



Quantum Technologies

Public Policies in Europe

2023



**Quantum ideas
are born in Europe**

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Foreword

On behalf of the QuantERA network, we are proud to share with you the Quantum Technologies Public Policies Report.

Together with the representatives of the Quantum Community, we have succeeded in mapping the European Quantum landscape for the second time.

We are amazed by the efforts taken to strengthen the European Quantum Ecosystem and we hope to see further developments in the future.



Sylwia Kostka

QuantERA Programme Coordinator

“

Our European Quantum Flagship may have a much bigger budget than QuantERA, however, it would probably not even exist without QuantERA because the pan-European cooperation between member states for Quantum Technology really is the foundation on which we can build a long-term future for a thriving European quantum ecosystem.



Tommaso Calarco

Chairman of Quantum Community Network, Quantum Flagship QuantERA Strategic Advisory Board

“

The QuantERA group has demonstrated that Europe is the leader in this world activity, world-class work, transforming our understanding and ability to work it into economic advantage.



Sir Peter Knight

Chairman of QuantERA Strategic Advisory Board

“

QuantERA is a genuine European success story, managing a joint research program of the European Union, its member states and several associated countries. It is exceptional for the quality and number of scientific contributions to quantum, and played a fundamental role in advancing the European research agenda in quantum.



Gustav Kalbe

Acting Director DG CNECT C – Digital Excellence and Science Infrastructure, European Commission



QuantERA network

Research Funders for Quantum Technology

QuantERA is the leading European network of public Research Funding Organisations for Quantum Technologies (QT). The programme brings together the scientific community, funding agencies and industry representatives to leverage transnational cooperation in QT.

Quantum Technologies Public Policies in Europe

“

In QuantERA, we have been able to bring together many, many agencies from almost all the countries in Europe. It is extremely important and has contributed to reinforcing and even building a great quantum community working on all subjects related to quantum science and technologies.



Elisabeth Giacobino

Agence Nationale de la Recherche (ANR)

Quantum Technologies in a nutshell

Background and impact

Nearly a century after the foundations of quantum mechanics were laid down, the physics world has given us technologies that are central to modern society. The next wave of innovations could lead to unbreakable encryptions and computers that are a million times faster. Scientists and engineers are making use of the “weirdness” of the quantum world to develop cutting-edge technologies.

At the onset of the 20th century, scientists learned to understand and apply the properties of quantum mechanics. This paved the way for discoveries with practical applications and allowed transistors, lasers and microprocessors to be developed: core technologies for computers, telecommunications, satellite navigation, smartphones, modern medical diagnostics and much more. These were the first scientific quantum breakthroughs, which brought all the basic technologies straight to the core of modern society.

In the 21st century, the scientists can now understand what happens at a sub-atomic level and control quantum behaviour to a degree allowing new technologies to be developed. Based on new discoveries at the fundamental level, researchers are anticipating a wave of technological ventures that will bring new platforms for sensing, intercept-resistant communication, molecular simulation and quantum computing. New sensing capabilities and inherently secure communications could redefine the medical and telecommunications industries. Some of the fields¹ that can be revolutionised by advances in quantum computing include medicine (development of new genetically-tailored drugs and therapies, and DNA research), computer security (data encryption), finance (optimisation of investment portfolios and improvement of fraud detection systems), climate change and environment (gravimetry, environmental processes modelling)², logistics and robotics (speed machine learning process). New technological ventures will certainly shape the new reality around us on many levels and will be essential for success in a wide and diverse range of industries and businesses.



¹ <https://digital-strategy.ec.europa.eu/en/library/quantum-technologies-and-advent-quantum-internet-european-union-brochure>

² https://defence-industry-space.ec.europa.eu/eu-space-policy/eu-space-research/quantum-technologies_en

Quantum Technologies in Europe

“ I'm really strongly confident that in the future QuantERA will still be a very important element of the Quantum Flagship.



Pascal Maillot

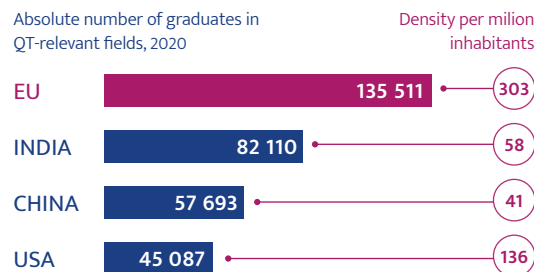
Acting Head of Unit, High Performance Computing & Quantum Technologies, European Commission

Towards European cooperation

Europe has a long tradition of excellence in quantum research. The **European Commission (EC)** recognised an emerging need to create a space where science could meet industry. The EC aims to coordinate research and funding efforts to enhance Europe's position among global competitors in a field of strategic importance.

Europe is the place with the highest number of quantum-relevant talents³, which is crucial to fostering cross-border cooperation between research teams, both academic and corporate, in different countries, companies and universities. The EC took advantage of this vital asset and prepared the funding instruments as Europe's response to the ongoing global race and the need to establish a chain of knowledge combining academia, industry and policy-makers.

QuantERA is the first programme designed to accelerate the development of QT in Europe.



Quantum Technology Monitor, McKinsey&Company, April 2023

Quantum Flagship

Aiming to strengthen Europe's position in the global quantum race, QuantERA cooperates with the **Quantum Flagship** which is a strategic research and innovation initiative established in 2018 by the European Commission. The EC initiative was launched to accelerate the development of QT and their transition to the market.

Mutual efforts are directed towards speeding up knowledge and technology transfers to put QT into everyday use.

Quantum Flagship in figures



€1 B
BUDGET



2018-2028
DURATION



+ 5 000
RESEARCHERS
INVOLVED

Quantum Community Network (QCN)

An active and consolidated community is a key factor in establishing and driving growth in QT research. The QCN is composed of distinguished members of the QT community, who have agreed to liaising with their national stakeholders. Currently, the QCN consists of members from 32 European Union and associated countries. The QCN is a European initiative engaging the large number of stakeholders in Europe and ensuring alignment of national programmes with the aims of the Quantum Flagship.

³ Quantum Technology Monitor, McKinsey&Company, April 2023; <https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/quantum%20technology%20sees%20record%20investment%20progress%20on%20talent%20gap/quantum-technology-monitor-april-2023.pdf>

QuantERA network

The QuantERA research funding programme brings together the scientific community, funding agencies and industry representatives to leverage transnational cooperation.

- QuantERA managed to efficiently mobilise, coordinate and pool financial resources between national and EU research QT programmes to fund ambitious research and innovation in jointly identified and selected topics of common interest.
- QuantERA was launched in 2016 as a result of common efforts of the European scientific community and national Research Funding Organisations (RFO) in Europe.
- Currently, the QuantERA network consists of 41 public RFOs from 31 countries.

Strategic Advisory Board (SAB)

SAB sets out strategic directions for QuantERA actions in advancing the QT field. SAB consists of up to 18 prominent QT researchers and representatives of industry.

QuantERA SAB 2022-2025



Alain Aspect, Institut d'Optique
Nobel Prize Winner 2022



Stefanie Barz, University of Stuttgart



Harry Bhurman, University of Amsterdam / CWI



Tommaso Calarco, Forschungszentrum
Jülich GmbH



Eleni Diamanti, CNRS and Sorbonne University



Nicolas Gisin, University of Geneva



Jennifer Hastie, University of Strathclyde



Igor Jex, Czech Technical University in Prague



Peter L. Knight, Imperial College London
Chairman of the Board



Jozef Lazar, Institute of Scientific Instruments,
Czech Academy of Science



Gerd Leuchs, Max Planck Society



Yehuda Naveh, Classiq



Saverio Pascazio, The University of Bari Aldo Moro



Thorsten Schumm, Vienna University of Technology



Andrew Shields, Toshiba Research Labs Europe



Jiri Vala, Maynooth University

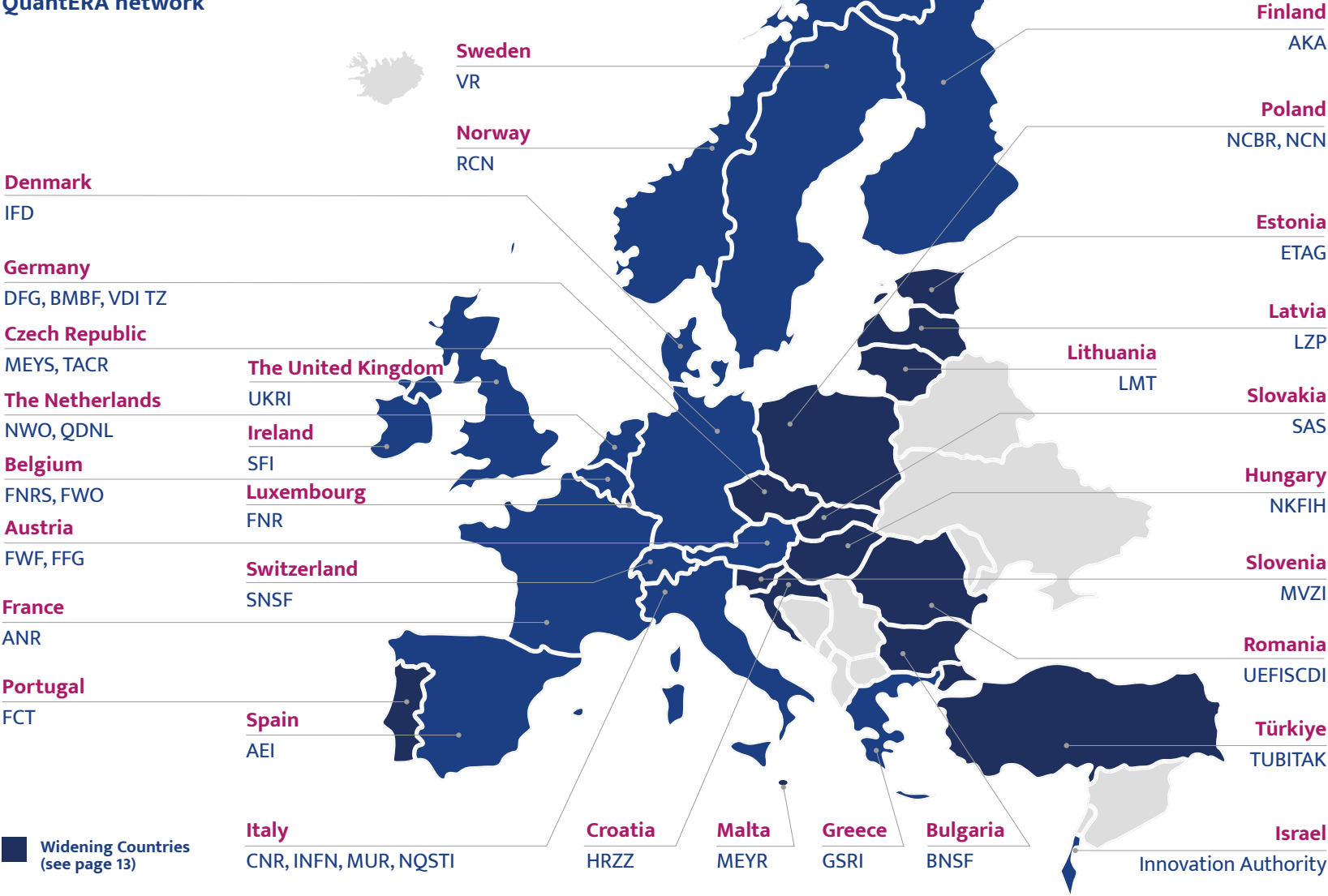


Dominik Zumbühl, University of Basel

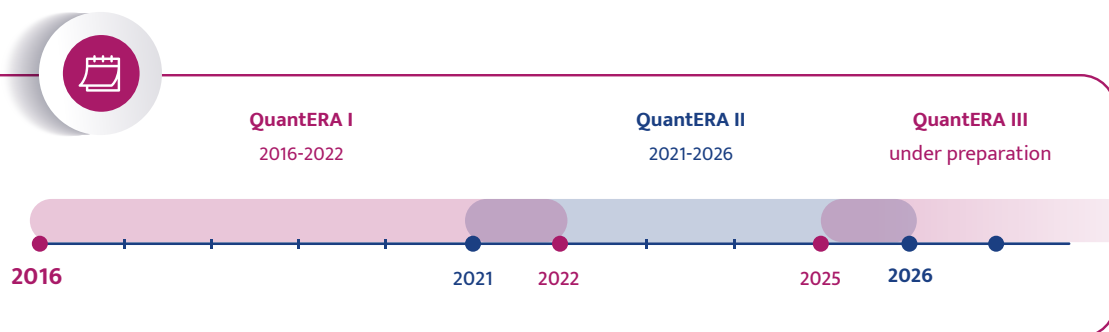


Marek Żukowski, University of Gdańsk

QuantERA network



QuantERA in figures



QuantERA calls for proposals

The main objective of QuantERA is to finance outstanding international research projects in QT through transnational calls for proposals. So far, QuantERA has successfully launched four calls for proposals. Due to a bottom-up approach and the broad scope of research in five areas, new ideas can grow and be put into practice.

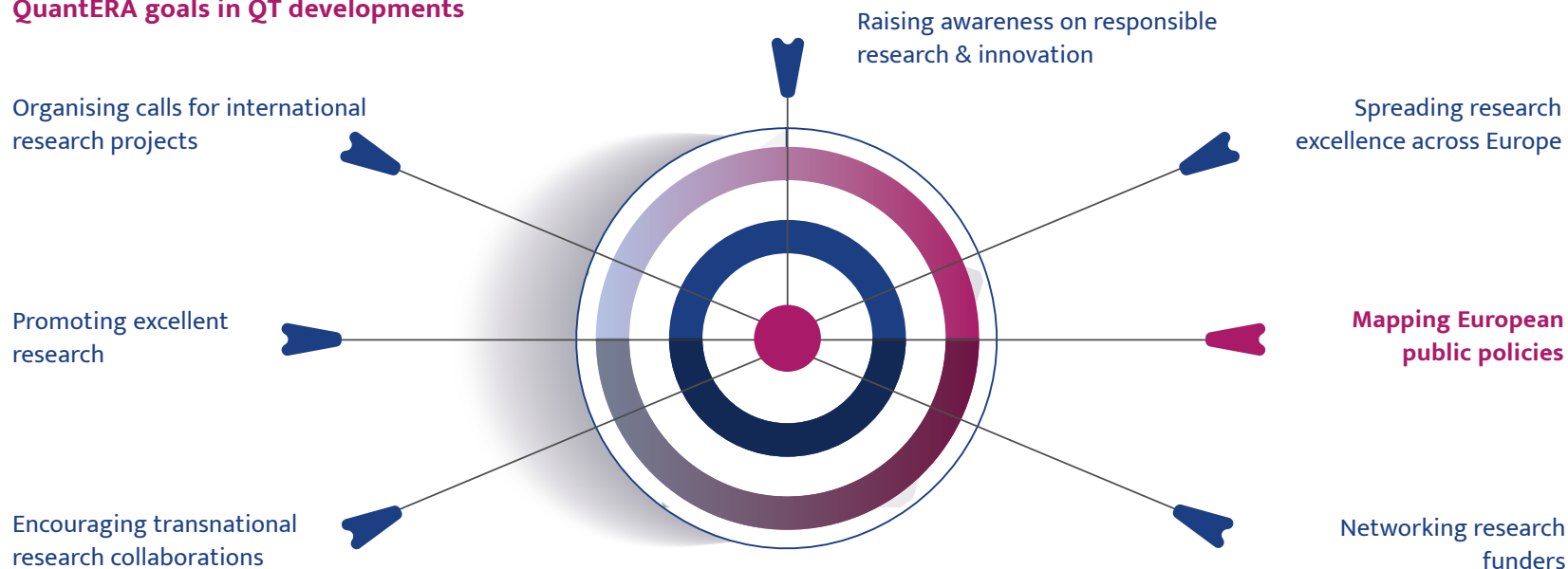
So far the QuantERA funding budget has amounted to over €89 M with 77 excellent projects funded⁴ under three transnational calls for proposals (launched in 2017, 2019, and 2021). On the date of this report, the results of the QuantERA call 2023 for transnational research projects are pending with budget of ca. €33 M.

QuantERA calls for proposals



⁴ <https://quantera.eu/quantera-funded-projects/>

QuantERA goals in QT developments



Mapping European public policies

As the landscape of national funding schemes in QT is undergoing continuous development, QuantERA strives to map and monitor developments in order to provide the research community with a coordinated Europe-wide

approach and to ensure effective support for high-quality research in QT. This report is an update of the **Quantum Technologies – Public Policies in Europe** report published in 2020.

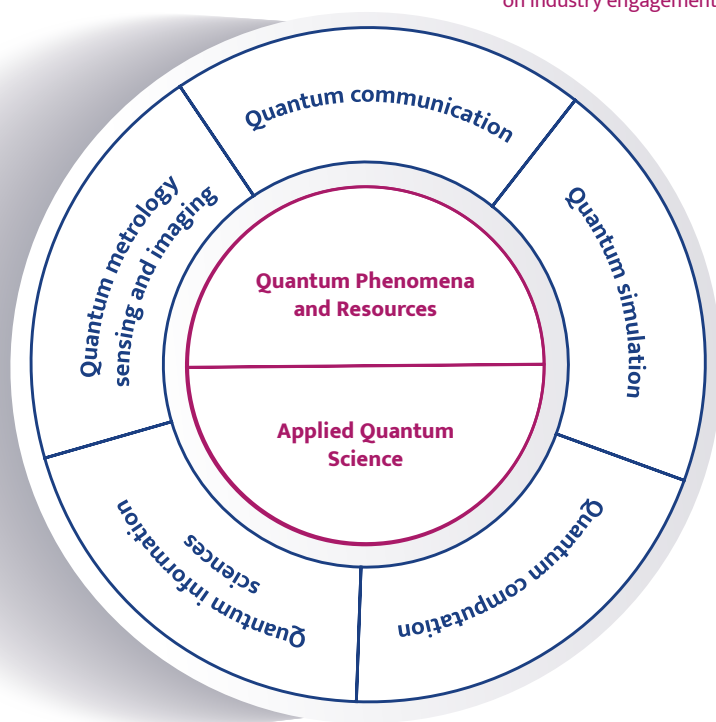
⁵ <https://www.era-learn.eu/support-for-partnerships/additional-activities/openness-inclusiveness-transparency/widening-and-inclusiveness>

Spreading excellence

QuantERA network introduced successful mechanisms to support inclusiveness and greater participation of less represented countries – **Widening Countries**⁵ – in the framework of the programme. As a result, research teams from the Widening Countries have been involved in almost 78% of the projects funded within calls: 2017, 2019 and 2021.

Areas of research

The QuantERA projects align with one of the two call topics: Quantum Phenomena and Resources (QPR) or Applied Quantum Science (AQS) and address one or more of listed areas of research.



Industry and quantum

Industry stakeholders are actively engaged in the QuantERA calls by funding applied science through one of the topic identified in the QuantERA call for proposals: Applied Quantum Science (AQS), strong collaboration with the Quantum Flagship and recommendations elaborated in the [QuantERA Guidance on industry engagement for the public sector](https://quanter.eu/wp-content/uploads/2021/12/D6.2_Guidelines_in_Responsible_Research_and_Innovation_in_QT1.pdf)⁶.

Responsible research and innovation (RRI)

QuantERA has set [Guidelines in Responsible Research and Innovation in QT](https://quanter.eu/wp-content/uploads/2021/12/D6.2_Guidelines_in_Responsible_Research_and_Innovation_in_QT1.pdf)⁷ to favour implementation of RRI in QuantERA funded projects.

QuantERA raises awareness on RRI which considers the potential impacts of scientific research on the environment and society by the following metrics:



public
engagement



open
access



gender



ethics



science
education

⁶ <https://quanter.eu/industry-qt/>

⁷ https://quanter.eu/wp-content/uploads/2021/12/D6.2_Guidelines_in_Responsible_Research_and_Innovation_in_QT1.pdf

About this report

Mapping European public policies is one of the main tasks implemented within the framework of QuantERA. QuantERA's first report on mapping public policies in Europe was published in 2020. Built on previous experience and the joint efforts of the QuantERA Consortium partners, as well as consultation with the EC and the QT Flagship, QuantERA has prepared this report.

In spring 2023 the QuantERA Consortium members supported by the national representatives of the Quantum Community Network completed the survey on the state of affairs within their respective countries with regard to the following:

- ✦ New developments (with respect to data from the previous report)
- ✦ Quantum Technologies at the organisational level
 - Funding QT research
 - Research priority areas in QT
 - Other undertakings
- ✦ Quantum Technologies at the national level
 - National agenda/strategy/programmes for QT
 - National Quantum Research Community and Innovation Ecosystem

The above information was collated in the form of a fact-sheet, summarising the efforts in QT research and funding at the organisational and national level. This report is the collaborative product of that process.

The report mainly aims to provide a snapshot of the European QT policy landscape, as well as funding instruments and priorities within the relevant RFOs for researchers. Moreover, it gives policymakers from the EC and various countries a reference and toolkit to establish potential measures and shape the future development of QT at the European level and in their own countries.



Key findings

The key findings are based on the results of an inventory conducted in the spring of 2023 among 41 members of the QuantERA Consortium, drawn from 31 European Union member states and associated countries.



National policies

National QT strategies and initiatives

- There has been a remarkable shift towards developing national QT strategies and initiatives in government agendas as compared to 2020
- 10 countries confirmed national funding programmes or strategies to support QT: Denmark, France, Germany, Hungary, Israel, Italy, Latvia, the Netherlands, Switzerland, the United Kingdom
- 5 countries have strategies that are in various stages of development: Ireland, Romania, Slovakia, Spain, Sweden
- 5 countries have significant government-funded initiatives: Austria, Denmark, Spain, Sweden, Switzerland

QT developments in Widening Countries

- 2 Widening Countries: Hungary and Latvia confirmed national funding programmes dedicated to QT and in another 2, namely Romania and Slovakia, national QT strategies are under development

QT government initiatives without an assigned budget

- 9 countries have prepared strategies/initiatives/roadmaps at the national level without an assigned QT budget, however, with certain recommendations and with QT being mentioned a research priority in their countries: Denmark, Estonia, Finland, Germany, Greece, Luxembourg, Norway, Romania and Türkiye

QT programmes within national recovery and resilience programmes⁸

- 5 countries have developed programmes/initiatives to fund QT research as part of their national recovery and resilience programmes: Austria, Germany, Italy, Latvia, Spain

Main strategic goals reflected in national QT strategies/initiatives

- Bringing together academic and industrial stakeholders
- Translation of research into applications
- Emphasis on projects in quantum computing

⁸ National recovery and resilience programmes have been established by governments as a result of European Union Recovery and Resilience Facility (RRF).



Trends in national approaches

Development of human capital

- Human capital development in QT is an increasingly recognised trend in national policies to strengthen education and support for researchers, especially in the early stages of their careers

Centres of excellence or innovation hubs

- These are set up to create an ecosystem of mutually supportive communities: academic, business and public sector organisations



Funding mechanisms

Calls for proposals

- A majority of countries funds QT research through open bottom-up calls, without defined thematic calls for the QT field nor any specific priority areas in their recommendations
- 9 countries have used targeted calls for proposals for QT

QuantERA significance

- In 2021, 7 agencies joined QuantERA, 5 of which are from Widening Countries: Czech Republic, Estonia, Lithuania, Luxembourg, Malta. All agencies highlighted in the survey that joining QuantERA was a key step towards pushing QT research in their countries and intensifying national efforts in this area
- As in the previous study, for a large number of countries QuantERA is the only way to support high-quality QT research and a catalyst for its further development



Executive summary

Quantum landscape in Europe 2023

As the landscape of national funding schemes regarding QT as well as national approaches towards QT are undergoing continuous development, the QuantERA programme continuously strives to map and monitor those developments.

National approaches to QT can be broadly classified into three categories:

- countries with a coordinated national programme (including those with strategies are under development)
- countries that do not have a coordinated strategy but do have significant government funding or programmes
- countries that are involved primarily through participation in international programmes, which is QuantERA.

Out of the 31 countries participating in the QuantERA programme, 15 have a national programme dedicated to funding QT or are in the process of developing one. 5 countries, despite not having national programmes dedicated to QT or having them in the pipeline have financial mechanisms to support QT

research. Investment in QT greatly varies among EU Members and Associated Countries as well as the duration of national funding programmes (for details see table on p. 20-21).

Quantum Technologies government initiatives without an assigned budget

In addition to national QT strategies/programmes or other government initiatives with specific financial allocations for QT research, a new trend can be distinguished compared to the previously published report. There have been expert studies/strategies prepared at the national level without an assigned budget, but with recommendations and identified priorities, which in the long run might serve as a reference point for QT national financial programmes. They are prepared as separate documents on QT or a part of strategic documents comprising a wider scope:

- Quantum Systems (Germany)
- Mapping of the QT area (Denmark)
- Estonian Research, Development, Innovation and Entrepreneurship Strategy for 2021-2035
- Finnish Quantum Agenda
- Operational Programme for Competitiveness, Entrepreneurship, and Innovation 2021-2028 (EPAnEK) and National Research and Innovation Strategy for Smart Specialization 2021-2027 (RIS) (Greece)
- Luxembourg National Research Priorities
- Long-term Plan for Research and Higher Education 2023-2032 (Norway)
- National 4th Plan of the new Strategy for research, innovation and smart specialization 2022-2027 (Romania), includes Digital economy and space technologies & Advanced functional materials
- 11th Development Plan (2019-2023) of Türkiye

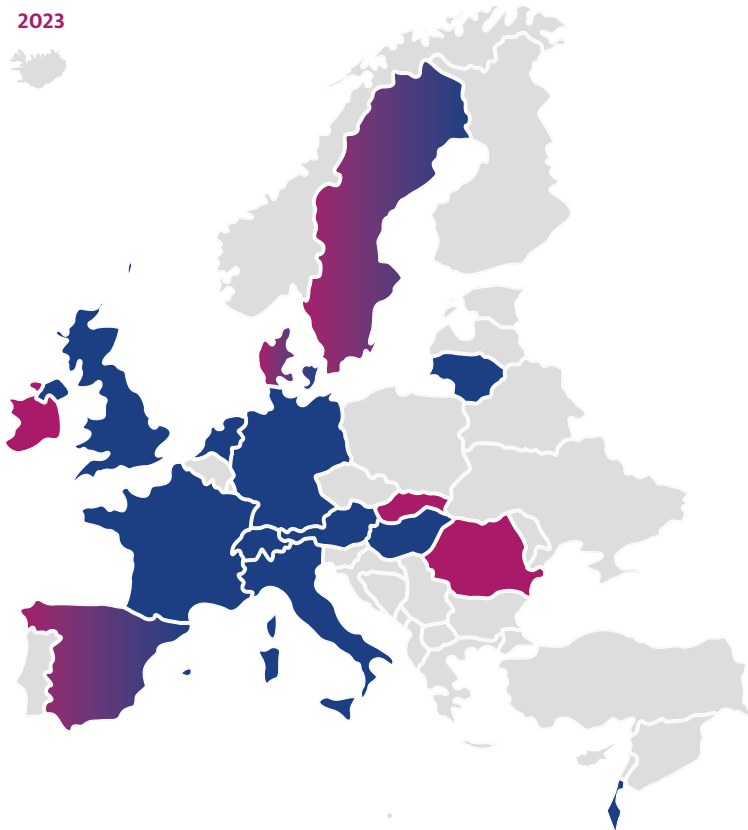
National quantum strategies

Quantum landscape in Europe
2020



The two comparative maps illustrate the national policies identified in the report in 2020 and the current trends. The map for 2023 also takes into account countries where national strategies/programmes are in preparation.

Quantum landscape in Europe
2023



- Countries with developed national quantum strategy and/or significant government contribution
- Countries with national quantum strategy in progress
- Countries with significant government contribution and national quantum strategy in progress

Table 1. Overview of national QT programmes and initiatives, 2023.

Country	National strategy / agenda / programme	Other national initiatives	Budget	Duration	New development*
Austria		Quantum Austria Funding Initiative	€107 M – shared between FFG and FWF, contains administrative expenses	2021-2026	✓
Denmark	Danish Strategy for Quantum Technology (DSQT)	Governmental budget allocation for QT Mapping of the QT area	DSQT: approx. €150 M Governmental allocation for QT: €20 M	DSQT: 2024-2027 Governmental budget allocation for QT: 2023	✓
Estonia		Estonian Research, Development, Innovation and Entrepreneurship Strategy		2021-2035	✓
Finland		Finnish Quantum Agenda			✓
France	Quantum Plan - France National Quantum Strategy		€1.8 B	2021-2025	✓
Germany	Economic Stimulus Package (ESP)	Quantum Systems (QS)	ESP: €2 B	ESP: 2020-2025 QS: 2022-2032	✓
Greece		Operational Programme for Competitiveness, Entrepreneurship, and Innovation (EPAnEK) National Research and Innovation Strategy for Smart Specialization (RIS)		EPAnEK: 2021-2028 RIS: 2021-2027	✓
Hungary	Quantum Information National Laboratory		€15 M	2021-2026	✓
Ireland	In progress				✓
Israel	Israel National Quantum Initiative (INQI)		~€350 M	2020-2025	✓
Italy	Italian Plan for Recovery and Resilience (PNRR); M4 Education and Research - Component 2 From research to business		PNRR: €170 M	2020-2025	✓
Latvia	European Union Recovery and Resilience Mechanism component „Digital Transformation” (DT)		€6.19 M + forecast of approx. €1 M investment from other sources	2022-2026	✓

Country	National strategy / agenda / programme	Other national initiatives	Budget	Duration	New development*
Luxembourg		Luxembourg National Research Priorities			
Netherlands	Quantum Delta NL		€615 M	2021-2028	✓
Norway		Long-term Plan for Research and Higher Education highlights quantum technologies as a particularly prioritised area for research and innovation		2023-2032	✓
Romania	In progress	National 4 th Plan of the new Strategy for research, innovation and smart specialization includes Digital economy and space technologies & Advanced functional materials		2022-2027	✓
Slovakia	In progress				✓
Spain	In progress	Quantum Spain (QS) Plan for Quantum Communication (PQC)	QS: €22 M PQC: €76 M		✓
Sweden	In progress	Wallenberg Centre for Quantum Technology (WACQT)	€88.5 M	2018-2029	✓
Switzerland	Swiss Quantum Initiative (SQI)	SPIN - Spin Qubits in Silicon	SQI: CHF 10 M SPIN: CHF 40 M	SQI: 2023-2024 additional funding planned for 2025–2028 SPIN: 2020-2023	✓
Türkiye		11 th Development Plan of Türkiye		2019-2023	
United Kingdom	National Quantum Strategy (NQS) National Quantum Technologies Programme (NQTP)		NQS: £2.5 B NQTP: £1 B	NQS: 2023-2033 NQTP: 2014-2024	✓

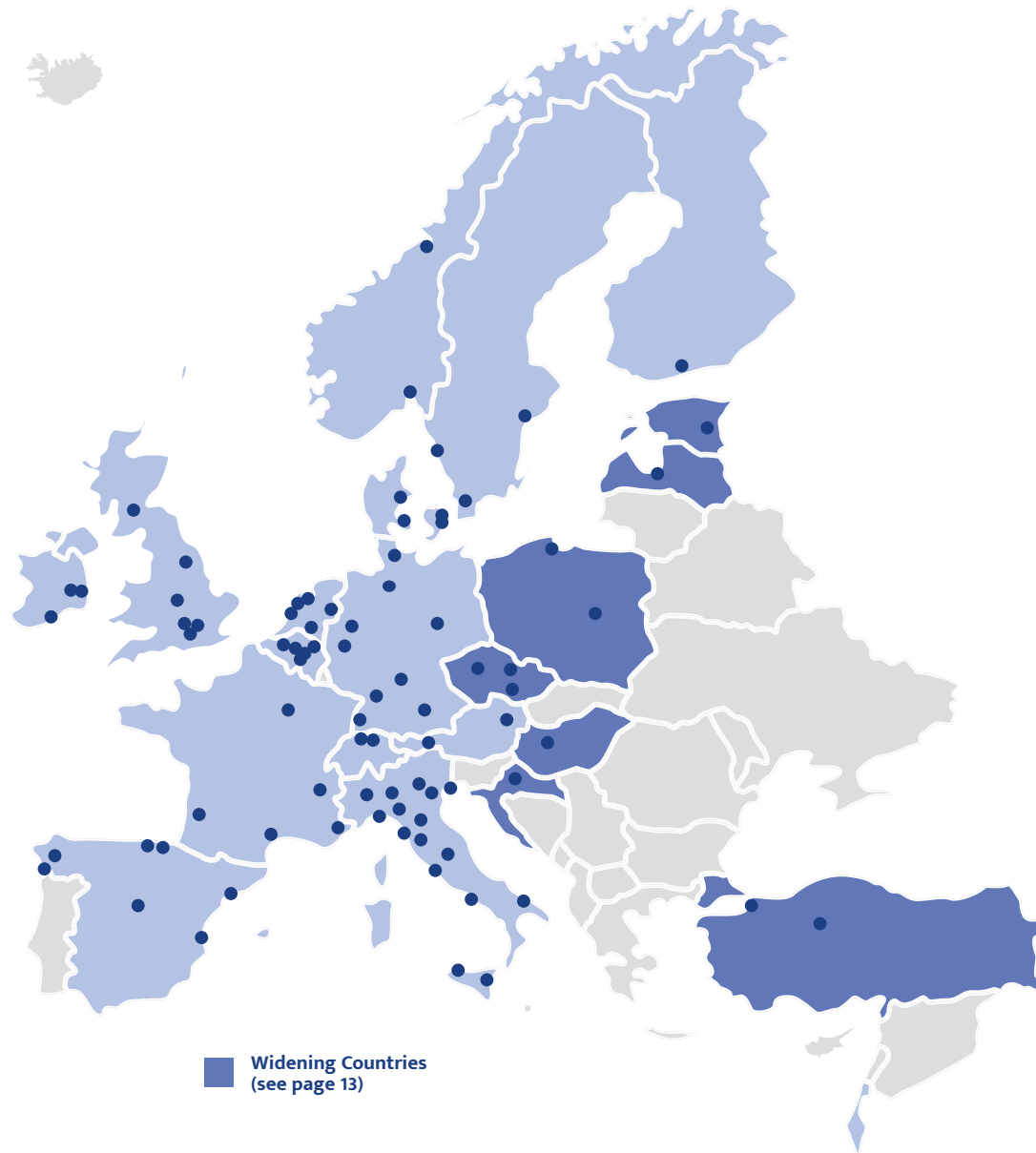
* in comparison with previous publication Quantum Technologies – Public Policies in Europe, 2020

Quantum Technologies hubs

Whether set out in a coordinated national strategy or not, most governments have implemented longstanding policies to establish centres of excellence or innovation hubs to create a space where academia can effectively collaborate with industry and government to identify priority areas of interest, conduct advanced research and launch start-ups.

QT hubs and main centres of research and innovation in Europe:

Austria – Vienna, Innsbruck
Belgium – Brussels, Leuven, Louvain-la-Neuve, Gent, Hasselt
Croatia – Zagreb
Czech Republic – Olomouc, Prague, Brno
Denmark – Copenhagen, Lyngby, Odense, Aarhus
Estonia – Tartu
Finland – Espoo
France – Paris, Paris-Saclay and Grenoble, Nice, Montpellier, Bordeaux
Germany – Freiburg, Hamburg, Hannover, Jülich, Leipzig, Munich, Stuttgart, Würzburg, Cologne
Hungary – Budapest
Ireland – Dublin, Maynooth, Cork
Italy – Roma, Trento, Trieste, Genova, Pisa, Bologna, Bari, Camerino, Catania, Florence, Milano, Napoli, Parma, Pavia, Padova
Latvia – Riga
The Netherlands – Delft, Eindhoven, Leiden, Twente, Amsterdam
Norway – Oslo, Trondheim
Poland – Warsaw, Gdansk
Spain – Barcelona, Madrid, Bilbao, San Sebastián, Santiago de Compostela, Vigo, Valencia
Sweden – Stockholm, Gothenburg, Lund
Switzerland – Villigen, Zurich
Türkiye – Gebze/Kocaeli, Ankara
The United Kingdom – York, Birmingham, Glasgow, Oxford, Harwell, Teddington



Conclusions

Three years after the release of the first report on national QT policies, the emergence of new national trends is remarkably noticeable. For some, these are high-budget national programmes, while for others, references and priorities are clarifying. It is worth emphasising that there are new developments in countries that did not have a developed QT national policy 3 years ago. They are preparing their own strategy, roadmaps and/or establishing a networking initiative bringing together QT representatives from science, industry and politics. As a result, further national efforts are expected to strengthen QT competitiveness and increase the capacity of QT networks.

Still, for some countries the QuantERA Programme is the only mechanism for supporting QT research and innovation. Accelerating the process of introducing QT to the market and society requires effort that goes beyond the national framework. QuantERA together with the Quantum Flagship trigger QT research in countries without a national QT policy and strongly support actions in countries which are more advanced in this field. Additional actions like attracting early career researchers, strengthening multilateral dialogue

with policy-makers regarding the design of future funding, stimulation of networking and exchange of best practices are crucial to reinforcing collaboration in QT in Europe, thus strengthening Europe's competitiveness. The synergy of national policies with European QT programmes seems to be a leading trend for the future, with the goal of keeping Europe's leadership in high-level QT research as creating a space to develop its application, and thereby boost European potential.



This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101017733

Public policies for Quantum Technologies in Europe – overview

AUSTRIA

Austrian Science Fund, FWF

Austrian Research Promotion Agency, FFG

Highlights

- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

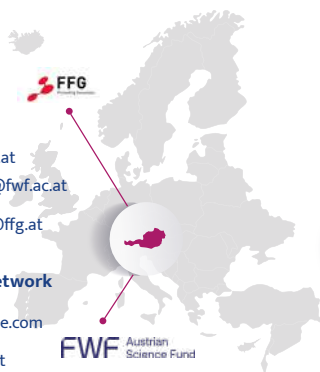
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National programme

On behalf of the Federal Ministry of Education, Science and Research (BMBWF) and funded by the European Union under the Development and Resilience Plan (2020-2026), the Austrian Research Promotion Agency (FFG) and the Austrian Science Fund (FWF) implement the **Quantum Austria Funding Initiative⁹** launched for the period 2021 to 2026.

FFG and FWF use a selection of their respective funding instruments for personnel and infrastructure for this purpose. Part of the funding is provided for research infrastructure in the highly innovative field of next-generation high-performance computing and quantum computing, as well as their interconnection.

Quantum Austria Funding Initiative



LAUNCH
2021



DURATION
5 years



BUDGET
€107 M

shared between FFG and
FWF incl. management

Funding instruments

The Austrian Science Fund (FWF) is the Austrian funding organisation for basic research. All areas of basic sciences and humanities are funded by FWF through various funding programmes, from stipends for young postdocs to grants for large research consortia.

The Austrian Research Promotion Agency (FFG) is the national funding agency for applied and industrial research and development in Austria. As a one-stop shop offering a diversified and targeted portfolio, the FFG gives Austrian businesses and research facilities quick and uncomplicated access to research funding with a mix of open and

Goals:

- support of basic research in the field of quantum physics, quantum computing, and next generation high performance computing
- assurance of Austria's continued competitiveness in the EU and globally
- successful usage of QT for innovative products and services

thematically-oriented funding programmes for national, European and international projects.

Both agencies fund QT research through thematic programmes:

- **Quantum Austria Funding Initiative**¹⁰ (FFG, FWF)
- **Quantum Science and Technology**¹¹, QFTE – (FFG, FWF)

Quantum research and technology spans the following topics:

- Specific preparation and control of quantum states
- New algorithms and mathematical theoretical concepts that make use of the superposition and entanglement of quantum states
- Developments and applications in quantum communication
- Quantum sensor technology, quantum metrology, quantum simulation, quantum computing and quantum information
- Development of ideas based on quantum phenomena in the neighbouring fields of physics, mathematics, chemistry and in biological systems

The average funding amount for QT projects per year is €5-15 M by FFG; €2-5 M by FWF. Funding has increased at both agencies since 2022 due to the launch of the Quantum Austria Funding Initiative.

9 <https://www.ffg.at/en/quantum-austria>

10 <https://www.fwf.ac.at/en/research-funding/fwf-programmes/quantum-austria-funding-initiative>

11 <https://www.ffg.at/quantenforschung-und-technologie> (in German only)

Other activities

In the context of the Quantum Austria Funding Initiative, the FFG and the FWF organised a networking workshop to bring together current researchers funded by the Initiative and potential interested researchers. Currently, there is no further networking meeting planned. Since the joint Quantum Austria networking meeting was a huge success, similar activities might be organised in the future.

Quantum ecosystem

Quantum research community

The quantum research community in Austria is highly distinguished by excellent research groups that perform high-quality innovative basic research in the fields of quantum physics and quantum computing at several key universities in Austria.

Aside from the very good networking capabilities of the researchers themselves, the quantum community shows a high degree of interconnection and the drive to bring people together to work on a common goal. Examples of these are the FWF special research programmes (SFB) which connect up to 15 project leaders and at least 2 research institutions. It goes even bigger, since recently the FWF introduced the Clusters of Excellence which also connected the QT research community even more.

Further, the Austrian flagship of quantum science is the Nobel prize-winner Anton Zeilinger, University of Vienna,

Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences.

Quantum innovation and industry

The basic quantum research community is also highly connected to industry. Many basic quantum researchers are building up companies, creating start-ups and providing the link between basic research and applied research.

Start-ups have emerged as spin-offs in Austria in recent years and have made companies successful. Several enterprises, especially small and large companies, are intensifying their R&D activities and technology transfer in the field of QT. QT are increasingly being identified as a new area of business.

FFG and FWF implement the Quantum Austria Funding Initiative launched for 2021-2026.

Funds are available to:

- **research basic technologies for QT systems**
 - **set up high-performance laboratories and technical equipment**
 - **expand Austria's capacities in the field of high-performance computing.**
-

BELGIUM



Fund for Scientific Research, F.R.S-FNRS

Research Foundation Flanders, FWO

F.R.S.-FNRS and FWO supports QT in Belgium. Funds are available to support basic research for QT systems.

National programme

At the national level, there is no specific programme related to QT or specific priority areas. F.R.S.-FNRS and FWO are the main bodies supporting QT in Belgium through bottom-up regular calls for research projects.

Funding instruments

The Fund for Scientific Research (F.R.S.-FNRS) is a research funding agency that promotes and supports basic scientific research in the French-speaking community of Belgium.

The F.R.S.-FNRS supports individual researchers and projects based on the criterion of excellence. The F.R.S.-FNRS supports:

- Temporary individual mandates: fellowships for doctoral students and post-doctoral internships
- Permanent individual mandates from starting positions (Research Associate) to senior positions (Senior Research Associate and Research Director)
- Research projects: small scale 2-year projects (operating

and small equipment costs) or bigger scale 4-year projects (personnel, operating and small equipment costs)

- Equipment projects: funds allocated for the purchase of large equipment
- Grants and credits for international collaboration: participation in joint programming (e.g. QuantERA) and bilateral research calls
- Scientific prizes

All the calls and programmes are bottom-up. There are no specific instruments to support QT topics. QT funding comes from the success of the researchers in the different calls based on the quality of the projects.

The national calls are open to all scientific domains, with no priority areas defined.

Awarded research projects

The F.R.S.-FNRS has awarded 11 research projects identified as being related to QT out of a total 551 awarded research projects (ca. 2%).

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The total budget awarded to QT research projects in 2021 and 2022 is approx. **€3,5 M**.

2021	2022
€1.6 M	€1.8 M

Table 2. Total budget awarded to research projects associated with QT

Mandates

The F.R.S.-FNRS funds permanent individual mandates from starting positions (Research Associate) to senior positions (Senior Research Associate and Research Director).

As of March 2022, the F.R.S.-FNRS funds **20** permanent researchers working in QT.

RESEARCH ASSOCIATE	SENIOR RESEARCH ASSOCIATE	RESEARCH DIRECTOR
11	4	5

Table 3. Number of F.R.S.-FNRS permanent researchers as of 03/2022 associated to QT

Research Foundation – Flanders (FWO) stimulates and financially supports fundamental scientific research, strategic basic research, clinical scientific research, the purchase of large-scale and medium-scale research infrastructure and the management of large computing capacity in Flanders.

With the financial resources received, mainly from the Flemish Government, FWO subsidises fellowships and research projects,

infrastructure, travel grants and international scientific cooperation. The FWO is a non-thematic, bottom-up funder. All areas in the QT domain are considered as high-priority areas and no priorities have been defined between the different QT domains.

QT research is mostly funded through regional open calls/programmes. These ‘bottom-up’ calls are open to all scientific domains, with no restrictions on theme/topic, and are evaluated by peer-review panels within the field. Also bilateral research programmes and a multilateral lead agency initiative in **FWO funding portfolio** provide opportunities for bottom-up funding. FWO participation in the QuantERA network implies a direct funding line for QT research.

Awarded research projects FWO

From 2021 till 2023 the FWO has awarded 16 research projects identified as being related to QT.

2021	2022	2023
4 €2.65 M	6 €3.2 M	6 €3.3 M

Table 4. Number and budgets of awarded FWO research projects associated to QT

More information on projects granted in Flanders can be found on the ‘**Flanders Research Information Space**’ (FRIS)¹², which includes a database on research funding in Flanders across all scientific domains.

¹² <https://researchportal.be/en>

¹³ <https://www.vlaio.be/en>

¹⁴ <https://www.wallonie.be/en/demarches?f%5B0%5D=public%3A284>

¹⁵ <https://innoviris.brussels/>

Other funding bodies supporting research projects related to areas of QT are: **VLAIO**¹³, innovation-oriented research for the Flemish-speaking community; **SPW**¹⁴, innovation-oriented research for the French-speaking community; and **Innoviris**¹⁵ for the Brussels region.

Other activities

Responsible Research & Innovation is not specifically addressed yet by F.R.S.-FNRS. That being said, some specific activities are nonetheless set up to foster a more responsible research and innovation environment, such as ‘open access publication incentives’.

The FWO research policy and its implementation is described on the FWO website, and in its five year **policy plan**.

Quantum ecosystem

Quantum innovation and industry

In January 2023 the BeQCI project took off, with the aim of introducing, evaluating and developing quantum communication infrastructure (QCI) in Belgium. The consortium unites theoretical, experimental and engineering expertise on QT, bringing together different university research groups, research centres, governmental agencies and private companies. BeQCI is part of the European EuroQCI initiative and is co-funded by the EU through the Digital Europe programme and the Belgian Federal Science Policy Office (Belspo) through the Federal restart and transition plan.

BULGARIA



Bulgarian National Science Fund, BNSF

In Bulgaria, research in QT is supported alongside other fields through annual national calls for basic research and bilateral cooperation with public funding of approx. €300 K per year.

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National programme

Quantum Technology research is supported by the Bulgarian Government via The Bulgarian Innovation Fund. The Fund focuses on funding for applied and innovation research.

Funding instruments

The Bulgarian National Science Fund (BNSF) is a public institution which finances project-based research. The BNSF also coordinates bilateral programmes with the Bulgarian Ministry of Education and Science, supports COST actions and participates in EC framework programmes. BNSF supports various types of research projects at national level:

- Grants for basic research projects
- Young researchers
- Bilateral research projects
- The National Scientific Programme “Vihren” to support excellent Principal Investigators (PIs) at different career stages
- The National Scientific Programme “Petar Beron I NIE” to stimulate the development of research potential in

Bulgaria as a necessary fundamental step in the creation of a sustainable scientific and innovation environment and for the development of a competitive high-tech economy in Bulgaria

The estimated funding into QT per year is <€1 M.

Quantum ecosystem

Quantum research community

The community of researchers in QT in Bulgaria consists of representatives of leading Bulgarian universities and research institutions of the Bulgarian Academy of Sciences. It is important to note that QT is attracting a great deal of interest among young researchers. Many scientific institutions in Bulgaria have attracted a lot of young investigators over the past 10 years. There is a good knowledge exchange between different groups.



Quantum innovation and industry

As part of the European Platform for Quantum Communication Infrastructure (EuroQCI), a National Plan for Quantum Communication Infrastructure has been launched in Bulgaria. The construction of EuroQCI is coordinated by the National Centre for Quantum Communication, Intelligent Security Systems and Risk Management – QUASAR – at the Institute of Robotics of BAS. With the goal of building a secure quantum communication infrastructure for exchanging sensitive data between institutions and businesses, the construction of Bulgaria's first quantum communication network was officially launched at the beginning of 2023. Within the next thirty months, the Centre's experts will pilot two quantum routes. With one of them, in the territory of Sofia, the information arrays of the Ministry of the Interior, the Ministry of Defence, banks, hospitals and the Ministry of Transport will be secured. The second route will be 280 km long and will connect Sofia with Greece.

In Croatia QT research is supported through participation in QuantERA and the project “Deployment of the first experimental QCI systems and network in the Republic of Croatia” co-financed by EU Horizon Europe Digital Programme in the amount of 50% and 50% from the national Recovery and Resilience Facility (RRF).

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National programme

In Croatia, a rich variety of research in the field of QT is financed through various projects and programmes conducted in scientific centres of excellence and infrastructure projects that are funded by the EU and supported by national sources:

- Centre for Advanced Laser Techniques (CALT)¹⁶
- Cryogenic centre of the Institute of Physics (KaCIF)¹⁷
- Scientific Centre of Excellence for Quantum and Complex Systems, and Representations of Lie Algebras (QuantiXLie)¹⁸
- Centre of Excellence for Advanced Materials and Sensing Devices (CEMS)¹⁹

The aforementioned centres have been working on QT development for a long time in Croatia and were described in detail in the previous version of the report.

¹⁶ <http://calt.ifs.hr/en/>

¹⁷ <http://kacif.ifs.hr/en/about-project/>

¹⁸ <http://bela.phy.hr/quantixlie/>

¹⁹ <http://cems.irb.hr/en/>

Important new developments since 2020 are:

- Slovenia-Croatia bilateral research project “Development of building blocks for a new European quantum communication network”, funded by the ARRS and HRZZ. In a collaboration between partners in Ljubljana and Zagreb, the project aims to realise central building blocks for building a quantum network in South-Eastern Europe. These include narrow-band sources of entangled photons of telecom photons and atom-based quantum memories to store these photons and the quantum information they carry for a sufficiently long time to facilitate connecting distant communication partners.
- Croatian Quantum Communication Infrastructure project, funded by the EU Horizon Europe Digital and national funds NPOO (description below)
- For the first time, a research team from Croatia was awarded funding in the QuantERA call 2021

Funding instruments

The Croatian Science Foundation (HRZZ) provides support to scientific, higher education and technological programmes and projects, fosters international cooperation and helps the realisation of scientific programmes of special interest in the fields of fundamental, applied and developmental research. The calls are bottom-up. Projects are funded through various funding programmes:

- **Installation projects** supports the development of individual research careers of young scientists and new research teams
- **Research Projects** for fundamental research as well as applied research that is conducted with clear technological, economic or social aims
- **Partnership in Research** supports partnerships in research between public universities or public scientific institutes or extra-budgetary sources of funding (not funded from the State budget) from Croatia or from abroad (private companies, local administration units, foreign foundations and agencies for funding research, foreign scientific organisations)
- **Young Researchers' Career Development Project – Training New Doctoral Students** fosters young researchers in the early phase of their career development (at postgraduate level) in the science and higher education system.

Within the HRZZ database, there are 16 individual Installation and Research projects related to Quantum Technologies being implemented from the period of 2015 with approximately €2.3 M, including the salaries of doctoral students funded through the programme Young Researchers' Career Development Project – Training New Doctoral Students.

The estimated funding into QT per year is <€1 M. No increase is expected in the next three years.

Quantum ecosystem

Quantum research community

There are several research groups working in the field of QT²⁰:

- Institute of Physics, Zagreb, research topics: quantum simulators with cold atoms, quantum optics, metrology with optical atomic clock, disordered quantum systems, localisation phenomena, ultrafast laser spectroscopy, quantum magnets, 2D Materials, ultrafast spectroscopy
- University of Zagreb, research topic: atomic gases/optics and photonics
- Ruđer Bošković Institute (Zagreb), research topic: quantum information, quantum entanglement, quantum cryptography, randomness, information security, quantum and quantum-assisted computing
- University of Split, research topics: ultracold atoms/quantum fluids
- University of Rijeka, research topics: optomechanics



Quantum innovation and industry

In 2019, the Croatian government signed the EuroQCI declaration to build a secure quantum communications infrastructure that will cover the entire EU. As a first step on this path, a Croatian Quantum Communication Infrastructure (CroQCI) consortium was formed, with the aim of deploying an advanced national quantum communication network. The CroQCI consortium brings together experts in the field of quantum systems, quantum and classical communication technology from major Croatian research institutions and universities, key public institutions and companies who have essential complementary research and technological expertise and will contribute equally to successful implementation of the project.

²⁰ <http://croqci.ifs.hr/activities/events/>

CZECH REPUBLIC



Ministry of Education, Youth and Sports, MEYS

Technology Agency of the Czech Republic, TA CR

The main instrument for systematic support of research in QT in Czech Republic is the QuantERA programme. TA CR joined QuantERA II in 2021. As a result, two national funding providers are involved in QuantERA – MEYS, which supports both fundamental and applied research and TA CR, which funds applied research only.

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National programme

Research in QT can be funded in Czechia in open bottom-up calls regularly organised by various national funding providers, but there is no research call specifically dedicated to the area of QT. Usually the calls are broad, do not focus on specific scientific domains and the topic is chosen by the applicant. For instance, the Czech Science Foundation supported several projects in QT in a call whose general scope was dedicated to fundamental research. Also, TA CR can support applied research in QT in bottom-up calls which do not thematically limit the proposals to only the QT area.

Funding instruments

The Ministry of Education, Youth and Sports (MEYS) is the central administrative authority responsible for R&D, particularly institutional funding for the higher education sector, research infrastructure policy and funding and international R&D collaboration.



MEYS funds research in QT primarily via its participation in the QuantERA programme, of which it's been a member since its launch and participated in all calls for proposals so far as a National Funding Authority.

Furthermore, MEYS provides institutional support to public universities and public research institutions for, among others, long-term development, basic and applied research and technology transfer on a non-discriminatory basis; thus research in QT can be financed from this support if the subjects concerned see fit.



For MEYS, the QT funding per year depends on the success of Czech applicants in QuantERA calls. **The average amount for MEYS is <€1 M.** The budget allocation dedicated specifically to R&D&I, depends largely on political negotiations and is constructed on a yearly basis.

The Technology Agency of the Czech Republic (TA CR) simplifies the state support of applied research and experimental development.

Even though TA CR does not have a national call focused specifically on QT research, researchers can use bottom-up calls which do not thematically limit the proposed projects for obtaining support in QT-oriented projects. **The average funding for QT per year is <€1 M.** International cooperation in QT is also supported through QuantERA by TA CR. TA CR joined QuantERA II in 2021 and participated in both calls that were launched under QuantERA II with a budget that allows all Czech researchers in highly-ranked projects to be funded. The priority areas in QT have not been identified either by MEYS or by TA CR; both organisations support successful project proposals in the QuantERA programme based on the criterion of scientific excellence. Currently there is no strategic research agenda for QT implemented by MEYS or TA CR.

Other activities

RRI is addressed by the TA CR by the following activities:

- Encouraging gender balance in the funded research projects, and aiming at gender balance, to the best of its capabilities, in the evaluation panel compositions

- Monitoring and analysing gender data and publishing statistics

Quantum ecosystem

Quantum research community

The community of researchers in Quantum Technologies in Czechia is well organised and consists of representatives of leading Czech universities and research institutes of the Czech Academy of Sciences. All relevant stakeholders in the field of QT are organised under the National Initiative for Quantum Technologies (NIKT), whose aim is to promote and support the development and usage of QT. NIKT supported the accession of Czechia to the QuantERA programme, the Quantum Flagship and the EuroQCI. It can also perform an advisory role for decision-makers and public officers in appropriate cases.

Quantum innovation and industry

Currently there are no Czech industrial companies dealing directly with QT. However, some enterprises and institutions have already shown interest in QT in the areas of IT security, cryptography and biometrics, e-infrastructures or nanotechnologies. Furthermore, IBM Central and Eastern Europe offers access to their quantum computer and is interested in cooperation with local companies. Another quantum computer will be installed in the national supercomputing centre IT4Innovations following its success in the EuroHPC call for proposals.

DENMARK

Innovation Fund Denmark, IFD

Highlights

- ✓ **National programme**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

Contact

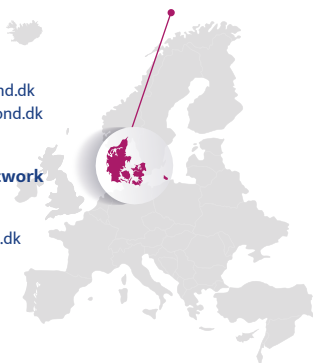
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Innovation Fund Denmark



National programme

In June, 2023 the Danish Ministry of Higher Education and Research published the first policy part of the **Danish Strategy for Quantum Technology**²¹. The second part, where the national investments will be specified, will be published in September 2023.

The ambition is to invest approx. €150 M in basic and applied QT research from 2023-2027. This budget will further boost the investment on €200 M made by the Novo Nordic Foundation to the Niels Bohr Institute at Copenhagen University in 2022. This investment will be placed on top of already very high investments to QT research at Danish universities. International cooperation within EU programmes, EUREKA and bilateral calls is mentioned as a high priority in the strategy. Within the strategy, Denmark will engage in activities that support the development of QT within key Danish sectors

²¹ <https://ufm.dk/en/publications/2023/files/strategy-for-quantum-technology.pdf>

such as the pharmaceutical industry, off and onshore transport and logistics, finance and fintech and in areas that will support cyber-security and the green transition of industry, households and clean energy.

Danish Strategy for Quantum Technology



LAUNCH
2023



DURATION
4 years



BUDGET APPROX.
€150 M

Priority areas

- High Performing Computers/Quantum computers
- Quantum simulators
- Quantum communication
- Quantum methodology

In 2023 the government has allocated €20 M for QT. A national Grand Solutions calls on early-stage QT research and an applied international call within EUREKA will be launched in the second half of 2023. In addition, the Danish government has made a [mapping of the QT area](#)²².

Funding instruments

Innovation Fund Denmark (IFD) is funding QT research and innovation through national open calls/programmes as well as in international co-funded programmes. The national calls are open to all scientific domains, with no restrictions on theme except on the organisational level. Those calls are open to for-profit as well as non-profit research organisations and collaborative projects.

The national calls are mainly organised under the Grand Solutions programme, which is aimed at collaborative projects based on excellent research focused on solutions of considerable value targeting societal and/or business challenges, opportunities and innovation needs.

Quantum research is sometimes specifically listed as one of the focus areas, but separate resources are not pre-allocated to the topic. In addition to the Grand Solutions open call, funding is available for industrial PhDs and industrial Postdocs with no restrictions on theme and therefore also including QT.

International co-funded calls have mainly been organised under QuanTERA and EUREKA, but IFD has also had QT projects funded within the SME-focused bottom-up EU partnership programme, Eurostars.

With the new Quantum strategy Denmark will from 2023-2027 engage in EU partnership programmes such as Chip JU and the partnership for innovative SME's – Eurostars, as well as global oriented EUREKA and bilateral calls.

Other funding instruments

QT projects can be also supported by:

- NovoNordic Foundation
- Villum Foundation
- Denmark's Export and Investment Fund
- The national basic research foundations (Independent Research Fund Denmark, The Danish National Research Foundation)

Other activities

RRI activities are important and addressed by the IFD, mainly focusing on gender balance and open access. The initiatives apply for all fields of science funded by the IFD.

Quantum ecosystem

Quantum research community

Historically, Denmark has a long tradition in the field of QT, dating back to Niels Bohr himself who started the Niels Bohr Institute at the University of Copenhagen (KU). Here and at the Technical University of Denmark (DTU), several internationally-renowned research groups are located, working on most aspects of QT, and its application to real world problems.

Lately, these strong research groups (including other universities

²² <https://ufm.dk/publikationer/2022/forskning-pa-kvanteomraadet-herunder-samspillet-mellem-universiteter-og-virksomheder>

²³ <https://dqc.dk/>

²⁴ Technology readiness levels (TRL)

such as Aarhus University and Aalborg University) as well as national Research and Technology Organisations (RTO) have succeeded in attracting public as well as commercial funding. In particular, at DTU and Copenhagen University, global ICT companies have invested heavily in platforms for cooperation with the Danish research community. In 2022 Denmark was selected as host country for the new NATO Center for QT, and the Novo Nordisk foundation announced a DKK 1.5 B investment towards the development of a fully functional quantum computer.

Quantum innovation and industry

Several start-ups have materialised within the QT domain over the last 2-5 years, and banks and large biotech companies are participating in Grand Solutions projects on Quantum computing.

Recently the **Danish Quantum Community**²³ was established as an initiative driven by the national research environments. On the funding side, TRL²⁴ development is covered by a wide range of funding opportunities, from basic research to the higher TRL levels, through national funding agencies to public funding bodies and venture capital.

QT is considered to be a Danish position of strength. The first part of Danish Strategy for Quantum Technologies was published in June 2023. The second part of the Strategy is expected in autumn. There are several opportunities to obtain funding in Denmark, all the way from basic research to commercialisation.



Estonia is rapidly expanding its competences and RDI capabilities in QT.

ETAG joined QuantERA II in 2021 to support Estonian researchers in international research consortia.

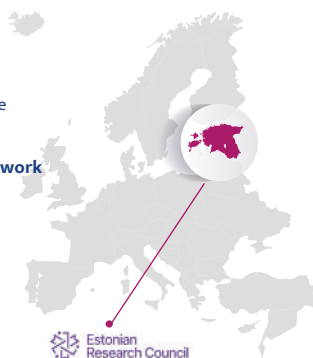
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National programme

At the national level, there is no specific programme related to QT or specific priority areas. ETAG is the main research funding organisation in Estonia. Sectoral ministries also fund research, but only in domains related to their field.

Funding instruments

The Estonian Research Council (ETAG) is a private body fulfilling public functions, responsible to the Ministry of Education and Research. ETAG maintains and develops a balanced, high-level and internationally successful research, development and innovation (RDI) system in Estonia, as well as a knowledge-based and sustainable Estonian society. Its main goal is to support the most promising research initiatives in all fields of basic and applied research. The ETAG acts as the National Contact Point for Horizon 2020, coordinates participation in the COST network and consults mobile researchers through the EURAXESS network and manages the Estonian R&D Liaison Office in Brussels.

ETAG is a bottom-up research funding organisation. There are no special theme-oriented calls related to QT, except ERA-NET's calls. ETAG joined QuantERA II in 2021. **The average funding for QT per year is approx. €0.75 M.** As ETAG funds all fields of science, there are no plans to increase the budget's funding especially for QT. All fields of science are financed equally if possible.

ETAG does not have a specific research agenda for QT. But **the Estonian Research, Development, Innovation and Entrepreneurship Strategy for 2021-2035²⁵** also covers quantum science. Focus areas such as: digital solutions across all areas of life as well as smart and sustainable energy solutions may also partly include QT.

Other activities

RRI is addressed by ETAG in the following activities:

- Encouraging gender balance in the funded research projects, and aiming at gender balance, to the best of

²⁵ <https://www.hm.ee/en/ministry/ministry/strategic-planning-2021-2035>

its capabilities, in the evaluation panel compositions in accordance with Gender Equality Plan for 2020-2027

ETAG supports QT researchers by covering their travel costs to international events and initiatives dedicated to QT research development, such as **Northern Prospects of Quantum**²⁶.

Quantum ecosystem

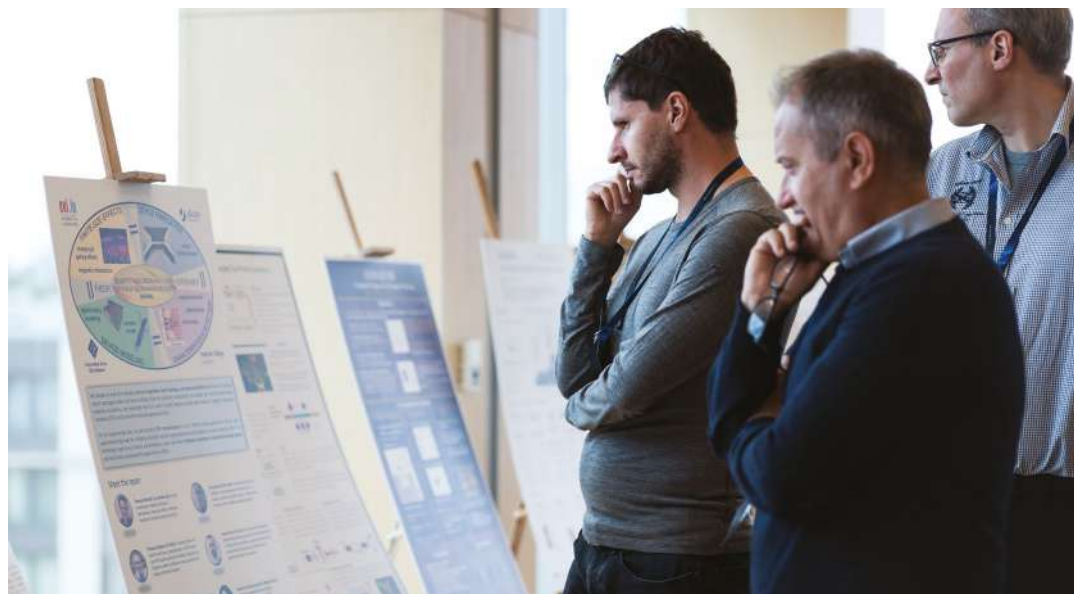
Quantum research community

In terms of the pillars described in the Quantum Flagship Strategic Research and Industry Agenda, Estonian R&D institutions have activities in quantum computing and quantum communication. Moreover, there is research in fundamental quantum science relevant for quantum information processing.

In quantum communication, the University of Tartu hosts a quantum cryptography research group funded through ERC, the US-Air-Force and national funding.

In quantum computing, the University of Tartu hosts:

- A research group on rare-earth-doped crystals at the Institute of Physics for quantum computing funded by national funding
- A research group in the Institute of Physics funded by the Nordic e-Infrastructure Collaboration along with negligible national funding



- A research group in theoretical computer science, funded by Horizon Europe (OpenSuperQPlus) and the Research Council of Norway, along with negligible national funding

The National Institute of Chemical Physics and Biophysics hosts a group on THz and low-temperature physics funded through ERC, which researches superconductivity with a view towards topological quantum information.

Funded by EuroQCI (EstQCI), the Ministry of Economic Affairs and Communications, in partnership with the state-run company Metrosert AS, will begin to realise a trans-metropolitan QKD network. The Quantum Technology will be

imported, but know-how for deploying and operating it will be developed domestically; research on single-photon detectors is planned.

Quantum innovation and industry

There is no QT industry in the sense of the QT Flagship SRIA in Estonia. There are, however, companies engaged in Post-Quantum Cryptography (most notably, Cybernetica AS), and two start-ups in classical detector technology adjacent to quantum sensing/metrology.

²⁶ <https://www.lmt.it/en/events/2558/northern-spin-of-quantum/r249>



Highlights

✓ Other national initiatives

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National programme

In Finland there is no national QT funding programme yet. However, the **Finnish Quantum Agenda (FQA)**²⁷ published in 2023, gives a recommendation for a future quantum programme. The agenda is the result of a joint effort by the working group of the Finnish quantum community. The working group recommends the following set of interconnected activities to address the opportunities and realise the potential of QT for Finnish society.

FQA recommendations:

- Coordinated research and innovation funding programme
- Long term programme and a roadmap for research and innovation infrastructures
- Targeted development of the Finnish QT ecosystem
- Increase of education and development of the educational offerings in QT
- Support for national and international cooperation

The total amount of research funding used for QT in universities and research and technology organisations in Finland in

2022 is about €45 M. A large majority of this funding comes from nonthematic funding programmes of the Academy of Finland and the European Union. Other funding comes from the private investments in R&D by companies. Using the current state of the area as the starting point, the working group has estimated the volume of research and innovation programmes.

Recommended volume of research programmes

Research programme for QT

- Academy of Finland
- 4 years duration
- Budget: €12 M
- €3 M per year
- with a volume of approx. €4 M cooperation with the Nordic countries, the USA and other likeminded techno-democracies

²⁷ <https://instituteq.fi/wp-content/uploads/2023/02/FQA-February-2023.pdf>

Innovation programs for QT

- Business Finland, targeted either at the whole area or at specific subareas
- 4 years duration
- Budget: €20-30 M

Professorships

- 5-10 new professorships during 2023-2027
- Based on reference obtained from Sweden (the Wallenberg foundation)

Funding instruments

The **Academy of Finland (AKA)** is an agency within the administrative branch of the Ministry of Education, Science and Culture, and the Academy's activities cover the full spectrum of scientific disciplines. The Academy selects the best and most promising research projects for funding by means of an international peer-review procedure. The national calls are open to all scientific domains, with no priority areas defined.

The **Academy of Finland** funds QT research mainly through its national bottom-up calls for funding. There are funding forms for research projects, individual researchers and research environments (e.g., research infrastructure) via which funding for QT research can be applied for. In addition, the Academy of Finland's Centre of Excellence programme 2018-2025 includes a national **Centre of Excellence in QT**²⁸. All in all, **the funding volume is around €5-10 M per year.**

Other activities

The Academy of Finland is committed to RRI and is addressed by the following activities:

- Promotion of equality and non-discrimination in research projects
- Open access publication requirement for funded projects
- Requirement for the preparation of a Data Management Plan, describing how the data will be stored during the project, how any legal and ethical issues related to data distribution will be resolved, and where the data will be made available after the end of the project

Quantum ecosystem

Quantum research community

In Finland, there is a globally-recognised community of researchers devoted to both theoretical and experimental work. Several members of the community are involved in the Quantum Flagship. The largest actors in the research area are Aalto University, VTT and the University of Helsinki. QT has also been identified as a topic of interest in the Universities of Tampere, Jyväskylä, Eastern Finland, Turku and Oulu. Various aspects of quantum foundations, materials, devices and components, as well as algorithms and software, are studied experimentally and theoretically with different intensities at these **universities**²⁹. The national

28 <https://qtf.fi/>

29 <https://instituteq.fi/wp-content/uploads/2023/02/FQA-February-2023.pdf>
30 ibid

OtaNano research infrastructure, which is the key state-of-the-art research infrastructure for micro-, nano- and QT in Finland, is one of the largest fabrication centres for micro- and nanoelectronic devices in the Nordic countries.

Quantum innovation and industry

There are currently about 11 companies working more or less exclusively on quantum-related themes, and their estimated current total revenue is €130 M. The start-up funding for QT in Finland is about €280 M since year 2000. The total number of ROI personnel working on QT in Finnish universities and research institutions is close to 550³⁰.

Finland has a strong base in research and innovation activities in Quantum Technologies.

The Finnish quantum ecosystem is internationally recognised and competitive.

Finnish Quantum Agenda gives a recommendation for coordinated research and the innovation funding programme.

FRANCE



French National Research Agency, ANR

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

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anr[®]
agence nationale
de la recherche

Funding instruments

The French National Research Agency (ANR) supports research in QT via national calls for proposals, as well as specific calls that can now be launched within the framework of the Quantum Plan. The ANR launches a yearly open call for proposals in 56 topics, each topic having a dedicated evaluation panel. One of these topics is Quantum Technologies, and each year its evaluation panel selects research proposals of high quality, distributed among various funding instruments:

- Early-career research projects: to support the development of new research lines carried by an early-career researcher, who obtained his/her PhD no more than 10 years ago, and

begun a permanent position no more than 5 years ago

- Collaborative projects: to support collaborative research efforts
 - Public/private collaborative projects: to foster the collaboration between public research and industry
 - Mono-partner projects: to encourage one experienced team to submit an innovative research project carried out within this team
 - Bilateral collaborations
- ANR's annual national call supports all areas in QT³¹:
- Quantum communications

Quantum Plan – France National Quantum Strategy



LAUNCH
2021



DURATION
5 years



BUDGET
€1.8 B

= €200 M of public
funding in QT per year

Expected impact:

- creating 16,000 jobs in the QE field by 2030
- aiming at 1-2% of French exports from QT activities

³¹ See the description of the QT open yearly call here: https://anr.fr/fileadmin/aap/2023/aapg-2023-V2.0_MAJ20220921_EN.pdf

- Quantum computing
- Quantum simulation
- Quantum sensors and metrology
- Fundamental research and development of new concepts

Since the launch of the National Quantum Strategy, specific areas can be targeted in additional specific calls (e.g., quantum sensors and metrology³², flying qubits³³).

Within this strategy, a €150 M programme called Programme et Équipements Prioritaires de Recherche (PEPR³⁴) was launched under the operation of three research organisations: CEA, CNRS and INRIA who appointed three pilots. In a first step they devoted about half of the budget to fund 10 "Directed Actions" in several key topics of QT for 10 consortia identified by the pilots. The PEPR also supports key platforms and equipment for QT.

Private entities can be supported by:

- **BPI-France**, a public investment bank that funds and invests in private entities through various schemes. QT is an area supported by BPI-France
- **"Credit Impot Recherche"**, where their taxes are reduced if they perform research and development activities
- Regional research funding programmes where QT projects could potentially apply and be funded (in some regions)

Other activities

RRI is addressed by the ANR by the following activities:

- Encouraging gender balance in the funded research projects, and aiming at gender balance, to the best of its

capabilities, in the evaluation panel compositions

- Open access guidelines presented to all newly-funded research projects during a yearly kick-off meeting
- Open access publication costs being accepted in the project's costs
- Requirement for the preparation of a Data Management Plan by each project at various stages

Quantum ecosystem

Quantum research community

France has a very active quantum research community, with the following (albeit not exhaustive) geographical distribution:

- Three large centres for QT that can be qualified as Hubs, around Paris, Paris-Saclay and Grenoble with expertise in quantum computing, simulation, communication and sensing
- Several important centres with specific expertise (e.g., Nice, Montpellier, Bordeaux)

In terms of National Quantum Research Networks, the French National Centre for Scientific Research (CNRS) supports networks called "Groupements de Recherche" (or GDR), which are structures that aim to foster collaborations between academic researchers, industry and any other stakeholders in a particular domain. In QT, such GDR are:

- GDR Gaz Quantiques
- GDR Physique Quantique Mésoscopique

³² Call soon to be launched at <https://anr.fr/>

³³ <https://anr.fr/fr/detail/call/pepr-quantique-appel-a-projets-calcul-quantique-au-vol/> in French only

³⁴ <https://www.cnrs.fr/en/cnrsinfo/french-quantum-national-rd-strategy-just-started>

- GDR Ingénierie Quantique, des Aspects Fondamentaux aux Applications (IQFA)

Quantum innovation and industry

Regarding QT Industry and Innovation ecosystem, several start-ups have been created in the past years (PASQAL, Quandela, Alice&Bob, Muquans, VeriQloud, CryptoNext, LightOn, NewCo).

Other institutions and companies are involved in following developments:

- Institutional technological platforms: CNRS Renatech+, CEA LETI and EuroNanoLab
- French industrials, Silicon foundry ST Microelectronics
- Large companies: ATOS (that has built a classical simulator for quantum calculators), Thales
- Potential users such as Total, Airbus, EDF, Orange
- Industry actors involved in enabling technologies, in particular for extreme cryogeny (Air Liquide, CryoConcept, MyCryoFirm) and lasers (MuQuans, ALS, Quantel, Thales)

With a predicted yearly public funding of €200 M in QT, France intends to take its place among the three countries having most funding in this sector (the two others being the USA and China), with the main goal of becoming the first country to have a prototype of a general quantum computer.

GERMANY



Federal Ministry of Education and Research, BMBF

VDI Technologiezentrum GmbH, VDI-TZ

German Research Foundation, DFG

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

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National programme

In 2020, the German government adopted the Economic Stimulus Package. It is administrated by the Federal Ministry of Education and Research (BMBF) to support new research projects comprising the fields of quantum computing, quantum sensing, quantum communication and enabling technologies, as well as overarching activities (e.g. education and outreach activities). Another part of the funds earmarked for QT within the Economic Stimulus Package is administered by

the Federal Ministry for Economic Affairs and Climate Action (BMWK) together with the German Aerospace Center (DLR).

In 2022 the BMBF launched the research programme **Quantum Systems**³⁵ with a duration of 10 years to promote research in all QT areas. With regard to quantum computing (including simulation) and quantum sensing (including imaging), the research programme defines key performance indicators (e.g. publications, patents, new products, etc.) to assess the development of the ecosystems.

Economic Stimulus Package



LAUNCH
2021



DURATION
5 years



BUDGET
€2 B

for QT, of which 1.1 B
administrated by BMBF
for research projects and
overarching activities

Mission: Within the next ten years, the programme aims to promote a globally leading position for Germany in quantum computing (including simulation) and quantum sensing technology (including imaging) and to strengthen Germany's competitiveness in the field of quantum systems – in alliance with other partners in Europe.

³⁵ https://www.quantentechnologien.de/fileadmin/public/Redaktion/Dokumente/PDF/Publikationen/BMBF-Forschungsprogramm-Quantensysteme_web_bf_C1.pdf (in German only)

Hence, the programme aims to secure technological sovereignty for Germany and Europe in quantum systems. At the same time it promotes the use of quantum systems for the benefit of technological change in the economy and society. The research programme is complemented by a new federal conceptual framework programme (“Handlungskonzept Quantentechnologien”) that was published in April 2023.

Funding instruments

The Federal Ministry of Education and Research (BMBF) provides funding for research projects and research institutions. The BMBF provides funding for excellent research projects related to any of the five research areas presently addressed by QuantERA. For the purpose of implementing calls and administrative support, the BMBF has commissioned the programme management agency VDI Technologiezentrum GmbH.

VDI Technologiezentrum GmbH is an innovation and research management consultancy, mainly working for clients from public authorities and institutions. In particular, VDI TZ is acting as a programme manager (“Projekträger”) on behalf of the Federal Ministry of Education and Research (BMBF).

The largely application-oriented BMBF research funding in QT is organised mainly through thematic calls. In these calls, universities, non-university research institutions, start-ups, SMEs and companies are funded in common projects, thus ensuring that the supported research activities address the needs of industry adequately.

The BMBF funding aims at three vertical and one horizontal (overarching) **research priority areas**:

- Quantum computing and simulation (hard- and software)
- Quantum-based measurement and sensing technology
- Quantum communication and cryptography
- Enabling technologies for quantum systems

Among the funding activities in the field of quantum computing hardware, **the BMBF funds projects on quantum computing demonstrators with more than €300 M until 2026**. The projects address different technology platforms and aim to provide cloud access to quantum computing set-ups.

At the same time, **projects on quantum computing software and use-cases for quantum computing are funded with more than €30 M until 2026**.

The thematic calls are complemented by open calls for certain aspects such as SME and start-up support as well as scientific preparatory/early-stage projects. Unless certain target groups are addressed (e.g. SME), the calls are generally open to universities, research organisations and enterprises.

Furthermore, BMBF provides institutional funding to non-university research institutes dealing with research on QT (e.g. Max-Planck- and Fraunhofer-society as well as Leibniz- and Helmholtz association).

³⁶ <https://www.quantentechnologien.de/bildung/quantum-futur-akademie.html> (partly in English)

³⁷ <https://www.quantentechnologien.de/bildung/quantum-futur-award.html> (in German only)

BMBF research programmes are regularly adapted, updated and evaluated. The predecessor of the current research programme (“Photonik Forschung Deutschland”) was successfully evaluated in 2021.

The German Research Foundation (DFG) is the central, independent research funding organisation in Germany. The DFG's primary task is to promote excellent knowledge-driven research across the entire spectrum of academic disciplines and scientific institutions. The priorities are set in a bottom-up process. Eligible individuals, groups or institutions can submit funding proposals to the DFG at any time and on any topic. The DFG's funding portfolio includes a broad range of different funding instruments, which cover all phases of the research process as well as a wide variety of project formats.

Projects related to QT are requested and funded in all of the DFG's applicable programmes. **The DFG granted a yearly amount of approximately €60 M for projects related to QT running in 2022**. The DFG does not have priority areas in QT. The funding schemes of the DFG are open to any topic.

Other activities

BMBF supports the following overarching activities related to QT:

- **BMBF Quantum Futur Akademie** – annual two-week programme for students of engineering or natural sciences³⁶
- **BMBF Quantum Futur Award** – prize for innovative scientific achievements in the field³⁷

- BMBF **Quantum Futur** early talent competition – funding for academic junior research group leaders³⁸
- BMBF **Quantum aktiv** – outreach concepts and open innovation for quantum technologies³⁹

Administered by the DFG, Germany funds 5 clusters of excellence whose research topics are closely related to QT:

- **ct.qmat** – Complexity and Topology in Quantum Matter⁴⁰
- **QuantumFrontiers** – Light and Matter at the Quantum Frontie⁴¹
- **CUI: Advanced Imaging of Matter**⁴²
- **Munich Center for Quantum Science and Technology (MCQST)**⁴³
- **ML4Q** – Matter and Light for Quantum Computing⁴⁴

Additionally, DFG supports good research practices in all areas of research. After a transitional period ending in 2023, DFG funding may only be granted to institutions that have implemented the guidelines laid down in the Code of Conduct for Safeguarding Good Research Practice in their own regulations.

Quantum ecosystem

Germany has an excellent starting position in basic research in quantum physics. In many different places throughout the



country, research on quantum technologies is being carried out with international visibility.

Quantum innovation and industry

Lately, a number of promising start-ups has emerged and also larger industries have started to address research into QT. The broad research in this field – consisting of a federally structured university landscape, non-university research institutions, departmental research and market-oriented research of companies – forms a promising basis for new ecosystems relying on QT.

The promotion and funding of QT in Germany follows a strategic approach considering scientific, economic, and structural aspects altogether. Consequently, the activities are implemented cross-departmentally and go far beyond the mere funding of research projects.

Education and workforce, procurement and infrastructures, innovation and technological utilisation are the building blocks for future technological sovereignty, sustainability and competitiveness.

38 <https://www.quantentechnologien.de/forschung/foerderung/nachwuchswettbewerb-quantum-futur-runde-2.html> (in German only)

39 <https://www.quantentechnologien.de/forschung/foerderung/quantum-aktiv-outreach-konzepte-und-open-innovation-fuer-quantentechnologien.html> (in German only)

40 <https://www.ctqmat.de/>

41 <https://www.quantumfrontiers.de/en/>

42 <https://www.cui-advanced.uni-hamburg.de/en.html>

43 <https://www.mcqst.de/index.html>

44 <https://ml4q.de/>

GREECE



General Secretariat for Research and Innovation, GSRI

In Greece research in QT is supported alongside other fields through national, bottom-up calls and bilateral cooperation.

Participation in the QuantERA programme provides an opportunity to support the local quantum community.

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Funding instruments

The General Secretariat for Research and Innovation (GSRI) is the main body responsible for setting and coordinating the implementation of research, technology development and innovation policy, and is the major direct funder of R&D.

QT research is funded through regional open calls/programmes in the context of the Operational Programme for Competitiveness, Entrepreneurship and Innovation 2021-2028 (EPAnEK) and the National Research and Innovation Strategy for Smart Specialisation 2021-2027 (RIS). The thematic field of QT can also be funded via bilateral programmes. It is envisaged that a bilateral cooperation research programme with Cyprus may include QT as a thematic priority. The calls may be open to all scientific domains, with no restrictions on theme, as long as they are compatible with RIS3.

GSRI is a non-thematic, bottom-up funder. All areas in the QT domain within the ERANET action are considered as high-priority areas and between the different QT domains no priorities have been defined.

Quantum ecosystem

Quantum innovation and industry

Within the current operational programme, SMEs are encouraged to participate in proposals to be funded. The exact amount of funding for QT has not been specified.



HUNGARY

National Research, Development and Innovation Office, NKFIH

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

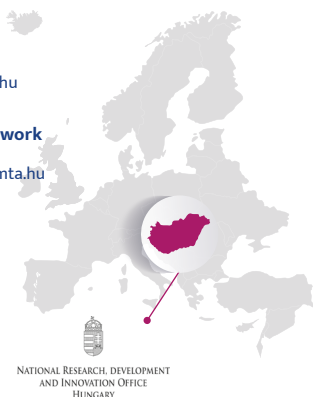
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NATIONAL RESEARCH, DEVELOPMENT
AND INNOVATION OFFICE
HUNGARY

National programme

Hungary has been among the first EU countries with a dedicated programme for QT. The first flagship programme – HunQuTech (2017-2021) – covered €11 M of funding.

In 2020, Hungary launched the National Laboratories programme. National Laboratories are conceived as knowledge centres and scientific hubs in areas with high potential for the national economy. National Laboratories are dynamic, institutionalised, collaboration-based arenas of discovery and experimental research that open up new, international dimensions and enable the social, economic and environmental utilisation of research results.

The main objectives of National Laboratories include:

- Concentrating domestic professional workshops in specific research fields
- Developing competencies necessary for addressing major global issues at the international level
- Utilising research results for social, economic and environmental purposes (knowledge transfer)

So far, 26 National Laboratories have been set up across the country in four major focus areas (Healthy Living; Safety and Security; Digital Transformation of Economy and Society; and Green Transition).

Quantum Information National Laboratory



LAUNCH
2020



DURATION
5 years



BUDGET
€15 M

Priority areas:

- Quantum communication network
- The building blocks of quantum computing
- Quantum computation and simulation of quantum systems

The **Quantum Information National Laboratory**⁴⁵ was launched within the first wave and aims to bring together national resources in physics, engineering, mathematics and computer science, and to focus their activities on specific theoretical and applied areas of QT.

Funding instruments

The National Research, Development and Innovation Office (NKFIH) is a national strategic and funding agency for scientific research, development and innovation. In accordance with its annual programme strategy, it funds both strategic programmes in targeted areas, such as QT, as well as bottom-up programmes.

Apart from the **Quantum Information National Laboratory** and the **HunQuTech programme** (already completed in 2021), funding in Hungary is provided through the following programmes:

Bottom-up programmes⁴⁶ run by NKFIH:

- Call for researcher-initiated thematic discovery research projects of Hungarian research centres in any field of science without thematic priorities
- “Frontline” – Research Excellence Programme providing targeted funding to world-class researchers with internationally prominent achievements

- Calls for research teams with significant achievements of internationally outstanding impact
- Calls for businesses and/or academy/industry collaboration, such as support of business RDI activities
- Researcher-initiated projects based on international cooperation, calls for cooperation with specific countries and calls based on bilateral R&D cooperation agreements
- Calls targeting young researchers - New National Excellence Programme offering research scholarships for students at various levels of studies; Postdoctoral and Young Researchers’ Excellence Programme

International programmes

QuantERA is the main vehicle for international collaboration in QT in Hungary.

Programmes run by the Hungarian Academy of Sciences

The Hungarian Academy of Sciences funds the “Lendület” Momentum programme since 2009 to support young scientists, scientists with exceptional, internationally-recognised achievements. As a result of these calls, several young scientist-led research groups working on QT are receiving support currently and have been supported through past calls.

Furthermore, higher education teaching and research training programmes on various levels also include elements of QT which are featured in doctoral schools, university courses as well as summer schools.

Quantum ecosystem

Quantum research community

The Quantum Information National Laboratory (and its predecessor, the HunQuTech programme) have had a structuring effect on the Hungarian QT community by bringing together a critical mass of outstanding Hungarian research groups and industrial partners. They also include several research groups that are winners of the prestigious Momentum programme of the Hungarian Academy of Sciences and ERC starting grants.

Quantum innovation and industry

In Hungary, research in QT, including fundamental science and applied research, involves a number of internationally recognised academic institutions, as well as industrial actors. The field is attracting ever-growing interest among young researchers as well.

Hungary has run national programmes for QT since 2017. The ongoing Quantum Information National Laboratory programme (2020-2025) provides €15 M funding for this field.

Bottom-up projects, including those led by young talents, complement this strategic initiative.

⁴⁵ <https://nkfih.gov.hu/quantum-information-national-laboratory/about>

⁴⁶ <https://nkfih.gov.hu/english-2017/calls-to-foster-rdi/system-of-domestic-rdi>



Highlights

✓ Defined priority areas

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National programme

At present, the QT research community in Ireland are drafting **Ireland's National Strategy for Quantum Technologies**. However, the National Strategy document has not been published until the publication of this report. Areas of focus under the national draft agenda include, but are not exclusive to:

- Establishment of quantum research as a priority
- Development of an on-chip quantum computer
- Commitment to infrastructure for Quantum Technologies
- Investment in educating quantum scientists and engineers

Funding instruments

Science Foundation Ireland (SFI) is the national Irish foundation for investment in scientific and engineering research. SFI invests in academic researchers and research teams who are most likely to generate new knowledge, leading edge technologies and competitive enterprises in the fields of science, technology, engineering and maths (STEM).

SFI funds QT research through many of its open calls and programmes that are open to all scientific domains. These include:

- Individual awards (Career Development Awards, Investigator Programmes)
- Target early career (Starting Investigator Research Grant)
- And more senior researchers (Research Professorships)

QT projects funded by SFI since 2020 mostly fall under the National Research Priority Areas of Future Networks, Communications and Internet of Things, Manufacturing and Novel Materials, and Digital Platforms Content and Application. QT projects have also been supported by SFI through infrastructure grants and Conference and Workshops funding. Although SFI has no specific QT programme, an estimated **fifty QT-themed projects have been funded by SFI over the last five years through an investment of approximately €50 M, i.e. approx. €10 M per year.**

Over the last five years, SFI has funded numerous QT-based projects that support the following areas:

- Quantum communications
- Quantum computing
- Quantum materials
- Quantum sensors

Other activities

Although not specific to QT, as the largest STEM funding agency in Ireland, SFI consistently develops initiatives to support gender balance, young researchers, open access, public engagement etc., that support all scientific domains. The policies and guidelines are published on the [SFI website](https://www.sfi.ie/funding/sfi-policies-and-guidance/)⁴⁷.

Quantum ecosystem

Quantum research community

Ireland has a well-established, strong and rapidly growing research community in QT both in academia and the private sector. There are over 35 Science Foundation Ireland-funded Principal Investigators directly involved in QT in Irish universities.

The main areas of expertise in QT:

- Trinity College Dublin – Photonic quantum technology research and science
- University College Dublin – Centre of circuit design for IoT applications

- Maynooth University – Theoretical research in both conventional and topological quantum computing
- University College Cork – Research into key advanced materials for the advancement of QT

Nationally, Ireland has a particular strength in quantum computing and Maynooth University currently leads the Quantum Community Network in Ireland.

Tyndall National Institute (TNI) is a leading deep-tech research centre in integrated ICT (Information and Communications Technology) hardware and systems. Specialising in both electronics and photonics – materials, devices, circuits and systems, TNI has established a national Quantum Computer Engineering Centre (QCEC).

The University College Dublin Centre for Quantum Engineering, Science, and Technology (UCD C-QuEST) is the national leading quantum research hub. C-QuEST brings together and further develops the considerable existing expertise on QT, while bridging between the worlds of academia and industry.

Specifically, Science Foundation Ireland supports research in QT through non-thematic individual-led research calls, Research Centres and Centre for Research Training programmes.

Quantum innovation and industry

The Irish government, with support from the EU, are investing in the EuroQCI (European Quantum Communications

Infrastructure) network, a secure quantum communication infrastructure spanning the whole EU, including its overseas territories. The main function of this new QCI network will be to enable an ultra-secure form of encryption so that large volumes of data can be transmitted safely, with the elimination of hacking vulnerability. IrelandQCI is supported by experts from six different universities, led by Waterford's Walton Institute in South East Technological University (SETU) and also includes specialists in QT from Trinity College Dublin and University College Cork's TNI, with support from University College Dublin (UCD) and Maynooth University (MU) and the Irish Centre for High-End Computing (University of Galway).

As well as the national public sector support, there is a growing number of QT R&D activities in the private sector based in Ireland, including multi-national corporations such as IBM, Intel and Google as well as several SMEs.

A draft of Ireland's National Strategy for Quantum Technologies has been authored by experts from across Ireland on behalf of the National Advisory Forum for Quantum Technologies.

The vision is to make Ireland an internationally competitive hub in Quantum Technologies by 2030.

⁴⁷ <https://www.sfi.ie/funding/sfi-policies-and-guidance/>

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

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National programme

The Israel National Quantum Initiative (INQI) is a joint venture of the leading R&D funding agencies in Israel. These include the Council for Higher Education, the **Israel Innovation Authority**⁴⁸ (under which **Israel – Europe Directorate for R&D (ISERD)**⁴⁹ is the agency in charge of R&D relations with the EC framework – the MFF), the Ministry of Science, the Ministry of Defence and the Ministry of Finance. These agencies all cooperate in INQI, which is headed by a small executive body in charge of the coordination.

Israel National Quantum Initiative (INQI)



LAUNCH
2020



DURATION
5 years



BUDGET
NIS 1.25 B
(~€350 M)

INQI is comprised of several lateral components, which have no preference to any sub-field of QT, and of 3 main focus areas:

- **Quantum sensing** – pushing mainly existing industries in this field, to mature the technology and assist in enhancing competitive edge on the market. An industry consortium was formed (and already concluded successfully) in a competitive process, and other projects were in various programmes, some top-down, and some bottom-up. The formed consortium had several targets in which it was asked to promote quantum sensing technologies for use in time, **frequency and time network management, Magnetometers and Gravimeters**. The consortium includes 9 academic groups from most of the Israeli universities as well as 5 participants from industry
- **Quantum computing and simulation** – aims to significantly enlarge the Israeli community in this sub-field. This includes several sub-components, including dedicated

48 <https://innovationisrael.org.il/en/contentpage/israel-innovation-authority>

49 <https://www.innovationisrael.org.il/ISERD/>

call-for-proposals for working on state-of-the-art quantum computing platforms in the cloud, investments in academia to generate large groups of training experts in the field, and investments in applied quantum computing infrastructure as a national project. The quantum computing **international consortium** involves players from Israel, Finland and Austria and its purpose is to develop **open technological building blocks for a quantum full stack computer in two different technologies: (a) “ion traps” and “superconductors” (b) demonstration of the technologies on 50-qubit computers.** In addition, the intention is to invest and encourage new start-up companies to form around this infrastructure to enhance the ecosystem

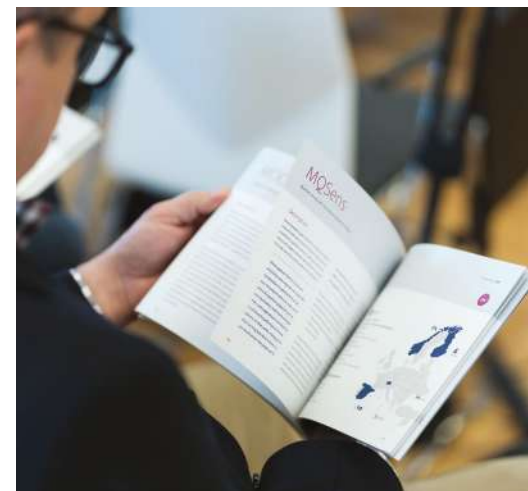
- **QKD** – started as a minor focus area, with the main project being a system-level testbed for QKD. Over the last few years, since the inception of the national quantum initiative and the success of the testbed project, the component has been enhanced through integration with an industrial consortium. Currently, a project for full network architecture and free-space capabilities is being established. This consortium’s main goals are to explore **open technological building blocks for quantum communication in 3 configurations: Point to point network, Free Space and Data Centres.** The consortium was comprised of 13 research groups from academia and 5 research groups from industry

The **lateral components** include:

- ♦ **A direct academic research fund** – the goal is to enlarge and support excellent academic research, preferably in a consortium of several researchers working together

- ♦ **Human capital** – this is a main tool for enlarging the Israeli QST community. This component is comprised of many different activities, including:
 - Funds to assist in the recruitment of new academic faculty in QST, including the formation of personal labs, scholarships for students and more
 - Funds oriented to improve and adjust education programmes, and to enhance the multidisciplinary nature of the field
 - Programmes for excellent PhD students
 - Programmes to support Israeli graduates going for post-doc fellowships abroad
 - Programmes to enhance the academic-industry interface (in both directions)
- ♦ **Substantial infrastructure** (mostly in academia) to support excellent QT research. This includes: large grants to form infrastructure facilities dedicated to QST fabrication, characterisation or other equipment, meant for common use; interface between academia and industry; and the relevant expert technical manpower required to operate the equipment and infrastructure
- ♦ **International collaboration** – incentives to be added to existing international collaboration platforms such as binational funds to push QT with foreign partners
- ♦ **Critical components for the QT industry** – funds dedicated to support the QT industry with regards to development of capabilities related to critical components (e.g., specialised laser sources)

Some components have already been budgeted and are operating. Some will be initiated in the following years.



The annual funding volume for QT-related projects cover an overall budget of 250M New Israeli Shekels.

Currently, INQI is in the process of evaluation (“a halfway evaluation”) to assess the progress and impact of the programme. There are no immediate plans to increase funding till 2025. However, it is worth noting that each organisation involved in INQI recognises the importance of the field and is committed to increasing its investment in QT beyond the planned funding, using other available funding resources. INQI will continue to explore opportunities to support research and development in QT and to leverage additional funding sources where possible to ensure the advancement of this critical area of research. One good example for such extra funding is European Partnerships like QuantERA and others (KDT) in which the government invests additional funding.

Funding instruments

The Israel Innovation Authority (IIA) is a statutory authority, set up by law to exercise Israeli Government policy in technological innovation. IIA provides a variety of practical tools and funding platforms aimed at effectively addressing the dynamic and changing needs of the local and international innovation ecosystems. It is responsible for and implements the various agreements between the Government of the State of Israel and European Government, and its personnel also operate the Israel – Europe Directorate for R&D (ISERD).

INQI funds research in QT through a structured approach that is centred around competitive programmes with a focus on excellence. The majority of research programmes fall under a competitive call for proposals, which includes both thematic and open calls. Most of the large calls are for collaboration activities (consortia). This approach allows the identification and prioritisation of research areas that have the most potential for impact and innovation, while also providing opportunities for researchers from a diverse range of backgrounds to contribute to common research efforts. Using this top-down and bottom-up approach aims to foster a vibrant research ecosystem that supports the advancement of QT and accelerates the pace of scientific discovery in this rapidly evolving field.

For each component of the INQI, one of the agencies is defined as the leading partner, and the activities of that component are operated through one of the budgeting and management platforms in that agency. For example, a direct academic research fund is operated through the Council for

Higher Education (through the Israel Science Foundation), while an industrial quantum sensing consortium is operated through the Israel Innovation Authority.

In order to create an infrastructure for researchers, INQI has with IIA initiated two international projects that involve research groups from Israel, Germany, the Netherlands and the United Kingdom. One project was established to create a Quantum hybrid system (SW and HW) as a multi-technology experimental laboratory infrastructure and the second aims towards Open infrastructure components integrated with silicon photonics for use in: (a) a Photonic quantum computer (photonic light source woven into a quantum computer); (b) a Powerful laser – Laser comb for multi-channel communication; and (c) an Optical Gyro.

In addition, there has been significant private sector investment in Israeli companies in the field of QT, amounting to over 250 million Euros. This investment figure does not include any internal R&D investments made by Israeli companies in the QT field.

Other activities

INQI promotes an open, excellence-based approach in all its activities. This includes a call for proposals that is executed through the Israel Science Foundation.

Quantum ecosystem

Quantum research community

Israel's QT academic research community is comprised of multiple research groups in 8 academic research centres.

Almost all the Israeli universities have formed QT centres, arranging and coordinating activities and developing infrastructure at the university level. These QT centres bring together researchers from varied fields, such as applied physics, engineering, computer science, and in some cases other disciplines.

Quantum innovation and industry

Israel's QT industry is seeing rapid development in the past 4 years, growing from about 3 companies to over 60 including many start-up companies. These include large companies as well as start-ups and quantum component companies.

The success of the Israel National Quantum Initiative (INQI) lies in its combined approach: government, academia, VCs, industries, community.

Since its approval, the QT eco-system has grown significantly:

- with 25-30% more academic groups
 - hundreds of new industry positions added
 - more than €250 M in VC investment
 - and multiple international collaborations.
-

ITALY



Italian Ministry for University and Research, MUR

National Research Council, CNR

National Institute for Nuclear Physics, INFN

National Quantum Science and Technology Institute, NQSTI

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

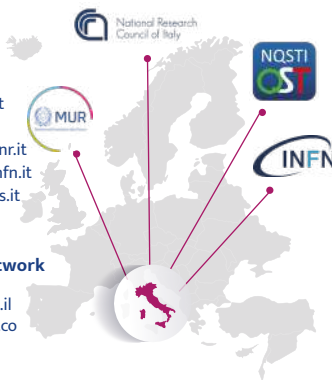
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National programme

The National Plan for Recovery and Resilience (PNRR) covering 6 Missions among which there is a specific one “M4 Education and Research – Component 2 *From research to business*” to finance fundamental and applied research projects to strengthen national research chains and promote their participation in strategic European and global value chains.

The Italian Recovery Plan goals:

- Advancing Italy as a key player in the field of QT for computers and simulators, both as a supplier of enabling technologies, as a developer of integrated platforms and algorithms, and as an industrial end-user
- Rendering Italy technologically independent with the creation of vertical production chains of quantum communication devices
- Creating in Italy, through the development of quantum sensing and quantum metrology, universal and highly reproducible measurement standards; for example, for time, frequency or electrical measure-

ments, with a strong impact on basic research, industry, the economy and society

- Promoting new interdisciplinary Higher Education courses (Master's Degree and PhD) in this advanced and rapidly evolving scientific sector to prepare highly-specialised personnel with transversal skills by involving industrial realities in training and academic research

National Plan for Recovery and Resilience (PNRR)



LAUNCH
2022



DURATION
3 years



BUDGET
€170 M for QT

€30 M for Quantum Computing alone
€30 M to create an open and accessible infrastructure for Photonics and Quantum Technologies
€115 M to kickstart the National Quantum Initiative

Within this mission QT have been included in the following projects:

- The National Centre for High Performance Computing (HPC) which aims to create the national digital infrastructure for research and innovation
- The National Institute of Quantum and Science Technology (NQSTI) – creation of a new consortium (detailed see below)
- The Integrated Infrastructure Initiative in Photonic and Quantum Sciences (I-Phoqs), a network of leading national research infrastructures (RIs), focused on Photonics and QST, providing a unique integrated, cross-domain and multi-faceted approach to complex scientific and technological questions

Priority areas:

- Quantum Computing and Simulation
- Quantum Communication
- Quantum Sensing and Metrology
- Quantum Technologies for Energy and Environment
- Quantum Infrastructures
- Education/Training in Quantum Technologies

For each of the priority areas, clearly defined goals were identified, their economic and social impact, and a detailed strategy for their implementation was prepared.

A comprehensive approach, taking into account structural, cross-sectoral factors and the emphasis on education make PNRR go far beyond a research funding programme, and is a building block for technological competitiveness and innovation.

Funding instruments

The Italian Ministry for University and Research (MUR) is the key RTD policy actor and funding agency in Italy at state level. MUR funds research in QT using different RFOs.

The National Research Council (CNR) is the largest public research organisation in Italy. Its duty is to carry out, promote and transfer research activities in the main sectors of knowledge for the scientific, technological, economic and social development of the Country. CNR is distributed all over Italy through a network of institutes aimed at promoting a wide diffusion of its competences throughout the national territory and at facilitating contacts and cooperation with local firms and organisations.

CNR is strongly committed to implementation of the PNRR. The QT field is going to receive around 30% of this funding. Further to PNRR activities, CNR has continued to participate in EU and National Projects in QT areas:

- European funded programmes: QuantERA; coordination support actions, such as the QFLAG, QTedu and QUCATS, QT Flagship initiatives such as QOMBS, MUQUABIS and PASQANS2 projects, EDF project ADEQUADE
- National funded projects: coordinated by Ministry of University and Research and Ministry of Enterprises and Made in Italy and the Italian Ministry of Defence
- Together with MUR (through Universities), CNR is funding specific Doctoral Schools related to QT

Before launching the PNRR, CNR funding volume was around €2 M per year over the past 5 years.

The National Institute for Nuclear Physics (INFN) is the Italian research agency dedicated to the study of the fundamental constituents of matter and the laws that govern them, under the supervision of the Ministry of Education, Universities and Research (MUR). It conducts theoretical and experimental research in the fields of subnuclear, nuclear and astroparticle physics. All of the INFN's research activities are undertaken within a framework of international competition, in close collaboration with Italian universities on the basis of solid academic partnerships. INFN joined QuantERA II in 2021.

The National Quantum Science and Technology Institute (NQSTI) is a new entity formed under PNRR but combines the experience of 20 leading research institutions in Italy. NQSTI is a consortium that teams up Italian entities carrying out competitive and innovative research in the field of QT, and stimulates future industrial innovation in this field, providing a forum in which novel ideas and opportunities are transferred to companies. In order to ensure a long-term positive effect on Italian economic growth and development, the whole innovation chain is considered: from the strengthening and coordination of the low-TTL research, to its translation into prototypes, favouring interfacing with industrial needs thanks to strong outreach and continued-education programmes. NQSTI joined QuantERA II in 2023.

Other funding instruments

The Ministry of University and Research and Ministry of Enterprises and Made in Italy: infrastructural funding for the development of Quantum Simulators based on Atoms and Photons (PASQUA project) and funding for Quantum communication (QUANCOM project), included the use of EU-matching funds for the National Deployment of EuroQCI QUID.

The Italian Ministry of Defence: industry-oriented calls taking into account quantum applications through the collaboration between research entities and Public Administrations (Projects QLAMP, QUSUB, Q4SEC, etc.)

Other activities

RRI is addressed by the CNR by the following activities:

- ◆ Encouraging gender balance in the funded research projects, adopting the Gender Equality Plan and aims, to the best of its capabilities, in the evaluation panel compositions
- ◆ Strongly encouraging Open Access
 - with the open access guidelines presented to all newly-funded research projects during a yearly kick-off meeting
 - with publication costs being accepted in the project's cost
 - and with each funded project preparing a Data Management Plan at various stages of the project
- ◆ Public engagement
 - active cooperation in Quantum Weeks events with specific initiatives devoted to the general

public, especially to young students, i.e., providing an interactive overview of the path toward current QT, from their early development to the most recent ones. In this context, the specific features of quantum mechanics and its applications will be addressed, moving then to information encoding, quantum computing and cryptography.

Quantum ecosystem

Quantum research community

The Italian Plan for Recovery and Resilience foresees the development of QT along three parallel lines, which are coherent with the Quantum Flagship vision:

- The creation, within the Horizon Europe programme, of a network of National Quantum Institutes to activate synergies and optimise the use of resources bringing research results in industrial products
- The inclusion of novel Quantum Computing capabilities within the High Performance Computing Infrastructure (HPC/QC)
- The realisation of a novel European Quantum Communication Infrastructure (EuroQCI)

Quantum innovation and industry

Private entities can count on the so-called “Patent box” (pursuant to Legislative decree nr. 146/2021) providing for an optional tax regime connected to the expenses incurred in carrying out research and development activities in relation to copyrighted software, industrial patents and legally protected designs and models.



The National Plan for Recovery and Resilience (PNRR) launched in 2022 has assigned around €170 M to QT with the ambition of advancing Italy as a key player in the field of QT for computers and simulators, both as a supplier of enabling technologies, as a developer of integrated platforms and algorithms, and as an industrial end-user.



Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

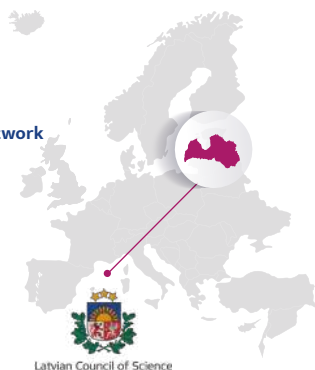
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Latvian Council of Science

National programme

In 2022, the Regulations of the Cabinet of Ministers were adopted⁵⁰ defining the rules on how to implement the European Union Recovery and Resilience Mechanism component “Digital Transformation”. The organ responsible for this action is the Central Finance and Contracting Agency. One of its objectives is reinforcement of the Quantum Technologies area. For the period until 2026, public investments in QT are planned. The investment aims are to increase the number of professionals with a high level of skills, able to use high technologies for development of knowledge-intensive new products and services, and to create a synergy between higher education, science and industry that promotes innovation with maximum commercialisation and export potential.

In addition, €1 M investments in the quantum field from other sources should be attracted.

⁵⁰ <https://likumi.lv/ta/id/334037-eiropas-savienibas-atveselosanas-un-noturibas-mehanisma-plana-2-komponentes-digitala-transformacija-2-3-reformu-un-investiciju>

Digital Transformation



LAUNCH
2022



DURATION
6 years



BUDGET
€6.19 M

+ forecast of approx.
€1 M investment from
other sources

Priority areas:

- Quantum algorithms and software
- Quantum sensors and devices
- Quantum communications and communication security

Within the Digital Transformation component the following activities are funded:

- Implementation of R&D
- Development and implementation of curriculum for learning and improvement in the learning process.

Expected impact:

- + 180 educated specialists and students with advanced digital skills in QT
- + 12 teachers and research staff for delivery of high-level study modules and research in the QT field
- + 45 publications in QT field

In order for Latvian scientists and specialists to cooperate so that the activities carried out are united with Europe and the world in 2022, a new initiative at the national level has been created. Scientists and faculty members from the University of Latvia (UL), Riga Technical University, the Institute of Solid State Physics at UL and the Institute of Mathematics and Informatics at UL have established the **Latvian Quantum Initiative**⁵¹. The association will help to oversee and coordinate quantum-related activities in Latvia, participate in European networks, follow the needs of Latvian industry and represent its interests in the development of QT.

⁵¹ <https://www.quantumatvia.lv/en/about/about-the-latvian-quantum-initiative/>

⁵² <https://www.lzp.gov.lv/en/fundamental-and-applied-research>



Funding instruments

The Latvian Council of Science (LZP) realises the state science and technology development policy by ensuring the implementation of research programmes and projects financed from the state budget, as well as European Union structural funds and other foreign financial instruments.

In the LZP, projects in the QT field are funded within the framework of ERA-net project QuantERA. For each of the QuantERA calls c. €600 K are allocated, but this sum is adjusted depending on the number of projects recommended for funding.

There are no other specific funding programmes in the LZP for QT. The LZP annually organises general calls within the

Basic and Applied Research Programme⁵². Researchers with a focus on QT can participate in these calls. The areas of QT research are chosen by the project initiators (bottom-up approach). In principle, they can undertake research of quantum phenomena and resources or do applied quantum research, and can target any area of QT, including areas defined in the QuantERA programme.

To date, supported QuantERA projects with Latvian partners belong to the following areas (some projects cover several areas):

- Quantum communication – 1
- Quantum simulation – 1
- Quantum computation – 4
- Quantum metrology sensing – 1

Other activities

The LZP respects Responsible Research & Innovation recommendations encouraging gender balance in the funded projects and open access. Project implementers are advised to use mass media to inform society on the research done and achieved results.

Young researchers participate in most of the QT projects. The LZP has a specific funding programme to promote young scientists. It promotes young scientists within the framework of Post-doctoral Research Aid⁵³. The themes may include QT topics. Sometimes research organisations invite young scientists to join quantum research teams, e.g., the Centre for Quantum Computer Science, University of Latvia in 2023 published international call for applications to postdoctoral positions⁵⁴.

Quantum ecosystem

Quantum research community

Most of the Quantum Technology research in Latvia is concentrated in two Latvia's largest universities – University of Latvia (UL) and Riga Technical University, and two independent institutes – the Institute of Solid State Physics, UL and the Institute of Mathematics and Computer Science, UL all located in Riga:

- Center for Quantum Computer Science, Faculty of Computing, UL – theoretical aspects of quantum information, computing, communication and cryptography

- Nanoelectronics Theory Group, Faculty of Physics, Mathematics and Optometry, UL – mathematical and computer models of quantum devices
- Laser Centre, Faculty of Physics, Mathematics and Optometry, UL – research in atomic and chemical physics, applications of lasers in QT
- Quantum Optics Laboratory, Institute of Atomic Physics and Spectroscopy, UL – development of optical frequency standards, ultrastable resonators, etc.
- Institute of Chemical Physics, UL – the development of nanostructured materials, nanocomponents, etc., eventually usable in future quantum computing devices
- Institute of Telecommunications, Riga Technical University – mathematical modelling, design of optical transmission systems, research into optical effects
- Institute of Solid State Physics, UL – research related to QT, photonics and electronic devices based on functional materials
- Institute of Mathematics and Computer Science, UL – implementation of quantum cryptography, development of software tools for the computing infrastructure

Quantum innovation and industry

A Latvian technology startup, Eventech Ltd, has developed best-in-class time-tagging technology targeting optical quantum communications in space. Several software companies undertake R&D in quantum algorithms in collaboration with academic partners.

⁵³ <https://www.lzp.gov.lv/lv/pecdoktoranturas-programma>

⁵⁴ <https://www.quantiki.org/position/postdoctoral-positions-centre-quantum-computer-science-university-latvia>



In Latvia, the largest public investment in QT is within the framework of the Digital Transformation action. It initiated the establishment of the Latvian Quantum Initiative, which linked leading scientists, teaching staff and organisations from the QT field.

The Latvian Quantum Initiative will monitor and coordinate activities related to QT in Latvia, participate in the European Quantum Technology cooperation networks, as well as follow the needs of Latvian industry and represent its interests in the development of QT.

LITHUANIA



Research Council of Lithuania, LMT

There are a few bottom-up, researcher-initiated research and international cooperation projects targeted to quantum research.

LMT joined QuantERA II in 2021.

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National programme

There is no specific programme at national level related to QT.

Funding instruments

The Research Council of Lithuania (LMT) fulfils the role of an expert institution tackling the challenges of scientific development at a national level. The Council is an advisor to the Lithuanian Parliament and the Government on research and researchers' training issues, implements programme-based competitive funding of research, administers the most important Lithuanian science development programmes, evaluates research performance and represents Lithuanian science in various European institutions and other international organisations.

LMT allocates funds to state-commissioned and researcher-initiated research, the projects of international cooperation projects, with some of them targeted to quantum research.

LMT joined QuantERA II in 2021. One QuantERA project has been conducted by a Project Coordinator from Lithuania.

There is no specific information available on the funding into QT within LMT. There are no specific priority areas related to QT. It is not known if funding for QT will be increased in the coming years.



LUXEMBOURG



Luxembourg National Research Fund, FNR

Highlights

- ✓ **Defined priority areas**
- ✓ **Other national initiatives**

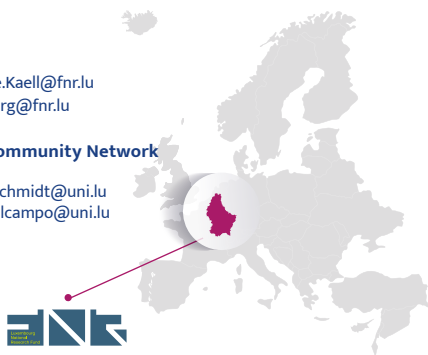
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National programme

Luxembourg does not currently have an official national strategy in QT. Together within the consortium, the Department of Media, Connectivity and Digital Policy (SMC⁵⁵) of the Ministry of State has elaborated a roadmap for the LuxQCI project, which translates the EuroQCI project at the national level (for more details see below). In Luxembourg, the priority area is currently focused on quantum communications, which does not exclude other areas of QT being explored in the future.

Funding instruments

The **Luxembourg National Research Fund (FNR)** is the main funder of research activities in Luxembourg. The FNR supports quantum research via its multiple national calls for proposals as well as through its international collaborations. The FNR has entered a number of cooperation

agreements with foreign funding agencies to provide funding opportunities for bi- or multilateral projects. Furthermore, FNR has joined several international consortia which provide funding opportunities for multilateral projects, QuantERA II included.

The FNR has developed various thematic and structural funding instruments to support research projects in priority areas for Luxembourg and to strengthen the exchange between science and society. Within the framework of these programmes, calls for project proposals are issued regularly. Retained projects will be partly or completely funded by the FNR.

The FNR has set up a vast funding portfolio⁵⁶ that covers funding for PhD candidates, early-career researcher projects, researcher projects, collaborative projects (national and international), talented and established leading researchers in strategically relevant areas for Luxembourg, public/private collaborative projects.

⁵⁵ <https://smc.gouvernement.lu/fr.html>

⁵⁶ <https://www.fnrlu/funding/>

Quantum research is embedded in the **Luxembourg National Research Priorities**⁵⁷ and within the total FNR funding budget. The FNR has no dedicated budget allocated to projects in QT. FNR joined QuantERA II in 2021. So far, no specific quantum-related calls have been done, except for calls within QuantERA II.

During the last 5 years, the FNR funding volume for QT-related projects covered an overall budget of nearly €12 M. As there is increased research done in this topic, it is expected that further projects are being funded over the next years.

Other funding instruments

Next to the FNR funding the Luxembourg public research institutions adopt their own strategies and funding to engage in QT (e.g. LuxIMPULSE for space-related works, **LIST**⁵⁸).

Furthermore **Luxinnovation**⁵⁹, the Luxembourg innovation agency, has supported several private companies and public organisations in submitting their proposals to the QT topic of Horizon Europe.

The research for QT, and in particular for LuxQCI is supported at a national level by the SMC and also by the Luxembourg Space Agency (**LSA**)⁶⁰.

Other activities

Responsible Research & Innovation is addressed by FNR in following ways:

- It promotes concrete suggestions⁶¹ to improve the responsible evaluation of funding applications
- Improving gender balance in research projects and assessment requirements (applicants, leadership, mentoring, conference speakers, reviewers, and panel members)
- FNR is the coordinator of the National Gender Working Group with the aim of establishing a concrete action plan to minimise the gender imbalance in research in Luxembourg
- Open access publication requirement for funded projects

Quantum ecosystem

Quantum research community

Luxembourg plays host to research in QT, in particular quantum computing, quantum simulation and quantum communication, both at the level of academic and applied research, as well as in the industrial sector.

At the University of Luxembourg, several groups at the **Department of Physics and Materials Science (DPhyMS)**⁶² pursue a QST effort - including the **ChenuLab**⁶³, **Complex Systems and Statistical Mechanics**⁶⁴, **Theoretical Chemical**

Physics⁶⁵, **Theory of Mesoscopic Quantum Systems**⁶⁶ and **Quantum Information Theory**⁶⁷ at the interface of quantum computing, quantum simulation and quantum control. Specific topics include quantum optimisation, quantum algorithms, machine learning, quantum matter, open quantum systems, energy-efficient quantum devices, quantum metrology, and topological quantum computing. Experimental activities focus on light-matter interactions and photovoltaics.

Moreover, the Interdisciplinary Centre for Security, Reliability and Trust (SnT) has a substantial research focus on quantum communication, particularly with expertise on the design and analysis of secure systems (**APSIA Group**⁶⁸) and the formulation, modelling, design and analysis of 6G communication networks (**SIGCOM Group**⁶⁹).

At the more applied level, activities in quantum computing have been initiated at the Luxembourg Institute for Science and Technology (LIST).

Quantum innovation and industry

Luxembourg has started research activities in the domain of quantum communications by establishing an experimental testbed at the University of Luxembourg. In a first step the focus will be on the terrestrial segment of such infrastructure and explore different ways and technologies in quantum

57 National Research Priorities

58 <https://www.list.lu/>

59 <https://www.luxinnovation.lu/about-luxinnovation/>

60 <https://space-agency.public.lu/en.html>

61 <https://www.fnr.lu/new-video-resource-for-funders/>

62 https://www.wen.uni.lu/research/fstm/dphym/research_areas/quantum_science_technology

63 <https://chenulab.com/>

64 <https://sites.google.com/site/massimilianoepositogennaro/home>

65 <https://www.tcpunilu.com/>

66 https://www.wen.uni.lu/research/fstm/dphym/research/theory_of_mesoscopic_quantum_systems

67 <https://sites.google.com/site/adolfodelcampo/>

68 <https://www.wen.uni.lu/snt/research/apsia>

69 <https://www.wfr.uni.lu/snt/research/sigcom>

communications, knowing that the first application will be Quantum Key Distribution (QKD).

Luxembourg intends to also explore different ways of setting up a QT using different technologies.

Luxembourg is also very active in the space segment of the Quantum Communications Infrastructure, with Luxembourg industry leading the development of the first European quantum satellite. Luxembourg industry is also deeply involved in the development of the Optical Ground Stations necessary for communication with the satellite.

In Luxembourg there is a vital and dynamic industry and innovation ecosystem created by different institutions with outstanding expertise focusing on future solutions for a digital society: [SES TechCom](https://ses-techcom.com/)⁷⁰, [LuxTrust](https://www.luxtrust.com/en)⁷¹, [LuxConnect](https://www.luxconnect.lu/)⁷², [itrust](https://www.itrust.lu/)⁷³, [InCert](https://www.incert.lu/)⁷⁴, [Restena](https://www.restena.lu/en/home-page)⁷⁵, [RHEA System Luxembourg](https://www.rheagroup.com/)⁷⁶, [Hitec Luxembourg](https://www.hitec.lu/)⁷⁷, [POST Luxembourg](https://www.post.lu/)⁷⁸.

From the Government side, the SMC is leading the LuxQCI project with the support of different partners. The duration is partly linked to the RRF which will come to an end in December 2026; nevertheless, this does not mean that the



activities will be stopped. The estimated budget for the project is €37.2 M funded from different sources (the Recovery and Resilience Facility (RRF), Digital Europe Programme (DEP), Connecting Europe Facility (CEF) programme, the Government and industry). The main goal is to develop and deploy a quantum communication infrastructure in Luxembourg through experimentation with the technology and consisting of a terrestrial segment and a space segment. First users should be the ministries and administrations in Luxembourg, as well as institutional entities. Critical infrastructure like energy, water supply, healthcare and data centres are also included and commercial entities could follow at a later stage, for example, financial institutions.

Quantum communication is an important area in Luxembourg with a very active space segment.

FNR joined QuantERA II in 2021 to support Luxembourg researchers in international research consortia.

⁷⁰ <https://ses-techcom.com/>

⁷¹ <https://www.luxtrust.com/en>

⁷² <https://www.luxconnect.lu/>

⁷³ <https://www.itrust.lu/>

⁷⁴ <https://www.incert.lu/>

⁷⁵ <https://www.restena.lu/en/home-page>

⁷⁶ <https://www.rheagroup.com/>

⁷⁷ <https://www.hitec.lu/>

⁷⁸ <https://www.post.lu/>

QT is still a nascent area of research and innovation in Malta.

Malta joined QuantERA II in 2021, which provided an opportunity to support the local quantum community, their specialisation and gave space for the development of the quantum ecosystem.

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National programme

There is no national QT strategic programme in place for Malta, with activities falling under one of the identified priority areas (e.g., future digital technologies).

Funding instruments

The Ministry for Education, Sport, Youth, Research and Innovation (MEYR) of the Government of Malta, through the relevant entities, is responsible for the promotion of research and innovation in Malta. MEYR provides the necessary guidance and oversight for matters related to policy, strategy and programme implementation associated with these areas and its scope includes Horizon Europe and QuantERA. MEYR took over responsibility for QuantERA in 2022 from the Ministry for Equality, Research and Innovation (MFER).

MEYR funds QT primarily through its involvement in QuantERA. Funding is allocated for one multi-year project for each funding round. No thematic calls are issued, relying instead on a bottom-up approach for selecting projects.

MEYR in principle supports all the five pillars of QT defined in QuantERA calls for proposals. Quantum communication, particularly QKD, will likely see prioritisation in the near future through the participation of Malta in the EuroQCI initiative of the European Commission.

Other activities

MEYR encourages gender balance in the funded research projects. Open access is strongly encouraged across the board.

Quantum ecosystem

Malta has a small QT research community. In the public sector, this is mainly concentrated in the QuantumMalta research group at the University of Malta. The private sector consists of one start-up that operates in the field of quantum communication.

Involvement in multinational projects such as QuantERA and EuroQCI provides an opportunity to find specific niches in the ecosystem to which the Maltese community can make a significant contribution.

NETHERLANDS

Quantum Delta NL, QDNL

Dutch Research Council, NWO

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

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National programme

The national strategy in the Netherlands is developed and implemented through the **National Quantum Foundation Quantum Delta NL (QDNL)** established in 2021 with a grant from the Dutch National Growth Funds (NGF) of €615 M for the period 2021-2028.

Quantum Delta NL is the public-private partnership of global tech companies, government agencies and major quantum research centres in the Netherlands. The mission of Quantum Delta NL is to position the Netherlands as a leading ecosystem in QT.

Quantum Delta NL programme (QDNL)



Progress in the strategic goals is summarised within the framework of the National Growth Funds programme annual reports of the developments.

Priority Areas

The national strategy developed and implemented by QDNL comprises different national funding schemes in the three catalyst areas (CAT 1-3):

- **Quantum Computing and Simulation**⁷⁹
- **National Quantum Network**⁸⁰
- **Quantum Sensing Applications**⁸¹

Accompanying these, the four Action Lines (AL 1-4) comprise initiatives in the following areas:

- **Innovation and research**
- **Quantum Ecosystem**
- **Human Capital**
- **Societal impact**

79 <https://quantumdelta.nl/catalyst-programs/quantum-computing-simulation/>
80 <https://quantumdelta.nl/catalyst-programs/quantum-network>
81 <https://quantumdelta.nl/catalyst-programs/quantum-sensing-applications>

Funding instruments

Quantum Delta NL (QDNL) comprises different national funding schemes in the areas described in the previous section. In 2023, QDNL joined QuanterA with a commitment of €1.75 M out of its national budget for research and innovation to facilitate and synergise the programme's excellent quantum research capacities.

QDNL Initiatives

- **SME programme**
- **Field lab programme**
- **Visitor's programme**
- **Infinity⁸²**
- **Top talent initiative⁸³**
- **Women in Quantum and Society**
- **Childcare pilot programme**
- **House of Quantum⁸⁴**
- **QuanterA**

The Dutch Research Council (NWO) is the largest science funding body in the Netherlands and ensures quality and innovation in science.

As part of the QDNL programme, NWO organises an annual or bi-annual national call on QT, in which one scientific

position can be applied for. A total budget of €42 M is available for the period 2021-2027.

NWO funding

Besides the QDNL programme, NWO funds QT projects through its regular funding instruments adding another €10 – 30 M per year on average. Examples of recently funded large projects include:

- 2020: **QuTech⁸⁵**. Budget: €12.5 M (NWO KIC Long Term Programme)
- 2020: **Quantum Inspire⁸⁶** – the Dutch Quantum Computer in the Cloud. Budget: €5 M (NWO Dutch Research Agenda, open competition)
- 2022: **QuMAT Materials for the Quantum Age**. Budget: €27 M (NWO Gravity programme, open competition)
- 2022: **Societal impact of Quantum Technologies programme**. Budget: €2 M (NWO Dutch Research Agenda, thematic call)
- 2022: **Quantum-engineered precision measurements**. Budget: €2 M (NWO ENW XL, open competition)

Total funding

The estimated funding for QT per year is:

- **QDNL: €50-100 M (increase expected in the following years)**
- **NWO: €10-30 M**

All initiatives that are being undertaken on a national level reflect the Netherlands' high level ambitions to develop and lead the developments in QT. This also involves activi-

ties in internationalisation and participation in European activities to strengthen co-creation and development.

Other activities

NWO and QDNL are committed to the Responsible Research & Innovation goals. NWO adheres to the **Netherlands Code of Conduct for Research Integrity⁸⁷** and aims for 100 percent Open Access publishing. Therefore, it is required that all publications emerging from NWO-funded research are made Open Access immediately upon publication⁸⁸. NWO is committed to being a fully inclusive organisation, for its own employees as well as for the researchers that work on NWO funded projects⁸⁹. NWO promotes gender equality on all fronts and has documented its actions to accomplish this in the Gender Equality Plan⁹⁰. QDNL has published a manifesto describing its inclusive organisational culture⁹¹.

All action line programmes of QDNL contribute to the development of an inspiring environment where the entire community of students, researchers, entrepreneurs and investors co-create without barriers and restrictions and provide excellent conditions to innovate, e.g., by providing infrastructure and knowledge for research, incubation and commercialisation of ideas for all stakeholders.

82 <https://www.infinityqd.nl/>

83 <https://quantumdelta.nl/top-talent-program>

84 <https://www.houseofquantum.com/>

85 <https://qutech.nl/>

86 <https://www.quantum-inspire.com/>

87 <https://www.nwo.nl/en/netherlands-code-conduct-research-integrity>

88 <https://www.nwo.nl/en/open-access-publishing>

89 <https://www.nwo.nl/en/diversity-and-inclusion>

90 <https://www.nwo.nl/en/gender-equality-plan-gep>

91 <https://quantumdelta.nl/our-community-s-culture>

The importance of QT to the Netherlands' research landscape is also shown by the fact that one of the 25 research lines of the Dutch Research Agenda (NWA) is “**The quantum and nano revolution**” (only available in Dutch). The NWA aims to bring science closer to society. NWO carries out the NWA research programme on behalf of the Ministry of Education, Culture and Science.

Quantum ecosystem

Quantum research community

The Quantum ecosystem in the Netherlands consists of all the people working on quantum solutions for a sustainable future. From scientists and engineers to investors, entrepreneurs and policy-makers – and all other disciplines needed to make it happen.

Quantum innovation and industry

Quantum Delta NL represents the five major hubs in the Netherlands. QDNL stands for the locations across the country and its respective specialist innovation hubs. Different research areas contribute to the goal of strengthening the national quantum ecosystem with universities, research institutes, companies and start- and scale-ups.

- **Delft:** quantum computing, internet & network, with QuTech, Kavli Institute, Microsoft, Intel and others
- **Eindhoven:** post-quantum crypto, quantum simulation & materials, with ThermoFisher, NanoLabNL and others
- **Leiden:** applied quantum algorithms, with aQa, Google, Shell, Volkswagen, Total and others



- **Twente:** quantum electronics and quantum photonics, with MESA+, Lockheed Martin, QuiX Quantum, Imec and others
- **Amsterdam:** applied quantum algorithms, quantum sensing & simulation, with QuSoft, CWI, UvA, VU, SURFsara and others

In addition, QT is studied, explored and utilised by Utrecht University, Maastricht University, Radboud University and the University of Groningen.

The National Quantum Agenda is realised mainly by Quantum Delta NL (QDNL), established in 2021 with national funding of €615 M for the period 2021-2028.

QDNL's goal is to position the Netherlands as a leading ecosystem in QT.

QDNL joined QuanterA in 2023.

NWO funds QT projects through its regular funding instruments.

NORWAY

Research Council of Norway, RCN



Highlights

✓ Other national initiatives

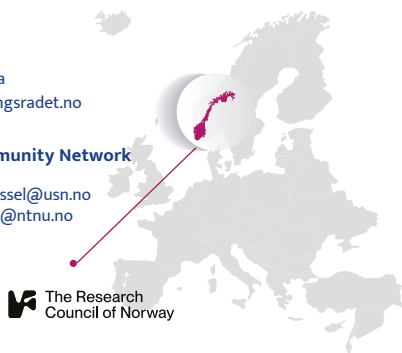
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National programme

At present, there are no specific future or ongoing plans for QT. However, the Norwegian government's **Long-term Plan for Research and Higher Education 2023-2032** highlights QT as a particularly prioritised area for research and research-driven innovation. As a result, it is expected that future funding plans and developments will reflect this priority.

Funding instruments

The Research Council of Norway (RCN) is one of the largest science-funding bodies in the Norway and ensures quality and innovation in science.

The Research Council of Norway (RCN) does not have any national calls specifically targeted at QT. However, researchers in this field can compete for funds from open calls alongside researchers from other areas.

There has been no top-down strategic prioritisation from the RCN, but funding for QT research has been granted

mostly within the areas of theory, simulation and computation/information sciences. Two large focused research centres have been granted 10-year funding:

- Centre for Quantum-Spintronics at the Norwegian University of Science and Technology
- Hylleraas Centre for Quantum Molecular Sciences at the University of Oslo

The estimated funding into QT per year is:

- RCN grants: €5-10 M
- Research centres in quantum-spintronics and quantum chemistry: €2-5 M

Since January 2021, 14 new QT projects have been granted funding with a total budget of €12.5 M.

The RCN supports QT research at the national level. Other funding opportunities exist at the national level for when QT research reaches higher technology readiness levels (i.e. Innovation Norway).



Other activities

All RRI initiatives are available for researchers in Norway, but no efforts are aimed specifically at QT research.

Quantum ecosystem

Quantum research community

Norway's quantum community is small but growing, with major research labs located in universities in Oslo, Trondheim, Bergen and Kongsberg. The community has established the Gemini Center on Quantum Computing, which includes the largest

universities (Norwegian University of Science and Technology and University of Oslo) and relevant research institutes (SINTEF and Simula).

The extent, focus and status of the Norwegian QT research community was mapped by the RCN in 2022.

Quantum innovation and industry

The Norwegian quantum community is pooling expertise in quantum computing to make Norway quantum-ready, with a particular focus on developing algorithms and software applications. Additionally, researchers are actively building collaborative networks across the Nordic region.

In Norway, research in QT is supported alongside other fields.

The “Long-term Plan for Research and Higher Education 2023-2032” highlights QT as a particularly prioritised area.

Since 2021, 14 new QT projects have been granted funding with a total budget of €12.5 M.

POLAND



National Science Centre, NCN

National Centre for Research and Development, NCBR

Highlights

✓ Other national initiatives

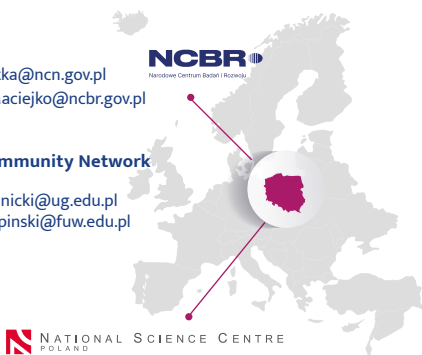
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 NATIONAL SCIENCE CENTRE
POLAND

National programme

There is no national or regional research agenda for QT, defining priority areas. Quantum technology research is funded through regular bottom-up calls for research projects.

Funding instruments

The National Science Centre (NCN) is a Polish government executive agency set up in 2011 to fund basic research. Since 2016 NCN has been coordinating QuantERA with the current aim of extending the programme through mechanisms available in Horizon Europe.

The NCN call portfolio⁹² currently includes eight domestic calls targeted at various groups of researchers, international calls launched by NCN in bi- and multilateral cooperation with foreign research-funding agencies, as well as a number of multilateral programmes launched by international consortia of which the NCN forms part – such as ERA-NETs. A bottom-up

⁹² <https://www.ncn.gov.pl/en/finansowanie-nauki/konkursy/typy>

approach is introduced in all calls for proposals, without any specific priority areas related to QT. Apart from QuantERA, there are no specific instruments for supporting QT topics. QT funding comes from the success of the researchers in various calls, based on the outstanding quality of the projects.

In the years 2020-2022, the NCN has financed 269 projects related to QT under domestic calls and multilateral cooperation with foreign research-funding agencies, with a value of approx. €51 M. Under the QuantERA programme, 22 projects were funded with a value of approx. €3.9 M.

The National Centre for Research and Development (NCBR) is a centre for supporting and developing innovative technological and social solutions, creating an ecosystem of knowledge and information about innovation. The most important task of the Centre is to support scientists and entrepreneurs in the creation of modern solutions and technologies that increase innovation, and thus the competitiveness of the Polish economy. The activities of the Centre, by launching dedicated programmes, are aimed at creating platforms for cooperation between science and business.

Apart from QuantERA, there are no specific instruments to support QT topics in NCBR. QT funding comes from the success of the researchers in various calls, based on the outstanding quality of the projects. NCBR has participated in all of the QuantERA calls (2017, 2019, 2021 and 2023). **An estimate about organisation funding into QT per year is <€1 M.**

The areas of QT research funded by NCBR over the last 5 years have been:

- Quantum communication
- Quantum computation
- Quantum information sciences
- Quantum metrology sensing and imaging – cryptology

Other funding instruments

In addition to the two government agencies, research is supported by the **Foundation for Polish Science**⁹³, which is a non-governmental organisation. The Foundation's portfolio consists of programmes dedicated to outstanding scientists and research teams in all fields of inquiry. It also assists innovative ventures and the commercialisation of scientific discoveries and inventions. There are no specific programmes related to QT.

93 <https://www.fnfp.org.pl/en/>

94 <https://ictqt.ug.edu.pl/>

95 <http://qot.cent.uw.edu.pl/>

96 <https://nisq.pl/>

97 <https://kcik.ug.edu.pl/>

QT research proposals can be submitted to most of the standard funding schemes open to all disciplines of science. Moreover, the Foundation for Polish Science funded three large-scale grants, which scale is comparable to a focused research centre:

- **International Centre for Theory of Quantum Technologies**⁹⁴, University of Gdańsk
- **Quantum Optical Technologies**⁹⁵, University of Warsaw
- **Near-term Quantum Computers**⁹⁶, coordinated by Center for Theoretical Physics Polish Academy of Sciences

Other activities

RRI is addressed by the NCN and NCBR by adopting a Gender Equality Plan.

Moreover, NCN adopted an Open Access Policy with regard to publications resulting from the research funded by the NCN in all funding schemes. Open Access publication costs are accepted in the project's costs. A Data Management Plan is required for all funded projects at various stages.

Early-career scientists are strongly supported by the NCN. More than half of the amount allocated by NCN annually, supports the development of early-career scientists.

Quantum ecosystem

Quantum research community

The **National Quantum Information Centre**⁹⁷ is a common forum for the broad research community focused on QT

topics. The aim of the Centre is to connect researchers mainly working within a theoretical framework and the foundations of quantum information technologies.

Quantum innovation and industry

A substantially broader community, which includes both Polish academia and industry on an equal footing, is represented by the recently created **Cluster Q** – Quantum Technologies Cluster¹⁰⁰. The aim of this network is to integrate the entire quantum community in Poland.

The goals of the Cluster are achieved through the activities undertaken:

- Developing resources and competencies in the area of QT to enable the delivery of solutions using QT to the market
- Increasing the knowledge and skills of Cluster Members
- Coordination and integration of activities of enterprises, universities, research organisations, associations and regional and local authorities in the area of capacity building of the Polish QT industry
- Supporting R&D projects and organising consortia
- Conducting educational and promotional activities
- Creating conditions for effective commercialisation of the results of QT R&D projects

In 2022 a new quantum community network was established – Cluster Q, integrating Polish industry with the research communities to develop national potential in QT.

PORTUGAL



The Foundation for Science and Technology, FCT

The Thematic Agenda for Research and Innovation in the area of “Cyber-physical Systems and Advanced Forms of Computation and Communication”, including QT is under development. Portugal has a small but active community in QT, which is well connected to European networks through participation in the programmes Quantum Flagship and QuantERA.

Contact

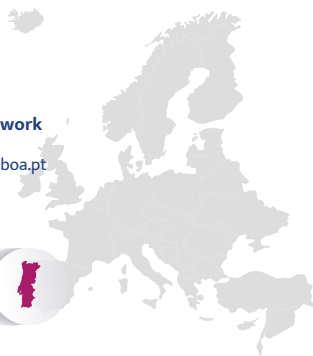
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National programme

There is no national programme for QT in Portugal. A Thematic Agenda for Research and Innovation in the area of “Cyber-physical Systems and Advanced Forms of Computation and Communication” including the QT area has been prepared using a bottom-up approach, with the involvement of experts from academia, research centres, companies, public organisations and civil society, within a framework of dialogue between different national actors. No priority areas have been defined since the Covid-19 pandemic interrupted the initiative; however, work is expected to be resumed when possible.

The agenda being developed considers four dimensions of reflection to address challenges and lines of research and innovation relevant to the country in a mid- and long-term perspective (2030):

- Infrastructure of cyber-physical systems and advanced computing systems
- Issues that cut across cyber-physical systems
- Methodologies, tools and design of cyber-physical

systems and advanced computing systems

- Emerging technologies and applications

Funding instruments

The Foundation for Science and Technology (FCT) is the national public agency for the support of research in science, technology and innovation in all areas of knowledge. It is a public institute with special governance under the tutelage and superintendence of the Ministry of Science, Technology and Higher Education. Not restricted to QT, FCT supports the scientific community in Portugal through different funding programmes, aimed at scientists, research teams and R&D centres. These programmes allow FCT to support advanced training, research, creation and access to research infrastructures, promotion of international networks and collaborations, communication of science and interaction with companies.

Funding in QT is available through:

- ✦ FCT structuring national annual open calls for R&D Projects in all scientific domains
- ✦ FCT **goPORTUGAL Initiative** promoting new thematic knowledge international networks:
 - **UT Austin Portugal Program** addressing several areas of knowledge through multidisciplinary research and enhancing technology transfer and commercialisation in a collaborative way between Portugal and the University of Texas and other institutions. The UT Austin Portugal Program provides initiatives in education, research and innovation.

Key areas:

- Advanced Computing
 - Nanotechnology
 - Space-Earth Interactions
 - Medical Physics
 - Technology Innovation and Entrepreneurship | UTEN
- **Carnegie Mellon Portugal Program (CMU Portugal)** promoting industry-academia relations as a driver of change with economic and social impact in the area of Information and Communication Technologies (ICT). CMU Portugal provides initiatives in advanced training research and innovation and industrial collaboration.

Key area is Information and Communication Technology with particular emphasis on:

- Data Science and Engineering
 - Artificial Intelligence
 - Machine Learning
 - Language Technologies
 - Data Analytics
 - Cloud Computing
 - Engineering and Public Policy
- **European Research Area (ERA)** participation through joint transnational calls launched by the QuantERA programme.

The estimated funding into QT per year is <€1 M.

Other activities

Scientific Employment Stimulus is an incentive programme for the hiring of researchers and the development of scientific employment plans and scientific careers by public or private institutions.

Beneficiaries are obliged to allow and ensure disclosure of the scope and expected outputs of their R&D projects, as well as of the publishable executive summaries related to the final execution reports, without prejudice to the requirements related to intellectual property protection, and all scientific publications generated within the scope of the project in a free access platform pursuant to the FCT, I.P. open-access policy.

In open calls, during the application phase, beneficiaries must undertake the fulfilment of applicable regulations including equal opportunity and gender equality.

Quantum ecosystem

Quantum research community

Portugal has a small but active research community in QT. It includes researchers working in the field over the last two decades, as well as recent newcomers contributing to the multidisciplinary character of the research activities. Most of the research has focused on quantum computation and quantum communications, the latter also at the experimental level. Activities in quantum sensing and metrology are incipient but progressing.

The community is essentially composed of academics, mainly from physics, mathematics, computer science and telecom engineering, working at university or research institutes. Overall, the community is well connected to European networks, namely participating in Quantum Flagship and QuantERA programmes.

Quantum innovation and industry

The involvement of industry in QT is still very modest but is evolving.

Recently, PQI – Portuguese Quantum Institute, the first organisation in Portugal dedicated to this domain, has been created with the goal of bringing the community together.

ROMANIA



Romanian Executive Agency for Higher Education,
Research, Development and Innovation Funding (UEFISCDI)

Highlights

✓ Other national initiatives

National programme

There is no national quantum strategic programme in place for Romania. However, quantum-related objectives are designed and implemented in the research fields: **Digital economy and space technologies & Advanced functional materials which are included in the National 4th Plan of the new Strategy for research, innovation and smart specialisation (2022-2027).**

Quantum research is also supported through participation in the QuantERA network and through the annual calls (open to all topics).

Another QT related project is **The Romanian National Quantum Communication Infrastructure – RoNaQCI**, which aims to develop a quantum communication infrastructure in Romania of over 1,500 kilometres and to create six metropolitan networks. The consortium benefits from the multidisciplinary expertise of 30 partners: 12 universities, 7 research institutes, 3 national agencies, 3 companies and 5 relevant stakeholders. It includes both the Romanian participants at QuantERA and 10-14 partners from all the Romanian quantum communication projects (QUTECH-RO, QSTRAT, QUANTEC).

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uefiscdi
Executive Agency for Higher
Education, Research, Development
and Innovation Funding



The national strategy for quantum communications in Romania is currently developed by a team coordinated by Babeş-Bolyai University in Cluj-Napoca through the project **Elaboration of the strategy for the development of national capabilities in the field of quantum communications (QTSTRAT)** funded by the Ministry of Research, Innovation and Digitalisation, with the National Institute for Materials Physics as the main partner. The project is funded between 2021-2023.

Funding instruments

The Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI) acts for the promotion of Romanian R&D and its integration in the international scientific community.

UEFISCDI funds QT mainly through national calls – open to all scientific domains, with no restriction on theme (bottom-up).

In 2021, a top-down call was launched with a specific quantum topic: call Solutions – 2021 – **Realisation of the National Centre in the field of quantum communications Quantec** with a dedicated budget of €1.5 M. The funded project will be completed in 2023. The 2021 call has been the only one dedicated to a quantum field, so far. Calls are open to all types of institutions with R&D activity within their domains.

In 2022, the 4th National RDI Plan was approved and UEFISCDI administrates (partially or totally) 7 programmes with instruments dedicated to:

- The development of human resources
- Increasing access to existing infrastructures and supporting the participation of Romania to dedicated research infrastructures networks/projects
- Intensifying partnerships for industrial research and experimental development activities
- Supporting European and international collaboration projects (like QuantERA among others)/partnerships/missions, but also through bilateral/multilateral collaboration schemes
- Developing the dialogue between science and society, by opening up the research and innovation system to citizens, civil society and end-users, as well as by involving pupils and young people.

Besides UEFISCDI, other funding bodies supporting research projects related to QT areas are the Ministry of Research, Innovation and Digitalisation, and also the Institute of Atomic Physics.

The estimated funding into QT per year is <€1.5 M. It is hard to predict if funding for QT will be increased in the coming years. Given the new National Plan and growing interest in this area, visions for the future are optimistic.

Other activities

RRI is addressed by the UEFISCDI by the following activities:

- UEFISCDI encourages gender balance in the funded research projects, and aims at gender balance, to the best of its capabilities, in the evaluation panel compositions
- Publication costs are accepted in the project's costs

Quantum ecosystem

Most of the QT research in Romania is concentrated in national institutes and universities: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH); National Institute for Laser, Plasma and Radiation Physics (INFLPR); National Institute for R&D in Microtechnologies (IMT); University Politechnica of Bucharest (UPB); National Institute for R&D of Isotopic and Molecular Technologies (INCDTIM-Cluj).



In recent years, Romania has taken important steps in supporting QT research:

- **the call realisation of the National Centre in the field of quantum communications – Quantec – was launched in 2021 with a budget of €1.5 M**
- **the projects QTSTRAT and RoNaQCI directed to developing q-communication area are ongoing.**

SLOVAKIA

Slovak Academy of Sciences, SAS



Highlights

- ✓ **Defined priority areas**
- ✓ **Other national initiatives**

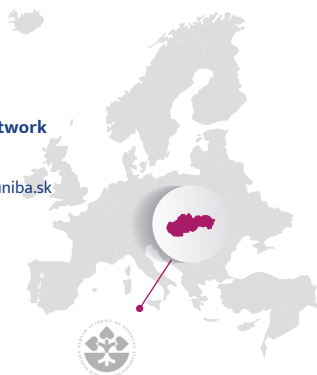
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National programme

The national strategic research agenda in quantum is developed through the mission of **QUTE⁹⁸ - Slovak National Center for Quantum Technologies**. QUTE.sk's long-term strategic vision is to prepare Slovakia for the quantum industry. QUTE Center started to create optimal conditions to increase Slovakia's competitiveness and excellence in research and innovation in QT.

As an active partner in QUTE Center, SAS participates in the following priorities:

- Creation of an educational study programme and the establishment of the international training center eduQUTE
- Creation of a virtual institute of quantum technologies iQUTE, which will bring together individual research teams
- Construction of quantum communication infrastructure netQUTE as part of the European initiative EuroQCI and the development of a single-photon detector for the needs of netQUTE

⁹⁸ <https://qute.sk/>

Priority areas

The QT field in Slovakia is centred around the following areas:

- Quantum and post-quantum communication networks
- Quantum information structures and metrology
- Quantum simulations and computational complexity

Funding instruments

Slovak Academy of Sciences (SAS) supports mainly theoretical research of quantum properties and fundamental concepts to develop quantum information and communication technologies and tools for simulating quantum systems.

The funding is realised through:

- participation in QuantERA joint calls
- activities coordinated by QUTE

QT in Slovakia is funded mainly by universities and research centres that allocate part of their budget for QT.



The estimated funding into QT per year is <€1 M. Concerning the plan to increase the public funding for QT in the next three years no information is available at present.

Other activities

In SAS QT is included in programmes without subject specification:

- SAS Gender Equality Plan
- SASPRO 2 Slovak Academic and Scientific Programme and IMPULZ scheme aiming to improve the scientific organisations of the Slovak Academy of Sciences (SAS) by recruiting internationally-recognised scientists and highly-talented young researchers who come from abroad or do not go abroad.

Quantum ecosystem

Quantum research community

The QT research community in Slovakia is grouped in the QUTE center. The most active partners there are the Institute of Physics SAS, the Faculty of Mathematics, Physics and Informatics Comenius University Bratislava, the Institute of Experimental Physics SAS, the Institute of Electrical Engineering SAS, the International Laser Centre of SCSTI and the Faculty of Informatics and Information Technologies STU in Bratislava.

Quantum innovation and industry

QUTE.sk's long-term strategic vision is to prepare Slovakia for the QT industry. It is focused on future industrial and security applications.

In 2020 QUTE Center was founded to increase Slovakia's competitiveness and excellence in research and innovation in QT.

SAS is an active partner in the QUTE Center and will also continue participation in QuantERA.

SLOVENIA

Ministry of Higher Education, Science and Innovation, MVZI

Highlights

✓ Other national initiatives

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National programme

There is no specific programme at national level related to QT. The QT field is supported through involvement in QuantERA and hosting the Center for Quantum Technology Slovenia (QUTES)⁹⁹. QUTES is an initiative of the Slovenian quantum technology community. It was established by Jozef Stefan Institute and Faculty of Mathematics and Physics, University of Ljubljana in 2016. Its main activities are the popularisation of QT: lectures, posters, news.

Priority areas

A national strategic research agenda for quantum technologies has not been established yet, but Slovenia supports all areas in QT:

- Quantum communications
- Quantum computing
- Quantum simulation
- Quantum sensors and metrology
- Fundamental research and development of new concepts

⁹⁹ <http://www.qutes.si/>

Funding instruments

The Ministry of Higher Education, Science and Innovation (MVZI) is responsible for regulating higher education, science and innovation in Slovenia. The Science Division as part of the Science Directorate defines the expert bases for the adoption of political documents in the field of research policy. It drafts laws and implements regulations on research activities. It establishes and enhances the system of comprehensive analyses and monitoring of the developments in research, develops new tools for attaining research policy goals and plans the required financial resources for research. When it comes to transnational activity, MVZI hosts the National Contact Points (NCP) network for Horizon Europe, offering advice and raising awareness concerning cooperation from the Slovenian research community. The ministry representatives sit in the EC Programming Committees. MVZI also participated in some Joint Programme Initiatives (JPIs).

The Ministry supports research in QT via transnational calls such as ERA-NET QuantERA with funding of €0.9 M



per three years and through Recovery and Resilience Facility (RRF) co-funding of the EuroQCI projects. Within QuantERA 2021 Call Slovenian Ministry finances 4 projects in an amount of €0.6 M. The SiQUID project is a project under EuroQCI in the field of Research and development in quantum communications with the aim of building a network for the distribution of quantum keys. €2 M was obtained from the DEP DEPLOY-NATIONAL competition and €2 M is a national contribution from RRF funds.

In 2021, the Slovenian National Research Agency published a call for new research programme funding where they prioritised at least one new research programme to be

from the QT field. One such research group was consequently established in 2022.

The estimated funding into QT per year is <€1 M. The amount has increased annually from €0.1 M to €0.3 M and no additional increase of the budget is planned for the next three years.

Quantum ecosystem

Quantum research community

The Slovenian QT community acts mainly through QUTES. Several research groups have joined the initiative recently and

the community is open for new members. QUTES brings opportunities for collaboration among its members on scientific and technological levels and also for the active promotion of QT. QUTES members are active in Quantum Flagship.

Slovenia has not developed any national strategic research agenda for QT yet, but has managed to increase the budget for projects related to the field from €0.3 M to €0.9 M for a period of three years.



Highlights

- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

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National programme

In Spain, QT research is supported by several funding bodies. At the national level, AEI funds QT through national open calls and the Centre for the Development of Industrial Technology (CDTI) funds specifically industrial partners. There are several other regional funding bodies, e.g. in the Basque Country, that can fund QT-related projects.

A national quantum strategy for QT is under preparation, led by the Ministry of Economic Affairs and Digital Transformation. This strategy aims to coordinate and align all state and regional initiatives in QT within the European framework.

Two national initiatives funded within the National Recovery and Resilience Programme have been launched recently:

- **Quantum Spain¹⁰⁰**, a €22 M initiative/project promoted by the Ministry of Economy through the Secretary of State for Digitisation and Artificial Intelligence. It aims to promote and finance a competitive and complete quantum computing infrastructure in Spain. The project involves 25 centres located in 14 Autonomous Communities, most of them integrated in the Spanish Supercomputing Network (RES)

- Complementary **Plan for Quantum Communication¹⁰¹**, a co-governed and co-financed research programme between the national Government and the Spanish autonomous communities to promote the development and implementation of quantum digital technologies and reinforce cybersecurity in Spain. This programme has a total budget of €76 M, of which 55 M come from the Ministry of Science and Innovation and 21 M from regions.

Another initiative worth mentioning is the **CUCO project¹⁰²**, the first large quantum computing project at both national and business level, which aims to make progress in scientific and technological knowledge of quantum algorithms through the public-private collaboration between centres and universities. At the regional level the Galician government invested €30 M in a QT programme aimed at quantum computation and communication. The Basque country included QT in the IKUR programme as one of its strategic areas.

¹⁰⁰ <https://quantumspain-project.es/en/about-us/>

¹⁰¹ <https://www.ciencia.gob.es/en/Estrategias-y-Planes/Plan-de-Recuperacion-Transformacion-y-Resiliencia-PRTR/Planes-complementarios-con-CCAA/Comunicacion-cuantica.html>

¹⁰² <https://www.cuco.tech/en/home/>

Funding instruments

The State Research Agency (AEI) is responsible for elaborating and implementing government policies on scientific research, technological development and innovation in all sectors, as well as for coordinating state-owned research institutions.

AEI funds QT through national open calls. The national calls are open to all scientific domains, with no restrictions on theme except on the organisational level. Those calls are open for non-profit research organisations and collaborative projects. There are four main types of research projects at the national level:

- **Excellence science projects** – to generate new general scientific knowledge
- **Challenge research projects** – to support research applied/oriented to solve societal and industrial challenges
- **Young researcher projects** – directed to non-staff young researchers (post-docs) affiliated to a public research organisation and supported by a research group. The goal is to support young researchers with innovative research lines
- **Public/private collaborative projects** – focused on the specific research demanded by the R+D+I departments of companies. Several partners can be funded but at least one company/industrial partner must be involved in the consortium. This is the only type of project that involves industrial partners

Other relevant calls funding QT are:

- International joint programming – to support international

cooperative projects: e.g. QuantERA projects

- Ramon y Cajal programme (5 year-funding) – to support the incorporation of excellent senior postdocs in national labs
- Scientific equipment – to support the acquisition of new scientific equipment
- A call for projects launched in 2022 by AEI, related to the Digital and Ecological Transitions (TED), which funded several proposals in QT (e.g. 4 projects for a total €1.4 M in the Physics panel)

All calls and programmes are bottom-up. There are no specific instruments to support QT topics. However, AEI has created a new area called Quantum and Matter Physics, which includes QT among the topics to be funded. Funding comes from the success of the researchers in the different calls based on the quality of the projects.

The estimated funding into QT per year is €15 M. Between 2018 and 2021 AEI has funded QT with around € 37 M for projects and €24 M for career researchers.

Since there is no specific QT programme, an estimation of the financial support of projects related to QT has been approached by selecting the projects from the AEI database.

Other activities

AEI promotes open, inclusive and responsible scientific and technical research in all fields of knowledge, as an essential factor for developing competitiveness and social welfare,

through the creation of an economic, social, cultural and institutional environment favourable to knowledge and innovation.

- Gender balance in the funded research projects is encouraged. AEI also aims at gender balance, to the best of its capabilities, in the composition of evaluation panels
- Open access is strongly encouraged
- A specific call for young researchers is organised

All the mentioned example-initiatives are available for researchers in Spain, but no efforts are aimed specifically at QT research.

Quantum ecosystem

Quantum research community

In Spain, there is a worldwide recognised community of researchers devoted to theoretical and applied work. There is also a significant community of experimental groups. Spain contributes to the European challenges with an outstanding scientific community. AEI has given support to the generation of national networks on topics related to quantum information and technologies, such as the Quantum Information and Technologies Network in Spain (RITCE), and the Cold Atoms Network. RITCE includes almost all top institutions involved in the quantum field and every year organises the Quantum Information in Spain (ICE) conference. Also, a platform for QT has recently been created in the CSIC, the largest research institution in Spain, to motivate transfer and collaboration between academia and industry.

Quantum innovation and industry

Regarding the Spanish Quantum Technology Industry and Innovation ecosystem, several start-ups have been created. Qilimanjaro Quantum Tech, a spin-off aimed at the development of quantum computers based on circuits of superconductors. LuxQuanta and Quside aiming at creating autonomous QKD devices. Other companies like GMV, Indra o Hispasat are starting to work on Project on quantum cryptography. Examples of software companies include Multiverse Computing, aQuantum, Quanvia and Inspiration-Q. The representative Association of the digital industry sector in Spain (Ametic) has created a working group that is monitoring the state of the art and needs of the Spanish QT industry.

Two national initiatives have been launched recently:

- **Quantum Spain initiative around quantum computing (€22 M)**
- **Plan for Quantum Communication to implement quantum digital technologies and the reinforcement cybersecurity (€76 M).**

AEI funding granted to QT has grown over the last four years to €15 M per year.
A national Quantum strategy is under preparation.





Highlights

- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

Contact

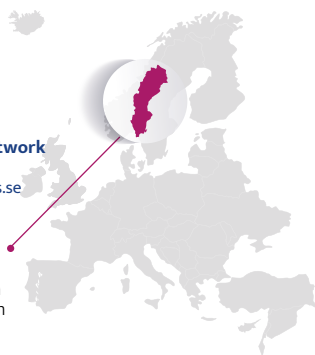
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National programme

A Swedish agenda for QT is under preparation. This document will describe the research and innovation within QT and will most probably guide Swedish future efforts within the field. Currently, the most important Swedish research programme is the **Wallenberg Centre for Quantum Technology (WACQT)**¹⁰³ – a 12-year SEK 1 B (€88,5 M) research programme that aims to take Swedish research and industry to the forefront of QT.

Priority areas:

Through an extensive research programme, the aim is developing and securing Swedish expertise within the main areas of QT:

- Quantum computing and simulation
- Quantum communications
- Quantum sensing

The main project is to develop a high-end quantum computer that can solve problems far beyond the reach of the best conventional supercomputers.

Swedish research within the field of QT is of high quality and has high visibility internationally. However, with Sweden being a relatively small country, not all areas are covered equally well. National and international collaboration is therefore a key. On the instrumentation side, Sweden is well equipped, but further efforts are needed in order to be competitive in this rapidly developing area.

Funding instruments

The Swedish Research Council (VR) is Sweden's largest governmental research funding body, and supports basic research of the highest quality within all scientific fields.

VR supports QT research through open calls/programmes, including QuantERA. The calls are open to all scientific domains, with no restrictions on theme. The priority has been to fund high-quality research and to support research with equipment that is of relevance and top-of-the-line.

¹⁰³ <https://www.chalmers.se/en/centres/wacqt/>

The QT field is supported in Sweden mainly through the activities of VR. Other entities involved in QT development are:

- The Knut and Alice Wallenberg Foundation¹⁰⁴
- VINNOVA¹⁰⁵
- Swedish Foundation for Strategic Research¹⁰⁶.

The estimated funding into QT per year is €2-5 M. This amount refers to research projects, including participation in LUMI-Q – the European Joint Undertaking EuroHPC, and funding provided for infrastructure of high relevance for the area.

Other activities

RRI actions are important and dealt with by Swedish Research Council. The initiatives apply for all fields of science funded by the VR in all funding schemes.

Quantum ecosystem

Quantum research community

There are 40+ active research groups, many of them working broadly, over several QT subfields. Three regional hubs can be seen in Stockholm (KTH, SU), Gothenburg (Chalmers & WACQT) and Lund (LU & NanoLund).



Quantum innovation and industry

There are several ongoing programmes for applied research and industrial PhD students. The number of SMEs are steadily growing (at least 10 start-ups) and there is large interest from industry overall.

The Swedish agenda for QT is under preparation.

The most important Swedish research programme is WACQT – a 12-year SEK 1 B research programme that aims to take Swedish research and industry to the forefront of QT.

¹⁰⁴ <https://kaw.wallenberg.org/en>

¹⁰⁵ <https://www.vinnova.se/en/>

¹⁰⁶ <https://strategiska.se/en/>

SWITZERLAND

Swiss National Science Foundation, SNSF

Highlights

- ✓ National programme
- ✓ Defined priority areas
- ✓ Specific funding programme
- ✓ Other national initiatives

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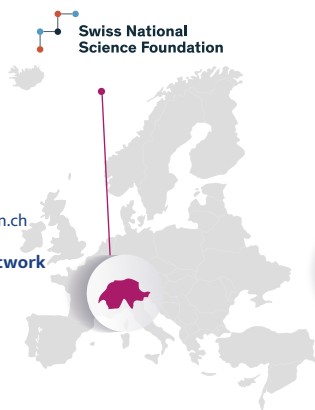
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National programme

In 2023 the **Swiss Quantum Initiative (SQI)**¹⁰⁷ was initiated in a “bottom-up” scheme with a mandate from the Swiss Federal government to the **Swiss academy for natural sciences**¹⁰⁸. The initiative will strengthen research and development in QT, secure the prominent position of Switzerland in this area and enhance international networking. It is endowed with an initial budget of **CHF 10 M** for 2023 and 2024 to support national projects as a priority. It is scientifically and strategically led by an SQI-committee of experienced QT-researchers from the Swiss QT community.

Besides this, the Swiss Quantum community is mainly supported through bottom-up funding schemes provided by the **SNSF** and **Innosuisse**¹⁰⁹.

In May 2021, the **Quantum Computing Hub**, a joint centre between the ETH Zürich (ETHZ) and the Paul Scherrer Institute (PSI), was established as a platform for quantum computing at PSI. It targets models including access to operational quantum computers, a testbed for companies interested in this area and research into technology scaling of quantum computing systems. It has been funded with CHF 30 M from the ETH Zürich for an initial 5-year period.

Funding instruments

The **Swiss National Science Foundation (SNSF)**, mandated by the federal government, supports basic science in all academic disciplines. The strategic goals of SNSF are:

Swiss Quantum Initiative (SQI)



LAUNCH
2023



DURATION
5 years



BUDGET
CHF 10 M

for 2023 and 2024. Additional federal funding is planned for 2025–2028

¹⁰⁷ <https://www.sbfi.admin.ch/sbfi/en/home/research-and-innovation/research-and-innovation-in-switzerland/sqi.html>

¹⁰⁸ <https://quantum.scnat.ch/>

¹⁰⁹ <https://www.innosuisse.ch/inno/en/home.html>

- To support high-quality research and researchers
- To bring research funding closer into line with the researchers' needs
- To support the spread of knowledge in society, the economy and politics and demonstrate the value of research

QT research is funded in two ways:

- Thematic calls/programmes with a specific goal (national and international level)
- Calls/programmes open to all scientific domains (bottom-up approach) with no restrictions on themes. This is the main funding scheme of the SNSF and includes national projects as well as bi/multilateral ones (Weave/Lead-Agency scheme). Part of this funding is dedicated to QT

The **National Centres of Competence in Research (NCCR)** promote long-term research networks in areas of strategic importance for Swiss science, the Swiss economy and Swiss society.

- **QSIT – Quantum Science & Technology**¹¹⁰ is active in a field which unites the key discoveries of the 20th century: quantum physics and information theory. It is funded through grants awarded by the SNSF, but also from other sources, in total for 12 years (2010-2022) and amounting to CHF 175 M. The total budget for 2018-2022 is CHF 53,85 M of which CHF 14,95 M is granted by the SNSF

110 <https://www.snf.ch/en/jwkQQuaOVwQV9fOz/page/researchinFocus/nccr/nccr-qsit#Funding>
 111 <https://www.snf.ch/en/7zxLOygtXFDuDCSe/page/researchinFocus/nccr/spin>

- **SPIN – Spin Qubits in Silicon**¹¹¹, a new NCCR, was launched in 2020. It is focused on quantum computing with spin qubits in silicon and germanium. For its first funding period (2020-2023), it is endowed with a total budget of about CHF 40 M of which CHF 17 M is granted by the SNSF

QT are gaining more and more importance in Switzerland. The **Quantum Transitional Call**¹¹² was launched at the end of 2022 with an envelope of **CHF 24 M** (including an overhead reserve of 15%).

The **average total public funding for research in QT (excluding local funding of universities and research institutions) amounts to over CHF 70 M per year (until 2022)**, among which about **CHF 54 M** originate from the SNSF. About 68% of the total funding stems from bottom-up funding instruments. Details on past- and currently-funded projects in QT can be found on the **SNSF data website**¹¹³.

Key Figures (million CHF per year)			
SNSF Funding	54	Bottom-up	46.6
		Top-down	7.4
Innosuisse Funding	2.63	Internal funds	1.47
		Business contributions	1.17
Other Funding*	15.48		
Total	72.11		

* From the NCCRs QSIT and SPIN
 Table 5. Summary of QT funding in recent years

It is likely that more funding will flow into QT in the next few years as the tendency is to support the growing Swiss QT network.

Priority areas

Since the core spirit of the SNSF is bottom-up, it does not directly specify priority areas. The latter are rather defined by the strategic community-driven orientations. Over the last 5 years, the most QT-targeted areas were:

- **Quantum information sciences** (average funding of CHF 16 M/year)
- **Quantum metrology, sensing and imaging** (average funding of CHF 13 M/year)
- **Quantum simulation** (average funding of CHF 10 M/year)

Other activities

The SNSF promotes the widest possible range of scientific research in Switzerland and this is rooted in its **strategic priorities**¹¹⁴. It is open to all groups and types of research, and promotes scientific careers, not just academic ones. In addition, the SNSF has its own **gender equality policy**¹¹⁵ and is fully committed to promoting a balanced representation of women and men in different roles and bodies, and in research as a whole. The SNSF also supports Open

112 <https://www.snf.ch/en/d09nVyBuCfh8ZF0I/funding/horizon-europe-quantum>
 113 <https://data.snf.ch/>
 114 <https://snf.ch/en/HaWHRra6wcsZUEoK/page/theSNSF/profile/strategy/strategic-priorities>
 115 <https://www.snf.ch/en/0PP6MZgVShTA9HDg/topic/research-policies>

Science through policies for **open access to publications**¹¹⁶ and **research data**¹¹⁷. All those policies and measures apply to all fields and are not specific to QT.

Quantum ecosystem

Quantum research community

Innosuisse¹¹⁸, is the Swiss innovation agency funding application-oriented research and development. The funding of Innosuisse is mainly bottom-up.

Within the National Centre of Competence in Research (NCCR) initiative, 44 research groups in Switzerland were part of the NCCR QSIT. The network has remained active after the end of the programme through the organisation of scientific meetings and exchanges like the **Swiss Quantum Days 2023**¹¹⁹. After the start of the new NCCR “SPIN”, about 18 research groups were involved in the programme. This has since grown to about 35 research groups from all over Switzerland including IBM research as a key industrial partner.

Besides, there are independent QT centres based at the EPFL, the ETHZ, the **University of Basel** and the **University of Geneva**. They carry out research and innovation in QT as well as educational activities. They are supported through a variety of local, national and European funding and comprise over 80 research groups.

116 <https://www.snf.ch/en/VyUvGzptStOEuOC/topic/open-access-to-publications>

117 <https://www.snf.ch/en/dMILj9t4LNk8NwYR/topic/open-research-data>

118 <https://www.innosuisse.ch/inno/de/home.html>

119 <https://swissquantumdays23.epfl.ch>

It is expected that the QT community will become stronger and more competitive, and benefit from higher levels of funding in the upcoming years.

Quantum innovation and industry

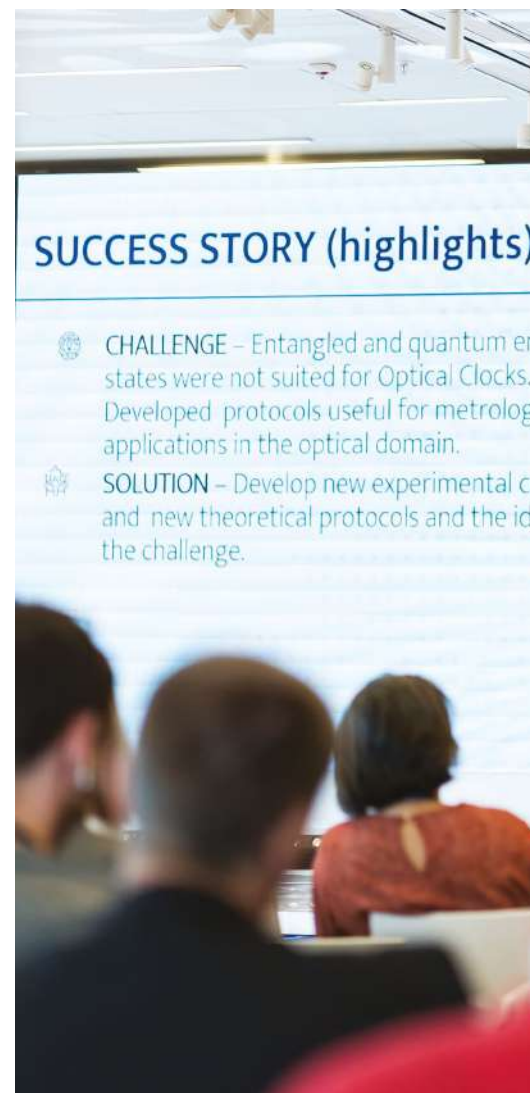
For the last couple of years, Innosuisse has supported a variety of QT-related innovation projects and start-ups with an average yearly funding level of CHF 2.6 M. Since 2023, Innosuisse can directly support innovation projects of start-ups and SMEs. Also, several QT start-ups have emerged from the NCCR QSIT (e.g. IRSweep, Qzabre, Qnami, Basel Precision Instruments).

The Swiss QT landscape has gained further importance during the last few years. The QT community is becoming increasingly organised around local and national networks.

In 2023, a National Quantum Initiative was launched with an initial budget of CHF 10 M for two years.

A new national programme in QT, the NCCR “SPIN”, was launched in 2020.

A special transitional Call in QT was launched by the SNSF in 2022 with a budget of CHF 24 M.





Highlights

- ✓ Defined priority areas
- ✓ Other national initiatives

Contact

QuantERA

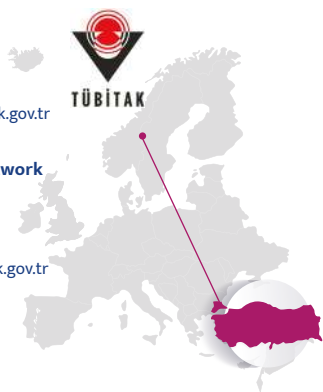
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National programme

QT are one of the priority technology areas stated in the 11th **Development Plan (2019-2023) of Türkiye**, which is the main strategy directing all public policy-making activities. There is not a specific strategy or roadmap for QT, however the technology roadmaps prepared within the auspices of Turkish Republic Presidency's Science, Technology and Innovation Council and with the technical support of TÜBİTAK has defined technological objectives in the field.

Motor, Big Data and Quantum Computing, Cyber Security Technology Roadmaps have dedicated technological objectives and/or critical products in QT:

- In the **Motor Technology Roadmap**, one of the critical products planned to be developed in Türkiye is “Quantum Level Energy Harvesting Micro-Nano Motors” under the technological objective: “Providing scientific and technological knowledge base on innovative micro-nano motors, which are significant for numerous future application areas”
- In the **Big Data and Cloud Computing Technology Roadmap**, there is also a critical product in QT under the techno-

logical objective: Cloud Computing Infrastructure Services (IaaS) as “Cloud Based Quantum Computing Services”

- In the **Cyber Security Technology Roadmap**, there is a dedicated technological objective as “Development of cyber security technologies using quantum cryptography and post-quantum cryptography technologies for detection, prevention and mitigation disposal methods and especially for software level cyber threats. In addition, the creation of technical infrastructures to detect security vulnerabilities of cryptographic software developed from open source”

Funding instruments

The Scientific and Technological Research Council of Türkiye (TÜBİTAK) is the leading agency for management, funding and conduct of research in Türkiye.

TÜBİTAK prioritises RDI topics with respect to the national technology roadmaps. **TÜBİTAK Priority RDI Themes document** is prepared with special foresight and prioritisation studies once in two years. Considering the current

prioritisation, 8 out of 264 topics included in TÜBİTAK's 2022-2023 Priority RDI Themes are related to QT.

If the project proposals submitted to TÜBİTAK refer to at least one of the topics defined in the current TÜBİTAK Priority RDI Themes, they receive extra points during the evaluation process.

TÜBİTAK has organised several national workshops related to quantum computing. It also organised online courses, summer schools and yearly activities for World Quantum Day.

Priority areas

TÜBİTAK 2022-2023 Priority RDI Themes include the following topics in QT:

- Quantum Information Systems: Fundamental properties of quantum computing, design of algorithms, software and quantum processors on quantum computing, design of cost-effective devices that can compete with classical products used in different fields and/or based on new physical properties
- Cloud Based Quantum Computing Services
- Quantum Level Energy Harvesting Micro-Nano Motors
- Quantum cryptography technologies
- Post-quantum cryptography technologies
- Products that use secure cryptography technologies against quantum attacks in encrypting public data
- Silicon-based nanoelectronic applications and quantum effects
- Semiconductor nanostructures, nano-crystalline materials, quantum wires, quantum dots

The above-mentioned topics are defined with their technical content, main objective, expected outcome and technology readiness levels.

Projects in quantum communications, quantum simulations, quantum information sciences, quantum metrology, sensing and imaging have been funded by TÜBİTAK in the last 5 years.

TÜBİTAK Informatics and Information Security Research Center (BİLGEM), one of the major public research centres in Türkiye, has established a division related to QT, which is expected to contribute to relevant research areas including quantum computing, communications and sensors.

The estimated funding into QT per year is €2-5 M. Funding through QuantERA call 2023 is €0.5 M. Currently, there is no plan to increase the public funding for QT.

Quantum ecosystem

Quantum research community

The quantum research community in Türkiye differs on the levels of **experimental and theoretical researchers**:

- The **experimental** community is strongly intertwined with optics and photonics research communities, where the connection is usually through quantum optics-related research topics. This section of the community is mainly interested in quantum cryptography, computing, communication and sensing

- Researchers focusing on the **theoretical aspects of quantum research** is the second main section of the community in Türkiye. Studies in this group are very diverse, covering research topics from the discovery of new quantum algorithms to applications of quantum thermodynamics in the space environment

Recently many universities have filled open faculty member positions through the Council of Higher Education (YÖK) specifically related to the QT research area.

The main national QT research networks in Türkiye are KOBİT (Quantum Optics and Information Meeting) and TÜBİTAK Research Institutes such as Research Institute for Fundamental Sciences (TBAE), National Metrology Institute (UME), and Informatics and Information Security Research Center (BİLGEM). KOBİT is a series of conferences and workshops that has been organised yearly since 2016. TÜBİTAK is the main scientific body in Türkiye, and different institutes under it focus on different aspects of QT. They organise workshops, online courses and summer schools, become partners in national and international projects (such as QuantERA), and mainly act as signalling beacons for national policies in QT.

Quantum innovation and industry

As an industry and ecosystem, besides several universities, research centres such as TÜBİTAK BİLGEM, UME and TBAE, recently, a major defence electronics company, ASELSAN has established a quantum research centre with TOBB University with the support of the Defence

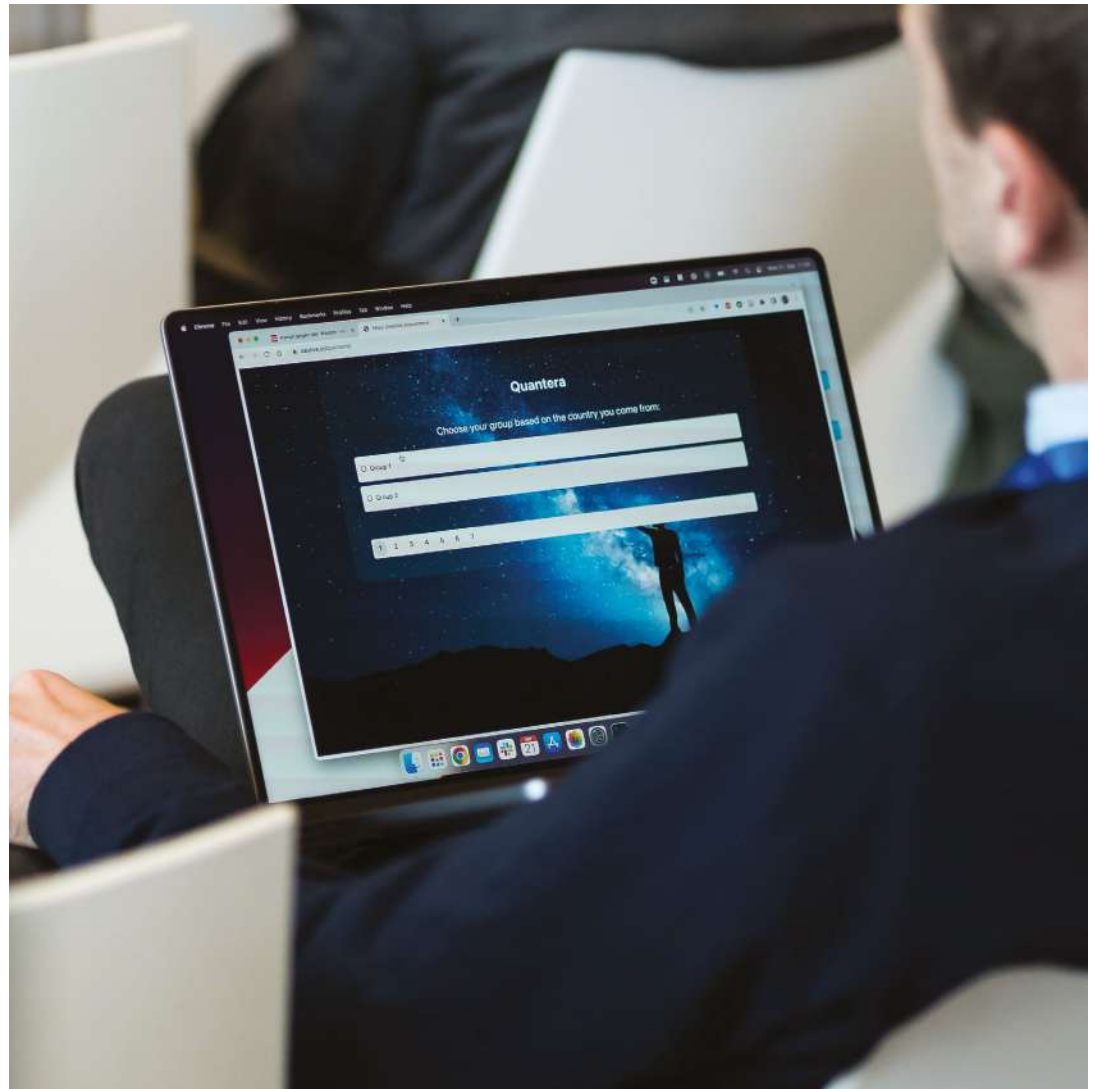
Industry Agency. Also, several SMEs have been founded specifically in quantum communications and sensors areas. Recently, large companies have shown interest in the area and started to found QT departments. Besides, several SMEs have been established.

Türkiye is represented in the Quantum Community Network (QCN) and contributes to and participates in the Horizon Europe programme. Moreover, TÜBİTAK BİLGEM is a member of ETSI QKD ISG and Quantum Industry Consortium (QuIC).

QT are one of the priority areas stated in the 11th Development Plan (2019-2023) of Türkiye.

TÜBİTAK 2022-2023 Priority RDI Themes document includes eight topics in QT.

Funding for QT through QuantERA call 2023 is €0.5 M.



UNITED KINGDOM

United Kingdom Research and Innovation, UKRI

Highlights

- ✓ **National programme**
- ✓ **Defined priority areas**
- ✓ **Specific funding programme**
- ✓ **Other national initiatives**

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National programme

On 15th March 2023, the UK Government published the **National Quantum Strategy**¹²⁰, which sets out a ten-year vision and plan for QT in the UK, committing to spend £2.5 B to research, innovation, skills and other activities in that period. The UK's 10-year vision is to be a world leading quantum-enabled economy, building on scientific excellence and creating a thriving quantum sector to ensure that QT are an integral part of the UK's digital infrastructure and advanced manufacturing base, driving growth and helping to build a strong and resilient economy and society.

National Quantum Strategy



LAUNCH
2023



DURATION
10 years



BUDGET
£2.5 B

This long-term commitment builds on the successful foundation laid by the **National Quantum Technologies Programme (NQTP)**¹²¹ and the UK sector which already has an established programme of public and private R&D with over £1 B of investment over the period 2014-2024. NQTP represents a vibrant, visionary partnership between government, academia and industry, one that is fast-tracking QT knowledge from laboratory to wider societal and economic impact. The overall aim of NQTP is to deliver economic prosperity, national security and value to society by nurturing the most exciting UK research talent and the best ideas to commercialise QT.

Goals:

- Ensure the UK is home to world-leading quantum science and engineering, growing UK knowledge and skills
- Support business, making the UK the go-to place for quantum businesses and an integral part of the global supply chain, as well as a preferred location for investors and global talent
- Drive the use of QT in the UK to deliver benefits for the economy, for society and for national security
- Create a national and international regulatory framework that supports innovation and the ethical use of QT, and protects UK capabilities and national security

A new Office for Quantum (OfQenquiries@beis.gov.uk) has been established within the Department for Science, Innovation and Technology (DSIT) and will be responsible for coordinating much of the activity across Government, academia, industry and with the UK's international partners.

Funding instruments

UK Research and Innovation (UKRI) brings together the seven Research Councils, Innovate UK and Research England. Quantum Technology in the UK is mainly funded through the UK **National Quantum Technologies Programme**, and is delivered by the following funding partners: Engineering and Physical Sciences Research Council (EPSRC), Science and Technology Facilities Council (STFC), Innovate UK (IUK), National Quantum Computing Centre (NQCC), Department for Science, Innovation and Technology (DSIT), National Physical Laboratory (NPL), Government Communications Headquarters (GCHQ), and the Defence Science and Technology Laboratory (DSTL).

During the first phase of the National Quantum Technologies Programme (2014-2019), **EPSRC** funded a national network of Quantum Technology Hubs through a £214 M investment in four hubs. In the second phase (2019-2024) EPSRC refreshed the Quantum Technology Hubs at the end of 2019, with a £94 M investment. The hubs act as the engine for UK QT ambitions, weaving the science of QT with ideas for their

commercialisation and delivering a route to market. Each hub brings together experts from universities, national laboratories, business development and industry partners to steer a proposed development.

EPSRC have now launched a **call for its next phase of Quantum Technology Hubs**, aiming to support up to five Hubs, each between £15 M – £19.5 M, over five years from 2024.

As well as continuing to support bottom-up research in Quantum Technologies via EPSRC's standard research schemes, a number of strategic calls have been launched in recent years, including:

- Collaborating at the quantum computing and ICT interface – 3 grants funded through EPSRC totalling £8 M
- International networks in Quantum Technologies – 8 networks funded through EPSRC totalling £3 M
- Quantum Sensing for Environmental Sciences – 4 grants funded totalling £2.8 M jointly invested by EPSRC and the Natural Environment Research Council (NERC)
- £70 M in the development of two short-term quantum missions focused on achieving key technological milestones around quantum computing and Positioning, Navigation and Timing (PNT). These will be jointly delivered by EPSRC, Innovate UK and the NQCC.

Other meaningful activities related to QT are described below.

- UK Research and Innovation, through EPSRC and STFC, has established the **National Quantum Computing Centre (NQCC)** in 2020 with the aim of working towards fully scalable, fault tolerant, general purpose quantum computing.

- **Quantum Technologies for Fundamental Physics (QTFP)** is a joint programme between STFC and EPSRC aiming to demonstrate how QT can be utilised to investigate key fundamental physics questions such as the search for dark matter, the nature of gravity and measurements of the quantum properties of elementary particles. 24 awards have been funded under this programme since 2020. The programme total value is £40 M.
- **The Industrial Strategy Challenge Fund (ISCF)** for QT, delivered through Innovate UK, has stimulated commercial development, delivering the value, mentoring and opportunity that underpins the NQTP. Businesses supported by ISCF with £153 M have raised £425 M in private sector financing since its programme started, twice the forecast estimate. That private sector support is expected to reach £715 M by 2025. Major funding has been provided through the Industrial Strategy Challenge Fund. A [directory of the ISCF funded projects¹²²](#) is available
- **In 2020, Innovate UK and NSERC (the National Science and Engineering Research Council of Canada) ran a joint call for business led bilateral projects** to exploit opportunities for the commercialisation of QT in the two countries. The eight winning projects shared grants of £2 M from UKRI and C\$4.4 M total investments from Canada

A new programme has been announced from 2023 with the National Research Council of Canada Industrial Research Assistance Program (NRC IRAP) to invest a total of

120 <https://www.gov.uk/government/publications/national-quantum-strategy>
121 <https://uknqt.ukri.org/>

122 <https://www.ukri.org/publications/project-directory-for-the-uk-quantum-technologies-challenge/>

up to £6 M in innovation projects. These will enable the advancement of QT and their commercial use cases.

Priority areas:

UKRI continues to fund QT through existing investments in:

- Computing and simulation
- Communications
- Sensing and imaging
- Metrology and timing
- Quantum information sciences

Other activities

UKRI has a responsibility to ensure that the activities and the research funded are aligned with the principles of RRI, creating value for society in an ethical and responsible way. UKRI recommends that researchers demonstrate awareness of and commitment to the principles of responsible research and innovation, following the **Anticipate, Reflect, Engage, Act (AREA)** approach described within the respective **framework**¹²³.

Trusted Research is a campaign that aims to support the integrity of the system of international research collaboration, particularly relevant to researchers in STEM subjects, dual-use technologies, emerging technologies and commercially-sensitive research areas, including QT. The UK's National Protective Security Agency (NSPA) has developed **guidance**¹²⁴

¹²³ <https://www.ukri.org/about-us/epsrc/our-policies-and-standards/framework-for-responsible-innovation/>

¹²⁴ <https://www.npsa.gov.uk/trusted-research>

¹²⁵ <https://quantumcity.org.uk>

for academia and industry on safe practice when collaborating on transnational research projects.

Science education activities:

- EPSRC funded two phases of **Quantum Technologies Fellowships** which support both the individuals and their teams to help realise the country's potential. In 2022, a total of 15 awards made
- **National Physical Laboratory (NPL)** skills programme support training and skills in QT through their STEM Futures programme
- **Quantum Technology Summer Schools** cover 2 separate programmes which in 2023 will offer 120 places based at the Universities of Birmingham and Bristol during July and August. Places will be awarded to students at PhD level from the UK, US and Canada
- **Quantum City**¹²⁵ seeks to raise the profile of QT amongst the public and schools to build the future QT workforce and facilitate discussions about the role of these technologies in society

Quantum ecosystem

Quantum research community

The UK National Quantum Technologies Programme is active right across the nation and combines:

- support for underpinning research through EPSRC's bottom-up research programmes as well as strategic calls and the Quantum Technology Research Hubs
- provision of skills through PhD studentships funded by EPSRC's Centres for Doctoral Training and Doctoral Train-

ing Partnerships, as well as PhD studentships funded and hosted by Dstl and NPL

- Innovation and commercialisation funding for a range of businesses, small and large, through support via Innovate UK

Quantum innovation and industry

The NQTP currently supports 49 quantum start-ups and there are over 160 companies active in the UK QT sector, and over 120 UK businesses partner with the UK national Quantum Technology research Hubs. The UK nurtures a highly skilled QT workforce, including over 470 PhD candidates and many fellowships; attracting more venture capital investment per capita into QT than any other country.

In 2023, the UK Government published the National Quantum Strategy with a ten-year vision for quantum in the UK and the commitment of £2.5 B to research, innovation, skills and other activities.

The UK is forging its research strength into market opportunities through the National Quantum Technologies Programme (NQTP).

QuantERA Consortium
– Research Funders for
Quantum Technologies





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