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NQSTI
National Quantum Science and Technology Institute

Quantum for Italy 2025

Executive summary

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PREFACE: NQSTI, the National Quantum Science and Technology Institute

Claudio Pettinari
NQSTI President,
Full Professor of General and Inorganic Chemistry
Università degli Studi di Camerino

"Quantum science and technology is rapidly reshaping the frontiers of innovation, offering transformative potential across communication, computation, sensing, and secure information. In this dynamic context, Italy has taken a decisive step forward with the establishment of the ***National Quantum Science and Technology Institute*** **(***NQSTI***)** — a coordinated national effort designed to strengthen the country's leadership and competitiveness in the quantum domain, a consortium that was founded by 20 Italian entities, but is currently expanding.
Supported by PNRR investments, *NQSTI* has created an integrated ecosystem that connects universities, research institutes, and industrial partners. This network not only enhances access to state-of-the-art infrastructures but also promotes technology transfer, cross-disciplinary collaboration, and advanced training for the next generation of quantum scientists and engineers. A recent and relevant milestone achievement in this process has been the creation of **Quantum Technology Fabs** designed to support industry and academy researchers in prototyping and validation of quantum devices - a concrete foundation for long-term life and sustainability and innovation capacity.
Today, *NQSTI* represents both a scientific hub and a strategic instrument for national growth. Its coordinated model supports Italy's participation in the European quantum agenda and ensures alignment with international initiatives. Through its open and collaborative approach, *NQSTI* stands as a **fundamental bridge between research, industry, and policy**, providing expert insight and evidence-based guidance for building the future of quantum technologies in Europe".

The fall of 2021 saw the creation of a group of 23 experts from Academia and Research institutions, following the publication of the Italian government guidelines. These experts shared an analysis of the QST know-how available in the country, of the obstacles to its full valorization and translation into economic growth and sustainable development, and a vision of the main directions capable of bringing the radical innovation requested by the guidelines. This study was then shared with leading enterprises operating in Italy: new goals and needs completed the report. The analysis represented the starting point for the elaboration of the ***National Quantum Science and Technology Institute*** as a PNRR proposal. The *NQSTI* coordination's programs aim **to overcome the current structural weaknesses** of the Italian systems, such as fragmentation of research lines and organizations, scarcity of personnel, poor funding, inadequate digital infrastructure, and lack of exploitation of the existing facilities/laboratories.
NQSTI's vision is that the extraordinary PNRR funding must be used to update technical facilities and strengthen the QST community in the next few years, but even more importantly, it must be channeled to drive the national community into an ordinary and sustainable condition of increased impact, visibility, and capacity to modernize and support the competitiveness of the Italian economy.
The ***National Quantum Science and Technology Institute*** (*NQSTI*) is a consortium that intends to:

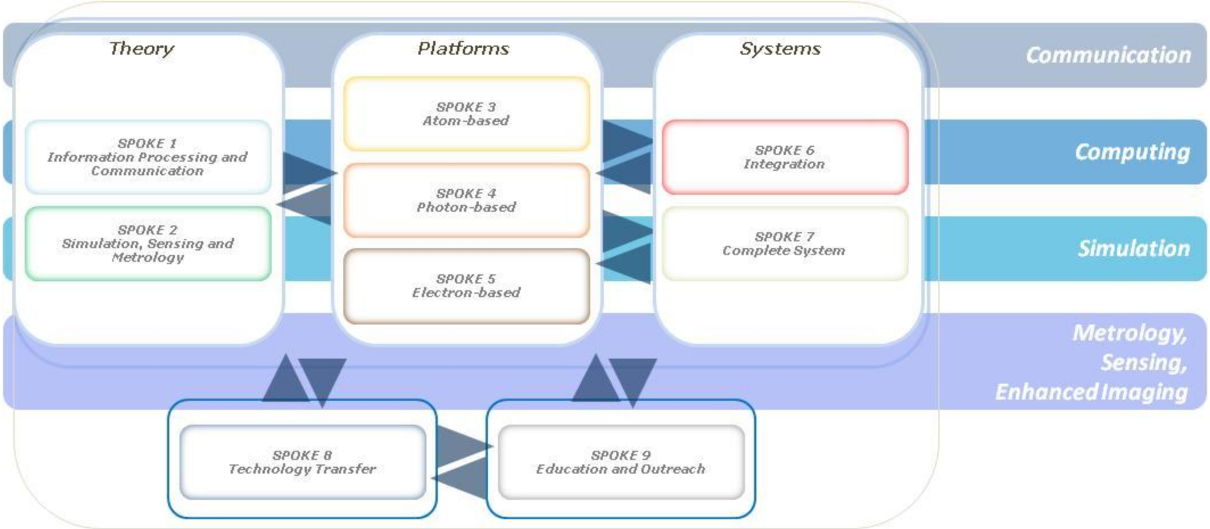
(i) team up Italian entities carrying out competitive and innovative research in the field of quantum science and technology (QST), and
(ii) stimulate future industrial innovation in the field, providing a forum in which novel ideas and opportunities are transferred to companies.
In order to ensure a long-term positive effect on the Italian economic growth and development, the whole innovation chain was considered: from the strengthening and coordination of the low-TRL research, to its translation into prototypes, favoring interfacing with industrial needs thanks to strong outreach and continued-education programs.
The ***National Quantum Science and Technology Institute*** long term goal is to contribute to the establishment in Italy of a Knowledge Transfer (KT) System for Quantum Technology i.e. to manage the activities and the processes through which knowledge, expertise and qualified personnel flow between the research system (institutes, universities, research centers) and the community of end users in the industrial sectors, in commerce, in the service and in the public sectors.
Within *NQSTI,* the goal is to create a dedicated **single-point provider for SMEs** where they will be able to find educational programs for their existing staff, new QST-trained personnel, and opportunities to innovate products and processes by participating, through dedicated open calls, in collaborative projects with our project participants. ***NQSTI* aims particularly to effectively connect low-TRL research with companies' R&D divisions**, either by leveraging on the existing industrial infrastructure or by stimulating the creation of new companies.

Serafino Sorrenti
NQSTI Honorary Chair
Chief Information Security Officer (CISO)
Presidency of the Council of Ministers of the Italian Government

"The ***National Quantum Science and Technology Institute*** **(*NQSTI*)** constitutes a precious national asset for the advancement of quantum technologies in Italy. Its **coordinated structure, scientific excellence, and deep understanding** of both the national and international quantum ecosystem make it an **indispensable partner** to the vigorous governmental initiatives currently shaping this strategic domain.
Thanks to its technical competence and **extensive network**, *NQSTI* serves as an **authoritative interface** between the research community, industry, and policy makers. In this pivotal phase of the digital transition, it plays a crucial role in supporting the integration of quantum-driven innovation into Italy's technological and industrial fabric.
This document is a tangible example of how ***NQSTI*** can serve as a **reliable and timely source of information and analysis** to assist policy makers in monitoring progress and shaping informed strategies for the future of quantum technologies in Italy".

***NQSTI* is organized in 9 Spokes**: the first 2 dedicated to establishing the theoretical and conceptual framework of the systems to be developed, and the following 3 dedicated to the technological platforms needed to implement those concepts defined in terms of the quantum of choice (atoms or molecules, photons, electrons), Spoke 6 dedicated to the integration of the developed devices into functional modules, Spoke 7 dedicated to research on system architectures. Spokes 8 and 9 are transversal Spokes dedicated to Technology Transfer and Education and Outreach, respectively (see *figure 1*).

Figure 1. The NQSTI Spokes' structure



Overall, the Partnership comprises 20 participants (public, non-profit entities, and private companies). The Hub was set up in the form of a limited liability consortium (SCARL) with the involvement of all public participants and is hosted in CNR central seat in Rome.
Its mandate is:

- ensure the coordination and management of the overall program towards the Italian Ministry of Research (MUR) and the Spokes, according to the agreement with the MUR and European/national rules for expenditures;
- monitor Spokes and participants, address gender-equality issues and diversity management;
- provide recommendations on the most appropriate solutions for achieving the selected research results;
- coordinate and promote interactions among "Spokes" and with stakeholder organizations;
- provide centralized program management support (e.g., periodic workshops, website hosting, etc.);
- promote educational programs and workforce development.

Within the Hub organization described above, *NQSTI* is scientifically coordinated by a steering committee formed by the Spoke leaders and chaired by Professor Fabio Beltram. Each Spoke is organized with a scientific coordination team comprising all activity leaders, and managing coordination is ensured by the Participants' representatives.

Fabio Beltram
NQSTI Scientific Coordinator
Full Professor of Experimental physics of matter and applications
Scuola Normale Superiore

"The ***National Quantum Science and Technology Institute*** **(*NQSTI*)** represents a strategic national initiative aimed at consolidating and advancing Italy's capabilities in quantum technologies. Through coordinated action and the support of **PNRR** funding, *NQSTI* has **modernized research infrastructures**, fostered collaboration among universities, research centers, and industry, **and trained a new generation of scientists**. Its **open and integrated model** has successfully unified national competences, enhanced technological platforms, and stimulated innovation and technology transfer. The recent establishment of **Quantum Technology Fabs** is particularly relevant since it ensures long-term sustainability by providing **shared facilities for the design, prototyping, and certification of quantum devices and systems**.
This document reflects ***NQSTI*'s strategic vision and outlines the national landscape of quantum technologies**, highlighting their essential role in strengthening Italy's scientific excellence, industrial competitiveness, and contribution to a vibrant quantum ecosystem".

The knowledge transfer system for QST

NQSTI is designed to effectively coordinate the efforts to bring science and development within all main stakeholders, *in primis* Research Organizations, Universities, and Industry, reconciling the different purposes and time horizons. This coordination will make it possible to overcome the current structural weakness that limits the ability to transform Italian *blue-sky* research into innovation. The aim is to create products and services with high added value, generating great opportunities for the social and economic well-being of the community (health, safety, energy, environment). It is equally necessary to combine the effort in research and innovation with a suitable upgrade of the education and training system. The goal to be achieved is the creation of a **learning ecosystem** capable of transferring the basic concepts of quantum science at all levels, from school to professional environments. It is necessary that the key concepts of quantum mechanics become an integral part of the training curriculum for all innovation actors, starting with engineers and computer scientists, as well as, naturally, chemists and physicists. This not only serves to train workers ready for the quantum revolution but also to create an advanced, informed society with open knowledge and attitudes towards quantum technology.

The long-term vision of *NQSTI* is the establishment of a national institute capable of structuring human resources, technical infrastructures, public and private investments to promote scientific research, technological development, and, in the medium term, industrial adoption of QST. In other words, a new ecosystem of innovation in which today's ability to study and manipulate single quantum objects (atoms, photons, molecules, nano-devices) results in tomorrow's industrial applications (see *box 1*).

Box 1. The National Research Plan for QST

The *National Research Plan 2021-2027* (*MUR*, 2020) sets a series of overarching objectives. Within the scope of the Extended Partnership and taking into account the other efforts financed within *M4C2* and by EC, the successful completion of our program will realize those objectives:

- Make Italy a key player of QST, both as a supplier of qualifying technologies, as a developer of integrated platforms and algorithms, and as an industrial end-user.
- Make Italy technologically independent by creating vertical production chains of quantum devices.
- Demonstrate the possibilities of QST for the increase in the efficiency of devices and systems and for improving the sustainability of industrial processes and the energy efficiency of consumer products.
- Set up at the national level a ***QT supply chain*** for:

i) integrated electro-optical, photonic and scalable hybrids;

ii) devices based on semiconductors, superconductors, molecular nanomagnets, photonic, atomic and hybrid systems;

iii) miniaturized quantum sensors based on neutral atoms, superconductors and opto-electro-mechanical devices;

iv) quantum imaging devices;

v) quantum interfaces capable of combining different platforms;

vi) test, validation and certification of QST systems.

All this is obtained by completing existing infrastructures, complementary in different areas (superconductivity, cryogenics, etc.).

- Create a *National Institute for Quantum Technologies* that allows to preserve and enhance the great national human capital and the key technologies for industrial development. *NQSTI* will have a federative role in the national community, and provide coordination and support between research and industrial development as well as between the different QST, within a network, and in synergy with the European strategy.
- Create new interdisciplinary paths of Higher Education (master's degree and doctorate) in this advanced and rapidly evolving scientific sector to prepare highly specialized staff and in possession of transversal skills involving industrial realities in training and academic research.

SPOKE 8 "Technology Transfer"

Among the various mechanisms to encourage the transfer of academic knowledge, the commercialization of research results (IPRs, licensing, spinoffs) is the tool that has generated the greatest number of insights in the last thirty years, both within the scientific literature and within institutional reports (*OECD* 2011, 2013, 2019). Although patenting and licensing activities represent effective ways to contribute to the development of the economy and society, several other ways exist through which scientific knowledge flows between public research bodies and non-academic organizations (see *box 2*).

Box 2. The Knowledge transfer (KT) for the EU

Knowledge transfer (KT) is a concept used broadly to describe the **flow of (scientific) knowledge between research organizations (including universities and PROs) and business**, with the objective of creating socio-economic impact through promoting better use of the (public) research base. This concept replaced the formerly used "Technology Transfer" (TT) to reflect the wider knowledge base than just technology being transferred. Nowadays, the term "knowledge exchange" is used instead to reflect the fact that **the flow of knowledge is neither one-dimensional in the direction "research organization to industry'**, nor only between the players on this scale (multidimensional), *European Commission* (2014).

The *European Commission* (2020) underlines how Knowledge Transfer **is a complex process that involves many non-scientific and non-technological factors**, as well as many different stakeholders. Good or high-quality research results are not enough for successful technology transfer; **general awareness and willingness,** both at the level of organizations and individuals, as well as skills and capacity related to specific aspects, such as access to risk finance and intellectual property (IP) management, are also necessary components.

NQSTI intends to push for the adoption of the most diverse mechanisms of knowledge transfer, both formal and informal, with an interdisciplinary and holistic approach: cooperative research, joint laboratories, personnel exchanges, participation and organization of roadshows and fairs. The several channels of technology transfer, in fact, play a different role according to the specific context in which they develop and according to the objectives declared by the organizations participating in the process (see *box 3*). Furthermore, informal mechanisms are often important catalysts for more formal instruments of exchange (Debackere and Veugelers, 2005). [1]

Gaia Raffaella Greco, PhD
Spoke 8 "Technology Transfer" Coordinator
Researcher
Istituto di Calcolo e Reti ad Alte Prestazioni del Consiglio Nazionale delle Ricerche

"As actors in the *National Quantum Science and Technology Institute*'s technology transfer activities, we first have to **analyze and understand the national QST system**. Knowledge on the international and Italian industrial quantum structure is scarce and scattered across multiple sources (academic literature, consulting and institutional reports, *EU-Cordis* repositories, IPRs, and VC's datasets).
Incomplete Information could lead to incorrect or worthless decisions at the national level and in companies' long-term choices. **Strategic monitoring is** always **ongoing**".

Box 3. The main goals of NQSTI Knowledge Transfer

Main Goals of *NQSTI* "Knowledge Transfer" are:
- *to translate **basic research** into **applied knowledge**;*
- *to know and to **collaborate** with **science-based companies**;*
- *to **develop "academic engagement"** in knowledge transfer;*
- *to boost the **"absorptive capacity" of companies**;*
- *to **create trust** and promote **team spirit** within the NQSTI network;*
- *to **reduce** socio-cultural, organizational and technical **barriers** between academia and companies;*
- *to take advantage of all **formal** and **informal** collaboration tools;*
- *to encourage the creation of **new companies** in the sector;*
- *to train a **new class of scientists and entrepreneurs** in the sector;*
- *to **attract investments** and talents, also through internalization processes;*
- *to **inform** main stakeholders about Quantum Technologies, scientific developments, initiatives, and use cases implemented at the national and international level;*
- *to obtain the maximum **economic and social benefit to society** from research activities on the technological frontier.*

SPOKE 9 "Education and Outreach"

Carrying out the ambitious and highly innovative program of *NQSTI* requires highly qualified and specialized personnel who are able to operate within scientific and industrial organizations both at the national and international level in an extremely advanced and rapidly evolving scientific sector. From the point of view of human resources training, these characteristics pose non-trivial challenges, also considering that interdisciplinary skills are required, transversal with respect to the usual disciplines into which the university system is divided.

[1] For more Information on NQSTI Spoke 8 "Technology Transfer" activities: https://nqsti.it/technology-transfer

These needs originate from the academic/research world and are driven more and more from the industrial demand, where the interest in QT has rapidly increased in the last decade, initially stimulated by large multinational companies, and progressively also from small/medium enterprises and spinoffs, focused on specific devices and/or applications.
The level of Italian university education is generally very high and internationally appreciated. In the QT sector, at the time of the writing of the proposal, a few specific degree courses dedicated to QT were present, coming mostly from physical science. Recognizing the relevance of human resources training from the perspective of a longer-term horizon of the *PNRR* duration, *NQSTI* has decided to invest in the development of quantum-technology-oriented education and training via the activities and resources of *Spoke 9*. In this effort, special care has been devoted to guaranteeing wide access to the QST field, taking into account factors such as gender equality and diversity.
The activities carried out by *Spoke 9* encompass all the levels from high school to higher education, but it also includes the essential training at the professional level both of high-school teachers and of industry employees, which is required to increase the amount of highly qualified personnel towards quantum technology (see *box 4*).

Elisabetta Paladino, PhD
Spoke 9 "Education and Outreach" Coordinator
Full Professor of Theoretical physics of matter, models, mathematical methods and applications
Università degli Studi di Catania

"An extremely **advanced and rapidly evolving scientific sector** poses non-trivial challenges. We need an **interdisciplinary training system** that goes beyond actual academic departments. The industrial ecosystem, as well as the ambitious and highly innovative program of *NQSTI*, requires **highly qualified and specialized personnel**".

The effectiveness of these actions is tightly connected to the general awareness of the extraordinary revolution that QTs are bringing closer and closer to everyday life, as witnessed by the decision of the *United Nations General Assembly* to declare 2025 the *International Year of Quantum Science and Technology*. Because of the broadness of the research, knowledge transfer, education and outreach activities carried out at the national level and within international collaborations, *NQSTI* is one of the *Distinguished Partners* of the *IYQ*[2].
Another aim of *Spoke 9* is to raise awareness on QST of civil society, particularly with companies and professional organizations that do not yet know the potential of quantum technology but might become relevant stakeholders in the future. A vast number of outreach initiatives at all levels have been undertaken and are in progress in the course of 2025[3].
To implement this work program *NQSTI* has exploited the expertise on education and outreach of the consortium partners, firmly based on the output of the *Quantum Flagship Initiative* under the *QTEdu Coordination and Support Action* and on the recommendation of the Italian *Programma Nazionale per la Ricerca 2021-2027* (*MUR, 2020*).

[2] More Information is on: *https://quantum2025.org/*.
[3] Detailed Information is on: https://nqsti.it/index.php/activities/outreach.

Box 4. The main goals of NQSTI Education and Outreach

Main goals of *NQSTI* "Education and Outreach" are:
- ***Identification of QST educational strategies*** *and available infrastructures and services;*
- *Establishment of* ***training courses for high school teachers*** *on QST topics;*
- *Establishment of* ***scholarships for specialized QST-training in industry*** *or joining academia/industry labs;*
- *Activation of* ***specialization internships*** *within existing Masters;*
- ***Activation*** *of new I and II level* ***Masters*** *in dedicated academic/****industrial laboratories****;*
- *Organization of* ***outreach events for civil society*** *and of info days dedicated to industries.*

The NQSTI Report: purpose and objectives

NQSTI objective for all the academic institutions involved is to strengthen cooperation with the private sector in two complementary directions: inducing the research community to respond to the needs of industry and encouraging the latter to contribute to a re-launch of the technologies available to QST researchers.

Within the process of research valorization, one of the actions envisaged was the drawing up of a dataset of possible users of the knowledge produced inside the academic institutions. Furthermore, NQSTI aims at informing the academic, the industrial and the institutional stakeholders on major technical advances, state of development, use cases implemented, real-market applications, and standards definition at national and international levels.

The Italian industrial sector analysis was driven by the need to understand the main dimensions of the *Quantum Science and Technology National System*, to comprehend the principal variables of the internal market (geography, size, collaborations, and industries involved), and to fully channel fundamental Technology Transfer, Education, and Communication initiatives.

It emerged early in the first meetings among the NQSTI partners that there was a need for a clear understanding of the national Quantum technological context, analyzing the essential characteristics, the value chain, the collaboration capacity, the research cooperation culture, and the propensity of the firms in Italy. Specific questions remain:

- *How many firms in Italy work on QST research projects?*
- *Where are they?*
- *What are the main characteristics?*
- *Who is collaborating with whom?*
- *What are the main topics of investigation?*
- *In which industries do they operate?*
- *How do they build their cooperative networks?*

Science-based firms are defined as organizations where the main source of technology lies in the R&D activities of the companies themselves (Niosi, 2000). The knowledge resulting from research, pure and applied, which is carried out in universities and other public research centers flows, thanks to the collaborative activities carried out to companies. However, only a knowledge base created thanks to internal R&D activities allows the company to benefit from the research that is carried out in other organizations (Cohen and Levinthal, 1989).

Through the construction of an *original dataset of firms*, the NQSTI Report intends to represent a first picture of the Italian QST Knowledge system, shedding light on the leading actors, analyzing primary industrial sectors and applications, investigating the geographical distribution of companies and spinoffs, questioning the strategic missions, and reflecting on emerging trends.
The scope of the document is to describe the current efforts towards the implementation and deployment of quantum technology (QT) in Italy, through the presentation of the main global dynamics and politics. Notably, the report includes four separate Chapters.

The *First Chapter* presents an investigation of the *institutional and consulting literature on quantum technology and markets*, analyzing industrial segments (quantum communication, quantum computing and simulation, and quantum sensing), public and venture capital financing, outlooks, and trends on a global scale. The aim of the Chapter is to represent international dimensions broadly by comparing the most relevant references and offering insights for further in-depth analysis.

The *Second Chapter* introduces European policies related to Quantum Science and Technology, explicitly describing the *Quantum Flagship* initiative and the *Quantum Europe Strategy*. The scope of the Chapter is not to analyze single European national policies, but to contextualize the Italian national system of innovation inside the European general framework.

The *Third Chapter* analyzes the QST system by investigating the original *NQSTI* dataset. It presents a *comprehensive overview of Italian companies entering the quantum industrial sectors*. Several key highlights emerged, including the geographical distribution of these companies, the industries to which they belong, and the markets they serve. One particular section focuses on the role of Italian startups, emphasizing their growing importance in this field (a list of these startups is provided in the text).

Finally, the Fourth Chapter aims to represent and analyze each Quantum "vertical" (computing, communication, simulation, and sensing), further highlighting synergies and interdependencies among them, and evidencing the relevant role played by supporting firms and other industries. Along with the analysis of the quantum sectors of application, a *particular focus will be on Italian research and industrial excellence, analyzing specific business case studies*.

Direct interviews were conducted to give voice to the protagonists who live in the Quantum industrial and academic sectors. Indeed, a specific set of questions has been asked to: ***academics*** with specific Technology Transfer backgrounds, ***venture capitalists*** operating in Italy, and ***CEOs and research managers*** of QST firms.
Relevant questions pertain to actual and future QST industrial applications, supply chain challenges, the current state of final markets, hypothesized outlooks, and underlying significant difficulties faced in strengthening coordination and excellence.

The Executive Report presents the primary evidence from Chapters 1, 2, and 4, with a focus on Chapter 3 "Italian QST System of Innovation".

A Quantum Revolution

QUANTUM SCIENCE AND TECHNOLOGY IS DISRUPTIVE

Quantum Science and Technology (QST) is based on the consequences of the most profound and revolutionary properties of Quantum Mechanics. QST is a highly innovative R&D sector with a high impact potential. Future development of these technologies promises to establish a new revolution in different fields. This approach has its foundations in the capability to manage and fully exploit the potential of quantum phenomena (superposition principle, entanglement, etc.), in which particles can assume different states at the same time or the same state in different places. Compared to other more traditional technologies, QST has the unique ability to enable solutions to problems today typically cataloged as impossible, irresolvable, or very expensive from an energy point of view, or to reach measurement sensitivity beyond what is achievable with traditional techniques.
The transformation envisaged is disruptive, considering the ability of QST to have a direct and far-reaching impact on all fields of science, from Information technology to biology, from telecommunications to engineering, medicine, and the environment. All this is expected to lead to an exponential growth in simulation power, to communicate Information in a totally secure way and, again, to create devices capable of carrying out measurements with yet unattainable precision. These solutions are made possible by exploiting specifically designed platforms that use novel systems based on atoms, molecules, photons, and innovative solid-state materials.

Milena D'Angelo, PhD

Professor of Experimental Physics of Matter (Coordinator of the 2nd level Master in QS&T; Leader of the Quantum Optical Technologies 2.0 Lab)
Dipartimento Inter-ateneo di Fisica
Università degli Studi di Bari

"The quantum revolution is being extraordinarily powerful in combining passion for fundamental physics with enthusiasm for transforming scientific discoveries into technologies for society"

Mikkel Ejrnaes, PhD

Researcher of CNR
SPIN - Institute for SuPerconductors, Innovative materials, and devices
Comprensorio Olivetti di Pozzuoli (NA)

"The Quantum Revolution has only scratched the surface"

DSQM, Digital Superconducting Quantum Machines

Claudio Puglia, PhD
CEO
Digital Superconducting Quantum Machines SRL
Website: www.dsqm.it

"The quantum revolution is unlocking the mysteries of the quantum world, paving the way for groundbreaking innovations in computing, communication, and sensing that will redefine the limits of human capability and revolutionize industries across the globe"

QUANTUM SCIENCE AND TECHNOLOGY REPRESENTS CROSS-SECTORAL FIELDS OF RESEARCH

These application domains are based on a common foundation of fundamental science, with prominent research institutes and companies assisting their objectives by providing novel concepts, instruments, techniques, and procedures. In particular, these are supported by cross-cutting areas covering engineering and control, software and theory, education and training, and general innovation and international cooperation activities.

Annamaria Cucinotta, PhD

Electromagnetic Fields (Full professor)
Dipartimento di Ingegneria e Architettura
Università di Parma

"The Quantum Revolution must enter in the Engineering Departments"

Antonio Cassinese, PhD

Matter Physics (Full Professor)
Dipartimento di Fisica "Ettore Pancini"
Università degli Studi d Napoli, Federico II

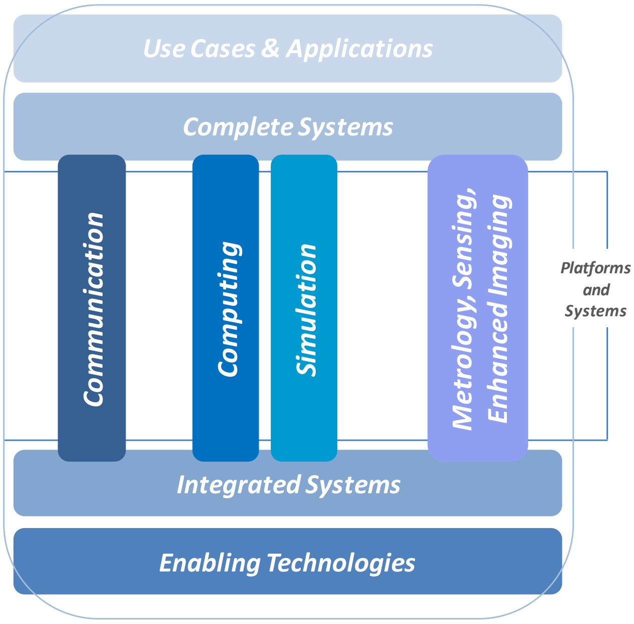
"Materials for quantum will drive us towards a true coming of age"

Vanni Lughi, PhD
Materials Science and Technology (Associate Professor)
Dipartimento di Ingegneria e Architettura
Università degli Studi di Trieste

"Materials are at the cornerstone of the development of all game-changing technologies"

THERE ARE STRONG COMMONALITIES AMONG THE QST PILLARS

Figure 2. The Structuring of Quantum Technology
Source: van Deventer et al., 2022.



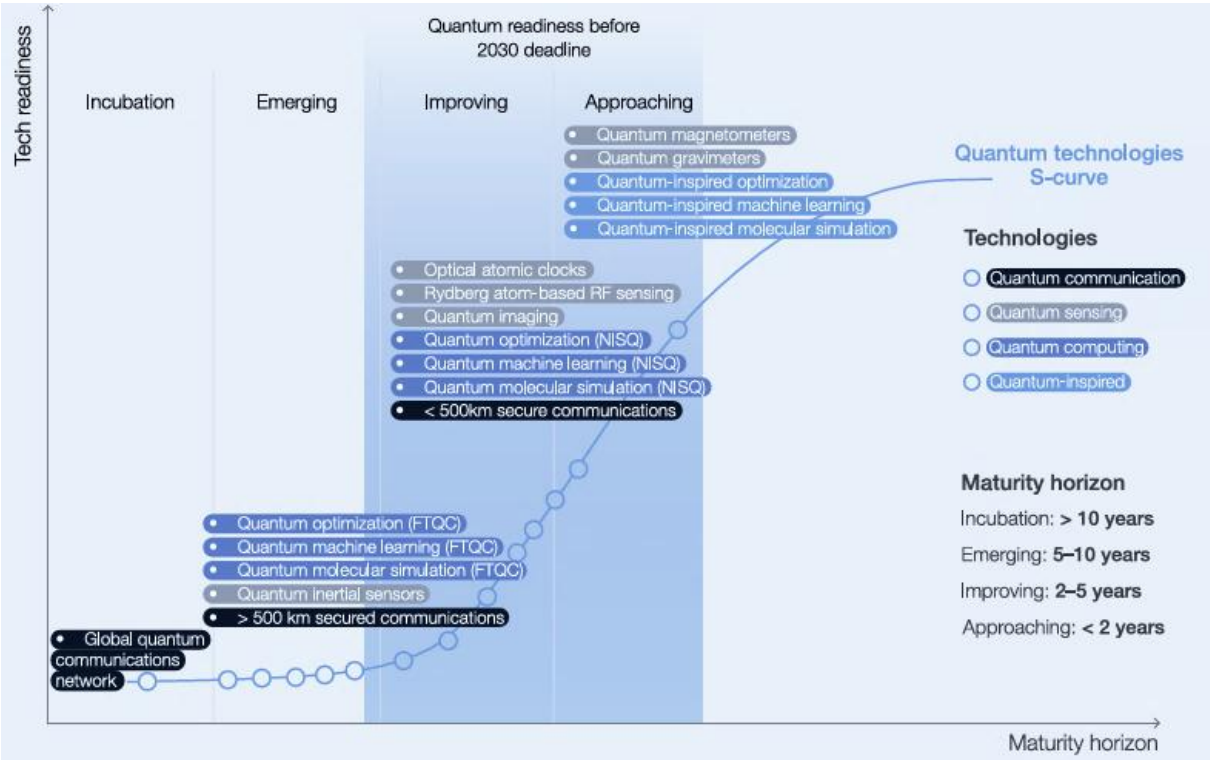
The *European Quantum Flagship* (2022) refers to four areas of research and innovation that represent the sector's primary application areas: communication, computing, simulation, and sensing and metrology.[4] In *McKinsey*'s report (2023), metrology is included in the sensing pillar, but it is not explicitly defined. In addition, quantum simulation is considered as a specific field in which quantum technology offers an advantage.
These pillars shape an imaginary 'Greek Temple' of Quantum Technology (*figure 2*), based on enabling technologies and a quantum subsystem. The pillars support complete systems and the development of case studies and real-world solutions (*CEN-CENELEC*, 2023a).
The pillars only represent a shortcut to facilitate the knowledge of the fields of study and applications of quantum technology, as they often communicate with each other in their development and diffusion. For instance, the advancement of quantum communications can aid in developing quantum

[4] *Roland Berger* (2024), as it will be better described later in the text, divides the quantum market into four segments: quantum computers, quantum sensing, quantum communication & cryptography, and supporting technologies (ST).

sensor networks or protocols for distributed quantum computing. Similarly, techniques for efficient quantum Information processing could be used in the construction of quantum repeaters for long-distance quantum communication.

QST SHOWS DIFFERENT LEVELS OF MATURITY

Figure 3. The S Curve of Quantum Technology
Source: World Economic Forum, 2024.



The ongoing quantum revolution means a whole new generation of technologies with the potential for far-reaching economic and societal impacts. Several innovations are already in development, while many others will be developed in the next few decades. As emerged earlier in the text, every *pillar* shows its proper growth path and level of maturity (see *figure 3*). While the current state of quantum technology is marked by exponential advancements, *quantum sensing* and *quantum communication* solutions work in real-world applications, and full-scale machines are expected in the next decade in *quantum computing*. Quantum devices have begun to scale enough to run minor variants of problems that classical computers currently find insurmountable, such as optimizing complex systems, simulating molecular structures for drug discovery, and solving large-scale linear equations (*World Economic Forum*, 2025).

Leonardo Quantum Lab

Massimiliano Dispenza, PhD
Head of Quantum Technologies, Optronics and Advanced Materials Labs
Leonardo S.p.A.
https://www.leonardo.com/it

What are the main areas of application for quantum technologies?

Sensor systems are surely among the first areas for applications, referring to Quantum sensing pillars. In particular, Quantum Imaging and Quantum sensing for Navigation are two big opportunities. Also Quantum Communications could be a close opportunity, though Quantum Key Distribution, one of first use cases, should propose also solutions to few open issues raised by National Security Agencies. Quantum Computing is a long run and a challenge still open for future 1 or 2 decades.

TASI, Thales Alenia Space Italia

Enrico Varriale
R&D&T Management – Observation, Navigation and Telecommunications
Italy
Thales Alenia Space Italia S.p.A.
https://www.thalesaleniaspace.com/it

What are the main areas of application for quantum technologies?

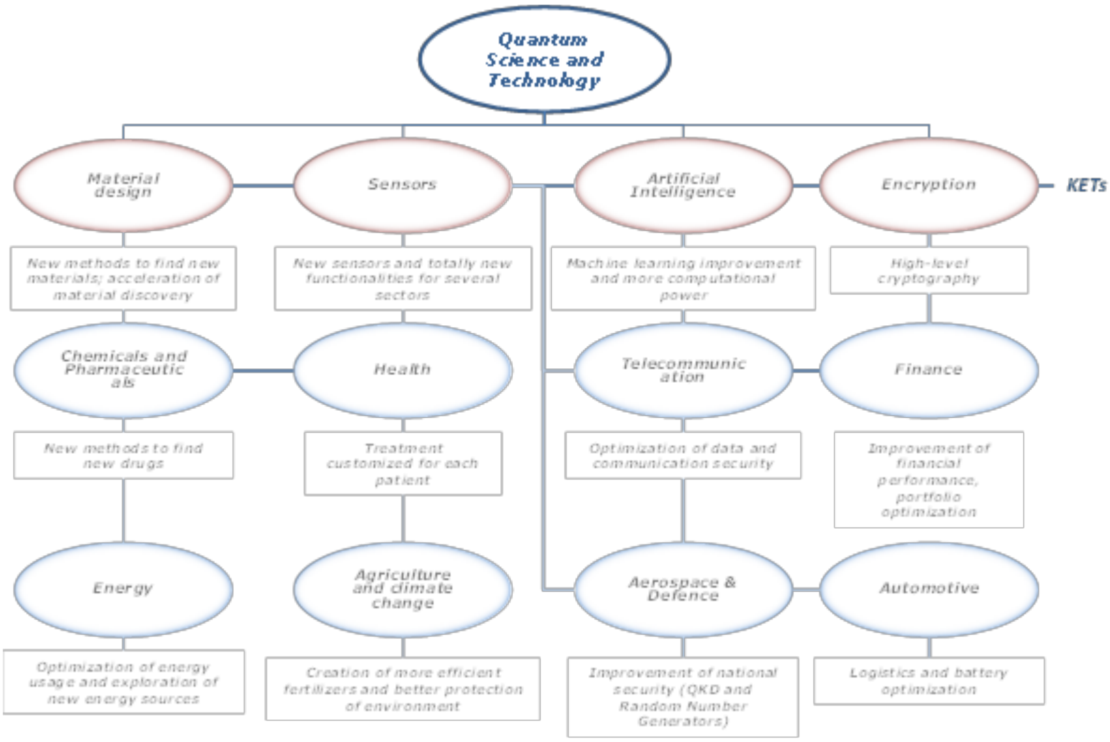
TASI has identified several potential applications for quantum technologies across all major domains within its business scope: *navigation, earth observation, telecommunications, exploration, and science*. This indicates the *pervasive potential* and significant impact that quantum technologies can have in the space sector.
There are specific areas of development with higher priority, driven primarily by market demand, which currently comes mainly from institutional clients. From our perspective, there's a *strong impetus in the telecommunications domain*, particularly for leveraging quantum technologies to enhance the security of links used for exchanging sensitive data. We also observe a growing interest in applications related to sensing and metrology.

Quantum sensing is more mature than other quantum technologies and has far-reaching potential. Applications are available in diverse fields such as microelectronics, logistics, and life science (brain injury imaging through magnetoencephalography). The main technologies used in these fields are solid-state spins and neutral atoms. Their impact will be measured by the degree to which the technologies will enable new possibilities or drastically improve existing options in terms of sensitivity, accuracy, or cost-efficiency.

Quantum communication ensures ultra-secure data transmission in a way that current technologies cannot. Several research projects were born with the idea to contribute to constructing a secure global quantum Information network. The quantum internet is expected to develop in the next 25 years, when satellites or terrestrial quantum repeaters could constantly amplify the signals to enable transmissions over long distances.

QUANTUM SCIENCE AND TECHNOLOGY ARE KEY ENABLING TECHNOLOGIES

Figure 4. The primary applications for quantum technology



The Quantum Revolution could impact almost all the scientific fields and, in the long run, several technological areas and industries. Many diverse consulting and government reports underline specific uses or emphasize industrial sectors. When discussing *Key Enabling Technologies* (KET) it is not easy to synthesize all the areas of QST interests. The figure above represents the main ones, highlighting the reasons for the emergence of radical innovations.

Vittorio Giovannetti, PhD
Professor of Theoretical Physics (Full professor)
Scuola Normale Superiore
Planckian

What are the main areas of application for quantum technology?

Quantum Communication can potentially enable ultra-secure data transmission using quantum encryption, such as Quantum Key Distribution (QKD), which ensures that eavesdropping is detectable. Quantum Sensing could in principle improve measurement precision in fields like medical imaging, navigation, and geophysics by exploiting quantum states like entanglement and superposition for higher sensitivity. Quantum Internet promises to revolutionize global connectivity by enabling instant, secure communication across quantum networks, offering breakthroughs in data privacy and computational speed.

Quantum algorithms, like quantum annealing, can optimize logistics, supply chains, and financial portfolios by solving large-scale, combinatorial problems faster than traditional methods.

Copan Group
Francesco Dal Dosso, PhD
Senior Innovation Manager
Copan Italia S.p.A
Website: www.copangroup.com

"Quantum technologies have the potential to impact many fields of our society and with the QuBi project we aim to bring this impact to the biomedical and clinical fields"

What are the main areas of application for quantum technology?

From our understanding, being outsider in quantum technologies, we see the main applied and market-ready fields in quantum computing and cryptography. However, we see high potential in the biomedical field where quantum sensing could bring unprecedented level of sensitivity and specificity in detecting, identifying and analyzing pathogens, cellular material and tissues.

Rigetti Computing
Stefano Poletto, Director of the Quantum engineering department
Rebecca Malamud, Senior Marketing & Communications Manager
Rigetti Computing
https://www.rigetti.com/

What are the main areas of application for quantum technology? What are the target markets?

Quantum computers harness the unique processing capabilities of quantum mechanics to exponentially reduce the time and energy needed for high-impact computing. This computational power unlocks the potential to address complex problems across industries that were previously unsolvable by classical computers alone. *Applications* include:
Pharmaceutical: Design and optimize new druglike molecules for known targets, Aid drug discovery;
Finance: Optimize returns and manage risk for investment portfolios;
Machine Learning: Train better AI with less computational overhead;
Logistics: Reduce time and fuel costs by optimizing vehicle routing.

COLLABORATION BETWEEN ACADEMY AND INDUSTRY IS CRUCIAL

Quantum effects and established concepts from quantum science have become new technological applications and have helped develop new products and services. Stronger relationships with the industrial partner, while boosting scientific excellence, could facilitate the way towards market applications, helping to find new, productive, and commercial solutions. Several developed scientific and technological concepts are yet ready to enter the industrial value chain, offering relevant chances to develop new business organizations and new professional figures (*Quantera*, 2022).

Lutech

Ivano Pullano - Vittorio Piccinini
Quantum Technology Leader – Technical Director
LUTECH S.p.A.
website: *https://www.lutech.group*

"Lutech sees quantum technologies as the next frontier for accelerating AI, alongside High-Performance Computing systems. These technologies have the potential to transform security, optimization, and advanced modelling. To create sustainable solutions for enterprise applications, collaboration with universities, startups, and technology partners is crucial. We are actively monitoring advancements in various technologies and working with Innovation Centers to identify and expedite emerging needs"

What, in your opinion, can be an outlook for the quantum supply chain? What are the challenges?
The quantum supply chain is becoming a global ecosystem, demanding a mix of advanced capabilities from material science to precision engineering. A key challenge is developing fault-tolerant systems through robust hardware error correction, while also shrinking quantum components to make them scalable and practical. Progress depends on aligning innovation, manufacturing, and infrastructure to support reliable quantum technologies at scale.

IT Svil

Carlo Mancuso
CEO & Founder
IT Svil s.r.l. (Salerno, Italy)
website: www.itsvil.it

"IT Svil promotes collaboration between research, industry and institutions as a key process for accelerating the development and adoption of innovative technologies such as quantum technologies. In fact, it has founded 2 spinoffs in collaboration with UNISA: INNOVA4TECH and X-For."

Geomatics Research & Development

Daniele Sampietro, PhD
Applied Geophysics Manager
GEOMATICS RESEARCH & DEVELOPMENT
website: www.g-red.eu

"Quantum science and technology are opening new frontiers in measurement and sensing, enabling levels of precision and sensitivity that were previously unattainable. We strongly believe that structured support to academic spinoffs is essential to turn research breakthroughs into societal and industrial value and a stronger integration between public research, specialized SMEs, and institutional funding can accelerate the transition from lab prototypes to real-world impact"

Antonio Carbone

Head of Investment and Partnership
Italy, Europe
Day One
*Website: **www.day-one.biz***

"Venture building plays a critical role in developing new quantum innovations by fostering the collaboration of multidisciplinary teams, providing resources, and accelerating the commercialization of groundbreaking quantum technologies from concept to market"

QUANTUM TECHNOLOGY CAN DETERMINE THE PROSPERITY OF COUNTRIES

If predictions are fulfilled, advanced countries will split between those with direct access to QST and those without, with serious problems for strategic infrastructures and national security. It is now widely understood how the control of technologies based on substantial scientific advances and incorporating innovations can determine, soon, the prosperity of countries or entire regions of the planet. A high level of expertise in these technologies will become the fundamental element for economic development and our societies' digital self-determination in the next decade.
The development of QST will inherently involve those realities capable of bringing these technologies to an industrial level (micro- and nano-electronics, photonics, software, etc.) and those able to enhance and to exploit them. This overall coordinated effort will be necessary to maximize the benefit of this radically new technology. Moreover, such activities through QST would acquire a notable advantage of competitiveness in highly technological fields such as the pharmaceutical, chemical, aeronautical industries, and unbridgeable in others, such as research and applications on new materials, cyber-security and energy resources.

QST FORECASTS SHOW A RAPID PACE OF DEVELOPMENT

The development of quantum technology is expected to have a substantial effect both socially and economically worldwide. *Yole Développement* (2021; 2024) forecasts that by 2030, the total market for quantum technology (computing, cryptography, sensing) will reach US$2.9 billion.
The market research company estimated a 18% and 30% *Compound Annual Growth Rate* (CAGR) for the periods "2020-2025" and "2020-2030", respectively. The three main market segments, quantum computing, quantum sensing-timing, and cryptography, grew between 2020 and 2030 to reach US$1,147 million, US$598 million, and US$1,163 million, respectively.
Roland Berger (2024) underlines how quantum technology has started to achieve significant market growth only in the past decade, thanks to theoretically and practically proven technological benefits of quantum mechanics applications, which are significantly more potent in secure communications, sensors, computing, and simulation. The consulting company predicts a market size by 2021 of around 1 billion US dollars. This value is expected to increase tenfold by 2025 and hit 50 billion in 2030. Outlooks are brighter in comparison to the *Yole*'s report. Internal pillar trends look similar in quantum sensing and quantum cryptography. *Roland Berger* (2024) underlines that each quantum segment represents around 25% of the total market; however, it is expected to shrink to around 10% by 2040, with quantum sensing showing a stable share of 3% (see *figure 5*). Still, the consulting company

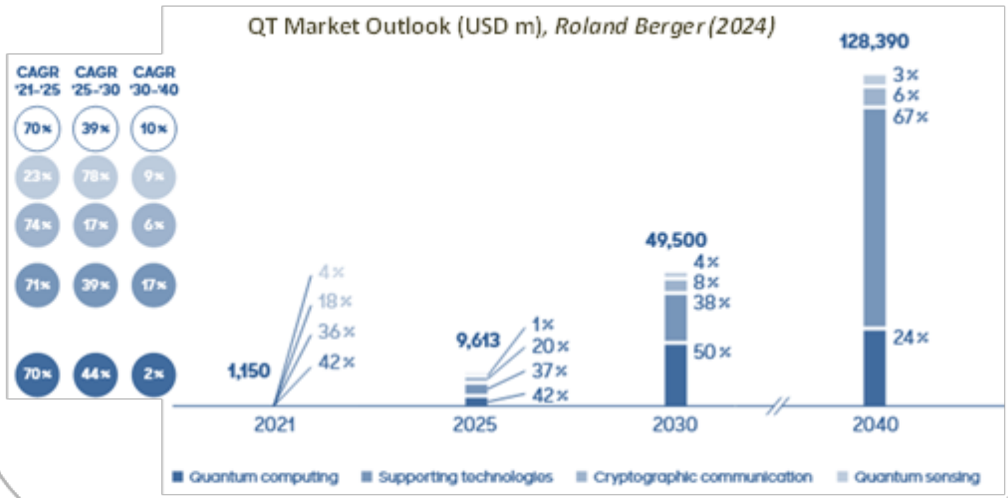
highlights how quantum computing is currently the most important market driver, accounting for more than 40% of the total dimension, and reaching around 50% by 2030.

Figure 5. The Quantum Technology Market Scenarios

Quantum Technology Market Scenarios, *McKinsey (2024; 2025)*

	Quantum computing (24; 25)	*Quantum Communication (24; 25)*	*Quantum sensing (2024)*	*Quantum sensing (2025)*
2035	*28-72 B $*	*11-15 B $*	*0,5-2,7 B $*	***7 – 10 B $***
2040	*45-131 B $*	*24-36 B $*	*1-6 B $*	***18 – 31 B $***

Based on existing development road maps and assumed adoption curve



CONSULTING REPORTS DO NOT AGREE ON SINGLE PILLAR'S DIMENSION DEVELOPMENT

McKinsey (2024) published "Quantum Technology Market Scenario", based on existing development roadmaps and an assumed adoption curve. Quantum Computing, particularly, will represent the largest segment in 2035, showing a similar rate of growth to quantum communication. Quantum sensing has a tiny dimension compared to the other pillars, both by 2035 and by 2040.

CONSULTING REPORTS UNDERLINE THE PIVOTAL ROLE OF SUPPORTING TECHNOLOGIES

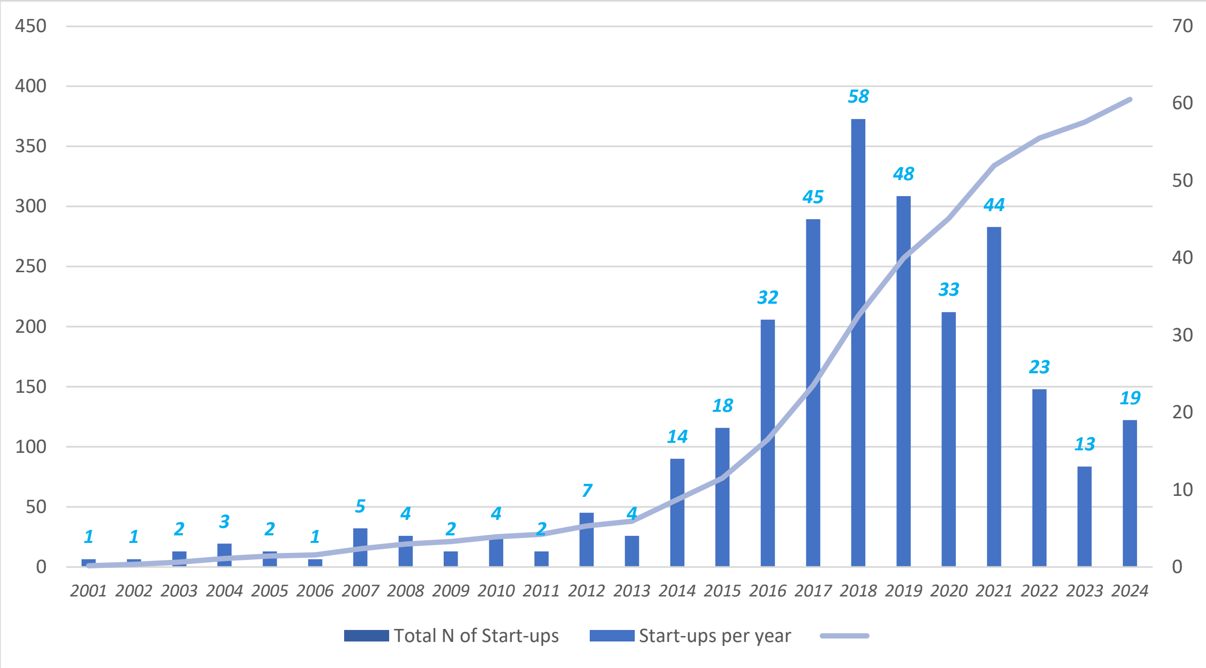
Figure 6. The Quantum Technology Global Players
Source: Yole Intelligence, 2024.

In the Market Analysis, *Roland Berger* (2024) underlines the pivotal role the *supporting technologies* play, as vital enablers of quantum computing. As commercialization and automation will develop soon, technologies to cool chips or trap atoms, such as optics, lasers, photonics, cryogenics, packaging, electronic components, or software systems, will particularly increase, doubling their size by 2040. The trend could have a significant impact on the quantum sectors and represent a strategic entry point for firms not directly engaged in quantum technology, which could take a significant role inside the *quantum value chain.*

QED-C (2025) in the *State of the Global Quantum Industry* report highlights how QST comprises both *pure-play* companies and established technological organizations, including universities, laboratories, SMEs, MNCs, and other actors that dedicate a portion of their research activities and resources to Quantum Technology. At the global level, pure-play companies would exceed 500, while partial players would number more than 5,000 organizations (see *figure 6*).

A CLEAR TREND EMERGES IN QST STARTUP CREATION

Figure 7. The Number of Quantum Companies, 2001-2024
Source: McKinsey, 2025.



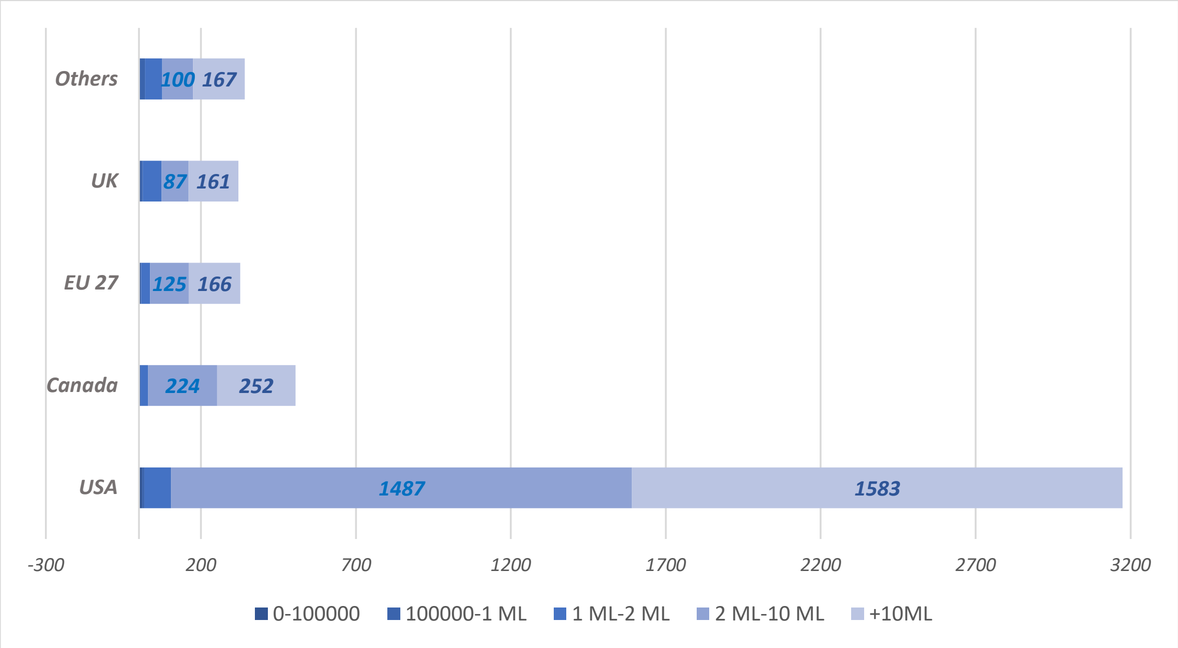
According to *McKinsey* (2025), approximately 368 startups globally are involved in the Quantum Technology ecosystem. In *figure 7*, the trend in startup creation from 2001 to 2024 can be analyzed. Particularly, the peak in VC investments reached almost $2.5 billion in 2022 (*IQM et al.*, 2024). In 2023, venture capital financing saw a net decline, with the United States experiencing an 80% decrease. During that period, *SandboxAQ*, *Rigetti Computing, D-Wave,* and *Origin Quantum* closed some of the biggest deals, i.e. $500 million in *Special Purpose Acquisition companies*: $345 million, $300 million, and $149 million, respectively.

NATIONAL CHAMPIONS OF INNOVATION: NO EUROPEAN BIG TECH GIANTS

European Policy Centre (2023) underlines the main differences between Europe and the United States in the dimension of quantum organizations. In the United States, big tech companies as *IBM*, *Google*, *Intel*, and *Amazon* are also trying to express themselves as leaders in QST. A vivid startup base would instead populate European markets.
Specifically, the report stresses the most significant number in new science-based firms' establishment in 2021, with companies leading the way in Europe, such as *IQM* and *Bluefors* (Finland), *Pasqal* and *Alice&Bob* (France), *Plancq* (Germany), *Delft Circuits* and *QBlox* (the Netherlands), and *Multiverse*

(Spain). These National Champions of Innovation would need significant capital for industrial development and scale-up.

Figure 8. The size deal in Quantum Technology, 2018-2021
Source: EIB (2024, PitchBook).



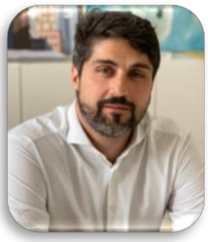
EUROPEAN PRIVATE INVESTMENT MARKET MUST BE DEVELOPED

The *European Commission* (2024) strongly warns of the need to develop private investment markets for deep technologies, as the private funding in quantum technology is very limited. There is no European company in the global ranking on private investments in startups, as five are from the US and four belong to China.
The *European Union* attracts only 5% of global private funding compared to 50% of the funding allocated by the United States. As evidenced in *figure 8*, the gap in private funding regards both the lower number and the lower overall value of funding rounds (seed, early, and growth stage).

Simone De Liberato, PhD

Chief Technology Officer, Quantum Italia
Website: [Quantum Italia]

“With its scientific capital and growing deep tech ecosystem, Italy has all the cards to become an important player in the quantum industry. We need to facilitate access to capital and create easy paths to the world of public procurement, inspired by the US SBIR mechanism”



Jacopo Drudi

Operating Partner, United Ventures
Website: www.unitedventures.com

“The Quantum Revolution can relaunch the competitiveness of Italy if we create an ecosystem involving public entities, corporates, universities and investors”

Nicola Redi, PhD

Managing Partner, Obloo Ventures
Website: www.obloo.vc

“Deepscover what matters: the future of quantum startups relies on outstanding infrastructures, system integration and effective business models”

Alessandra Scotti, PhD

Institutional Relations and Scouting Manager, LIFTT Spa
Website: www.liftt.com

“At Liftt, we aspire to drive innovation and growth in the rapidly evolving field of quantum technologies. We aim to impact the entire spectrum of emerging technologies in all major areas: computing, sensing and communication”

Emilia Garito, BSc

Founder and Chairman, Deep Ocean Capital SGR Spa

Website: www.deepoceanapital.it

"The future of innovation and the implementation of most scientific discoveries will depend on quantum computing. However, Science and Industry together have to be solution driven instead of technology driven. We all must be prepared to ensure that this computing power is only used for what society really needs and to solve the world's most complex problems. Let us prioritise the health sector and think about addressing cyber security needs through the development of quantum cryptography"

Quantum in Italy

The Italian QST market size and trends in reports

The *McKinsey* Report (2024) "Quantum Technology Monitor" investigates the main dimensions of the Italian national context, underlying how total public investment picked up to 144 million dollars and recognizing almost 70 different partners in the national network (among public and private organizations, see *table 1*). Particularly, the consulting firm discusses the pivotal role played by the PNRR Projects as *NQSTI* and *ICSC*, as well as the *QUID* project within the *EuroQCI* infrastructure.

Table 1. The McKinsey Report (2024) on Italy QST Dimensions

Figures	*Policies and newsà*	*Companies*	
~$ 144 Million *Total Public Investment*	*NQSTI Consortium launched in January 2023, is funded under NextGenerationEU and supports quantum technology education, technology transfer, and social outreach*	*Technology*	*N*
No reported Private Investment	*ICSC Spoke 10 focuses on QC applications, HD-SW, and scalability*	***Quantum Computing***	***2***
2% *Of QT-related patents have been granted to researchers based in Italy*	*QUID project within the EuroQCI infrastructure develops 13 QMANs in Italy connected to the IQB, and regions have developed strategies following EU to create ecosystems for startups and spinoffs*	***Quantum Communication***	***3***
~70 *Academic and Industry Partners as part of Italian QT System*	*- February 2024, Italy's first permanent multi-nodes connected to Italian Quantum Backbone, Naples (Funded BY MImit AND Meditech)* *- April 2023, SeeQC developed a joint-lab with Federico II University for first full-stack Quantum Computer"*	***Other (MNCs in Italy)***	***2***

The *Italian Strategy on Quantum Technology*, published in 2025, presents the most recent data. In the document, realized together with *Politecnico of Milano*, among the several QST stakeholders and international players, *31 Italian companies have been interviewed*:

- 14 companies and startups native to the quantum technology sector, and
- 17 large Italian players in the ICT and components sector such as system integrators, consulting firms and telco providers, which are differentiating their value proposition in the field of quantum technology.

Box: The Italian Strategy for Quantum Technology (2025)

In September 2025, the National Plan for the Development of Quantum Technology was adopted, marking an important step forward in strengthening the country's competitiveness and security. The new Italian Strategy for Quantum Technology aims to enhance research, promote industrial innovation, and strengthen technological capabilities.
The Italian Strategy for Quantum Technology is based on four priority axes:

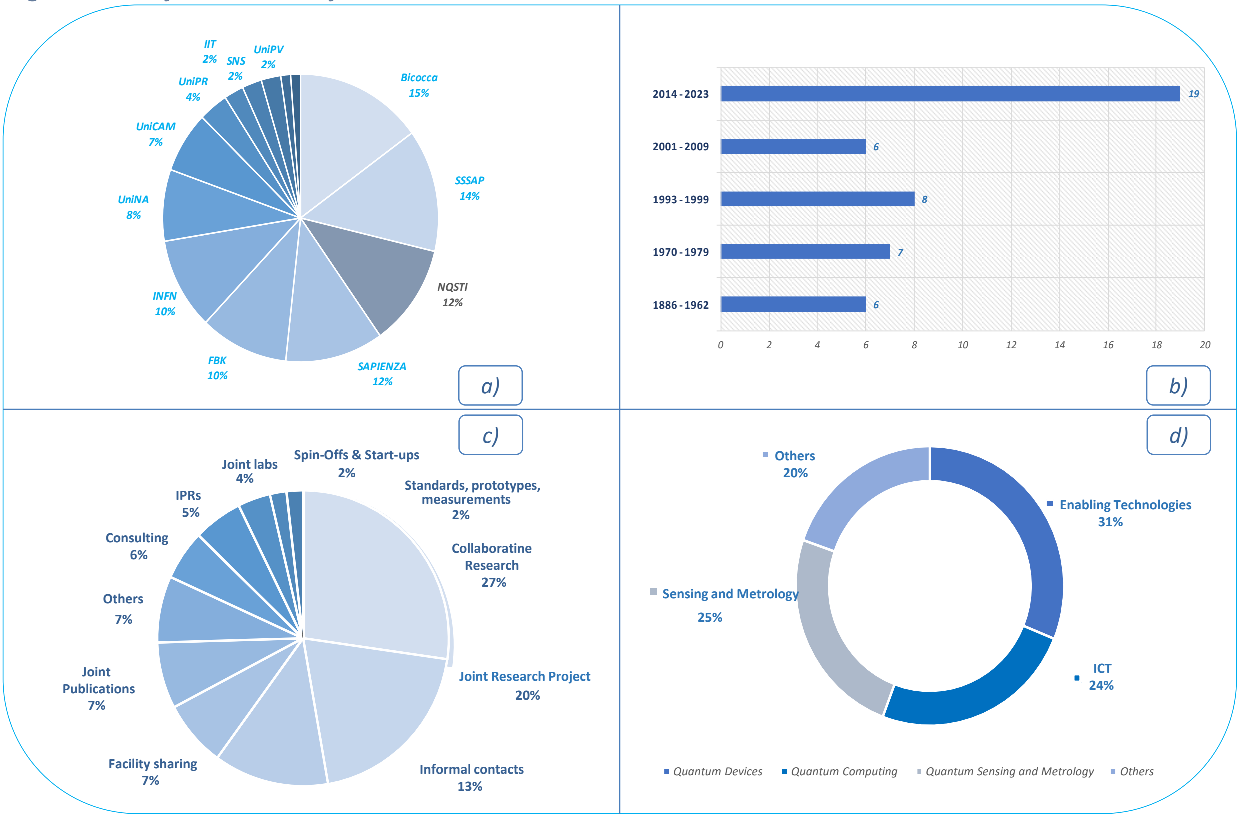
- *Scientific and industrial development in the five pillars of QT* (computation, simulation, communication, sensing, basic science);
- *Building an integrated national ecosystem capable of generating value along the entire chain*: research, technology transfer, industry, training;
- *Internationalization and security*: active positioning in EU programs and protection of critical technologies;
- *Governance and measurability*: concrete tools to coordinate, evaluate, and update strategic actions.

First evidence from the TTOs and Cordis Datasets

The first information on the national dimension of the Italian ecosystem for quantum technology was the result of a survey conducted among academic institutions participating in the Technology Transfer activities within NQSTI Spoke 8's network (see *figure 9*). The number of citations, the total number of firms that composed the dataset, was 87. Many companies have been cited several times by research organizations. These are the firms with the largest number of active collaborations and their main partners:

- *Airbus (Sapienza, INFN),*
- *CAEN spa (INFN, SSSAP, UniCAM),*
- *IBM Research EU (UniPR, IIT, CNR),*
- *Leonardo (IIT, Sapienza),*
- *SeeQC (UniNA, SNS),*
- *Telespazio (SSSAP, Sapienza),*
- *Thales (Sapienza, FBK),*
- *STMicroelectronics (UniPV, UniCT).*

Figure 9. The first evidence from the TTO dataset



To compile a list of companies representative of the national QST industrial environment, thereby expanding the sample of Italian organizations considered as much as possible, the second phase of the NQSTI research continued with an investigation into information about EU research and development projects. The *Cordis* dataset[5], established in 1994, provides free access to EU-funded research and innovation, featuring data on projects, topics, and publications supported by the EU's research programs.

Science-based firms form public-private partnerships to join EU projects with the aim of addressing the most pressing challenges through concerted research and innovation initiatives. European Partnerships are a key implementation tool of *Horizon Europe* and significantly contribute to achieving the Union's political priorities, reducing the fragmentation of the research and innovation landscape[6].

Particularly, *table 2* describes all the Italian companies with more than one participation in *Horizon Europe*[7].

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[5]https://cordis.europa.eu. Accessed May 2024.

[6]https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/european-partnerships-horizon-europe_en. Accessed September 2024.

[7] *Commpla srl, Day One srl, Trust-IT Services srl, and Warrant Hub spa* are not included in the list as they serve as supporting firms to the research projects: *Commpla* and *Trust-IT Services* work as software and product developers for digital marketing services; *Day One* and *Warrant Hub* are strategic consulting partners for funding and other marketing services for deep tech companies.

Table 2. The Italian companies with more than one participation in Horizon Europe

	City	Project
E 4 COMPUTER ENGINEERING SPA	Scandiano (RE)	***DECICE***
		MaX
EPHOS SRL	Milano	***QLASS***
		FUTURE
ERICSSON TELECOMUNICAZIONI SPA	Roma	***NANCY***
		ALLEGRO
FORESEE BIOSYSTEMS SRL	Genova	***SiMulTox***
		TwistedNano
LEONARDO SPA	Roma	***CARIOQA-PMP***
		MUQUABIS
		MaX
MICRO PHOTON DEVICES SRL	Bolzano	***QSNP***
		SEQUOIA
OSPEDALE SAN RAFFAELE SRL	Milano	***PolArt***
		KATSIM
QTI SRL	Firenze	***QuNEST***
		PROMETHEUS
		QPIC1550
TELECOM ITALIA SPA	Milano	***QuNEST***
		NextGEM
		NOUS
		QSNP
		ALLEGRO
THALES ALENIA SPACE ITALIA SPA	Roma	***LaiQa***
		PASQuanS2.1
		QUDICE
		Qu-Pilot
THINKQUANTUM SRL	Vicenza	***QSNP***
		QUDICE
		Qu-Pilot

ThinkQuantum

Marco Lamonato, MBA
Business Development and Strategic Projects
Website: www.thinkquantum.com

"Quantum cryptography emerges as the natural evolution of security in response to the capabilities of quantum computers; within the quantum landscape lies both the challenge to current encryption and its most promising solution."

When it comes to technologies like QKD and QRNG, the applications that can be targeted are geopolitically sensible, for this reason relying on a European supply chain (and in turn an Italian one) for all critical components is strategic going forward.

The Italian QST System of Innovation: the evidence from the NQSTI datasets

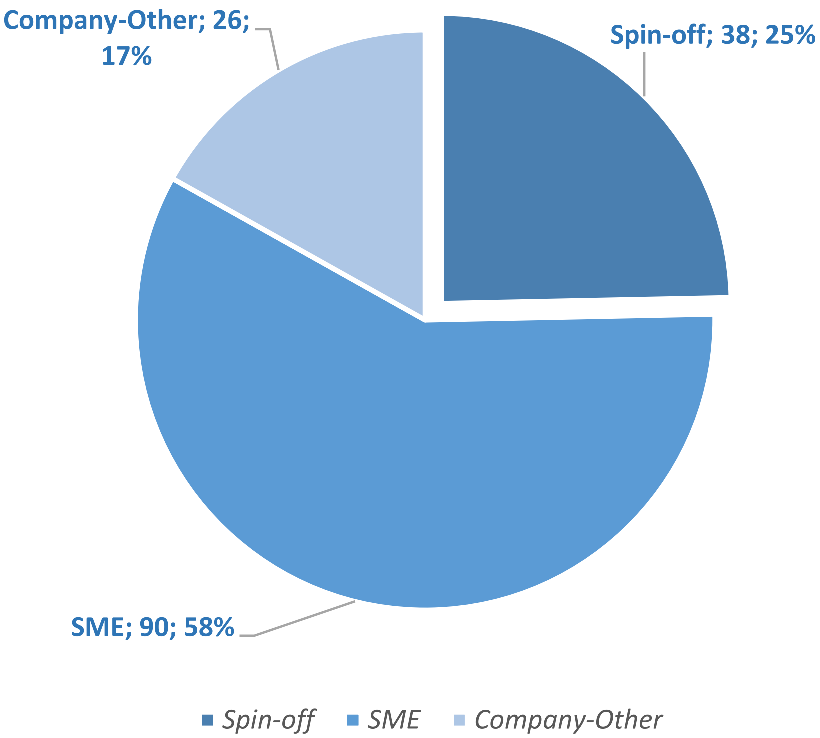
After completing the dataset with information available in institutional reports, in consulting and technological literature, specialized magazines, and the companies participating in TT and technological events, the scientific literature on QST was collected. The reports describing QST sector structure in a general way or presenting specific industrial fields (sensing, computing, imaging) were then investigated. Still, to have an idea of the companies directly involved in the QST research, the datasets belonging to *Quantum Flagship* (*Quantera*), *QUIC* (*Quantum Industry Consortium*[8]) and *EPO* (*European Patent Office*) reports (*EPO*, 2023a; *EPO,* 2023b) have been analyzed.

THE ITALIAN QST SECTOR IS TAKING SHAPE

The total number of companies active in the Quantum fields or having a collaborative research project with an academic partner in the first NQSTI analysis is ***154***. A number beyond any possible esteem made by Spoke 8 "Technology Transfer" components at the beginning of the NQSTI project.
Of the Italian (or having a production or research subsidiary in Italy) companies around ***58%,*** 90 firms, ***are SMEs*** (Small and Medium enterprises). As highlighted, the *Cordis* classification also gave us a dimensional variable to draw some possible analyses (see *figure 10*).

[8] European Quantum Industry Consortium, QUIC Member List. Accessed September 2024. https://www.euroquic.org/members-list/

Figure 10. The dimension of the firms in the sample



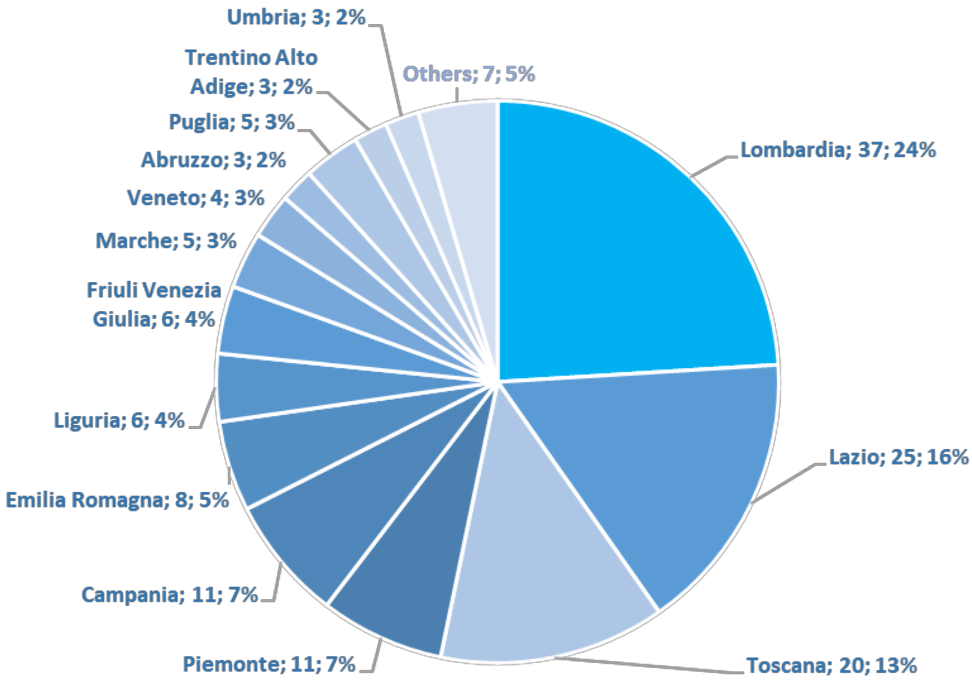
Consequently, around 17%, ***26 organizations***, are ***large companies***. *We can highlight the limited number of big firms in relation to the disruptive characteristics of quantum technology*. There is a growing need at the national level to communicate more effectively and demonstrate the advantages and use cases.
It is also worth noting the number of **spinoffs** that represent almost 25% of the total sample (**38 companies**)[9].

A LIMITED NUMBER OF LARGE COMPANIES POPULATE THE QST SECTOR

Lombardia hosts almost a quarter of the total sample, as 37 Quantum Science and Technology companies populate this region (*figure 11*). Lazio shows 16% of the private organizations, 25 firms. The total amount could be overestimated, as many companies have headquarters in the Italian capital. Still, Toscana hosts 20 companies, representing 13% of the total. So only three regions are home to more than 50% of all the QST companies (53%).
Emilia-Romagna (8), Campania (11), and Piemonte (11) show low percentages, but the number of local firms could be promising considering specific QST fields.

[9] The authors considered startups with a website, valid Information in newspapers, or research programs (already registered on the official website of the Italian *Camera di Commercio*) for the analysis. A list of the startups of the sample is given in the NQSTI Report (full version).

Figure 11. The geographical distribution of the sample

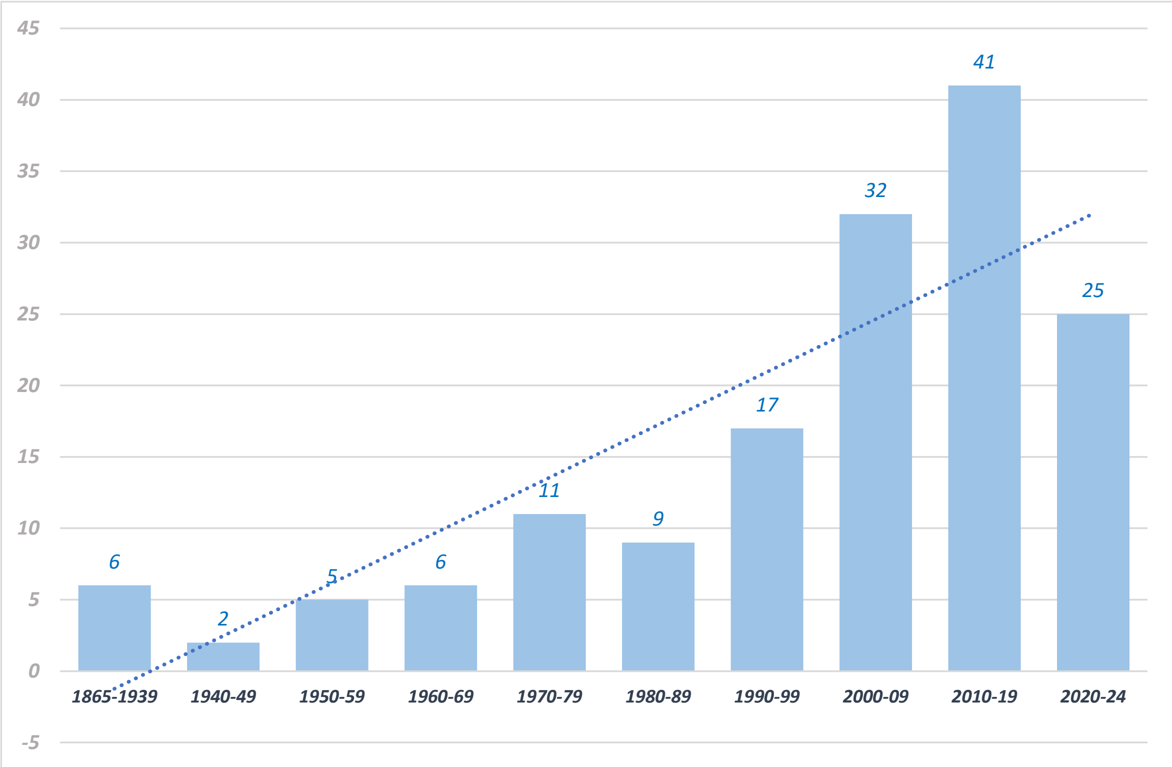


LOMBARDIA, LAZIO, AND TOSCANA GIVE HOME TO MORE THAN HALF OF THE QST COMPANIES

The analysis of the years of establishment of the Italian Quantum Science and Technology organizations shows a clear development path (see *figure 12*). First, it is evident that companies with a long history cohabit with firms of recent establishment and startups.
While until the end of the year 1980-89, the number of new companies remained constant (6-11 firms each year), it grew almost exponentially, reaching a peak in 2010-2019 (41 companies).

ITALIAN STARTUPS ARE A LIVING REALITY

Figure 12. The year of birth of the firms in the sample



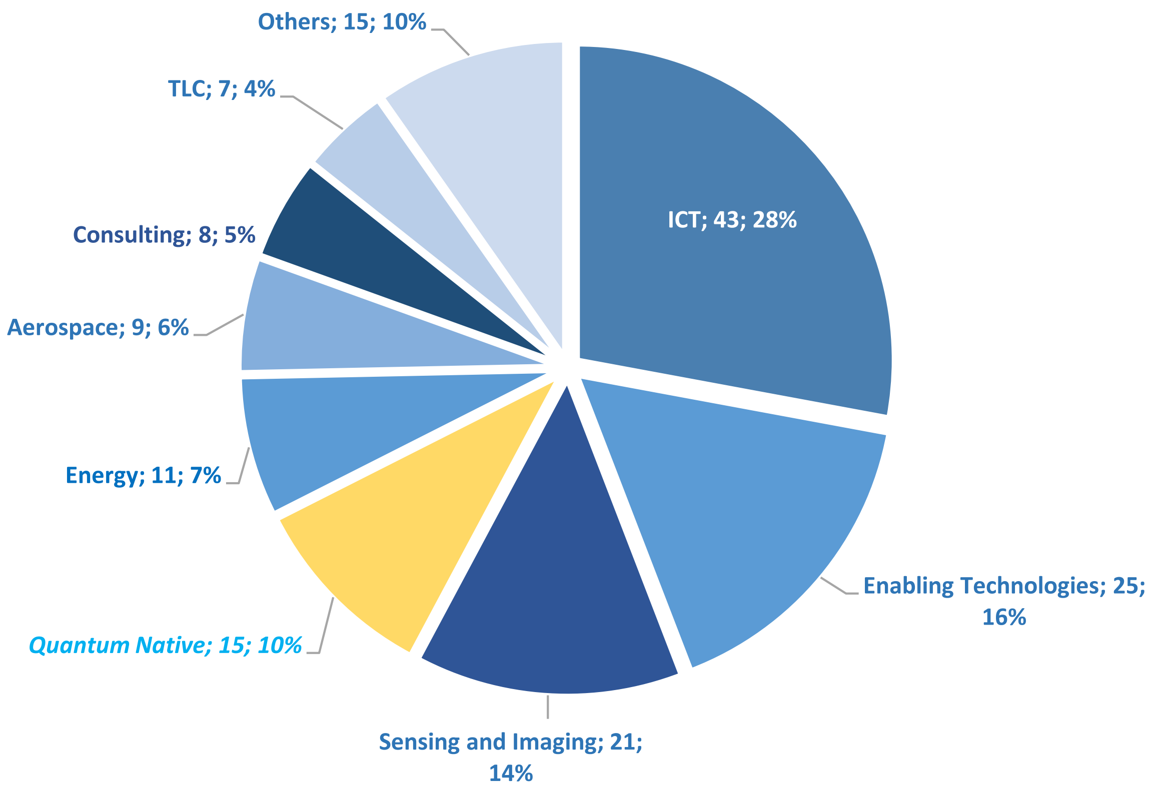
Undoubtedly, the trend is the consequence of the technological shifts experienced in quantum science over the last 30 years, driven by the discovery of principles of isolation and entanglement of quantum objects. Scientists learned to observe and control matter at the microscopic level, manipulating large ensembles of particles and trapping an electron or an atom emitting a single photon. These properties of quantum can now theoretically and practically be translated into new applications, new processes, and innovations for the industrial and end users.

ICT, ENABLING TECHNOLOGIES, AND SENSING AND IMAGING HOLD THE BIGGEST PERCENTAGE

The author already underlined the limits of the classification of QST by verticals; the analysis tries to understand the main areas of interest of the companies of the NQSTI dataset. As evidenced in *figure 13,* the *Information and Communication Technologies* industry holds the most significant share with a percentage of 28%, representing 43 companies involved (both software and hardware). *Enabling Technologies* represent 16%, with 25 firms active in the sector. *Sensing and Imaging*, however, shows 21 companies, representing 14%. *Quantum Native Enterprises* form a group of 15 firms representing

10% of the total. Two of these organizations (*SeeQC* and *Xanadu*) have joint laboratories in Italy. Therefore, 13 Italian companies were born through the development of quantum technology (*1 in Sensing and Imaging, 3 in Telecommunications, 3 engineer Quantum Software, 3 operate in Quantum Computing, and 3 develop Key Enabling Technologies*).

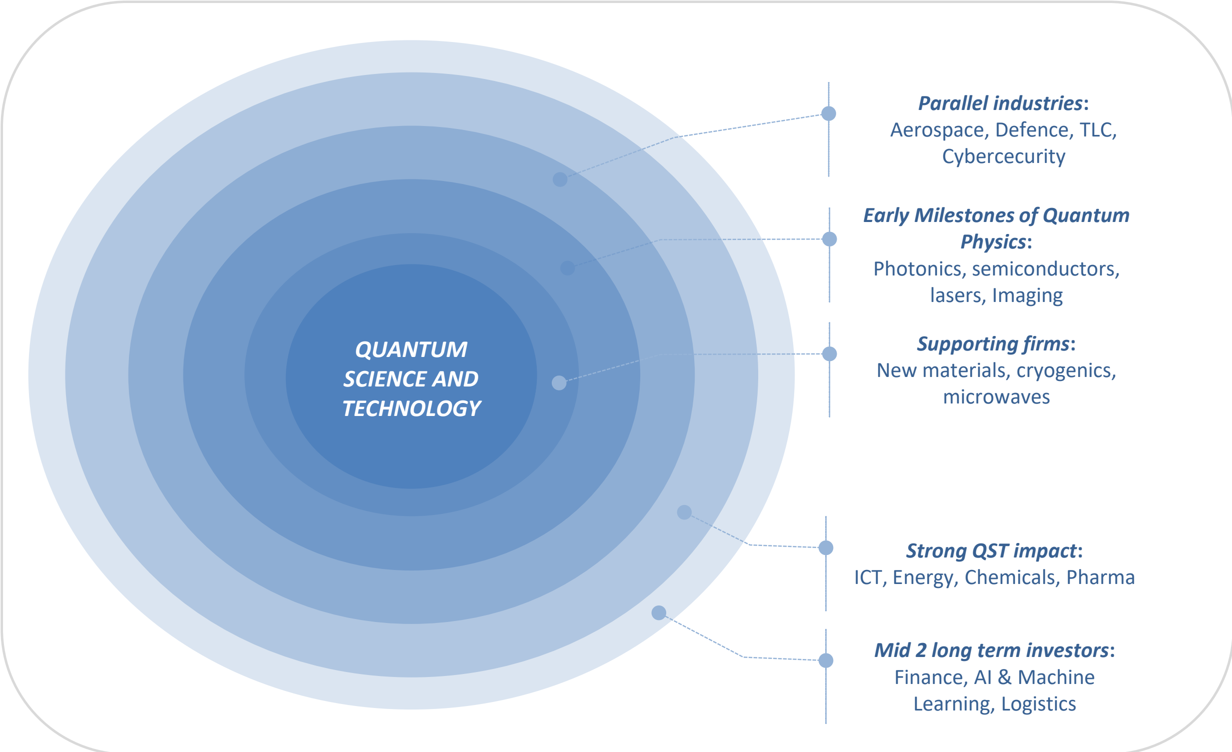
Figure 13. The Technological Industries of the companies



The difficulties in classifying many of the sample companies, the investigation of the mission, the analysis of participation in European projects, the collection of primary data, the investigation of several case studies, and newspaper articles led the author to offer a *qualitative representation* of the companies' economic activity (see *figure 14*).

The *model is organized around concentric levels* that define the intensity of quantum science and technology in the activities of the companies (from central to peripheral roles). Organizations whose mission refers to quantum science have been established in the last 10 years. The startups are described in a specific paragraph in the full report. To this *core ensemble* are associated organizations providing supporting technologies to research and the industrial supply chain. At the first level (second circle around "quantum core"), there are the firms of supporting sectors, such as those that develop research and production activities in new materials, advanced cryogenic systems, or microwave apparatus.

Figure 14. A quantum-intensity representation: evidence from the Italian dataset



The second level of proximity is represented by the firms that produce transistors, lasers, electronic systems, and photonics, which we defined as "Early Milestones of Quantum Physics". Parallel industries such as aerospace, defense, and cybersecurity, do not move directly along the QST value chain; they develop quantum research and technology for space, for telecommunication, and to guarantee national security.

QUANTUM-CORE COMPANIES DO NOT TOTALLY DEFINE THE QST SECTOR

Industries where QST would have a strong and immediate impact are just beginning to investigate quantum research, with specific collaborations. These sectors involve not only ICT and logistics, but also the pharmaceutical and chemical sectors, as well as the diagnostic landscape (including NMR and others). "Final users", as well as other classifications described in the report, are often integrated into the QST sector as they develop specific technological projects and have an industrial target to reach.
Finally, the last circle describes industries where QST will have a mid-term impact. Companies pursue a technological competitive advantage and want to be a "first mover" in the competitive arena.

QUANTUM STARTUPS ARE AN ACADEMIC ISSUE

Several contributions in economic literature emphasize spinoffs' role in launching new products and services from scientific research. They can represent an effective *trait d'union* between the scientific discoveries and the market along the technological value chain. Spinoffs, in particular, represent an alternative instrument for commercializing academic knowledge. This mechanism does not damage open science and allows society to reap the economic benefits at regional and national levels.

Rappert, Webster, and Charles (1999) define university spinoffs as those firms whose products and services have developed on technological ideas or scientific know-how that has been generated in the academic environment by a member of the faculty, staff, or by a student who created (or co-created with others) the business. The founder can also leave the university to develop a new company or start an entrepreneurial activity while remaining in the academic institution. It is not relevant whether this person or these people are a full-time student, or professor, or the distance in time that passes from initial research to commercial development, but whether the research conducted within the research organization was necessary for the company to create that product or service.

Research spinoffs represent a bridge between public research and the market. They are those subjects capable of "translating" scientific activity so that it can be managed by companies already on the market, adverse to a specific type of research risk.

Photon Technology Italy

Daniela Salvoni, PhD
CEO and founder
Photon Technology Italy SRL
Website: *www.snspd.com*

"PTI is the first innovative startup in Italy for the production and commercialization of superconducting single photon detectors with unparallel performances. We aim to actively contribute to the Italian ecosystem of scientific and industrial excellence, fostering innovation and collaboration in the field of quantum technologies"

QSensato

Vito Giovanni Lucivero, PhD
CEO & Founder
Quantum Sensing and Metrology Industry (Bari, Italy)
QSensato SRL, Spinoff of Università degli studi di Bari
Website: www.linkedin.com/company/qsensato

"QSENSATO, the first Quantum Sensing startup in Southern Europe, will bridge the gap between AMO physics and integrated photonics, through the development and commercialization of laser-written vapor cells, atomic-photonic chips and complete atomic quantum sensors"

Quantum2pi

Ugo Chirico, PhD
CEO & Founder
Quantum2pi SRL
Website: www.quantum2pi.com

"We envision a future where advancements in Quantum Computing will revolutionize cybersecurity and unlock unprecedented computational power, opening new opportunities for all of humanity. We help companies to become quantum-resistant using Post-Quantum Cryptography and Quantum Key Distribution"

Random Power

Massimo Caccia, Ph.D.
Co-founder and C.E.O.
Random Power SRL
Website: www.randompower.eu

"Random Power (RaP!) harnesses the quantum properties of semiconductors for generating endless streams of random bits, made robust by the very same laws of Nature to protect our digital life"

THE MAIN CHALLENGES FOR THE QST SECTOR TO FACE IN THE FUTURE: SCALABILITY, STANDARDS, COOPERATION, EDUCATION, AND TRAINING OF THE WORKFORCE

Roberto Gunnella, PhD

Experimental Physics of Matter and applications (Associate Professor))
School of Science and Technology- Physics Section
Università degli studi di Camerino

Limited access to large scale foundries and facilities funded by public entities. *Limited investments from public and industry for research infrastructures* in the Universities for research and *human resources formation*.

Rotonium

Roberto Siagri
CEO & Founder
Rotonium Srl
Website: *www.rotonium.com*

"In a rapidly evolving market, still dominated by centralized, expensive and complex solutions, our edge-quantum approach to photonic qubits at room temperature – supported by a robust patent portfolio, collaborations with research centers of Italian universities and a new tech-transfer model – simplifies access to quantum technologies to industries"

The quantum supply chain is still in its early stages and faces significant fragmentation. For photonics, the supply chain is in Europe. For our photonic quantum computing, major bottlenecks include access to specialized foundries for thick silicon nitride wafers, high-purity single-photon sources, and room-temperature CMOS-compatible detectors. There are also lengthening development time due to long fabrication lead times, lack of optimized PDKs, and limited standardized testing infrastructure. To overcome these challenges, we need in Europe more silicon photonics manufacturing plants and regional design centers to reduce dependency and accelerate development. Coordinated public-private funding are crucial to strengthening the ecosystem and mitigate geopolitical vulnerabilities.

Planetek Italia

Cristoforo Abbattista
Head of SpaceStream Strategic Business Unit
http://www.planetek.it

First of all, the development of the technologies and their TRL improvement. Then training of the current working people and incorporation of young people already used to manage Quantum techs. That is also the reason for which *Planetek* is currently funding a *master in Quantum techs from the University of Bari* whose goal is not preparing students for the academic professional path, but to train them for working into an industrial company.

Planckian

Michele Dallari
CEO
***Website**: www.planckian.co*

"The collaborative approach (along the computing value chain) helps drive innovation and ensures that solutions are optimized for real-world applications from the outset"

The *quantum supply chain is rapidly evolving*, with an increasing number of players focusing on gaining a competitive edge in specific segments of the value chain, such as the *hardware layer, control electronics, cryogenics, middleware, firmware, and software* in quantum computing. By combining this with a co-design approach—where quantum circuits and algorithms are developed to match the specific characteristics of current hardware and problem requirements—quantum computing providers can accelerate technology validation while also building early relationships with potential end-users. This collaborative approach helps drive innovation and ensures that solutions are optimized for real-world applications from the outset.

QuantumNet

Alfredo Troiano, PhD
Sole Director
***Website:** www.quantum-net.it*

"At QuantumNet, we believe quantum technologies are the future of innovation. We support research, spinoffs, and strategic collaborations to accelerate real-world applications and bridge the gap between science and industry"

The quantum supply chain is growing rapidly, fueled by increasing demand for quantum computing across various industries. However, key challenges include the scalability and reliability of quantum hardware, the shortage of skilled professionals, and the complex supply of materials needed for quantum systems. Additionally, integrating quantum technology with classical computing will require hybrid models. Despite these hurdles, the outlook is positive, with continued investment and research paving the way for transformative changes in the future.

Exprivia

Pietro Noviello
Exprivia Research Manager
Website: https://www.exprivia.it/

"Sourcing specialized skills is a major challenge. Quantum computing requires a high level of technical and scientific expertise, which is currently limited to a niche of experts."

First, *scalability* is a critical hurdle: building systems with enough qubits while maintaining consistency and reducing errors is a major technological barrier. Furthermore, *manufacturing quantum hardware* requires specialized materials and complex infrastructure, which could cause *supply chain bottlenecks*, especially with growing demand. Another key issue is *standardization*. As quantum computing is still in its infancy, there are different and non-standardized approaches. The lack of recognized technical standards makes interoperability between different components and platforms difficult, slowing progress. Finally, *sourcing specialized skills* is a major challenge. Quantum computing requires a high level of technical and scientific expertise, which is currently limited to a *niche of experts*. In summary, the quantum computing supply chain has enormous potential, but realizing it will require overcoming technical, manufacturing and training hurdles, as well as developing a more standardized and integrated ecosystem.

Italtel

Fabrizio Bianchi
Technical and Project Manager
Website: http://www.italtel.com

"At *Italtel*, Quantum Technologies are a strategic pillar shaping the future of secure communications. We focus on Quantum-safe solutions to strengthen cybersecurity, foster trust, and transform innovation into tangible impact for the quantum era"

At *Italtel*, we design security solutions that anticipate future challenges by integrating quantum-resilient technologies and adopting a crypto-agile strategy, ensuring adaptability as threats and algorithms evolve.

The transition toward a quantum-safe ecosystem presents key challenges, including maintaining backward compatibility, managing progressive migration, and ensuring coordination across a supply chain where standards, certifications, and interoperability frameworks are still taking shape.

NQSTI National Quantum Science and Technology Institute S.c.a.r.l.

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