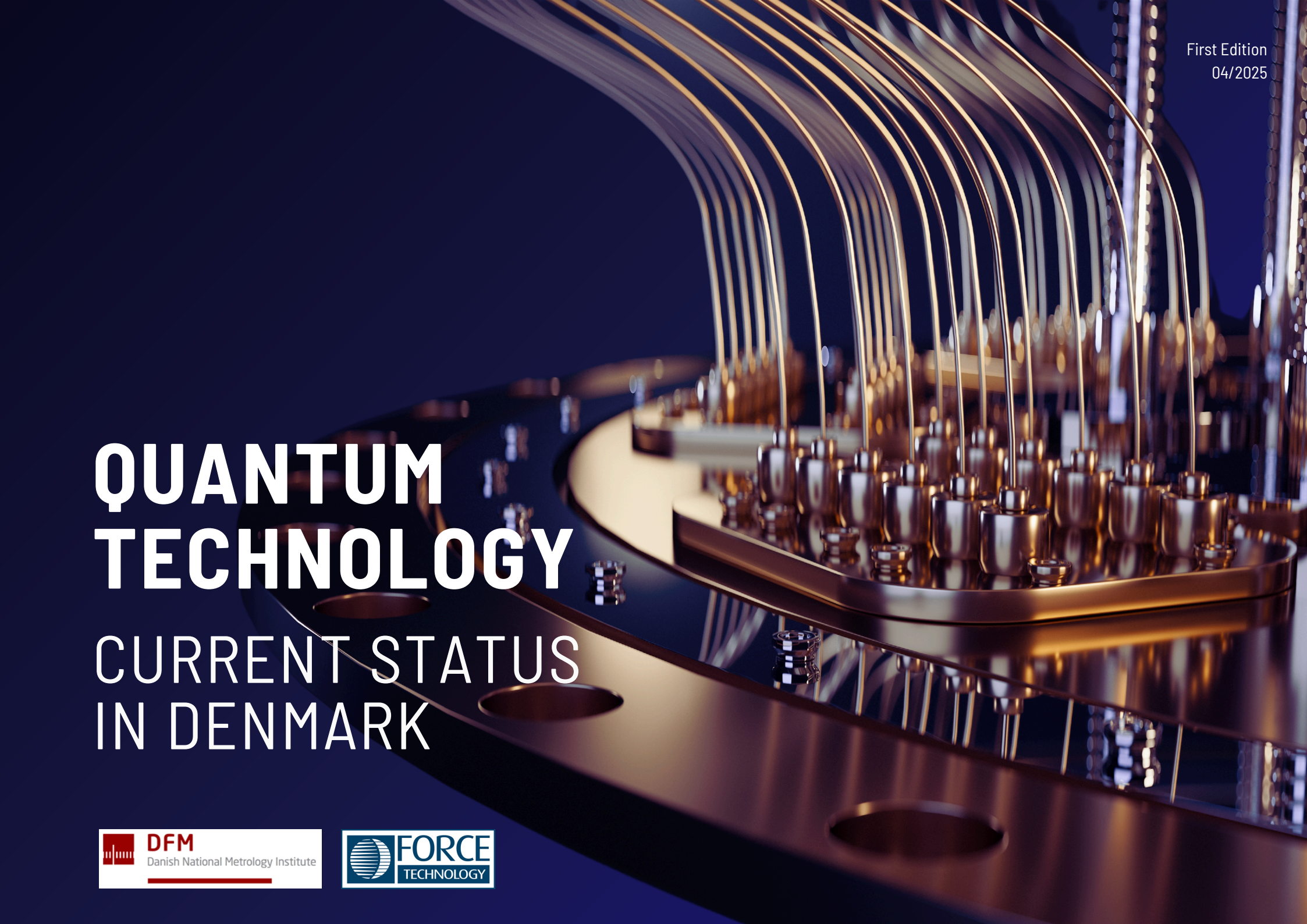
First Edition
04/2025



QUANTUM TECHNOLOGY

CURRENT STATUS IN DENMARK

DFM
Danish National Metrology Institute

FORCE TECHNOLOGY

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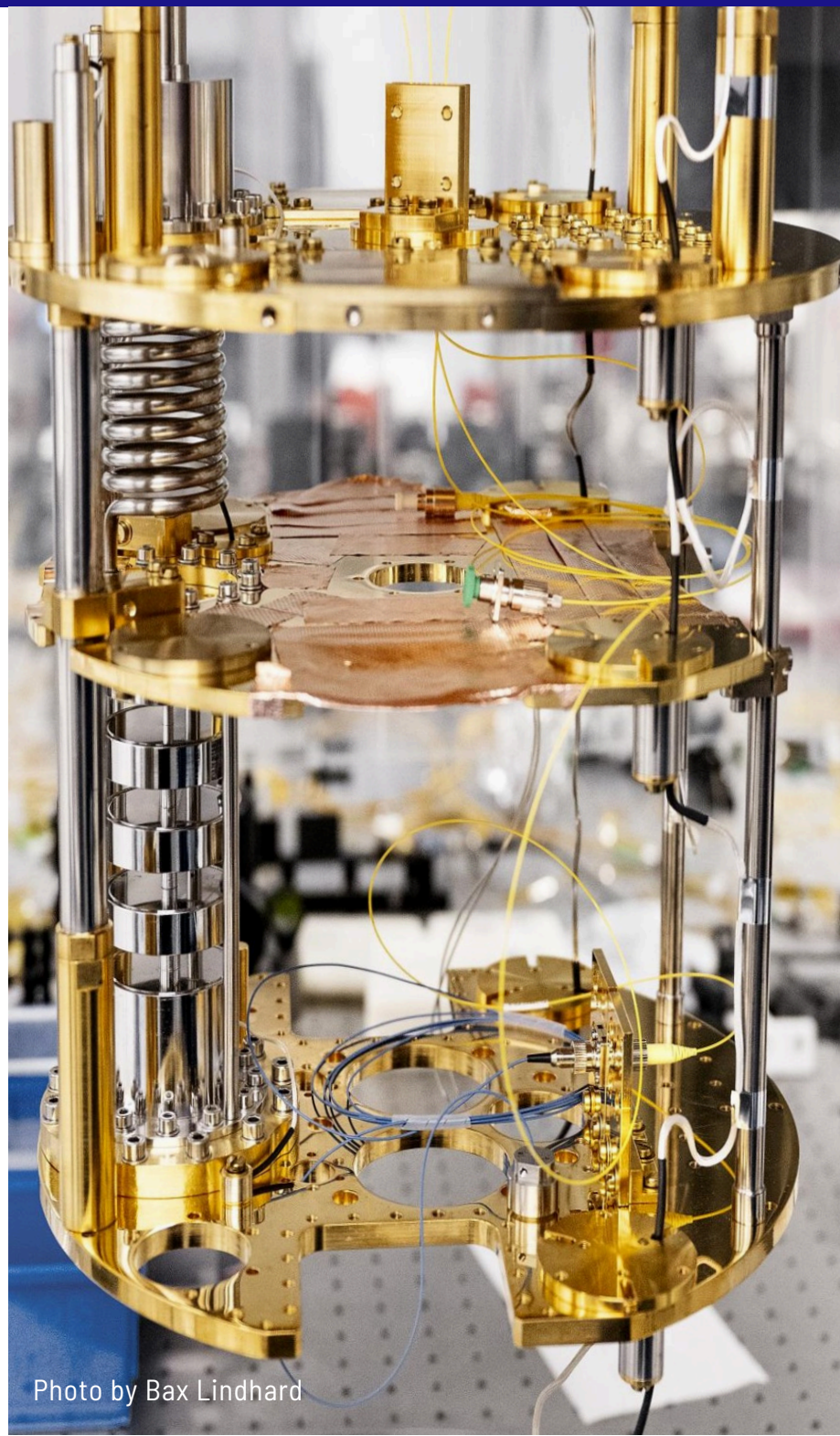

Photo by Bax Lindhard

PREFACE

In September 2023, the Danish Government unveiled a national strategy for quantum technology, focusing on research and development, commercialization, safety, and international cooperation. Denmark is committing significant investments in quantum technology, reflecting the billions DKK already allocated and the substantial future funding planned. Globally, quantum technology holds immense strategic importance, with implications for security, as its potential can be exploited militarily and poses risks to cyber and information security. At the same time, quantum technology offers a global competitive edge in innovation. It drives advancements across computing, healthcare, artificial intelligence, and energy efficiency, which is a key reason for the international push in this field. In light of both the Danish Government's and the EU Commission's directives, there is an urgent need for Denmark to develop and implement these strategies effectively.

This report aims to illuminate the current state and intricacies of Denmark's quantum technology ecosystem.

Through an in-depth, interview-based study, DFM (Dansk Fundamental Metrologi) and FORCE Technology have gathered insights from diverse stakeholders across research and industry. The work has been partially commissioned by Dansk Standard and funded by the Ministry of Higher Education and Science. The study investigates how best to implement future quantum technologies while fostering a robust and collaborative infrastructure in Denmark. Significant advancements in utilizing the principles of quantum mechanics are paving the way for ground breaking applications across various domains. These applications leverage quantum mechanical phenomena such as entanglement and superposition to achieve unprecedented levels of performance and functionality.

The development and application of quantum technology require a multidisciplinary approach, bringing together physicists, engineers, computer scientists, and industry experts. As research progresses and quantum technology integrates into everyday life, it is expected to drive significant innovation and economic growth, further solidifying Denmark's leadership in this transformative field.

The following participants were interviewed in the survey: Accelink, Atlant3D, CenSec, ConScience ApS, Danish Life Science Cluster, Dencrypt, DigitalLead, DTU Elektro, DTU Fysik, DTU Nanolab, EnergiNet, EnergyCluster, IBM, Indesmatech, KMPG, Kvantify, Københavns Universitet - Quantum Optics, Københavns Universitet Quantop, Københavns Universitet NQCP, Maybell Quantum Industries, Microsoft, MQS, NLIR, Partisia, Qpurpose, Quantum DTU, Quantum Foundry, Quantum Machines, Riverlane, SiPhotonic, SDU (Ctr. QM), Sparrow Quantum, Topsil, Trifork, Zeuxion, and three large companies (anonymized).

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Foto: Noah Wotton, Unsplash

CURRENT INITIATIVES

Several ongoing initiatives, relevant to this report, facilitate and support the growing quantum ecosystem:

Quantum Denmark (national strategy): Quantum House Denmark and Quantum Test Center Denmark, offer specialized quantum testing, entrepreneurial support, and a collaborative hub for synergy and innovation.

International Collaboration (national strategy): Partnerships via the Innovation Centre Denmark / the Ministry of Foreign Affairs enhance global knowledge exchange, testing opportunities, and investments.

Export and Investment Fund of Denmark (national strategy): Invests in quantum ventures, bridging research and commercialization opportunities.

Danish Standard and Standardization (national strategy): Establishes technical and safety guidelines to promote secure and consistent technology adoption.

Enhanced Access to Quantum Computers (national strategy): The Danish e-Infrastructure Cooperation (DeIC) expands opportunities to work with quantum hardware and algorithms.

Innovationsfonden's Quantum Program (national strategy): Bridges basic research and market-ready solutions, funding both academic and commercial projects.

Danish Quantum Community: Unites universities, companies, and public institutions to raise awareness and foster a stronger quantum ecosystem.

NATO DIANA: A defence-focused innovation accelerator (Defence Innovation Accelerator for the North Atlantic) supporting quantum-related research with potential security and defence applications.

BioInnovation Institute Quantum Accelerator (Novo Nordisk Foundation): Offers deep-tech startups in the quantum and life sciences sectors access to mentorship, funding, and specialized lab resources, helping drive commercialization.

Novo Nordisk Foundation Grants: Provide substantial support for leading-edge research and education, strengthening teams and fueling commercialization.

Dansk Industri Digital: Fosters digital innovation within quantum technologies across businesses, strengthening industry engagement and competitiveness.

Collectively, these measures address many of the challenges examined in this study, including the need for specialized infrastructure, stronger funding and investment mechanisms, and more robust international ties. This study explores how such initiatives can guide and support the quantum ecosystem, offering insights for decision-makers seeking to foster sustained growth in this emerging field.

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THE AIM OF THIS STUDY

The overarching goal of this study is to provide insights that will strengthen Denmark's infrastructure for quantum technologies. These insights were obtained through interviews with key stakeholders and experts in the field.

The study focused exclusively on companies based in Denmark for which quantum technology is relevant.

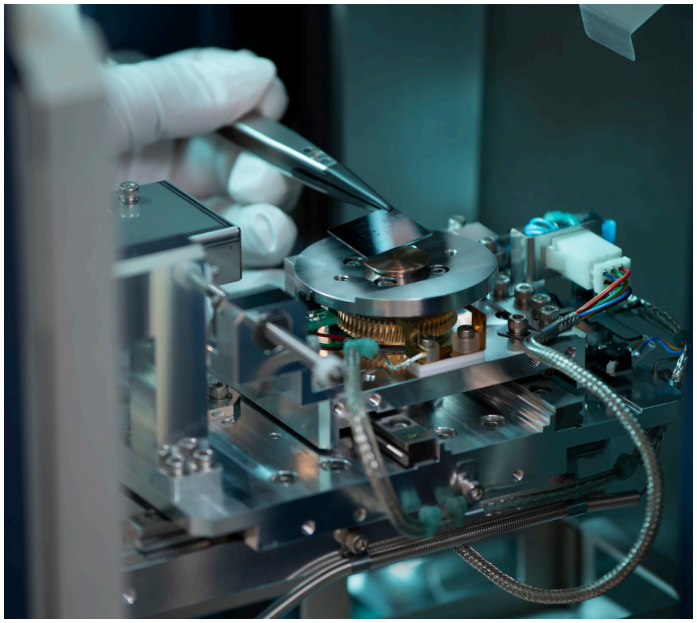
The study has four main objectives:

1. Examine how Danish industry is engaging with quantum technology.

2. Gather insights into collaboration practices.

3. Assess how existing test facilities can be adapted to support future quantum technology testing.

4. Identify the need for new standards to support the development and implementation of quantum technologies.



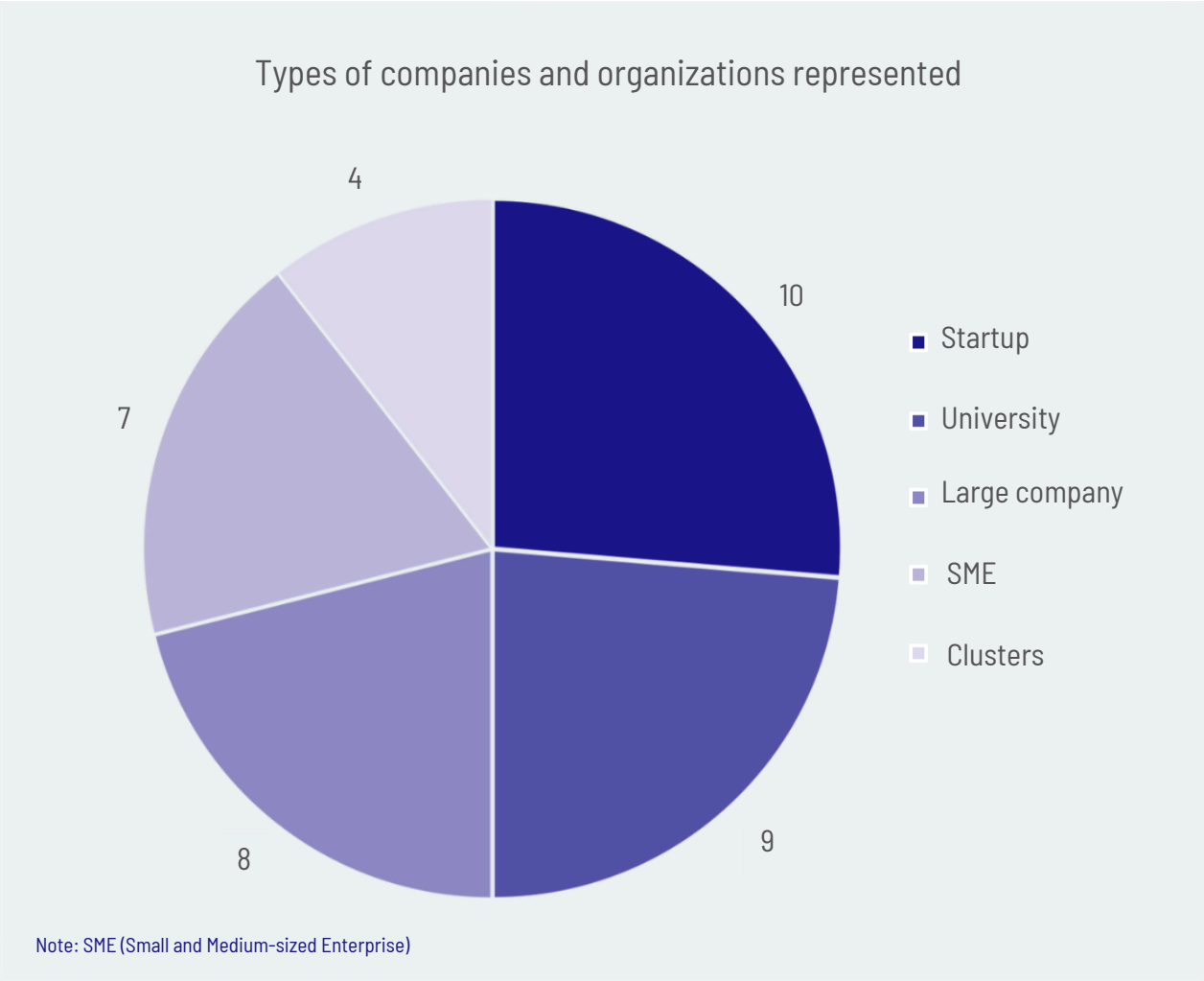
METHOD

A total of 55 actors were identified as relevant for inclusion in this study. This list was elaborated with input from the Danish Quantum Community, Danish Industry, the Danish Business Authority, and the Ministry of Foreign Affairs. Of these, 38 organizations participated in the survey. DFM and FORCE Technology conducted 38 structured interviews each of approx. 30 minutes duration, using a manuscript, ensuring uniformity in the Q&A's. The interviews were conducted in late summer and autumn 2024.

The interviews focused on:

- Position in the Ecosystem: Role and importance of quantum technology.
- Barriers to Development: Challenges faced by organizations.
- Collaboration: Nature and significance of partnerships.
- Testing Facilities and Certification: Need for access to testing and certifications.
- Standardization: Role of standards in scaling quantum technologies.

The format allowed for detailed insights during a workshop with participants, enhancing the understanding of Denmark's quantum technology landscape.



PART 1: ECOSYSTEM, MATURITY, IMPORTANCE NOW AND IN THE FUTURE

This section provides an overview of the Danish quantum sector. The survey participants fall into the following categories: Universities, startups, SMEs (Small and Medium-sized Enterprises), clusters and large companies. This covers quantum related activities for enabling technology providers, end users, test and demonstration facilities, startup accelerators, venture capital firms, foundations, research and government entities etc.

Their diverse backgrounds reflect the collective focus within the Danish quantum ecosystem. Overall, research activities dominate the Danish quantum landscape.

"Our go-to market strategy is to focus on teaching, education, and development because that is where we see a market today."

CONSCIENCE

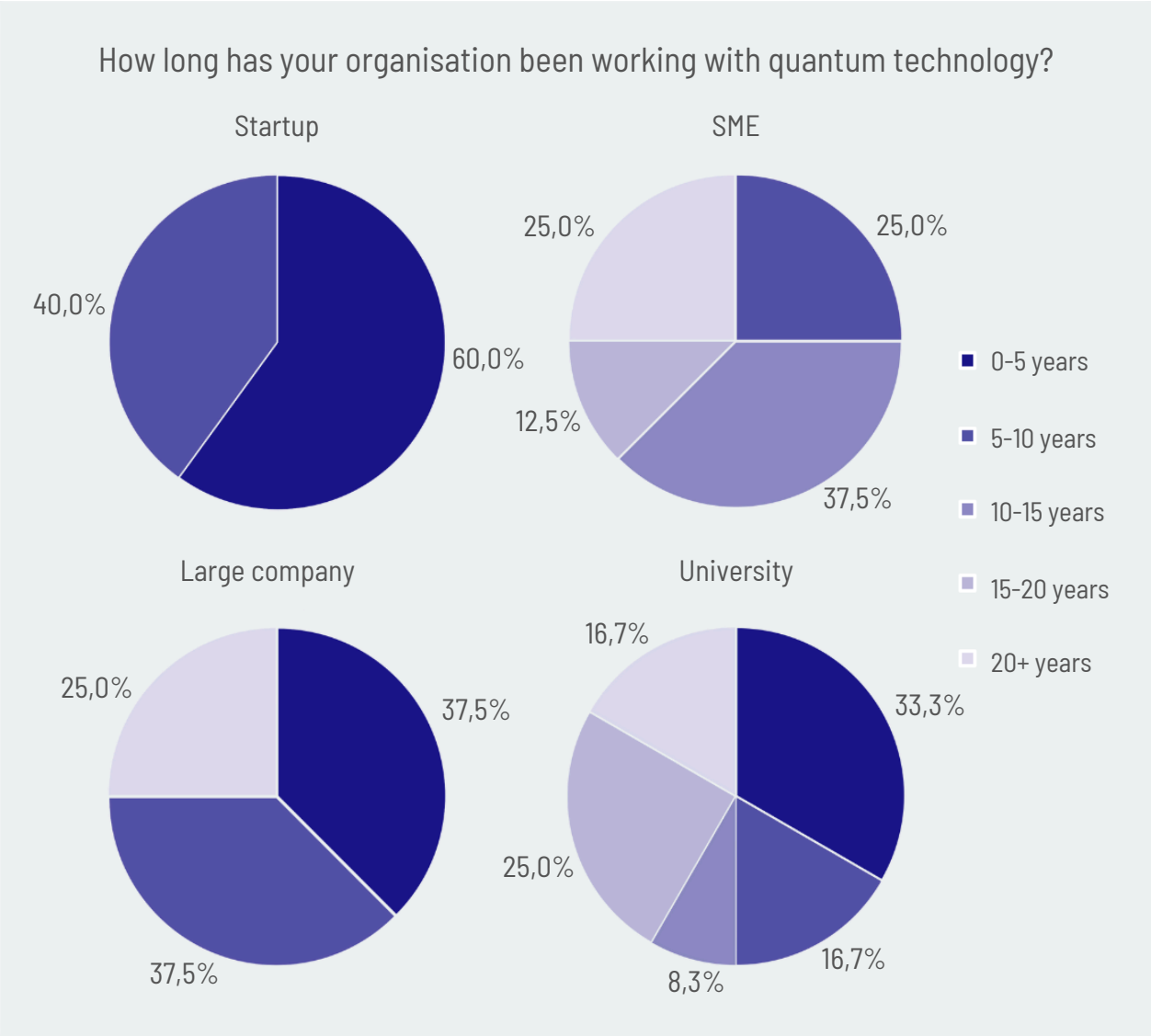
"When we make a competence center, as we just did in the area of chips and focus on quantum chips, then it is the universities with their profiles and research that can create cohesion [...] of course it will influence the labor market and create startups. "

QUANTUM DTU

"The main goal is, of course, to create a general quantum computer that can solve all our problems. Presumably, before we reach that stage, we will be able to design quantum computers that will be good at solving specific problems. And our main goal is to develop some form of (quantum) technology. Either a general or specific (technology), which should be able to solve problems within medical science or the green transition. "

NQCP

INVOLVEMENT IN QUANTUM



Companies were asked about the duration of their involvement in the quantum industry. Responses indicate that engagement in quantum technology varies significantly across organizations — from well-established institutions to emerging startups — each with their own timeline and level of commitment.

Universities' engagement dates back to the very early days of quantum mechanics, but the involvement in quantum technologies for different university groups varies from 5 years and up. Many participating companies are recently founded startups, which have worked with quantum technology for less than 10 years. Consequently, it highlights the potential value of forming a quantum community to involve small and emerging enterprises in the quantum technology domain.

SMEs have a widely varying involvement in the field, ranging from 0 to 20 years. Most large companies have been involved within the last 5-10 years but two large companies show long involvement of more than 20 years. Such varied levels of experience suggest there may be value in providing tailored support and fostering collaboration among different types of organizations in the quantum technology sector.

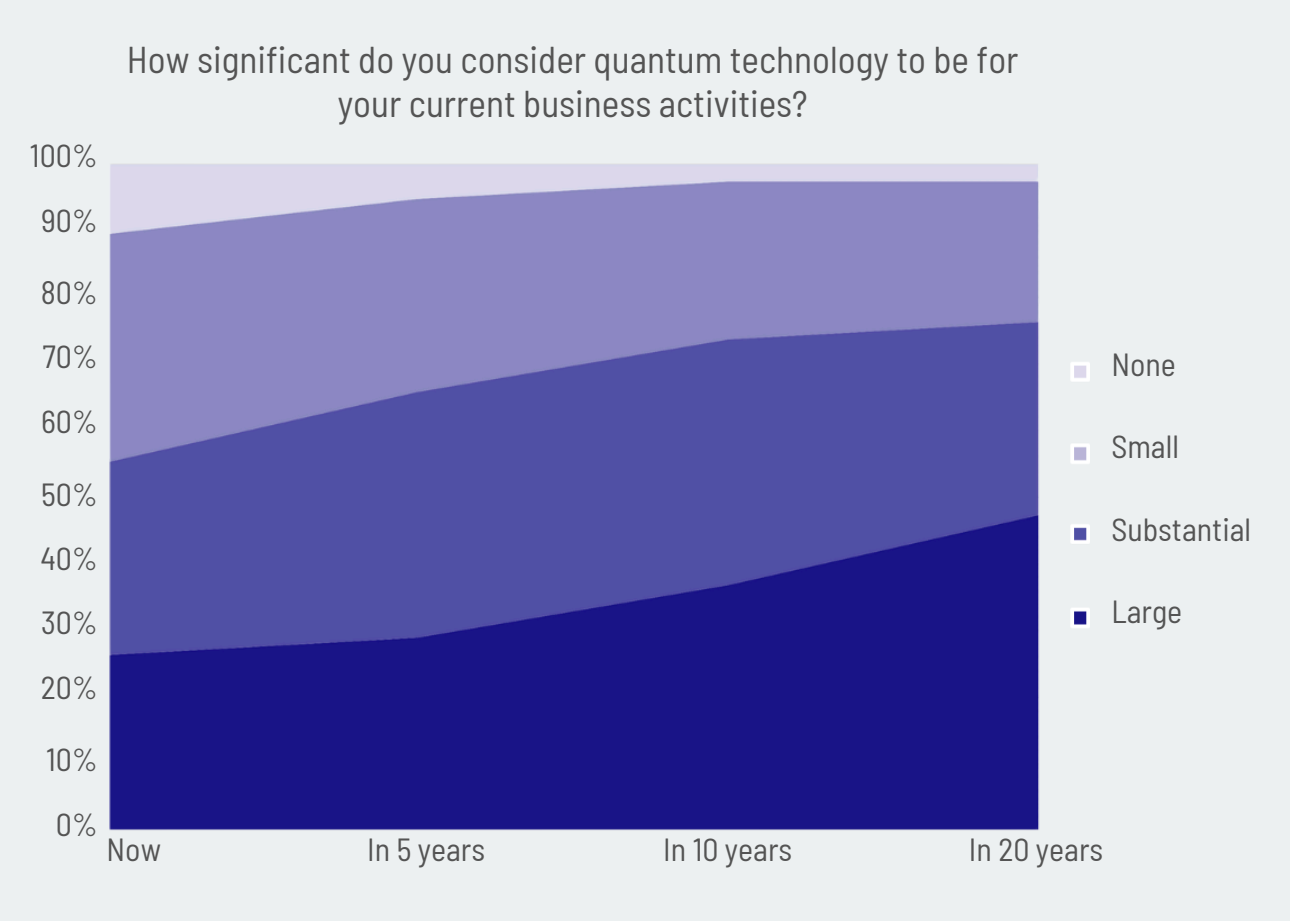
INVOLVEMENT IN QUANTUM LOOKING FORWARD

In our survey, companies were asked about the significance of quantum technology in their operations. Their insights reveal a gradual yet transformative shift—from limited early adoption to a future where quantum becomes central to business strategies. The projections over 5, 10, and 20 years capture this evolving landscape, highlighting growing investment and integration.

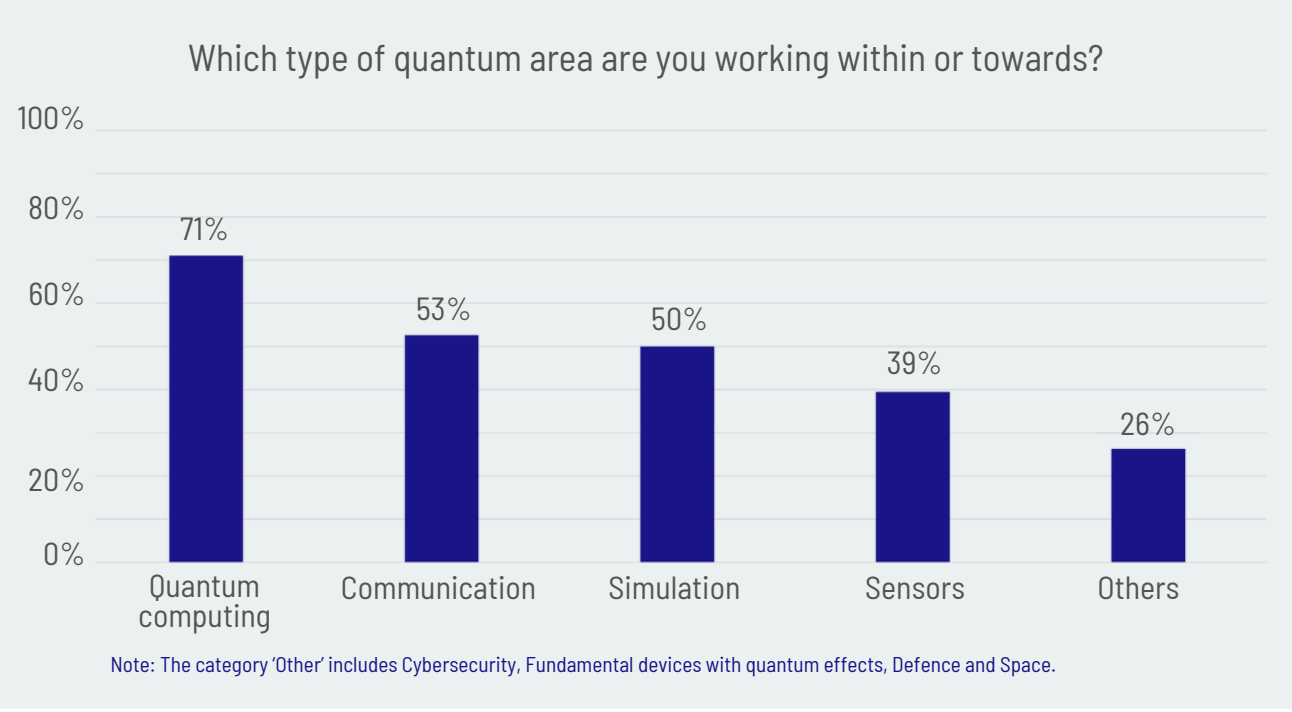
In 5 years, more businesses expect to adopt quantum technology, and more players will move from having no quantum activities to small and substantial involvement.

By 10 years, the distribution becomes more evenly split between substantial and large quantum shares, reflecting increased investment.

20 years on, 45% of businesses anticipate large-scale quantum engagement, transitioning from substantial shares. This shows a long-term vision where quantum becomes integral to many companies' strategies.



INVOLVEMENT IN QUANTUM: AREAS



Note: The category 'Other' includes Cybersecurity, Fundamental devices with quantum effects, Defence and Space.

As quantum technology expands in scope and potential impact, understanding the areas in which organizations are active becomes crucial for identifying development pathways and possible collaborations.

Participants responded to which area within quantum their activities are directed. Responses found quantum computing as the dominating area of involvement and also a large number of activities in communication, simulation, and sensors. Other domains of activities include cybersecurity, fundamental devices with quantum effects, defence and space. Whereas 39% of the organizations focus on a single domain, 16% engage in all. This diversity highlights both specialization and the growing interdisciplinary nature of quantum technology.

"I want to make sure that people realize that when we see that 71% of the survey respondents work in quantum computing, it is because quantum computing is an area that is booming right now. It is not something that we build far out in the future, because there are enormous investments right now, billions are used for building and selling quantum computers. There are quantum computing companies, none in Denmark are full-stack quantum computer companies, the closest in probably Finland IQM, and they grow strongly right now, because they build quantum computers, and they sell them".

QUANTUM MACHINES

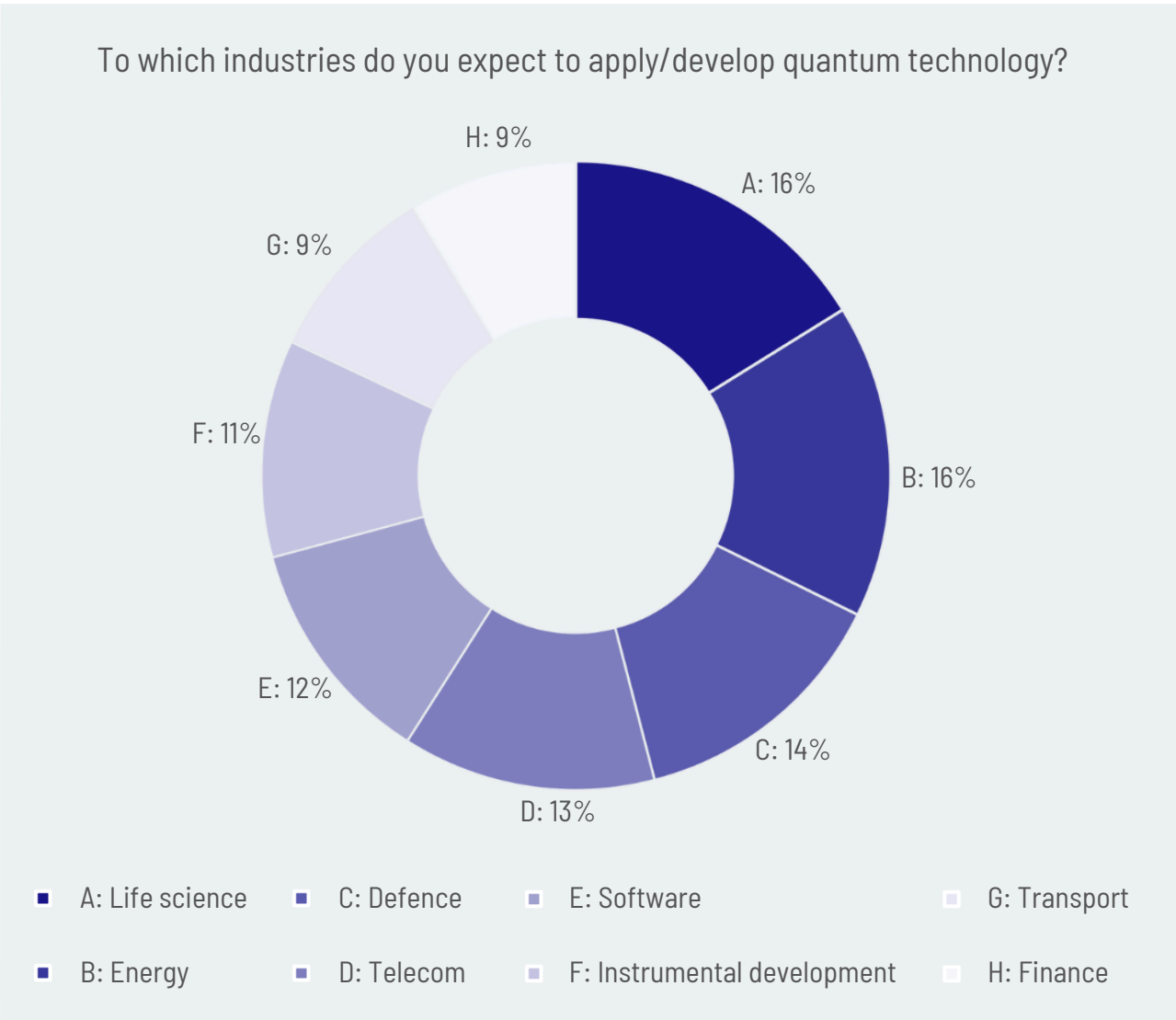
INVOLVEMENT IN QUANTUM: INDUSTRIES

As quantum technology continues to evolve, pinpointing key industries is vital for steering advancement and uniting efforts. This analysis highlights how sectors such as life sciences, energy, defence, telecommunications, and software plan to leverage quantum solutions, offering insights into emerging applications and investment opportunities.

Participants provided a broad and evenly distributed range of responses regarding the industries in which they expect to use or develop quantum technology. Life sciences and energy emerged as primary focuses, followed by defence, telecommunications, software, instrument development, transport, and finance. Some industries are already exploring pilot projects, indicating a shift from fundamental research to practical implementation. Overall, these findings underline the broad potential for quantum technology across various sectors. A number of respondents expect to be involved in all industries.

"We are interested in getting into [...] the hardware side, not the simulation side"

TOPSIL



PART 2: CRITICAL PREREQUISITES AND NATIONAL ECOSYSTEMS

This section explores the barriers faced by individual organizations and the ecosystem in general, focusing on critical areas such as funding, talent acquisition, and infrastructure. Overcoming these is key to fostering innovation, retaining talent, and ensuring Denmark remains competitive in the global quantum landscape.

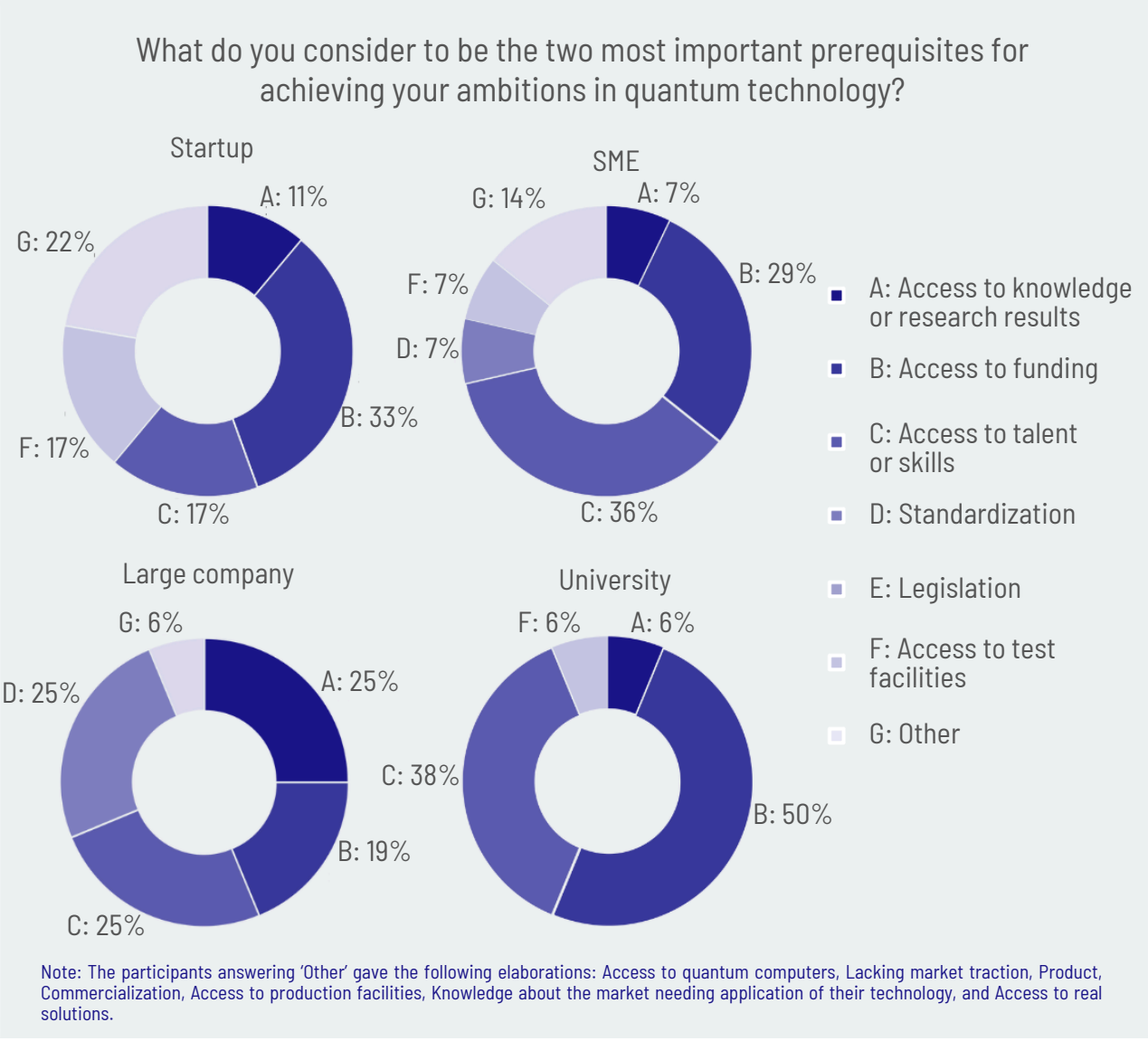
" We make quantum chips, and it requires very large investments which are not possible for a company. The access to facilities and cleanrooms, like DTU Nanolab and KU Quantech that can be used for chip production, is crucial for us."

SPARROW QUANTUM

"The importance of the ecosystem is crucial. Some also call it a cluster. It is not a cluster with people with the same degree in quantum physics, but it is people with different knowledge, with different aspects of a field of knowledge. To give a parallel, there is a reason why most of the world's hearing aid companies are situated in the Copenhagen area [...] Here we have all the disciplines that are needed to produce hearing aid in terms of professionals and a job market across companies and there are also research environments doing open research while the companies are doing their private research, and there are collaborations across. This is what creates a cluster [...] In that same way, we have a beginning quantum cluster [...] We are in the middle of the tornado's eye and have the opportunity to build a cluster that can secure a long-term sustainable growth centered in Denmark if we do it right."

QUANTUM MACHINES

CRITICAL PREREQUISITES



Note: The participants answering 'Other' gave the following elaborations: Access to quantum computers, Lacking market traction, Product, Commercialization, Access to production facilities, Knowledge about the market needing application of their technology, and Access to real solutions.

The respondents were asked to identify the two most critical prerequisites. The responses vary significantly between the different organization types.

Funding was identified as one of the most critical prerequisites with emphasis on long-term funding. For large companies, access to knowledge, talent and standardization proves more important, as one respondent indicated that low funding rates limit engagement in a strategically new direction.

For all participants, talent acquisition is essential, highlighting the importance of a skilled labour force and a need to seek resources internationally.

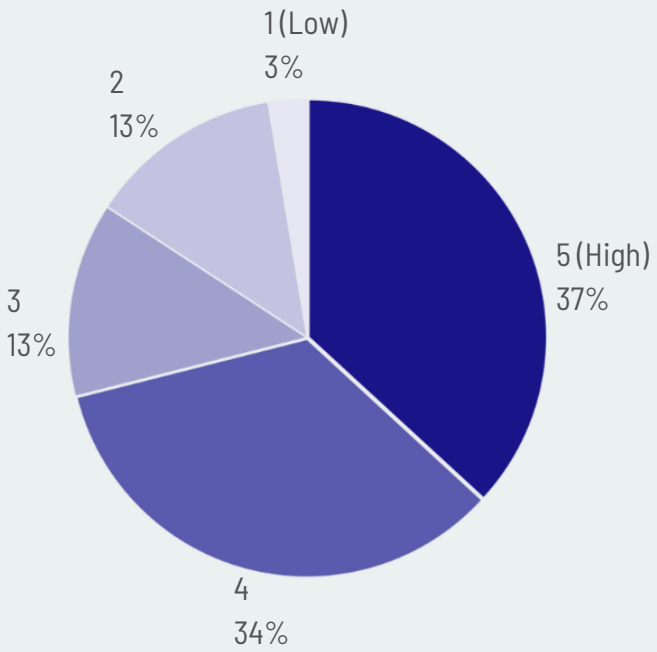
In addition, some of the respondents highlighted the importance of access to customers and more in-depth market knowledge. Also, the availability of production facilities and access to quantum computers proved crucial.

"We are competing against some really big universities out there, so if we are to be competitive, we simply need to have some resources behind us".

NQCP

NATIONAL ECOSYSTEMS AND INITIATIVES

To what extent is the realization of your ambitions dependent on access to a national ecosystem within quantum technology?



71 % of the respondents assigns significant importance to the access to a national ecosystem in order to realize the organization's ambitions within quantum technology. Many respondents emphasize that the impact of a national ecosystem depends on its size and to which extent it allows for access to cutting edge equipment. If national availability is limited, the organizations will seek solutions internationally. At the same time, there is a broad consensus that a well-established national infrastructure is highly beneficial across different organizations.

"We need more funding so we can hire more people, so that I can attract some really sharp minds to Denmark, so we can achieve a fantastic development."

QPURPOSE/SDU

"Universities, companies and other initiatives having different profiles, but being placed geographically close to each other, can give good synergies [...] Collaborations inspire across universities and startups."

QUANTUM DTU

"The area where we have a problem is in relation to test facilities [...] that is where we see a need."

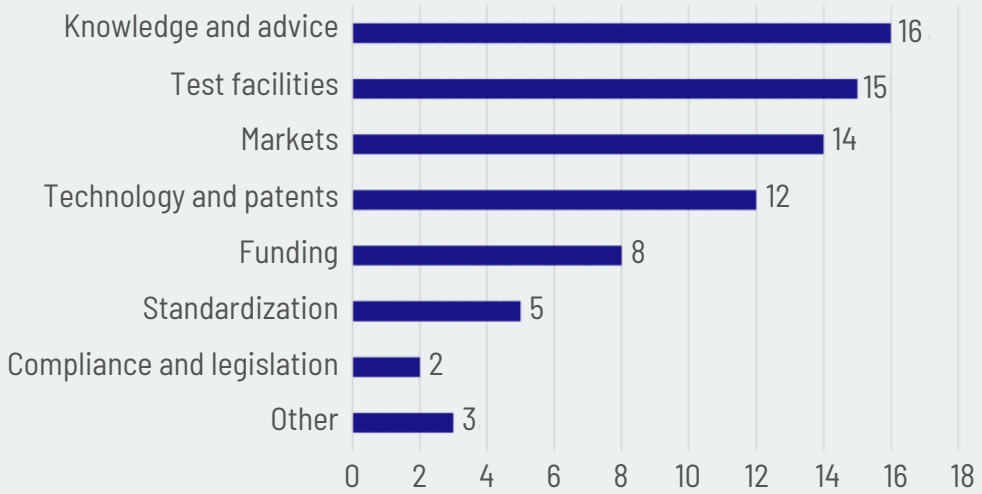
TOPSIL

PART 3: COLLABORATION

WHY COLLABORATE

This section examines how the participants in this survey collaborate within the quantum ecosystem, nationally as well as internationally. In relation to realizing their ambitions in quantum technology, companies identified several important factors to access through partners. Access to knowledge and advice is considered most significant as it ensures the organizations stay updated with the most recent advancements and innovations in quantum technology. This leads to more informed decision-making and the ability to leverage cutting-edge techniques and methodologies. Access to test facilities, highlighted by 15 respondents, allows organizations to conduct experiments and validate their quantum technology solutions, enhancing the quality of research and development, fostering innovation, and ensuring that the technology meets required standards.

In relation to realizing your ambitions in quantum technology, what is important to access through partners?

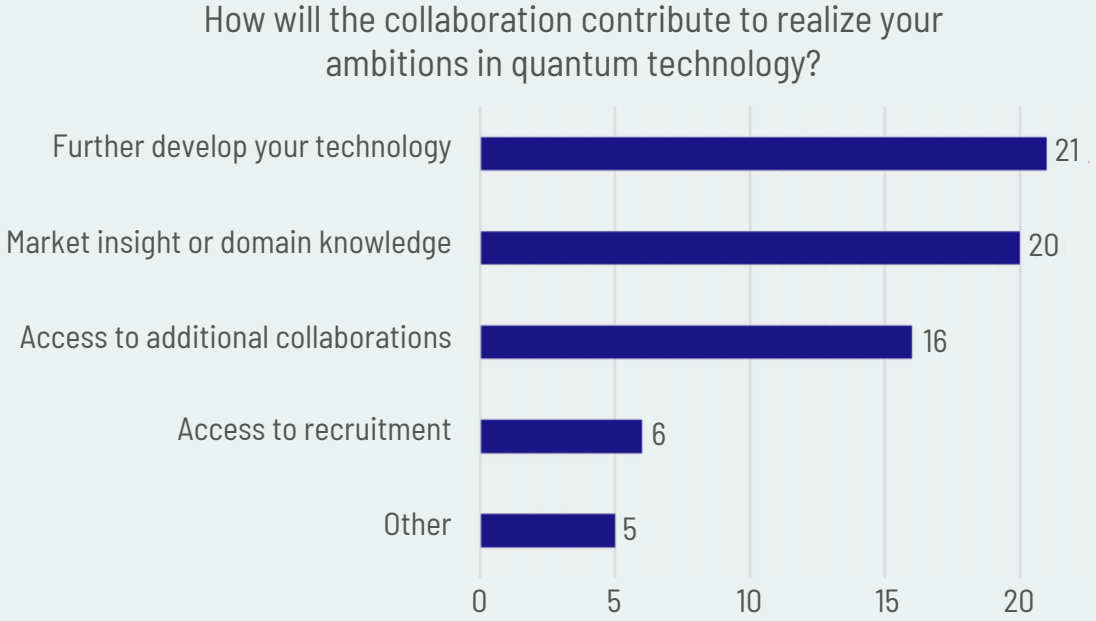


Note: The participants answering 'Other' indicated the following elements: Competencies, Providers of solutions, and Access to production facilities.

WHY COLLABORATE

In the rapidly evolving world of quantum technology, alliances among universities, industry, and government open fresh avenues for innovation. The participants were asked what they expect to gain from collaborations in the context of the national quantum ecosystem. Most participants estimate that "further development of technology" is the most important aspect followed by the category "market insight / domain knowledge". In addition, "access to additional collaboration" plays an important role. Furthermore, collaborations can pave the way for "recruitment", and also help securing infrastructure, give access to hardware and test facilities, quantum computers and compensate for the lack of market pull, as mentioned by the respondents in the category "other" in the figure.

In relation to "further development of technology" many respondents emphasized the importance of knowledge sharing and expert insights. This points to the importance of test centers in the future development of the quantum technology sector, as these can unify access to domain knowledge and facilitate iterative advancements through specialized facilities. The survey further revealed how startups see value in collaborating with larger companies to benefit from their extensive experience and resources, highlighting the essential nature of a robust national ecosystem.



Note: The participants could choose the two most important of factors. Participants answering 'Other' indicated the following: Secure infrastructure, Lack of market pull, Use of quantum computer, Access to hardware and test facilities.

"Quantum technology is not something that comes out of a garage. It comes from a very strong research environment where one has come so far that the next step is to further develop it in an industrial and commercial setup [...] It is important for us to continue the interaction with the research groups and the funding of such collaborations by the Innovation Fund plays an important role."

SPARROW QUANTUM

INTERNATIONAL COLLABORATION

International collaborations in quantum technology offer several unique contributions that are crucial for achieving companies' ambitions. Access to the latest knowledge is considered the most significant emphasized by 25 respondents. This is followed by access to international talent, which 19 respondents pointed out as essential for advancing quantum technology. Potential for funding is another key point, recognized by 16 respondents. International influence on future markets through standardization is noted by 10 respondents as an important factor. Additionally, 10 respondents mentioned other contributions, such as field experiments in laboratories in other countries, access to production-ready solutions, access to other markets, use of quantum computers, and commercial partners.

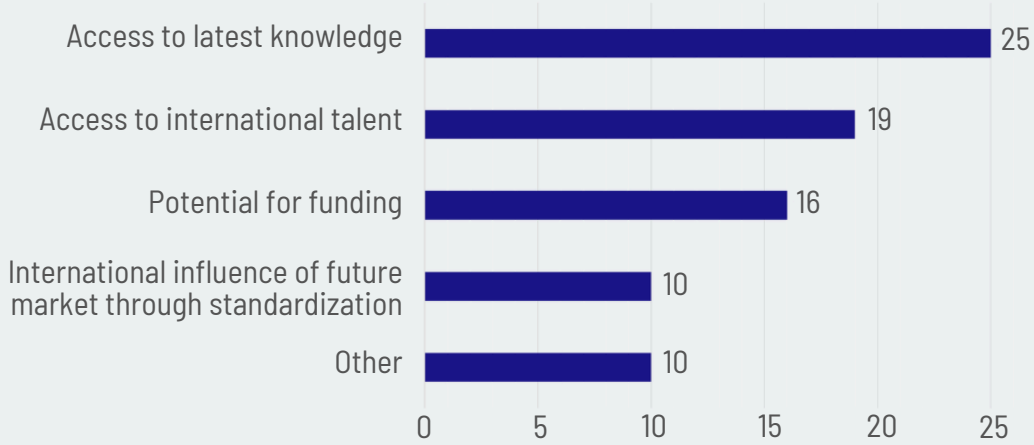
"As researcher and research group, you are for good reasons focused in the area in which you are working. With Quantum DTU we have the possibility to have a helicopter view and facilitate international collaborations established into all corners of the DTU quantum research."

QUANTUM DTU

"The customers we have within quantum now use the products we have, but it may not be the optimal substrate, so we would like to get into some projects and have some partners where we try to define substrates for quantum electronics and also quantum sensors."

TOPSIL

What are or could be the unique contributions from international collaboration in relation to achieving your ambitions in quantum technology?



Note: The respondents answering 'Other' elaborated the following: Field experiments in laboratories in other countries, where they have been at the forefront, Access to production-ready solutions, Access to other markets, Use of quantum computers, and Commercial partners.

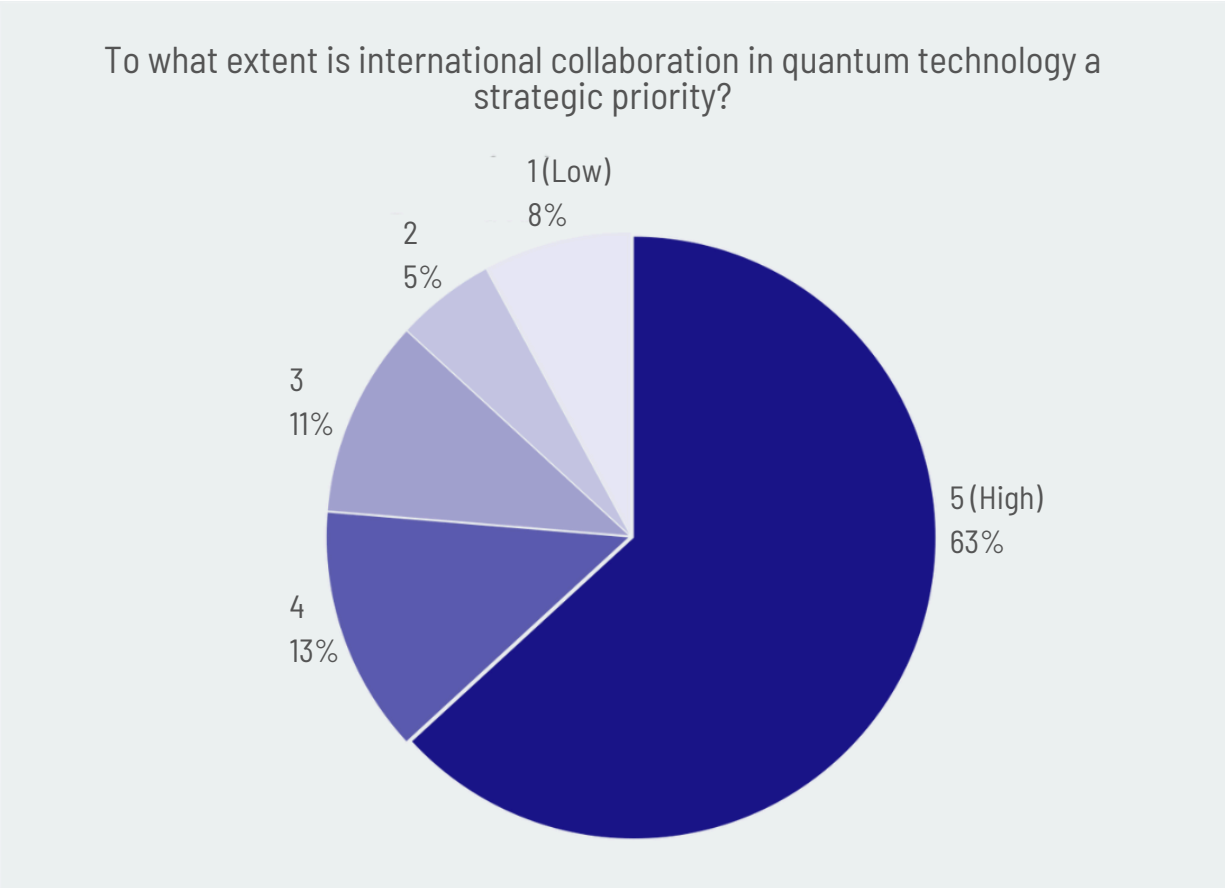
INTERNATIONAL COLLABORATION

By collaborating with leading experts and international talent, stakeholders not only benefit from shared expertise, but also gain opportunities to influence the global quantum ecosystem. Such active involvement helps Denmark and other European players position themselves competitively, ensuring that their initiatives align with global advancements while contributing to the broader evolution of the quantum field.

The survey found an overall opinion in favour of collective efforts and strategic partnerships through national and international collaborations to help advance quantum technology, drive innovation, and overcome market challenges.

Whether through national partnerships or international alliances, collaborations enable organizations to access the knowledge, resources, and markets that drive technological advancement. For most stakeholders, both national and international collaboration is crucial.

International collaboration in quantum technology is considered a strategic priority, with varying degrees of importance attributed to it by stakeholders. Of all answers, 63% of the respondents find international collaboration a strategic priority.



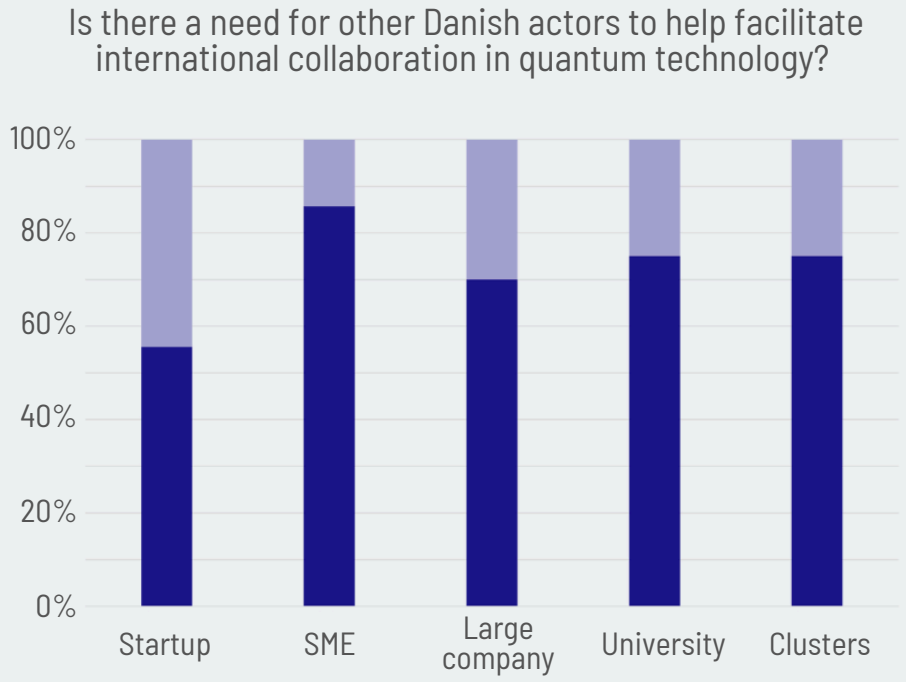
"It is important for us to work with the best in the world."
QPURPOSE/SDU

"I don't think you can have a purely national approach when it comes to quantum."
TOPSIL

INTERNATIONAL COLLABORATION AND FACILITATION

According to this survey, there is a strong demand for one or more Danish actors to facilitate international collaboration in quantum technologies and a number of respondents have benefited from joint Danish initiatives to built networks internationally, for instance delegations organized by the Ministry of Foreign Affairs.

A majority of organizations across all types see a need for such a facilitator. Larger organizations and SMEs emphasize this need, while startups only show a slight majority in favour. For many quantum startups, collaborations have been a requirement from the outset, which is why strong international networks are often already established.



71% says yes,

there is a need for other Danish participants to help facilitate international collaboration within quantum technology.

"Next month we are going to Germany with the Danish delegation, and it is important for us because it increases our opportunity to network."

CONSCIENCE

"We have benefited from being out there with some of these structures at the various embassies around the world, such as in London, Hong Kong, and Japan."

QPURPOSE/SDU

PARTICIPATION IN EXTERNALLY SUPPORTED RESEARCH PROJECT

71% says yes,

their organization participate in externally supported research projects, such as EU or IFD, in collaboration with other Danish participants within quantum technology.

"We have good partners and opportunities in Denmark and that is a big reason why we established a business in Denmark."

CONSCIENCE

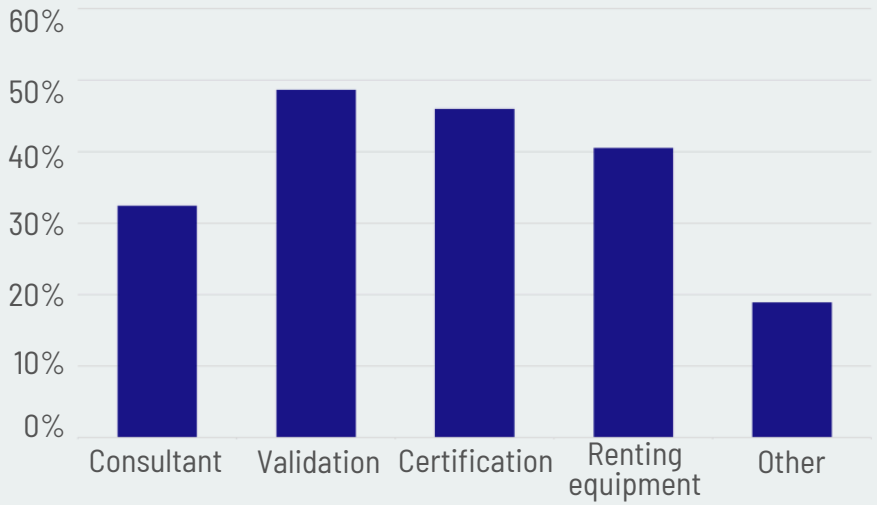
Foto: FORCE Technology

PART 4: THE NEED FOR ACCESS TO TEST FACILITIES AND CERTIFICATIONS

As quantum technologies transition from research to practical applications, the need for specialized test facilities and certification processes is growing. This section explores the current and future requirements for test infrastructure and its role in validation, quality assurance and commercialization. Ensuring that these facilities keep pace with technological advances is essential to support the quantum sector.

The anticipated demand for external testing, demonstration or development facilities covers several key areas, including the need for standardized testing protocols and internationally recognized certification frameworks. While the types of services required vary among participants, validation and certification remain particularly important, with more than 45% expressing a need for these.

Which types of services do you expect your organization to utilize in relation to test facilities in the future?



Note: The category 'Other' includes the following: Technicians for chip fabrication, External collaborations, Access to quantum computer hardware, and None, as everything will be handled via partners and customers.

"When you do hardware and have to get started, establishing laboratories is very expensive. The Quantum Test Center might help other companies to get started if it is well constructed [...] For such access to create value, for instance for access to an optical laboratory, a company might need exclusive use of the equipment for a year."

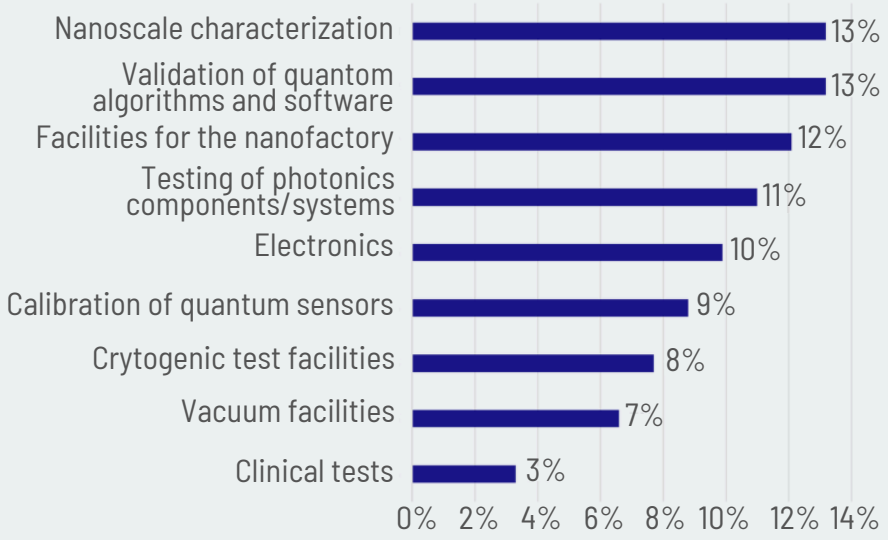
SPARROW QUANTUM

ACCESS TO EXTERNAL FACILITIES

Quantum technology often requires advanced equipment that may not be readily accessible to all organizations. To address this, we aim to identify the most critical facilities that organizations need for testing their quantum technologies. The survey reveals a relatively even distribution among the predefined test areas, which include nanofabrication facilities, validation of quantum algorithms and software, testing of photonic components/systems, electronics, nanoscale characterization, cryogenic test facilities, vacuum facilities, and the calibration of quantum sensors. A few also identified a need for clinical tests related to the life sciences.

As new discoveries emerge and market demands shift, the necessary testing procedures can change, requiring adaptable and responsive test strategies. Through continuous monitoring of the technological landscape and collaboration with key stakeholders, these dynamic needs can be promptly recognized and addressed. A well-functioning infrastructure can ensure that developments at test facilities keep pace with current needs.

Within which fields do you expect your organization will need access to external test, demonstration, or development facilities?



14% says the expected needs do not fall into the predefined categories and some needs are hard to define at the current stage.

"Some of the equipment that is needed to do these tests is super expensive equipment and therefore it makes sense that we have shared facilities. Many instruments cost 5 Mkr [...] they are not required fulltime by a single company, so it makes sense to share among different companies [...] It has the potential to support the collaboration between different players to share different facilities."

QUANTUM MACHINES

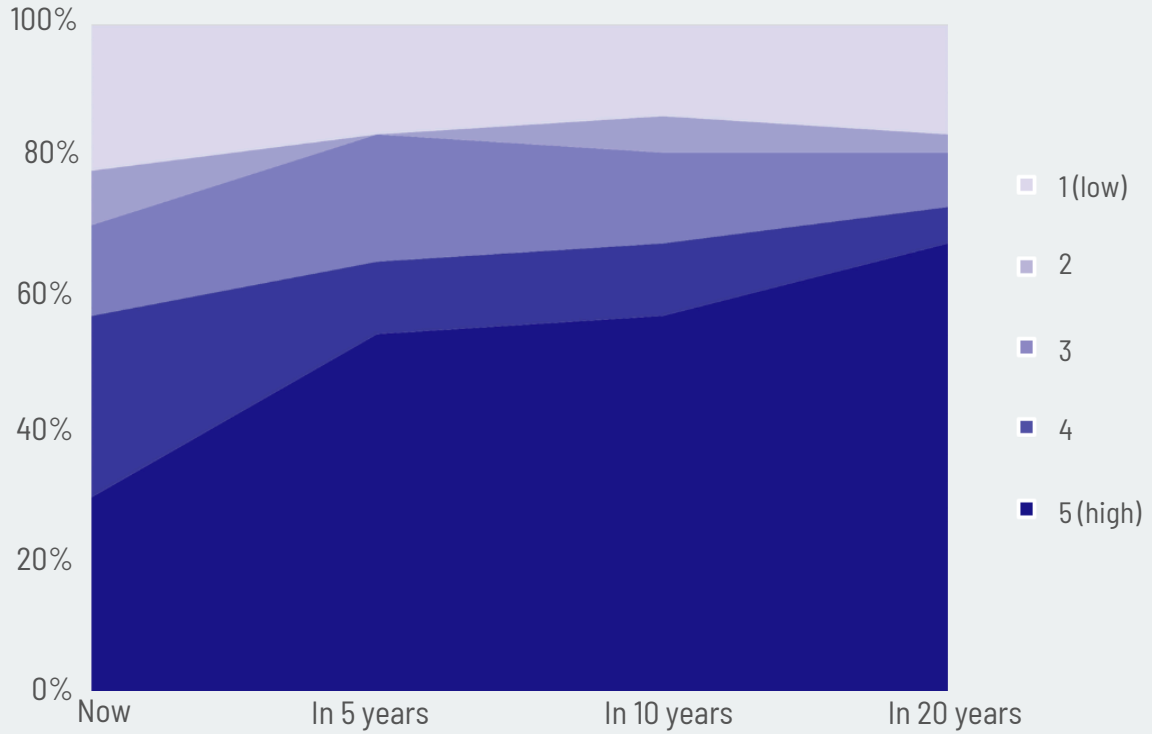
FUTURE NEEDS FOR EXTERNAL TESTS, DEMONSTRATION, OR DEVELOPMENT FACILITIES

The organizations express a growing need for access to external test, demonstration or development facilities, including the certification of products and services within quantum technology. This need is expected to increase significantly within the next 5 years, driven by the necessity to test quantum chips, quantum sensors, and other quantum devices. This aligns closely with the capabilities of research and technology organizations (RTOs).

"I expect that in 10-20 years we will be more self-sufficient so that we have more of the machines we need to calibrate, test, and quality-check our things. It is also a hope I have, because our development would runs faster if we have everything in-house. (...) we will become more and more self-sufficient over time... but of course, it may be that when we scale up, we will need some completely different services that we cannot facilitate ourselves."

NQCP

To what extent does your organization need or benefit from access to external test, demonstration, or development facilities, including certification of products and services within quantum technology?



PART 5: STANDARDIZATION, SUPPORTING AND SCALING QUANTUM TECHNOLOGIES

Standardization plays an important role in the scalable and secure adoption of quantum technologies. It can support interoperability, help building trust, and provide a framework for best practices.

Given the long-term nature of developing effective standards, there is a growing discussion about the need for action in 2025 and beyond, particularly in areas such as encryption, photonics, and terminology. Engaging early in standardization efforts may help improve compatibility and interoperability across the sector, while offering organizations the opportunity to contribute to the evolution of quantum technology. Addressing these areas now could help stakeholders position themselves to support innovation, build trust, and strengthen Denmark's role in the global quantum landscape.

"Especially when talking about how good a qubit is, these sub-elements of the quantum computer. People do not have a standardized way to measure it. There are different methods and different equipment used to measure them, which means that the same qubit might give different results depending on how [it is measured] and who measures it. This is not ideal when comparing and developing internationally."

NQCP

"Our wish is to establish a purity standard for the substrate and a standard for the surface properties of the substrate..."

TOPSIL

STANDARDIZATION IN VARIOUS FIELDS

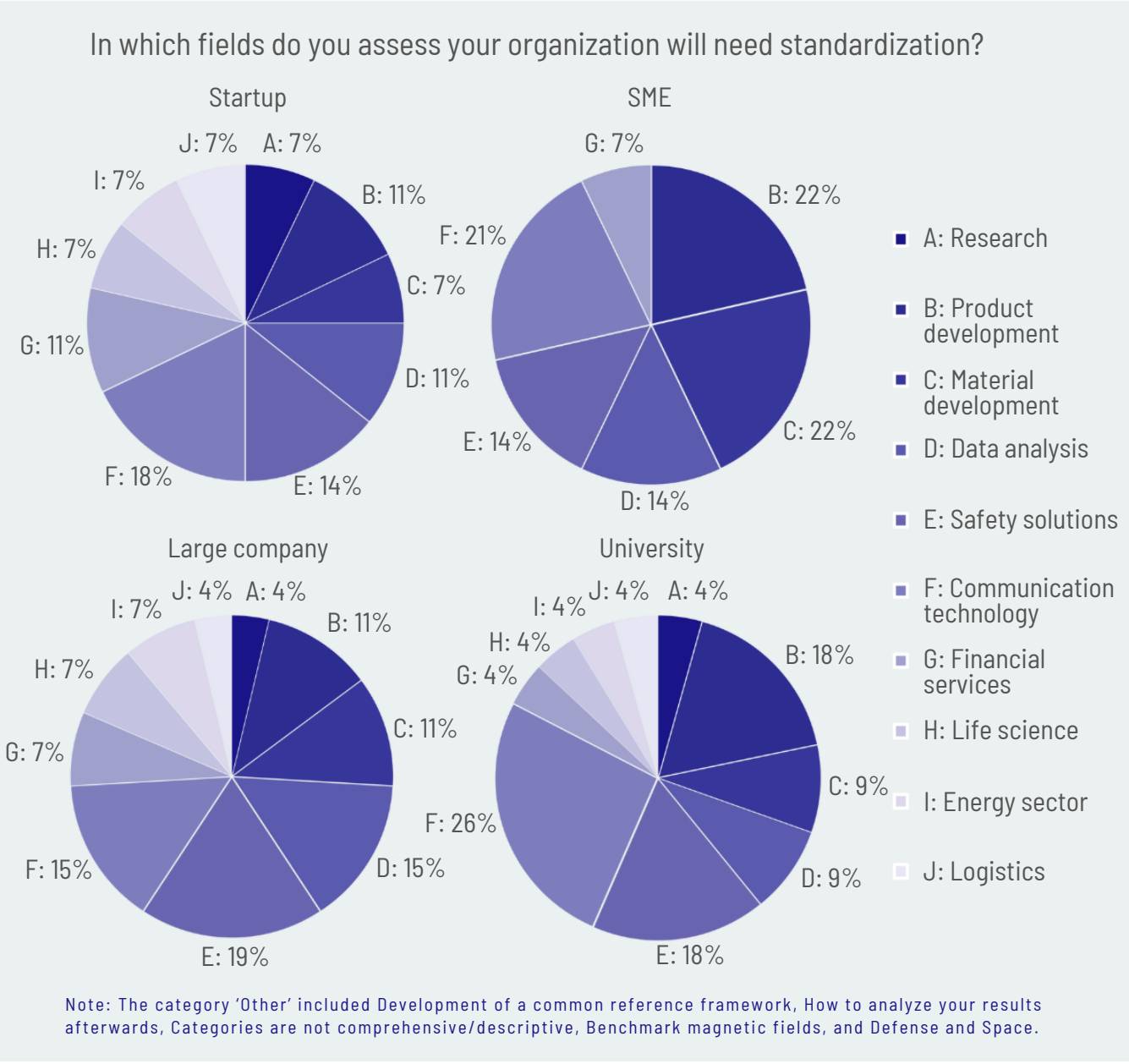
As quantum matures, regulatory standards will ensure security and data integrity. Adhering to these standards gives a competitive advantage, particularly in quantum encryption, where standardization fosters trust and a wider adoption.

Across companies and organizations, the need for standardization is primarily found within communication technology and safety solutions. Furthermore, there is an explicit need for standardization within quantum material development and product development, in particular for SMEs. Overall, the answers reveal a relatively even distribution across the different categories and thus, standardization could be beneficial to several areas.

Within the categories of data analysis, safety solutions, and communication technology, focus is on facilitating interoperability between different quantum technologies and systems. This will enable various devices and platforms to communicate and work together seamlessly. This is crucial for data analysis and secure communication, as it allows for the integration of different technologies and ensures consistent and reliable results.

"..we would benefit from standardizing qubit measurements already now."

NQCP



Note: The category 'Other' included Development of a common reference framework, How to analyze your results afterwards, Categories are not comprehensive/descriptive, Benchmark magnetic fields, and Defense and Space.

STANDARDIZATION IN VARIOUS TOPICS

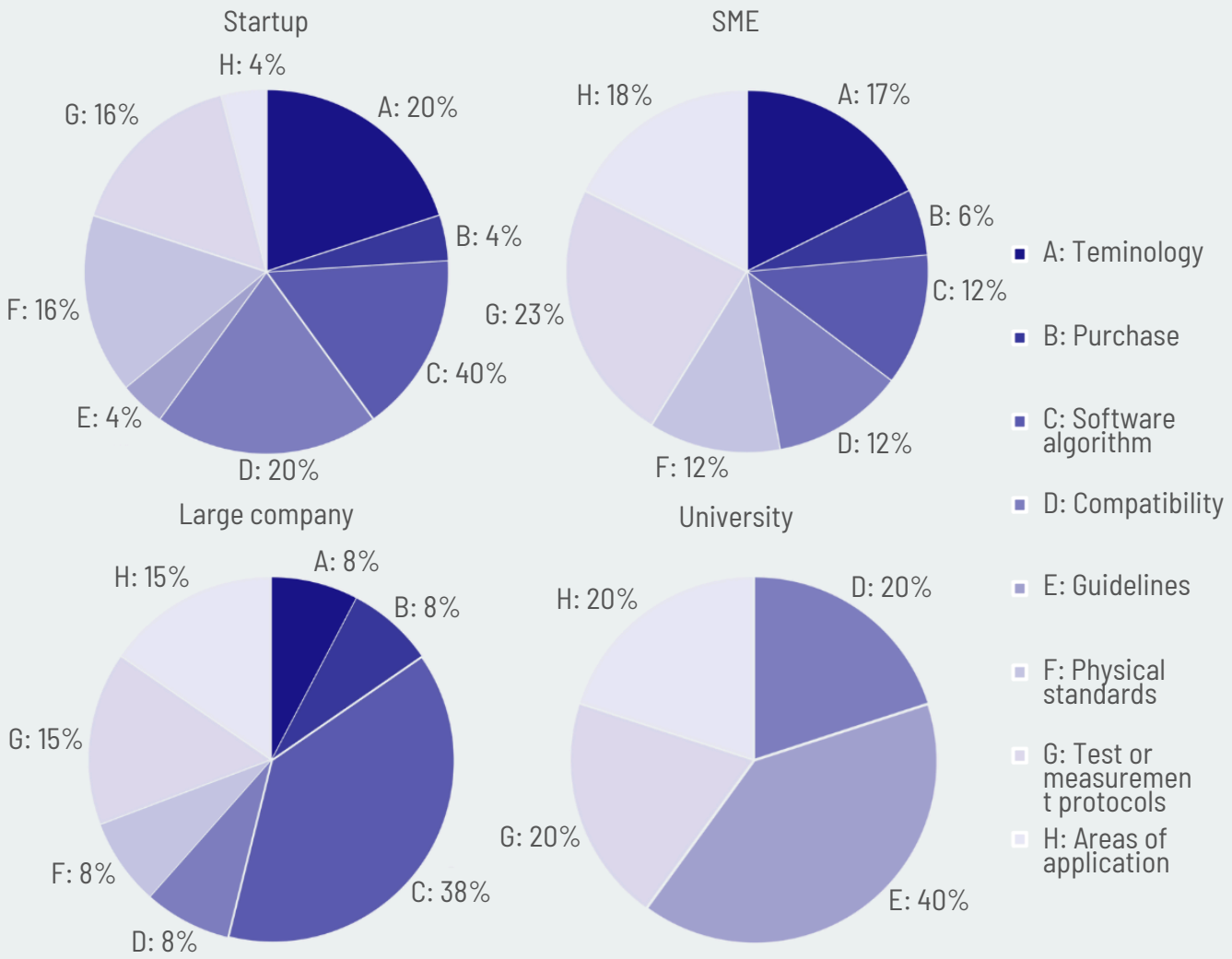
Participants identified the main topics for standardization in terminology, software algorithms, compatibility, and test/measurement protocols. While these areas could streamline quantum technology across organizations, varying levels of support for early development of standards were identified.

Many large companies see value in frameworks for quantum software algorithms, arguing they reduce risks, and simplify testing especially for encryption and data processing. Yet, some fear rigid requirements might stifle innovation or add complexity. Universities favour guidelines that encourage consistent research methods and reproducible outcomes, bolstering academic rigor and easing the transition to industry. Still, some express a concern that uniform standards could limit exploratory research.

"It is important to have a common language to make reasonable comparisons in the research done across universities in a field that moves fast. We experience this already in quantum computing where measurements with very distinct parameters are published to highlight own work [..] there is the risk that we lose transparency."

QUANTUM DTU

In which topics does your organization see a need for standards or a common language across companies and countries?



Note: The category 'Other' included Development of a common reference framework and Categories are not comprehensive.

STANDARDIZATION IN VARIOUS TOPICS

53% says yes,

there is a need for common standards in enabling technologies, particularly in cybersecurity, photonics, and algorithms.

SMEs advocate for standardized test and measurement protocols in quantum technology to reduce research and development costs, leverage existing frameworks, and ensure reliability. More than half of the surveyed stakeholders emphasize the need for common standards—especially in cybersecurity, photonics, and algorithms—to boost market confidence and attract investors. For instance, a quantum substrate producer struggles to source optimal materials due to the lack of uniform benchmarks, and a standardized qubit assessment method is needed to unify measurement approaches.

Additionally, Quantum Key Distribution (QKD) is seen as crucial for future cybersecurity. By using quantum mechanics to detect eavesdropping, QKD enhances communication security. As quantum computers threaten current cryptographic methods, QKD offers a proactive defence against emerging risks.

"If we as a university compare our work to the commercial reality, it is crucially important that there exist guidelines. To have measures regarding real development in an area is what GTS institutes and others should ensure [...] One must realize that this involves commercial interests."

QUANTUM DTU

"Standards are an important tool for promoting the use of quantum technology nationally and internationally. Standards are a solid basis for achieving compliance, safety, development and efficiency for quantum technology, and they therefore also help to support a coherent and efficient quantum ecosystem."

DANSK STANDARD
(co-funded the report)

Info: *Learn more about the national standardisation committee for Quantum Technologies, S-874, at: https://www.ds.dk/da/udvalg/kategorier/it/quantum-technologies.*

Standards are continuously developed and updated to meet market needs, a process led in Denmark by Danish Standards. Committees, typically meeting 2–3 times a year, make democratic decisions based on expert input, dialogue, and documentation.
Clear standards support compliance, security, development, and efficiency. Committee meetings are key to this, enabling knowledge exchange and broad consensus to ensure the best outcome.

Foto: FORCE Technology

STANDARDIZATION IN VARIOUS TOPICS

Currently, 25% of the surveyed organizations report a strong need for standardization in quantum technology, reflecting an immediate awareness of its value. However, looking ahead 20 years, almost 90% of the participants see a medium to high need for standardization—indicating that the vast majority believe standardized protocols, methods, and best practices will be crucial for fully realizing the technology's benefits in the long term. This shift suggests that as quantum applications become more widespread, interoperability and regulatory alignment will play a key role in ensuring seamless integration across industries.

Although this points to growing interest in aligning on common frameworks, many respondents also emphasize the importance of preserving flexibility and innovation in a field that remains highly exploratory. Balancing standardization with the need for continued experimentation will be critical as quantum technology advances, ensuring that regulation supports rather than hinders progress.

"It would be an advantage if there was either an independent testing company or a standard for how it should be tested."

CONSCIENCE

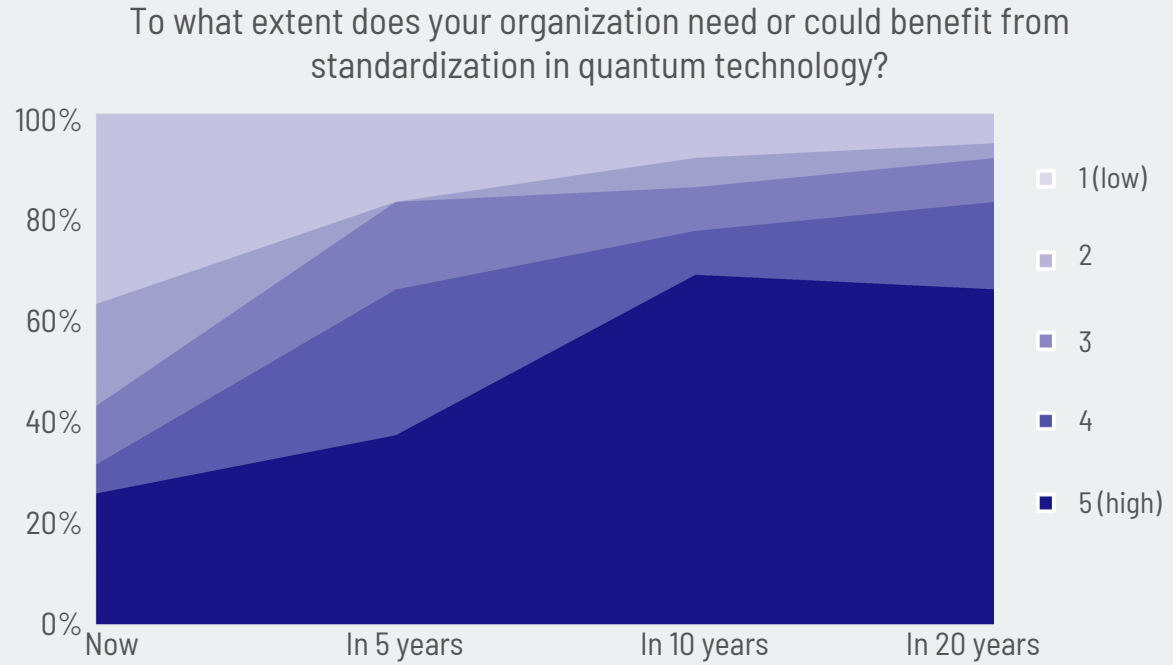


Foto: Noah Wotton, Unsplash

OBSERVATIONS AND OUTLOOK

The aim of this interview-based survey is to provide an overview of current quantum technology activities across a wide range of players in the Danish quantum ecosystem. The Danish quantum ecosystem is evolving rapidly with a broad expectation that this field will become increasingly prominent in the coming years.

Levels of engagement within quantum technology vary considerably among stakeholders, and practical applications remain in the early stages of development. Although quantum computing stands out as the dominant field, there is also notable activity in communication, simulation, and sensors. Moreover, quantum technology is expected to have a growing influence across a wide variety of industry sectors.

Collaboration both nationally and internationally plays a key role, and a national quantum infrastructure is rated of high importance among most of the participants.

The significant support for collaborating towards building a strong national ecosystem stem from the clear benefits for the individual players in this field. The national infrastructure must be sufficiently advanced to meet diverse requirements, otherwise, alternative solutions will be sought internationally.

At the current stage, many activities within quantum technology rely heavily on the access to funding. Together with the need for talent, this makes up the most important prerequisite necessary to continue and grow the activities within quantum technology.

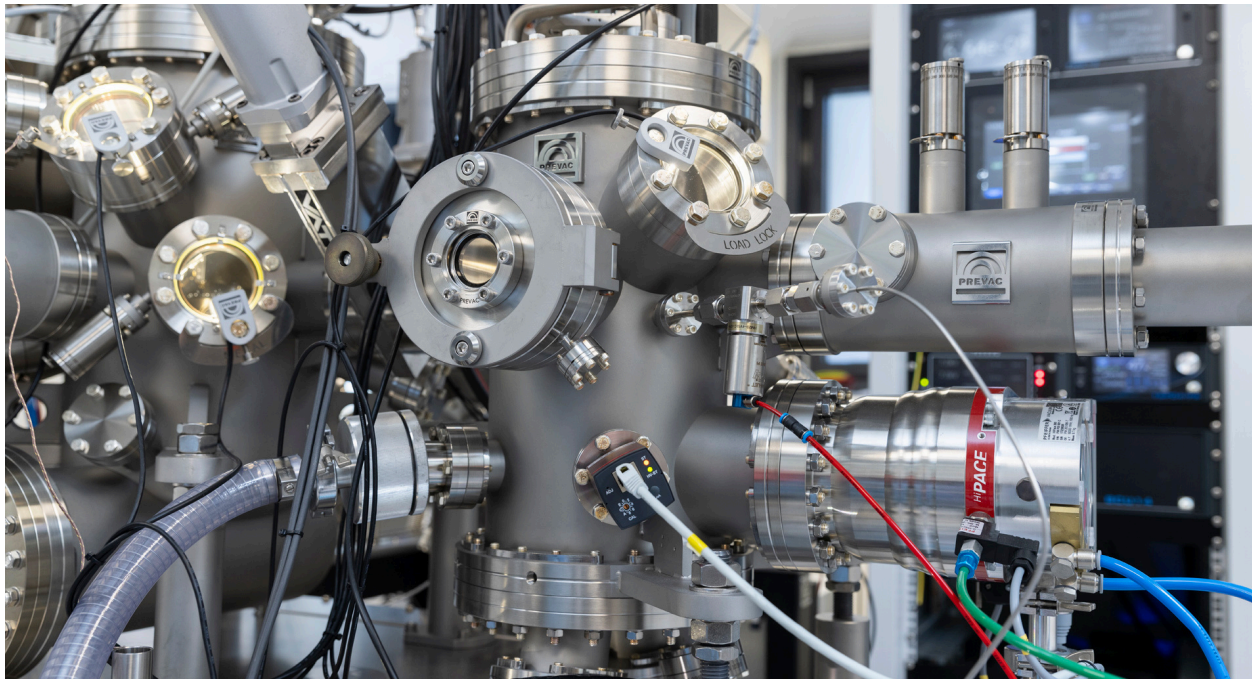


Foto: Noah Wotton, Unsplash

OBSERVATIONS AND OUTLOOK

Key barriers, including limited funding, talent shortages, and infrastructure constraints, highlight the need for targeted investments in ecosystem development. The national quantum ecosystem must accommodate the growing demands of stakeholders while fostering collaboration across organizational and international boundaries. Test facilities and certifications will play an increasingly vital role in validating and commercializing quantum technologies, bridging the gap between research and market readiness.

The Danish quantum ecosystem is poised for significant growth, with stakeholders from academia, startups, SMEs, and large companies playing distinct roles in shaping its future. For some larger companies there is a demand for off-the-shelf solutions rather than involving in research developments within quantum technology. Although Denmark has a strong foundation in research and innovation, addressing several critical gaps will be essential to ensure sustainable development and global competitiveness.

Generally, the field is in its early stage and the need for standardization is currently limited. By anticipating future challenges and risks, Danish Standards can help establish a solid foundation for the successful commercialization of quantum technologies. Early engagement in pre-standardization efforts and international initiatives will position Denmark as a leader in the rapidly evolving quantum domain.

The findings of this survey highlight Denmark's potential to solidify its position as a global quantum hub. This requires a unified approach that integrates funding, talent, testing, collaboration, and standardization efforts. In addition, there is strong alignment between the planned infrastructure (see page 3) and the specific challenges addressed by participating organizations, showcasing existing gaps and providing guidance for next steps as the quantum community continues to evolve.

By addressing the challenges head-on and leveraging existing strengths, Denmark can unlock the transformative potential of quantum technologies and secure its place at the forefront of the quantum revolution.

It is our hope that the insights and analyses presented herein contribute meaningfully to ongoing discussions and decision-making processes. Should any clarifications be needed or if further dialogue is desired, we remain available and committed to supporting the next steps.

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