up our response to any future pandemics or outbreaks, and offer hope to the millions suffering from rare diseases.

Quantum technologies could make European industries more resilient

Europe's economic success depends on reliable access to key inputs such as semiconductors and energy. Supply chain disruptions and Russia's invasion of Ukraine have highlighted how important it is to lead the development of the technologies that will shape the future.

Quantum technologies could unlock more efficient ways to generate energy or to gather and process information. On a grander scale, **quantum technologies have the power to shape future societies and disrupt**

[2] In this report we use quantum and quantum technology interchangeably, referring to the industry as a whole. When referring to specific segments, we specify quantum computing, quantum communication and quantum sensing.

[3] Quantum computing just might save the planet | McKinsey

[4] The scientific community and the Intergovernmental Panel on Climate Change (IPCC) have established a rise in global temperatures of 1.5°C to 2°C above pre-industrial levels as the threshold beyond which our civilisation may struggle to cope with the effects of climate change. The value of 1.5°C was adopted as the goal of the Paris Agreement, which calls for countries to take concerted climate action to reduce greenhouse gas emissions in order to limit the worst effects of climate change.

entire industries. European innovators, corporations, investors and policymakers need to steer the development of quantum technology to facilitate a more robust, resilient and cohesive European Union.

From promise to reality

Two European scientists won the 2022 Nobel Prize in Physics. Alain Aspect (France) and Anton Zeilinger (Austria) shared the prize with John Clauser (United States) for their ground-breaking experiments on entangled quantum states. Their work has cleared the way for new technology based upon quantum information.

"It has become increasingly clear that a new kind of quantum technology is emerging. We can see that the laureates' work with entangled states is of great importance, even beyond the fundamental questions about the interpretation of quantum mechanics."

Anders Irbäck, Chair of the Nobel Committee for Physics

Despite a world-leading academic foundation in quantum technologies, European quantum companies consistently lag behind global peers. The European Union is home to 25% of all quantum companies worldwide, but accounts for less than 5% of global funding. Companies struggle to scale commercial operations due to a lack of knowledgeable investors or commercial partners.

A system of market-leading companies, expert investors and early industrial adopters will enable European quantum ventures to translate scientific excellence into transformative quantum technology innovations. In this report, we outline a number of actions for public and private institutions targeting two critical junctures: the transition from technological breakthrough to a commercially validated proof of concept, and the wider commercial scale-up of products and services. Together, public and private institutions can bridge the funding and knowledge gaps between academia, founders, investors and end users and make Europe a global leader in quantum technologies.

State of play: How might quantum technology reshape the European economy?

What is quantum supremacy and when will we get there?

"Imagine an early computer in the 1970s and asking it to be able to recognise voice and search the internet — it would be impossible. But you could use it to run a spreadsheet."

Enrique Lizaso Olmos, Multiverse chief executive officer

Quantum supremacy is the point when a quantum computer can perform a task that even the most powerful supercomputer cannot complete in a realistic[5] amount of time. Since it does not matter how useful or practical the task is, current trials focus on problems that could be easily solved by quantum computers, not necessarily tasks that would be useful in the real world.

Quantum supremacy is an important, albeit still academic, goal for developers of quantum computers and a step towards fulfilling the technology's promises. Google claimed to have reached this point in 2019 with its 53-qubit machine. IBM and other researchers, however, challenged the claim with a different mathematical approach to complete the calculation just as fast with a classical computer.[6]

Other claims of quantum supremacy have followed, by teams from the University of Science and Technology of China (USTC) with a 56-qubit computer in 2021 and Xanadu, a Canadian quantum computing company, in 2022.[7]

It is still unclear how many qubits will confer true quantum advantage in practical applications. Some researchers put the minimum at 1 000 qubits and the timeline for achieving this around a decade from now.[8] New ways to manipulate qubits or alternative methods for quantum computing may emerge and bring this reality closer.

However, increases in computing power will need to be matched by better correction of decoherence errors and other quantum noise. A quantum computer needs to be fully error-corrected and fault-tolerant in order to provide mathematically accurate, practically useable results. Progress in this area has been slow.

Quantum technologies are divided into three main segments

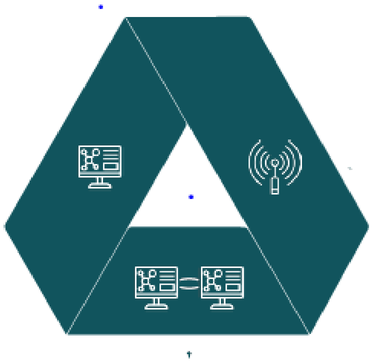
- **Quantum computing and simulation** is the largest segment and has attracted nearly 85% of quantum technology investments over the past two decades. The principles of quantum mechanics enable **quantum computers** to make calculations that are currently not feasible even for powerful supercomputers. One special-purpose type of quantum computer, the **quantum simulator**, can replicate the properties of complex systems (such as molecular interactions) that could previously only be tested in the real world.
- **Quantum communication** is the second largest segment, accounting for 13-14% of total investments in the quantum industry. Quantum communication refers to both the transfer of quantum information across space to enable parallel and remote computation, and the secure transfer of data. **Quantum cryptography** could

5 Any computer will eventually reach a solution, but it could take too long to be of practical use. For example, a classical computer would take 900 years to solve some integer factorisation problems commonly used for encryption.
6 Math may have caught up with Google's quantum-supremacy claims | Ars Technica
7 Quantum computational advantage with a programmable photonic processor | Nature
8 In November 2021, IBM launched a 127-qubit quantum processor named Eagle, which currently takes the top spot as the largest, theoretically most powerful superconducting quantum computer. IonQ, another quantum computing company, unveiled Aria in February 2022, which may take the top spot.

ensure security of communications and data, even in the face of rapidly increasing quantum computing decryption capabilities.[9]

- **Quantum sensing** is the smallest segment, making up 1-2% of all investments in the quantum industry. **Quantum sensors** are built from quantum systems that provide measurements of important physical quantities (for example gravity, time or force) that are orders of magnitude smaller and more accurate than classical sensors.

Figure 1: Quantum has the potential to enable new capabilities across industries



Hardware dominates the quantum computing value chain now, but the focus will shift to software and services as the sector matures

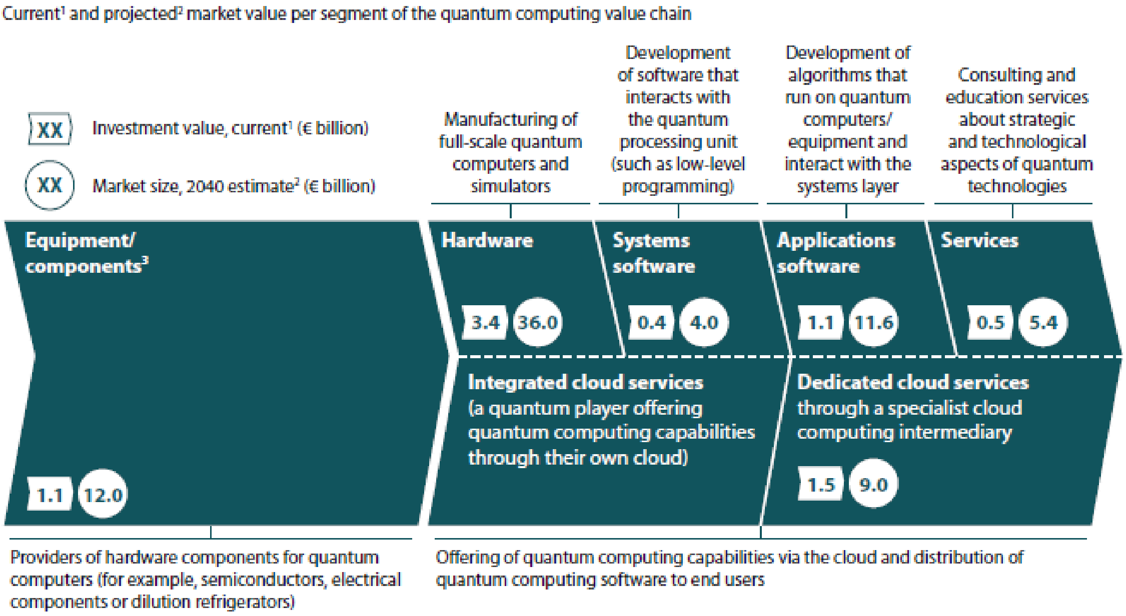
The quantum computing value chain is similar to its classical computing counterpart: Component and hardware manufacturers make the quantum computing equipment and software developers and service providers build and deploy end-user applications for it. Quantum computing power or services can be accessed by purchasing and installing hardware and systems software, or through cloud-based services that complete the environment (see Figure 2).

The **biggest market segment today is the hardware market**, which has attracted an estimated 75% of all investment in quantum technologies over the last two decades. Component manufacturers currently capture most of the industry's revenues and margins because components can be installed in multiple hardware setups. Quantum computer manufacturers and software developers still generate revenue primarily through consulting services and joint research projects.

As commercial applications emerge **over the next five to ten years, hardware and software providers are expected to capture the bulk of the value**. As quantum computers and software become more standardised, we expect applications and services to take a bigger slice of the sector's profitability. Nevertheless, hardware is expected to remain the biggest segment and benefit from lower costs as the technology and production processes mature.

9 Existing encryption methods are particularly vulnerable to the advent of quantum computing, with some projections that some protocols could be compromised in the next 15 years (The Economist, "Secrets Unsquirrelled," 16 July 2022).

Figure 2: Hardware is the leading segment in the quantum computing value chain



1. Total raised funding by quantum computing and simulation players.
2. Market per segment in 2040 estimated based on similarities with the high performance computing market.
3. Market for equipment/components estimated at one-third of total hardware market.

Source: Capital IQ; Crunchbase; PitchBook; Quantum Computing Report; expert interviews.

Quantum technology could transform key industries within the next decade

Core European industry segments have much to gain from the rapid progress of quantum-enabled applications, and much to lose if they are slow to react. Quantum computing could give a competitive edge to Europe's key industries. Companies need to look beyond today's uncertainty, complexity and high cost, and guide the development of quantum technologies to their benefit.

The impact from quantum computing is expected to be most disruptive for the chemicals and pharmaceutical industries, as quantum-based simulation of molecular processes may replace the need for time-consuming lab-based research and development and testing.

Use cases and industrial applications are also taking shape in the sustainable energy and automotive industries. These could see transformative developments in the next five to ten years, for example as quantum simulation uncovers new materials, optimises existing processes, or opens up new frontiers for automation (be it power grids, smart buildings or autonomous vehicles).

Figure 3: Significant impact of quantum in the short term is expected notably across sustainable energy, chemicals and pharmaceutical industries

Impact of quantum technologies[1]

Industry	Key segment	~2025–30	~2030–35	Industry size	EU strategic importance
Global energy and materials	Oil and gas	●	●	4-9	
	Sustainable energy	●	●	1-4	Strategic focus
	Chemicals	●	●	1-4	Core industry
Pharmaceuticals and medical products	Pharma	●	●	1-4	Core industry
Advanced industries	Automotive and assembly	●	●	1-4	Core industry
	Aerospace and defence	●	●	<1	
	Advanced electronics	●	●	<1	
	Semiconductors	●	●	<1	
Financial industry[2]		●	●	>9	
Telecommunications, media and technology	Telecommunications	●	●	1-4	
	Media	●	●	1-4	
Travel, transport and logistics	Logistics	●	●	4-9	
Insurance		●	●	4-9	

Economic value ● Incremental ● Significant ✓ Disruptive **EU strategic importance** ✓ Strategic focus ✓ Core industry **EU strategic importance** ■

1. Relative impact on the industry; absolute impact depends on relative impact as well as the size of the industry.
2. Includes asset management.

Source: Industry reports.

Capturing the economic benefits from quantum technology requires European public and private investors and companies to lead the commercialisation of this powerful technology. The challenge for Europe is to simultaneously accelerate the development and scaling of breakthrough applications and encourage their wider adoption by leading industrial players.

Quantum advantage in the fight against climate change

Quantum technologies could help the European Union become the first carbon-neutral continent by 2050. They could enhance existing tools to monitor climate change and adapt to its effects. And they could make it easier to save energy and reduce the carbon footprint of computing, transport and electricity generation.

Quantum technologies could help us generate more power from renewable sources. Power grids were not designed to handle intermittent power, varying with the sun or wind. Quantum optimisation could make it easier to stabilise grids with large shares of renewable electricity, and could also improve renewable energy generation, for example by calculating the optimal placement of wind turbines on a wind farm.

Quantum simulation could help us to uncover superior materials for photovoltaic cells, wind turbines, batteries and carbon capture components. In chemistry, better simulations could discover and develop synthetic fuels, green plastics and other biodegradable materials. A faster research and development process is also cheaper, which will make it easier to bring these new products to market and deploy them on the large scales we need.

On the demand side, quantum optimisation could direct traffic flow and parcel shipping schedules in ways that use the least energy. Quantum computers themselves are expected to need less cooling and work faster than classical supercomputers. A direct comparison is not yet possible, but less energy per calculation could meaningfully improve energy efficiency. Quantum sensors in smart buildings could continuously track and manage energy consumption.

Quantum optimisation could also help improve the climate, weather and ecosystem models that underpin mitigation and adaptation planning. Sensors that can measure electric and magnetic fields, motion and optical signals could provide the data for these models. Smaller and more accurate quantum sensors could further improve our understanding of climate change, for example through better satellite monitoring of greenhouse gases other than carbon dioxide. Methane and aerosols — two potent contributors to climate change — are especially hard to measure with existing sensors due to spectral interference from other gases.

Quantum sensors could also make it easier to prepare for the disastrous consequences of climate change, giving us advance insights into glacier melting, sea level rise and weather hazards. Their smaller size will help change the way we farm to be more precise, resilient and environmentally friendly.

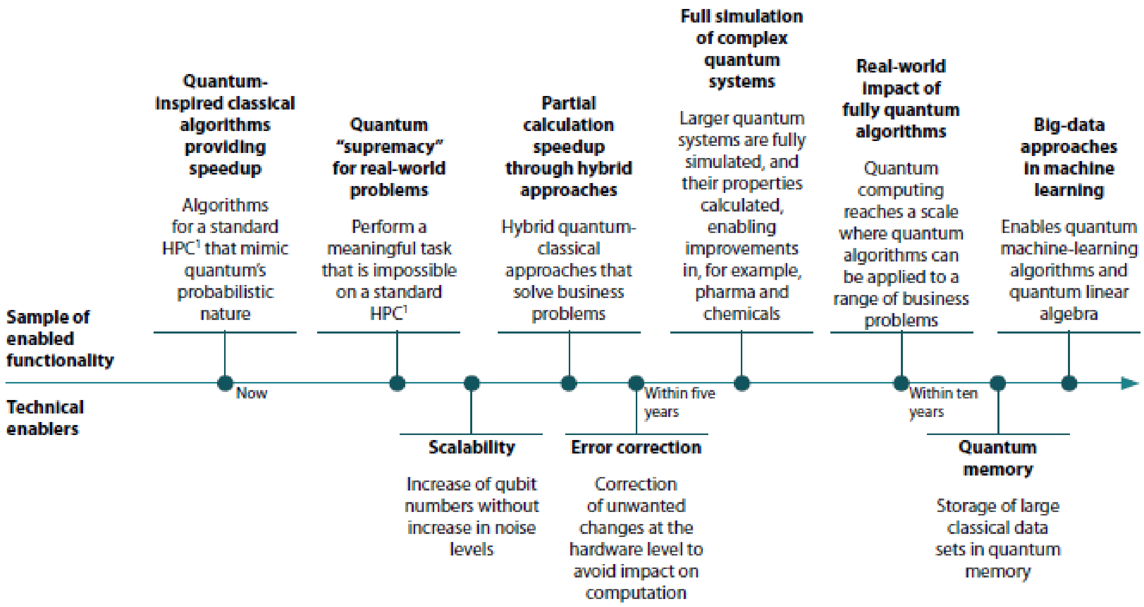
Our actions today will shape the quantum world, even if it is a long way off

Quantum technology promises to facilitate the twin transition to a green and digital economy in Europe. A flourishing European quantum industry will be able to guide the development of the technology so that it serves the objectives and reflects the values of the European Union. **We need to invest in this industry today to reap the best economic and societal benefits.**

Although it may take between ten and 20 years for quantum computing to reach full its potential, we might already see fully developed quantum algorithms and simulations of complex systems in the coming decade. Because we see quantum computing as the segment that will contribute the bulk of the industry value, our projections are based on development roadmaps by the leading quantum computing hardware players.

By 2040, when quantum computing will have reached its full potential, the market could be as large as €78 billion in an aggressive disruption scenario.

Figure 4: Quantum computing is likely to find practical applications in the next five to ten years



1. High-performance computer.

To gain the most benefit from an emerging technology, it is best to engage early in the design and development phase. Consider where artificial intelligence was a decade ago and how it is now ubiquitous: shaping our Spotify playlists, answering our customer service questions and diagnosing medical conditions. Quantum technology is at this critical stage of development now.

Although fully-fledged quantum computers might be decades away, the quantum race is already on between the US private sector, the public sector in Europe, and emerging players from China and other Asian countries. An increasing number of public and private sector players are signalling their intention to be a part of the quantum revolution. They are drawing up **strategic investment plans** and spurring policymakers to develop **strategic orientations**.

Large private tech companies in the United States, such as Google and IBM, are spending lavishly on the development of quantum technologies, primarily on quantum computing hardware. These companies are betting heavily on the commercial benefits of quantum technologies.

As Europe does not have such deep-pocketed tech titans, it has relied on strong public support to build a successful fundamental research and development base. It has laid the groundwork for a quantum revolution that could directly benefit wider society, reflecting democratic and humanistic European values.

The European Commission has launched a series of ambitious policies to support the development and deployment of quantum technology in the private sector. Specifically, its **EU 2030 Digital Compass proposed that the first computer with quantum acceleration should be deployed in Europe by 2025 and that the European Union should be at the forefront of quantum capabilities by 2030**.

Two programmes to advance Europe's quantum ambitions

The **Quantum Flagship Programme** will allocate €1 billion of funding over a ten-year period to consolidate and expand European scientific leadership and excellence in this research area in order to kick-start a European industry in quantum technology.

The official flagship document has been endorsed by over 3 500 representatives from academia and industry calling on the European Commission to support and invest in quantum technology as a key enabling technology.

The European Commission will provide further support to quantum technologies through dedicated activities under the **Digital Europe programme**.

Quantum technology investment trends: Why private investment is lagging in Europe

As the development of quantum technology advances and application areas emerge, investors are growing more interested in the industry. However, volumes of private funding for quantum technologies in Europe are still behind those in other regions. If the funding bottlenecks persist, Europe will struggle to establish a world-leading quantum industry.

The main advantage of the European quantum industry stems from an exceptional knowledge and talent base, nurtured by significant public funding. Unfortunately, the overall level of investment in European quantum ventures is low, hampered by a fragmented environment and unfamiliarity with the technology among investors and end users.

This report analyses investment trends in the quantum industry in two areas — **transfer of knowledge** and **access to finance** — to identify the strengths of the European quantum industry and pinpoint the bottlenecks that need urgent attention.

Transfer of knowledge

STRENGTHS	BOTTLENECKS
Finding 1: Europe has a strong and internationally recognised science and talent base, however...	...European quantum technology company founders have limited commercial experience.
Finding 2: The number of quantum startups has skyrocketed in Europe since 2015, however...	... European startups find it hard to scale up because of limited evidence of commercial viability or hesitance to commercialise.

Finding 1: Europe has a strong, internationally recognised science and technology base, but company founders have limited commercial experience.

The key asset of the European quantum industry is its capacity to develop and nurture talent.[10] A flourishing quantum industry needs employees from varied scientific backgrounds: quantum physics, chemistry and statistics. The quantum industry is already experiencing talent shortages that are likely to get worse as the industry grows.

Academic breakthroughs are the first step towards unlocking value from quantum technologies. European organisations are prominent in all segments of the quantum value chain. The experts consulted for this report highlighted that many of the top research groups for the development of components and hardware in different qubit technologies were based in Europe. This is also true for research groups focusing on system software and applications.

[10] While in absolute terms large economies such as China and India are ahead, the per capita density of quantum talent is higher in Europe. The United Kingdom is at the top of the table with over 1 800 quantum-related talents per million people, followed by the United States (around 1 000) and the European Union in third (around 700).

A second important condition for the development of complex, multidisciplinary technologies is the ability to connect innovations. Europe's second advantage in quantum science is the historically strong research and technology organisations (RTOs) and the world-leading quantum initiatives and research programmes at Imec, Fraunhofer, CEA and VTT.

> **"Europe's research and technology organisations are one of the cornerstones of a competitive European quantum industry. Research and technology organisations are a typical European phenomenon: high-tech, collaborative, supporting the private sector while driven by public purpose. In this unique role, RTOs are the oil in the European competitiveness machine, smoothing the interactions between academic knowledge and industrial capacities.[11]"**

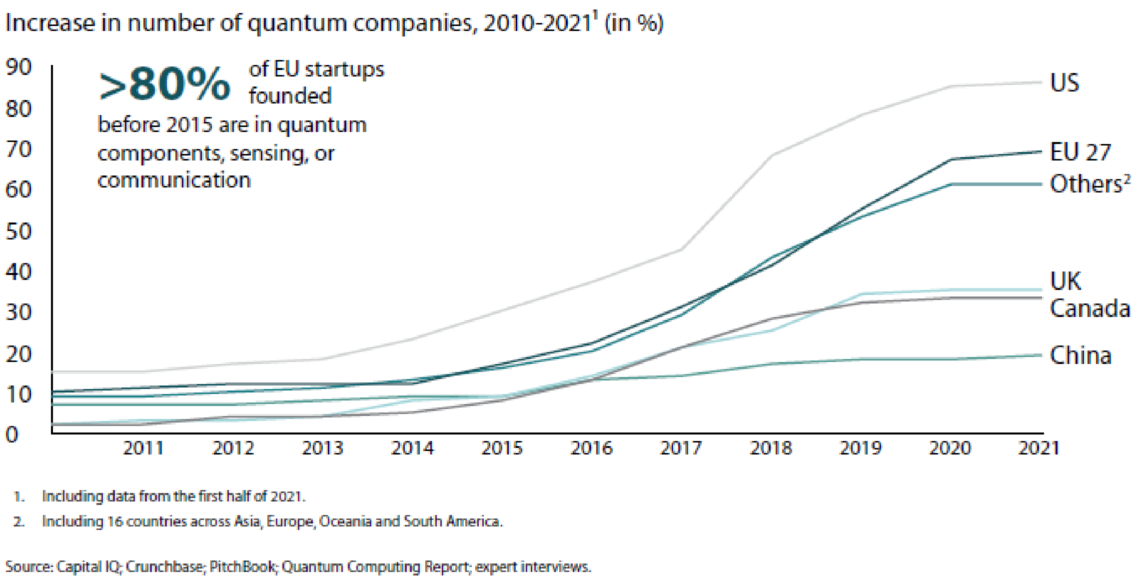
These organisations play a crucial role in supporting the growth of early-stage companies because they link up industry and academia across the entire value chain. As the European Investment Bank (EIB) Advisory Services previously noted in a study on research and technology organisations' access to finance, **access to technology infrastructure speeds up the development and adaptation of new technologies, especially so-called deep tech, such as quantum technologies**.

However, **the transfer of scientific excellence into commercial success also requires business experience**. Some European companies may have excellent scientific outcomes but overlook the areas investors focus on (product development, client acquisition or retention). A common theme that emerged from our interviews was that European founders of quantum startups often do not communicate well with potential investors due to limited financial and business knowledge.

Finding 2: The number of quantum startups has skyrocketed in Europe since 2015, but scaling them up is challenging because of slow commercialisation or limited evidence of commercial viability.

The strong European academic foundation has translated into a rapidly growing universe of young quantum technology businesses. Globally, the number of quantum companies has tripled, while in the 27 EU Member States it grew by a factor of four, from fewer than 20 in 2015 to 80 by the end of 2021. This places the European Union closely behind the highly developed US market.

Figure 5: Quantum startup activity has skyrocketed since 2015



[11] Access to finance conditions for research and technology organisations (RTOs) and their academic and industrial partners (eib.org).

The diversity of companies is also growing. Before 2015, when the quantum industry started to take off, the majority of European quantum technology startups were developing quantum components for communication or sensing. Since then, many new quantum computing hardware and software players have emerged.

However, many of these young companies struggle to raise the funding they need to survive and grow. **They often lack a proven track record, solid and established business models, or customer relations because they were too slow to focus on commercialisation.** This is particularly problematic for university spinoffs, for reasons that go beyond the business acumen of the founders.

While some universities and research institutes offer robust support, others, including some renowned institutes, tend to slow spinoffs down with long and complex procedures and negotiations. They need to become more effective in transforming academic breakthroughs into successful companies with the speed to match the progress in the quantum industry.

A second limitation is that **corporates in Europe are slow to take up quantum technology projects** because they perceive the development risk as too high or the potential payoff too far beyond the horizon of quarterly and annual reporting. There is an acute need to increase awareness of the potential benefits of quantum applications among potential end users so that quantum technology startups can secure the customers they need to attract investment.

Reliable commercial partners are essential for the long-term success of young quantum companies in Europe. For entrepreneurs, especially ones coming from academic backgrounds, it may be difficult to predict who their final customers and beneficiaries will be, or what the final product and/or service will look like. **The lack of collaboration with end users outside the quantum value chain is a significant obstacle to commercial development.**

Access to finance

STRENGTHS

Finding 3: The European quantum industry derives its strength from patient public capital, which has accelerated the development of fundamental research and high-risk early-stage ventures.

However....

BOTTLENECKS

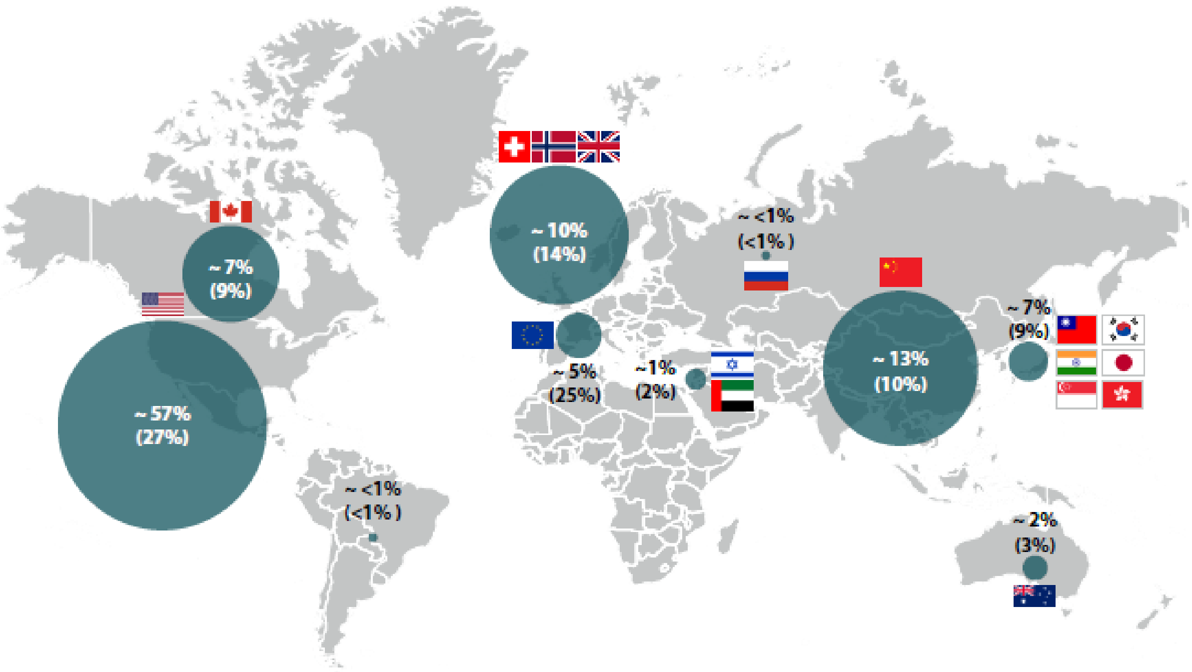
Finding 4: The pool of specialised private investors is limited and generalist investors have not filled the gap due to uneven knowledge and risk perception.

Finding 5: European quantum ventures raise fewer and smaller financing rounds compared to other leading regions, especially in later stages.

The European Union is home to 25% of all quantum companies worldwide, but accounts for less than 5% of global funding. The difficulties entrepreneurs have in demonstrating the technology's potential or traction with customers to investors creates friction. The underinvestment in the industry undermines the ability of European companies to develop and grow.

Figure 6: Despite having 25% of quantum companies, Europe has attracted only 5% of global financing

Share of global funding amount (and share of quantum technology companies) by region[1]



1. As of 2021. High-quality data on Chinese quantum technology investments are not available. As far as we know, well-funded Chinese players are mostly government-funded/owned research institutions. Startups have begun to emerge in recent years.

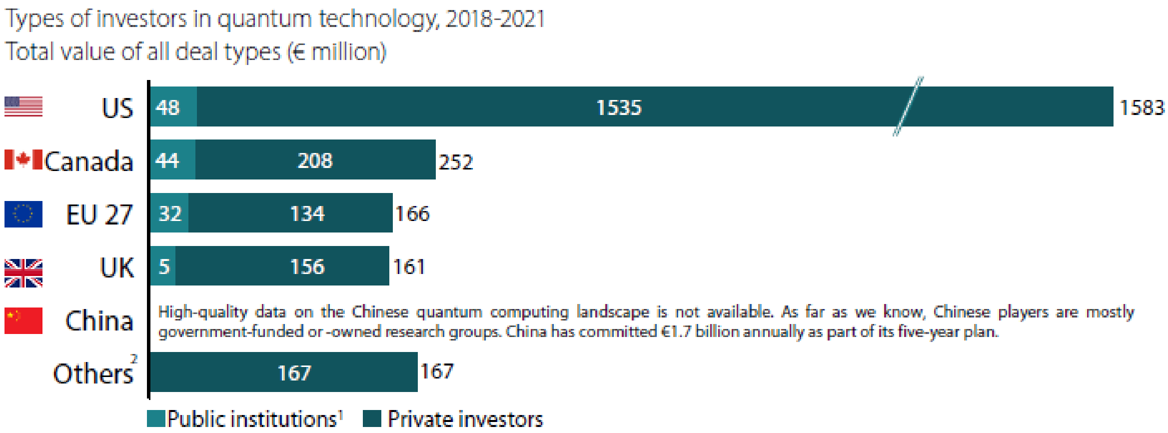
Source: Capital IQ; Crunchbase; Quantum Computing Report; PitchBook.

Finding 3: The European quantum industry derives its strength from patient public capital but needs stronger private capital flow to thrive.

Patient, non-dilutive public capital underpins Europe's stellar academic base and large pool of early-stage quantum technology ventures. Governments and public institutions in Europe invested €30 million to €35 million in quantum technology research between 2018 and 2021. Such support helps bridge the highest-risk stage of development — the so-called valley of death between fundamental research and early-stage commercialisation.

Strong public support is not uncommon for nascent industries such as quantum technologies, but it is disproportionately large in Europe. **Public financing in the European Union makes up around 20% of Europe's total financing of quantum companies (around €170 million)**. In the United States, although total funding was ten times larger (€1.6 billion), public funding accounted for just 3%.

Figure 7: Europe relies on public financing more than other regions



1. Includes governments, sovereign wealth funds and universities.
2. Including countries across Asia, Europe, Oceania and South America.

Source: PitchBook.

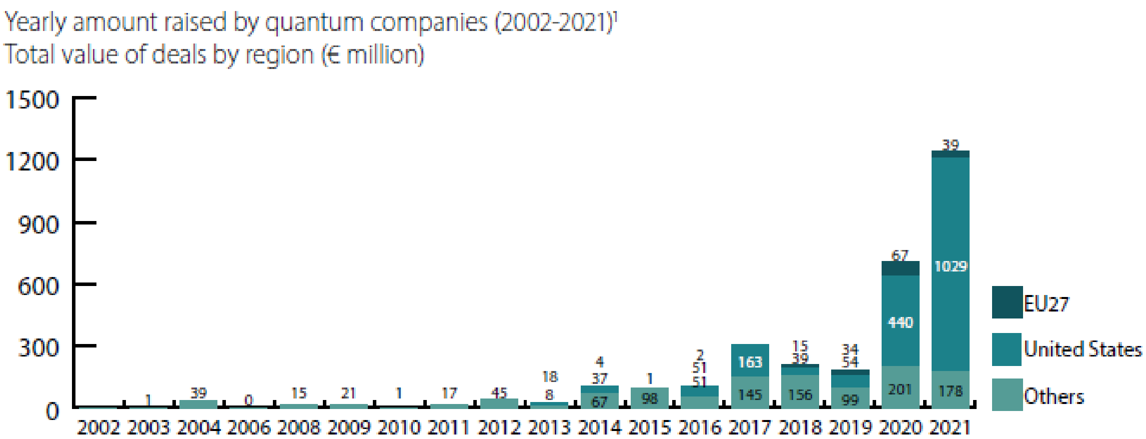
A vibrant quantum technology industry in Europe will require public and private funding to go hand in hand. Public financing still has an important role to play, for example in the development of supporting infrastructure (pilot lines, testing facilities, and quantum cloud computing or communication networks). **The European Union has earmarked €6.1 billion in funding for quantum technologies over the 2021-2027 period**. Germany alone has committed to €2 billion in investment over five years, about €0.5 billion of which was already deployed in 2022. Private investors need to step in, as they are best suited to supporting companies in the long run.

Finding 4: Europe faces a multi-year financing gap due to a limited pool of private investors that understand the specific market and technology risks of quantum technologies.

Private funding for quantum technology is on the rise globally, yet the European Union is lagging behind by a significant margin. Despite the vibrant European quantum startup landscape, the region has consistently underperformed in securing growth funding. Out of the €1.2 billion raised globally in 2021, quantum companies based in the European Union accounted for a mere €39 million, just over 3%.

The funding gap will only get worse without immediate action. Private funding for quantum technologies almost doubled between 2020 and 2021. Growth is expected to remain strong as quantum technology commercialisation gains traction.

Figure 8: European quantum companies raised only 3% of total financing in 2021



1. China was excluded from this overview due to lack of data transparency; for seven out of 19 deals in the second half of 2021, the deal amount was not disclosed.

Source: PitchBook.

The low funding volumes for European quantum technology companies are linked to the lack of specialised investors able to provide support throughout the entire company life cycle. Investment in quantum technologies requires specialised knowledge of the counter-intuitive laws of quantum mechanics and understanding of complex new technologies that have not yet been tested in the commercial market. European deep-tech investors are scarce and those that exist tend not to invest large sums. A lack of understanding makes it difficult for generalist investors to assess the disruptive potential, technology risk or viability of quantum technology business ideas.

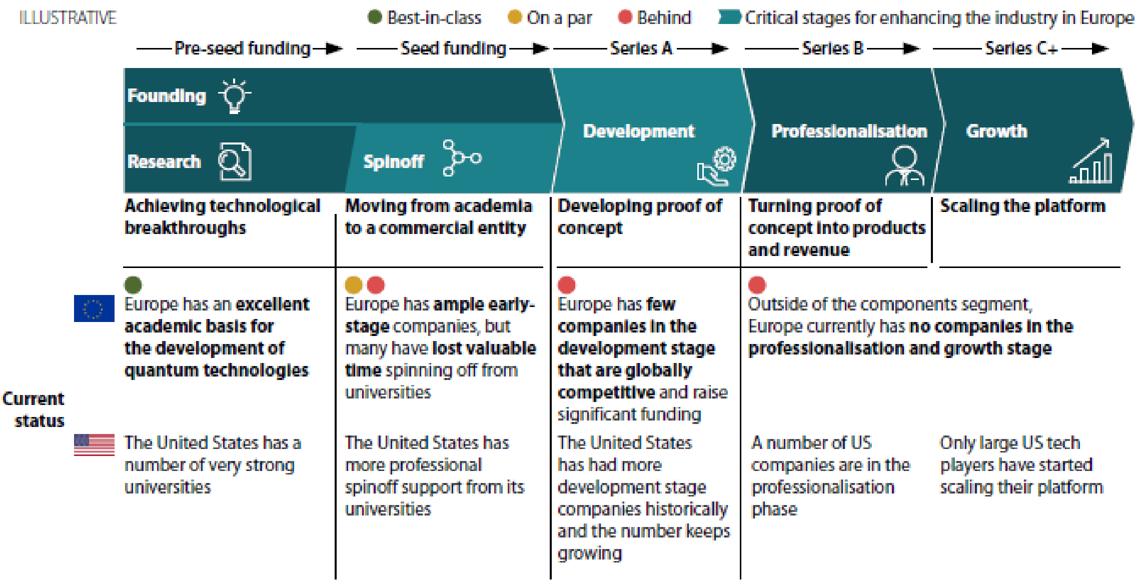
Furthermore, **there is a misalignment between the timescales of quantum development and the return horizons of average investment funds**. The massive return potential of quantum technology is too far in the future to counterbalance the high levels of uncertainty today. Mature quantum hardware may take five to ten years to materialise, which puts quantum companies out of step with traditional investor expectations of product development and revenue timelines.

Finding 5: Quantum ventures in Europe raise fewer and smaller financing rounds compared to their counterparts in other leading regions.

Limited access to finance in the early stages has impeded the growth of European quantum startups and is preventing them from reaching the scale needed to become market leaders. The public sector has played an important role in seeding early quantum research and development, but is unable to meet the demands of the scale-up stage.

A lack of appropriate funding for European companies impedes their growth and creates barriers to attracting investors seeking different risk profiles and more mature business models in later-stage funding rounds. **A self-sustaining quantum investment industry requires private European investors to step in.**

Figure 9: Early-stage financing in Europe is significant in comparison to other regions, but later-stage growth financing is substantially lacking



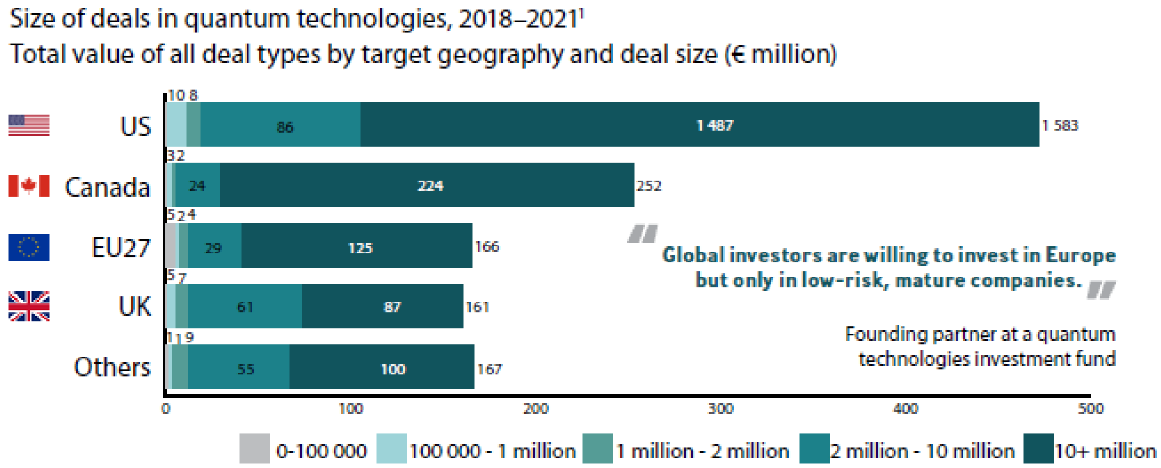
Rounds raised by region[1]	Seed: # deals	Seed: Median value (€ million)	Early-stage venture capital: # deals	Early-stage venture capital: Median value (€ million)	Later-stage venture capital: # deals	Later-stage venture capital: Median value (€ million)
EU	6	1.44	12	2.83	0	-
US	14	2.45	20	3.62	10	15.2

European startups have not received any later-stage funding, partly because they have not yet reached the growth phase (as of end-2021)

1. Based on public data available on Pitchbook; actual rounds are likely higher.

The lack of private funding for European quantum companies is evident in both the lower number and the lower overall value of funding rounds. The deal sizes for European quantum startups in all business life cycle stages and fundraising rounds (seed, early and growth stage) are smaller than those for comparable companies in the United States and Canada.

Figure 10: European companies are behind when it comes to raising rounds of more than €2 million



1. Excluding China, because of a lack of data transparency.

Source: PitchBook.

The cumulative effects of underinvestment are beginning to show. There are relatively few mature European quantum technology companies in the highest-value segments. In fundraising terms, **European companies raise today what companies in the United States were raising half a decade ago**. This further shrinks the pool of available growth capital: Many global investors are not interested in European early-stage small and medium-sized enterprises, as they perceive these companies to be too high risk.

Recommendations: How to build a dynamic quantum technology environment

The European Union is well-positioned to transform a vibrant universe of early-stage quantum companies into an industry of market-leading firms, expert investors and early adopters. Bold, coordinated actions are needed from all market players to shrink the funding gap, help quantum companies grow and thrive, and establish the European Union as a leading global quantum player.

We need to act now to bridge the knowledge gaps between academia, founders, investors and customers. We need to strengthen the industry at two critical junctures: the transition from technological breakthrough to a commercially validated proof of concept and the wider commercial scale-up of products and services. Private sector funding needs to match the significant sums coming from the public side.

The quantum industry may still be in the early stages of development, but it will become an unrivalled engine of economic growth, a source of competitive advantage for traditionally strong industries, and a draw for talent for the jobs of the future. We recommend the following subsets of activities to ensure we can meet Europe's quantum ambitions, supported by cross-cutting policy actions:

1. **Develop tech transfer:** Simplify the transfer of scientific leadership into commercially successful early-stage quantum technology ventures. Streamline public financial support for Europe's already strong research base to accelerate the transfer of fundamental research into a diverse pool of commercially viable quantum startups and reward the adoption of commercial best practices. Direct programmatic support for quantum-specific IT infrastructure (such as testing facilities and cloud computing solutions) that would enable earlier and cheaper experimentation and catalyse commercial partnerships.
2. **Fund growth finance:** Increase investment to accelerate the growth of promising and strategically important European quantum companies. Ensure that the most technologically advanced and commercially promising companies can access capital needed to grow and scale. Focus on expanding the volumes and types of funding available to quantum technology companies from both private and public sources to encompass pre-IPO (initial public offering), IPO and post-IPO financing.
3. **Widen adoption:** Create a flourishing quantum technology sector by bridging knowledge gaps within the investment community and increasing industry uptake of quantum technologies. Focus on capability-building activities with both first-time investors and end users, especially larger corporates in Europe's core industries. Lower the perceived risk of co-developing and deploying industrial applications based on quantum breakthroughs so that quantum startups can demonstrate their commercial viability faster.
4. **Amplify the impact of the preceding activities through EU-wide policy support:** Use strategic funding initiatives for related fields (such as semiconductors and supercomputing) to advance essential capital-intensive quantum projects. Convene industry consortia, inter-governmental bodies and innovation clusters to identify procurement incentives that would accelerate the uptake of quantum technologies in strategically important areas.

STRENGTHEN TECHNOLOGY TRANSFER

- Reorient grant funding to set up research and development projects for commercial success.
- Support quantum spinouts through technology transfer funds.
- Provide programmatic funding and planning support for quantum-related enabling infrastructure.

1

FUND GROWTH

- Attract more quantum ventures to existing European Innovation Council blended finance funding schemes.
- Increase venture capital funding available to quantum technology startups through a thematic European Investment Fund (EIF) line dedicated to strategic digital technologies.
- Increase the funding volumes of the EIB's venture debt and EIF's European Scale-up Action for Risk Capital (ESCALAR) and IPO Initiative to support later-stage quantum technology companies.

2

WIDEN ADOPTION

- Set up a dedicated quantum finance lab to bridge the knowledge gap between investors and the quantum industry.
- Support first-time funds investing in quantum ventures through dedicated capability-building programmes.
- Blend financial incentives with skill-development activities to foster commercial partnerships between quantum startups and industry.

3

AMPLIFY THROUGH POLICY SUPPORT

- Leverage the EU Chips Act or existing supercomputing infrastructure to scale up capital-intensive developments in the quantum sector.
- Collaborate with industry consortia and intra-governmental bodies to accelerate the uptake of quantum technologies in strategically important areas.

4

Strengthen tech transfer: Translating scientific leadership into commercial ventures

Reorient grant funding to set up research and development projects for commercial success

Grant funding has enabled Europe to develop a world-leading knowledge base in quantum technologies. Such bottom-up support for individual quantum research projects is a key step in bringing promising technologies to maturity. It could play an important role in bridging the gap between research projects and commercially viable spinouts.

Several successful programmes under the EU research and innovation funding programme Horizon Europe already fund the development of proof of principle and technological validation (corresponding to Technology Readiness Level, or TRL, 1-4). At these early stages of scientific research, companies can also access grant funding from the European Innovation Council (EIC) Pathfinder or the European Research Council. For projects in five key areas — supercomputing, artificial intelligence, cybersecurity, advanced digital skills and wider use of digital technologies — additional funding is available under the Digital Europe programme.

To reach a larger number of quantum technology startups, these programmes could set up specific calls for quantum technologies. For example, under the EIC Work Programme 2022[12] there is a dedicated call for "Alternative Quantum Information Processing, Communication, and Sensing." Such a model could be replicated in other Horizon Europe or Digital Europe activities.

The impact of these programmes would be amplified by a **commercialisation-focused grant funding scheme that links the capital provided to commercially relevant milestones**, for example, the development of a product prototype, intellectual property transfer and patent negotiation, or the integration of business capabilities. Such a funding scheme should also be streamlined, simple and with clearly communicated process and selection criteria. Finally, given the importance of collaboration, it should provide incentives to European universities and research institutions to pool resources.

The EIC Transition scheme, which funds activities to support both technological and business development, provides a template for how this could work in practice. For grant recipients with commercial promise, the EIC Pathfinder could incorporate a range of financial and non-financial incentives to track progress towards

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[12] EIC Work Programme 2022.

commercial milestones (such as patent and intellectual property rights protection) that seamlessly link into the EIC Transition scheme. Other grant programmes should explore ways to replicate this model.

Support quantum spinouts through technology transfer funds

Together with the bottom-up approach of supporting individual research projects outlined above, a top-down seeding of dedicated quantum technology transfer funds could help identify and support a much larger number of promising research teams developing products for the commercial market.

Academic research is often considered too novel and too high risk to be financed by traditional venture capital investors, and only a handful of European funds have tech-transfer seed investment on their radar. Technology transfer funds are important because they bridge the so-called valley of death between the initial intellectual property spinout and the entry of industrial partners or investors.

Unfortunately, existing technology transfer initiatives are not well-suited to supporting quantum ventures because they are limited by a generalist approach confined to a specific research institution. **A dedicated support scheme for technology transfer funds interested in quantum research would encourage tech-transfer offices to adopt quantum-relevant key performance indicators and actively seek out and support quantum projects and intellectual property with commercial promise.**

To break down silos and tackle the technology transfer challenge on a larger scale, the European Investment Fund (EIF) is providing support to thematic pan-European tech-transfer structures or funds — both financially and through feedback on the structuring of appropriate technology transfer instruments.[13] These intermediaries typically invest in projects or startups, from proof of concept up to standard venture capital or private equity series A and B rounds.

A pan-European technology transfer fund with quantum technologies as a focus would give scale to a fragmented sector and provide a visible platform to quantum ventures and investors. Examples of such thematic, inter-institutional tech-transfer funds backed by the EIF include the Czech i&i Biotech Fund I[14] and the deep-tech-focused University Bridge Fund in Ireland.[15]

Provide programmatic funding and planning support for quantum-related enabling infrastructure

Public funding over the years has enabled the development of the exceptionally strong knowledge and talent base of the European quantum technology sector. We recommend continuing to invest in foundational technologies whose high risk or scale place them beyond the reach of private investors. These investments need to prioritise the long-term competitiveness of the European quantum sector and follow a comprehensive roadmap to strengthen Europe's capabilities across the value chain.

Examples of such foundational technologies include testing facilities and pilot lines, hardware and cloud solutions for quantum computing and a quantum communications network linking EU quantum data centres. This backbone of enabling technologies would both accelerate the growth of European quantum startups and help retain and attract key talent. Concerted investment and collaboration with innovation hubs would be instrumental.

To bring profoundly useful quantum applications to market, we need to develop large-scale, error-corrected quantum machines and increase qubit counts. Pilot lines and access to rented quantum computing power lower the cost of prototyping. Open testing facilities allow for pre-industrial, experimental production on a small scale. Both are deemed critical for the further development of commercially viable quantum solutions, as they lower the barriers for experimentation with not-yet-proven technologies. Small quantum startups and large corporates exploring the opportunities of quantum technologies all stand to benefit from investment in the area.

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13 The EIF is also a cornerstone investor in KU Leuven/CD3 (Belgium), Chalmers Innovation Seed Fund (Gothenburg, Sweden) and Karolinska Development (Sweden).

14 EIF to invest €25 million to support biomedical tech transfer in Central Europe.

15 EIF invests in a new Technology Transfer fund for Ireland.

Fund growth: Increase investment to accelerate the growth of promising and strategically important quantum ventures

Once Europe's scientific superiority is successfully reflected in ventures with access to essential quantum resources for the development of commercially viable applications, we must ensure that European companies can scale up and grow into global leaders. Investors will need to re-think their investment criteria and expectations. A range of tailored financial instruments will further help startups and small and medium-sized enterprises achieve critical business milestones aligned with quantum technology development time frames.

Attract more quantum ventures to existing European Innovation Council blended finance funding schemes

A promising way to boost financing for quantum startups in Europe is through the European Innovation Council Accelerator. It combines grants (up to €2.5 million) with equity (up to €15 million[16]) as a minority stake in a funding round led by a professional private investor. Some quantum companies have already received funding under this scheme.

The EIC Work Programme 2022, "Technologies for Open Strategic Autonomy," identifies a set of key strategic areas (including quantum technologies) and corresponding specific objectives for which highly innovative startups and small and medium businesses are invited to propose pioneering solutions and breakthrough innovations. The call would offer an increased grant component of up to €2.5 million for technology development (technology readiness level 5/6 to 9), combined with an investment for scaling up in the range of €0.5 million to €15 million.

A dedicated quantum EIC Accelerator Challenge could catalyse EIC support for quantum startups, because they align selection criteria with the technological and commercial aspects relevant for quantum technologies. Such a challenge could include new applications of quantum technologies on the ground and in space, in line with the needs of the EU secure connectivity programme,[17] a proposal for a multi-orbital connectivity infrastructure (with both space and ground segments) under a public-partnership model.

Increase venture capital funding available to quantum technology startups through a thematic European Investment Fund line dedicated to strategic digital technologies

Europe faces a substantial lack of private capital in the quantum industry, which is hampering the growth of EU-based quantum ventures. Public sector investors in venture capital funds, such as the EIF, could have an important role as a catalyst in this area.

Within its mandate, the EIF has developed a new dedicated thematic funding line under InvestEU Equity that is directly relevant for the quantum sector. The funding line will channel around €7 billion into venture capital, private equity and private credit funds over the next decade, approximately €2 billion of which will be dedicated to financial intermediaries or investors that back strategic digital technologies, including quantum (among others).[18] It was modelled after a scaled-up vision of two successful EIF InnovFin equity pilots: EIF InnovFin Artificial Intelligence and Blockchain Technology and EIF InnovFin Space.

This funding line will provide equity investments and co-investments to or alongside business angel, venture capital, private equity and private credit funds that invest primarily in the EU 27. Generalist, specialised or mixed investment strategies are all eligible. The programme will purposefully encourage diversified geographical distribution to ensure a balanced allocation of capital to the private equity industry.

This dedicated programme will increase the total amount of funding earmarked for both early-stage and growth-stage quantum ventures established and operating within the European Union, and claw back investment market share from American or Chinese investors. European venture capital funds, specifically early-stage generalists, would also have an incentive to increase investment in quantum technology because of better visibility into exit opportunities. Crucially, access to EU-based investors would provide companies with invaluable advice and

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16 In some cases (for example cases of strategic importance for the European Union), this upper limit has been removed.

17 2023-2027 EU secure connectivity programme: Building a multi-orbital satellite constellation | Think Tank | European Parliament (europa.eu).

18 Other technologies related to cybersecurity, artificial intelligence, blockchain and distributed ledger technologies, cloud computing, internet of things, 5G-based services and microelectronics.

access to networks that would accelerate the development and adoption of quantum technology in key European industries.

Given the lack of European investors specialising in quantum technologies, the dedicated investment programme will be combined with a capability-building initiative for investors (see recommendations under 3.2).

Increase the funding volumes of the EIB's venture debt and EIF's European Scale-up Action for Risk Capital (ESCALAR) and IPO Initiative to support later-stage quantum technology companies

Quantum companies need capital with high tolerance for risk to scale up, but most do not fall directly into the sweet spot for venture capital investment. They have longer time-to-market validation, higher development risk, and in some cases, higher capital intensity. Venture capital may not even be a good fit for some — it is expensive and dilutive, especially over the longer time horizons and multiple investment rounds necessary to reach commercial launch.

Quasi-equity instruments such as venture debt, de-risking instruments for scale-up private equity, or easier access to public equity markets offer alternatives that may better meet the need of quantum scale-ups. Unfortunately, such instruments often have a broad scope and limited funding capacity. That diverts attention — and capital — from more complex emerging technologies such as quantum. **Dedicated scale-up funding capacity for quantum technologies needs to meaningfully increase** in order to provide sustained support to the multitude of young quantum companies as they mature over the next decade.

Non-dilutive scale-up funding

Less dilutive financing such as hybrid capital (quasi-equity or venture debt) could be an important growth-enabler. The European Investment Bank has launched a €500 million thematic venture debt facility for key enabling technologies[19] under InvestEU. Investment tickets under this facility range from €5 million to €50 million, a better fit with the needs of less mature quantum companies than the flagship European Growth Finance Facility, whose minimum ticket size is €7.5 million.

However, the scope of the thematic venture debt facility for key enabling technologies is broad and includes artificial intelligence, 5G, edge, internet of things, industry 4.0, advanced materials and advanced manufacturing. There is a risk, therefore, that quantum would not get the attention it needs under such a facility. To ensure the right level of dedication, **the EIB and the European Commission could develop a new dedicated thematic window under InvestEU that would focus on higher-risk key enabling technologies such as quantum**. The setup could be similar to other successful concepts, such as the Energy Demo Projects, the Future Mobility Facility and the InnovFin Infectious Diseases Facility.

IQM Quandum Computers gets a €35 million boost from the European Investment Bank

IQM Quantum Computers, a European leader in building quantum processors, has received €35 million from the EIB[20] to accelerate the development of Europe's first quantum-dedicated fabrication facilities in Espoo, Finland. The loan is part of the European Guarantee Fund's venture debt product. The company benefited from the support of the EIB Advisory Services.

The financing will support the commercialisation of IQM's open-source processor design software KQCircuits, the IQM-led consortium Q-Exa for quantum acceleration for high performance computing centres (HPCs), and the opening of the quantum fabrication facility. With this funding, IQM will have full control over quantum processor development, which will strengthen its European leadership.

IQM is building Finland's first commercial 54-qubit quantum computer with the Finnish company VTT, and Q-Exa is building a quantum computer in Germany. The computer will be integrated into an HPC supercomputer to create an accelerator for future scientific research. IQM has over 160 employees with offices in Paris, Bilbao, Munich and Espoo.

[19] Eligible technologies cover healthcare, artificial intelligence, quantum, 5G, edge, internet of things, industry 4.0, advanced materials and advanced manufacturing (apart from climate tech and future mobility, which are covered through a separate envelope).

[20] Finland: IQM's quantum fabrication facility gets a €35 million boost from the EIB

Some quantum companies may need even larger amounts of funding before they can generate revenue. Many quantum projects require financing above €100 million as they start to commercialise. The European Investment Bank could consider expanding its venture debt programme eligibility beyond €50 million, or could provide alternative additional debt financing linked to the achievement of milestones that are realistic for quantum technology companies.

Scale-up equity funding

European Scale-up Action for Risk Capital (ESCALAR) is another prominent initiative building on a European Fund for Strategic Investments pilot. It was specifically designed by the EIF to support scale-up financing. Unlike standard direct pari-passu investments, ESCALAR proposes asymmetric share classes or fund units of the fund (or its side fund) that benefit from additional protections. ESCALAR will reduce both the EIF's investment risk and its expected return compared to other, riskier share classes or fund units and at the same time will provide higher upside return for other share classes. ESCALAR targets fund managers with a specific investment strategy covering scale-up financing.

Public equity markets can offer a substantial pool of capital for scale-ups. Unfortunately, a significant proportion of EU companies seek to fund their growth by accessing finance beyond the European public equity markets. The EIF-led IPO Initiative (under InvestEU)[21] aims to help technological and innovative companies access European public equity markets. The initiative will seek to strengthen the European Union's public market environment by supporting investment funds that target pre-IPO and/or public equity market investments in European small and medium firms and mid-caps (with up to 3 000 employees).

Widen adoption: Bridge knowledge gaps within the investment community and increase uptake of quantum technologies

Set up a dedicated quantum finance lab to bridge the knowledge gap between investors and the quantum industry

Quantum technology solutions need to be developed in line with the needs of core European industries, and EU-based companies need to retain key intellectual property and skills to ensure technological sovereignty and the long-term competitiveness of European quantum technology solutions.

Regular dialogue between a broad range of stakeholders will help bridge knowledge gaps and find creative ways to meet the specific and rapidly evolving needs of the quantum industry. We recommend setting up a dedicated European quantum finance lab that would convene key stakeholders, such as quantum entrepreneurs, corporate representatives from key industries, investors, academics and research and technology organisations, policymakers and regulators.

The quantum lab would be a forum to test ideas for new financing instruments and policies, showcase latest developments in the financing of quantum ventures, raise awareness of existing and upcoming funding programmes, and identify projects that could benefit from them. It would also foster an integrated financing chain for European quantum companies that spans innovation agencies, national promotional banks and institutions, the European Innovation Council, the innovation hubs of the European Institute of Innovation and Technology, and the wider investor community.

The EIB Advisory Services department is well placed to implement this recommendation, drawing on its experience setting up a finance lab for the space sector and its strong links with the innovation community and the European Commission.

Support first-time funds investing in quantum ventures through dedicated capability-building programmes

Knowledge gaps make it more difficult for generalist investors to seek out and evaluate investments in quantum technology companies. These gaps include limited understanding of the core technologies, the lack of an overview of the long-term development and commercial prospects of the market, and misalignment between a fund's stated investment criteria and the risk profile and development time horizons of quantum companies.

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21 Addendum for InvestEU IPO Initiative

A dedicated capability-building programme could educate investors and increase interest (and investment) in quantum technology. For example, the InvestEU windows for small and medium-sized enterprises and for research, development and innovation call for specific investment support activities to raise awareness among the investor community about strategically important digital technologies, facilitate matchmaking, showcase success stories and enhance the investment readiness of potential investment programmes.

Similar programmes include the recently launched CASSINI Seed and Growth Funding Facility, a skill-development programme for fund managers interested in the space sector,[22] or the BlueInvest capability-building programme for both fund managers and their (prospective) limited partners.[23] A quantum-dedicated programme should target fund managers that are still weighing up whether to start engaging with quantum, giving them access to market trends, investment studies and expert insights from industry organisations, the European Commission and public investors. They could also benefit from advice on how to structure a quantum-aligned fund, investment strategy and investment team. Finally, the programme could provide a forum to discuss business models and best practices, and to network with other fund managers active in other relevant sectors.

Blend financial incentives with skill-development activities to foster commercial partnerships between quantum startups and industry

A dedicated set of industry-building activities would need to **supercharge the uptake of quantum solutions by industry and give researchers more insight into commercial demand for quantum applications**. Because end users need to cross a threshold of what they view as possible and imagine things they have never seen before, it is crucial to link quantum technology companies with the potential end users of quantum-based applications as early as possible.

We recommend testing and exploring various incentives and partnership models to harness the market power and reach of industry consortia[24] and catalyse Europe's quantum technology sector. This will also ensure that disruptive quantum-based applications address the needs of key European industries and government entities.

Financial instruments could encourage quantum companies and industry partners to collaborate and develop end-to-end solutions. Examples of such bottom-up incentives include project-based funding for startups and industry working in a consortium, and risk-sharing facilities where the EIB takes a share of the risk and return of a ring-fenced research and development programme.

Industrial players already interested in co-developing quantum technology solutions also need to easily identify suitable partners. **Matchmaking initiatives** could include hackathons or the establishment of startup incubators with clearly defined goals, such as market validation, prototype development, customer acquisition, foundational enabling technologies/backbone, etc. **Better awareness of one-stop sources of information about specific quantum technology companies or clusters**, such as the European Enterprise Network, would also make scouting and collaboration easier.

One example of a top-down initiative to pool resources and help companies see beyond the possibility threshold is the Finnish technical research centre VTT's foresight programme to **help companies identify what they can do in their specific industry at each qubit capacity progression**. This is a powerful way to showcase the potential of quantum technology in geographic locations with dense industrial clusters (for example automotive clusters or pharmaceutical/chemical clusters) and focus development on the most relevant use cases.

22 CASSINI — Access to finance (europa.eu), supported by the European Commission, the EIF, the European Space Agnecy and the EU Agency for the Space Programme.

23 Maritime Forum (europa.eu).

24 Established pan-European quantum consortia can play an important role, for example the European Quantum Industry Consortium (QuIC), which includes several world-leading companies developing quantum hardware, software and enabling technologies. QuIC operates as a collaborative hub throughout Europe to build a vibrant ecosystem with strong links between small and medium firms, large corporates (including Thales, SAP, Airbus and BASF), investors and leading researchers.

Amplify the impact of the preceding activities through EU-wide policy support

Leverage the EU Chips Act or existing supercomputing infrastructure to scale up capital-intensive developments in the quantum sector

A number of existing EU-backed deep-tech initiatives supporting the development of semiconductors and supercomputing could help implement our recommendations faster and more efficiently. **Calls for proposals specific to quantum technologies would help direct funding to the companies that need it and enable long-term planning for a substantial capital investment in quantum chip production, testing facilities and other enabling infrastructure.**

Quantum technology meets semiconductors

The European Chips Act is a comprehensive set of measures to ensure security of supply, resilience and technological leadership in semiconductor technologies and applications. It aims to mobilise more than €43 billion of public and private investment to bolster Europe's competitiveness and resilience and help implement the digital and green transitions.

One key component is the Chips for Europe Initiative, which provides €11 billion in funding to strengthen the research, development and deployment of advanced semiconductor tools, including quantum chips. It will help set up pilot lines for the prototyping of new devices for innovative real-life applications, staff training, and the development of the semiconductor ecosystem and value chain. **Targeted calls for proposals for quantum technologies covering a pre-determined target funding level will ensure quantum technology does not get overlooked.**

In addition to the planned direct support for companies, some of the Chips for Europe Initiative funds are being deployed as financing schemes. For example, €125 million has been allocated to funding an EIF initiative to foster a more specialised venture capital and private equity community, via an InvestEU top-up. The initiative aims to educate the general public and innovation community about quantum technology and equip the venture capital and private equity community with the necessary skills to invest in such projects and businesses.

Quantum technology meets supercomputing

The development of quantum computing in Europe could benefit from the European High Performance Computing Joint Undertaking (EuroHPC JU), a joint initiative between the European Union, European countries and private partners to develop a world-class supercomputing industry in Europe. **Local quantum-meet-supercomputing centres of excellence — such as one currently being developed in Finland[25] — offer a blueprint for collaboration.**

Finland's quantum processor is comparatively small (just five qubits), but can already integrate with the pan-European LUMI supercomputer. This will make it possible to do things that could not previously be done, and will shed a light on how the quantum processor fits into the supercomputer workflow for real end-user problems. Investments in technological developments and projects to support this integration could yield benefits for initiatives and shorten the time frame for the development of commercially validated applications.

Collaborate with industry Consortia and intra-governmental bodies to accelerate the uptake of quantum technology in strategically important areas

Many potential applications for quantum technology touch areas of strategic priority for the European Union. Beyond activities to encourage collaboration between players in core industries and quantum companies, Europe should explore public procurement for innovation initiatives as a way to encourage focus on product development and client acquisition.

Procurement incentives are particularly powerful when they shorten the time it takes for quantum companies to find clients and generate revenue, two important signals of business maturity for investors. The incentives could also prompt quantum technology companies to seek out customer feedback to fine tune their products. Finally, they could provide an important stamp of approval that would encourage industries to also explore quantum solutions.

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[25] The Ecosystem: Finland punches above its weight in quantum | (sciencebusiness.net).

For example, the European Union could provide dedicated support for quantum applications that would advance the European Green Deal. These could include collaboration projects between large energy providers and startups or specific challenges under the EIC (Pathfinder, Transition and Accelerator, depending on the level of technological maturity).

Conclusion

European quantum companies have the potential to lead the global quantum technology industry. Breakthroughs and leadership by European researchers underpin many promising quantum startups. Patient public capital has accelerated the development of world-class quantum talent and a vibrant and diversified community of early-stage quantum ventures.

The European Union is home to 25% of the world's quantum companies, yet accounts for less than 5% of global funding. Companies struggle to scale commercial operations due to a lack of business experience, knowledgeable investors or commercial partners. As a result, European quantum companies do not have enough funding and cannot compete with counterparts from other leading regions.

A community of market-leading companies, expert investors and early industrial adopters could enable European quantum ventures to translate scientific excellence into transformative quantum innovations. We recommend a mix of policy and financing measures to accelerate the journey from academic knowledge to large-scale commercial success.

First, we need a shorter path from research projects to commercially successful spinouts. This will require more commercial focus from grant programmes, expanded investment from technology transfer funds in quantum ventures and investment in important IT infrastructure to reduce the costs of prototyping and collaboration.

Second, we need more investment to accelerate the growth of these promising young quantum ventures. Blended finance instruments such as the European Innovation Council Accelerator need to reach more quantum startups facing the post-spinout valley of death. They need to be supported by a significant expansion of private venture capital, boosted by an EIF funding line for strategic digital technologies. Larger volumes of non-dilutive scale-up funding from the EIB and EIF could bridge the later-stage funding gap.

Third, we need to mobilise investors and corporates to create a knowledgeable quantum community and increase industry uptake of quantum technologies. A dedicated quantum finance lab could encourage regular dialogue between a broad range of stakeholders. Dedicated capability-building programmes could increase the number of investors with knowledge of quantum technologies. Financial instruments and skill-development activities could encourage more corporates to test and co-develop quantum solutions.

Finally, we need targeted policy support and capability-building activities to augment the impact of the above-mentioned activities. The quantum industry will benefit from the long-term horizons and large pools of capital envisioned for strategic technologies such as semiconductors and supercomputing. Public procurement incentives could shorten the time it takes for quantum companies to find clients and reach investor milestones.

Quantum technologies offer a vision of a healthier, more sustainable and resilient Europe. They will one day enable disruptive innovations that could transform our societies, economies and almost all industries by solving problems that have eluded even our most powerful computers. From chemicals and life sciences to finance and renewable energy, quantum technologies can speed up the development of ground-breaking new products and improve the ways we do things now.

A quantum leap in finance

How to boost Europe's
quantum technology industry

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PDF: ISBN 978-92-861-5404-1

2022-0112