Key Performance Indicators for Quantum Technologies in Europe

March 2025

Abstract

The European Commission has recognized quantum technologies as a strategic asset, launching several initiatives to enhance and expand Europe's leadership and scientific excellence in this field. These efforts aim to foster the growth of a competitive European quantum industry and position Europe as a global leader in quantum technologies, driven by innovative research, industry collaboration, business development, and investment.

Launched by the European Commission in 2018, the Quantum Flagship unites a diverse community of researchers, academic institutions, and industry leaders across Europe. By bridging the gap between fundamental science and practical technology, the Quantum Flagship seeks to unlock the full potential of quantum innovations in areas such as computing, simulation, communication, and sensing. This collaborative environment ensures that the program not only excels in academic research but also leads to tangible technological advancements that benefit both society and industry.

The Quantum Strategic Advisory Board (SAB), part of the governance structure of the European Quantum Flagship, plays a pivotal role in shaping the strategic direction of the program. The SAB supported the development of the Strategic Research and Innovation Agenda (SRIA)[a], which outlines Europe's key objectives and research priorities in quantum technologies. The SAB also defined a set of ambitious Key Performance Indicators (KPIs) to guide, track, and monitor the progress of quantum technologies across Europe. Ongoing oversight from the SAB ensures that the program remains aligned with Europe's broader research and innovation goals while adapting to the evolving landscape of quantum technologies.

The KPIs monitor six key areas within the quantum sector: Ecosystem, Quantum Communication, Quantum Computing, Quantum Simulation, Quantum Sensing and Metrology, and Education.

This document presents the KPI values for 2024, alongside perspectives for 2030. The 2030 vision assumes continued support for fundamental research and basic science, coupled with strong interaction between European industry and academia to maintain excellence and drive future breakthroughs that will benefit society.

The information in this document reflects the collaborative efforts of academic, public, and private sector representatives from the Quantum Coordination Board (QCB), the Quantum Community Network (QCN), the European Quantum Industry Consortium (QuIC), the Strategic Advisory Board (SAB), and the Flagship Coordination Office through the Coordination and Support Action (QUCATS). The 2024 KPI values were measured in early 2025 through surveys of SAB, QCB, QuIC, and QUCATS members, and were defined based on the best available knowledge within the European quantum community. These values were verified and validated by the SAB.

[a] 2024 Strategic Research and Industry Agenda: https://qt.eu/media/pdf/Strategic-Research-and-Industry-Agenda-2030.pdf

A color scale has been adopted to assess the health of the KPIs in relation to their progress towards the ambitious 2030 targets. A green color indicates that the KPI is on track to meet its 2030 goal. The document also highlights KPIs that are ahead of schedule, demonstrating Europe's exceptional progress in the quantum field. References and explanations are provided at the end of the document. Some 2030 KPI targets are still under discussion, and in such cases, "n/a" is indicated. The SAB is actively working to define these 2030 targets, and the outcomes of these discussions will be used to evaluate the achievements of 2025.

As the Quantum Flagship continues its journey, this document serves as a testament to the collective efforts of Europe's quantum community and the strategic guidance provided by the SAB, reinforcing Europe's position as a leader in the global quantum revolution.

KPI Scorecard

KEY

- Ahead of schedule
- On schedule
- Needs progress
- Behind schedule

KPI Ecosystem	2021 value	2022 value	2023 value	2024 value	2030 target
Investment (M€)	344 M€	408 M€	551 M€	344 M€	1000 M€
Lab-to-market (SMEs members of QuIC)	79	95	99	101	250
Lab-to-fab infrastructure and value chain (facilities)	1	9	22	30	60
Job Creation	n/a	n/a	3850	5777	10000
Patent Creation/IP Retention (rank)	n/a	n/a	Top 2 globally	Top 2 globally	Top 2 globally
Supply Chain & Strategic autonomy (components)	0	35	44	48	60

KPI Quantum Communication	2021 value	2022 value	2023 value	2024 value	2030 target
Performance (subsystems)	2	5	11	12	20
EU Technical Leadership: Q. Information Networks (km)[b]	1.3 km	1.3 km	1.3 km	10 km	500 km
EU Technical Leadership: Q. Secure Networks (km)	-	-	248 km @1.4 bits/s[c]	248 km @1.4 bits/s[c]	n/a*
Deployment (areas; maximum number of nodes per area)	1 (8)	15 (10)	16 (10)	20 (10)	25 (75)
Adoption (services/use-cases)	5	9	10	10	30

KPI Quantum Computing	2021 value	2022 value	2023 value	2024 value	2030 target
Performance (q. computers with q. advantage)	0	0	0	0	3
EU Technical Leadership: circuit size (Size of Clifford Unitary)	-	-	20	20[d]	n/a*
EU Technical Leadership: Entanglement (size of GHZ-state)	-	-	24	24[d]	n/a*
EU Technical Leadership: factoring (Shor's algorithm)	-	-	15	15[d]	n/a*
EU Technical Leadership: error correction	-	-	-	-[d]	n/a*
European Impact Leadership (use-cases)	70	70	97	102	500
Accessibility (facilities)	0	4	6	9	10
Accessibility (HPC/QCS network)	0	0	0	2	5

[b] Entanglement distance between quantum processing nodes/ distance for entanglement generation refers to heralded entanglement generation between quantum processing nodes.
[c] Achieved with an entanglement-based protocol (BBM92).
[d] In 2024 a benchmarking method to measure these KPIs was proposed. The values of these KPIs were not ready for the time of the KPI publication.
* These KPIs were recently defined and work is ongoing to define the 2030 targets.

KPI Quantum Simulation	2021 value	2022 value	2023 value	2024 value	2030 target	
Performance (simulators with q. advantage)	0	0	0	0	8	
Increase market adoption (real-life applications)	0	0	0	0	12	
Performance (available EU q. simulators)	-	-	-	4	n/a*	
Increase market adoption (use cases)	-	-	-	1	n/a*	
European Technical Leadership (qubits)[e]	-	100	100	100	5000	

KPI Quantum Sensing and Metrology	2021 value	2022 value	2023 value	2024 value	2030 target	
Market Readiness (product/service classes)	3	5	6	8	20	
Next-generation Technologies	0	2	5	6	7	

KPI Education	2021 value	2022 value	2023 value	2024 value	2030 target	
Outreach (events)	7	33	38	122	100	
Education: modules (validated modules)	0 (0)	20 (12)	45 (21)	56 (32)	180 (90)	
Adoption (entities/institutions)	1	17	43	47	225	
Diversity and Equity (entities/institutions)	0	10	15	18	90	

[e] Number of qubits in Europe's EU27 most advanced quantum simulator.
* These KPIs were recently defined and work is ongoing to define the 2030 targets.

KPIs Ecosystem

1. Investment

Total amount of EC investment in the form of venture capital (EU quantum start-ups), corporate seed-funding (EU incubators & accelerators), and EU public investment (EU public-private ventures).

2021 value	344 M€
2022 value	408 M€
2023 value	551 M€
2024 value	344 M€
progression/year	+90 M€
2030 target	1000 M€

Remark: The 2024 value was obtained with a new, more reliable methodology. The decrease in not attributed to this new methodology but to fewer new projects in the last period of Horizon Europe.

2. Lab-to-market

Number of quantum start-ups, spinoffs, incubators, accelerators, as well as public private joint ventures in Europe (given for all pillars, including established EU companies that enter the field).

2021 value	79
2022 value	95
2023 value	99
2024 value	101
progression/year	+20
2030 target	250

Remark: The KPI is measured as the number of Small and Medium Enterprises (SMEs) members of QuIC.

3. Lab-to-fab infrastructure and value chains

Number of EU research institutions offering open application labs, testbeds, production cleanrooms, with testing, prototyping and calibration service facilities accessible to European SMEs, covering TRL 2-6.

2021 value	1
2022 value	9
2023 value	22
2024 value	30
progression/year	x1.6
2030 target	60

4. Job creation

Number of jobs in quantum technologies.

2021 value	n/a
2022 value	n/a
2023 value	3850
2024 value	5777
progression/year	+15%
2030 target	10000

Remark: The 2024 value may be underestimated due to some missing companies. The academic sector is not considered.

5. Patent creation and IP retention

Quantum-related European patents granted versus distribution of granted patents globally.

2021 value	n/a
2022 value	n/a
2023 value	Top 2 globally
2024 value	Top 2 globally
progression/year	-
2030 target	Top 2 globally

Remark: Relative rank in international patent families by country of origin.

6. Supply chain and strategic autonomy

Number of components (supply chain) of quantum technologies which were formerly imported to EU and are now produced in EU that are of strategic importance and needed for self-sufficiency.

2021 value	0
2022 value	35
2023 value	44
2024 value	48
progression/year	+3
2030 target	60

KPIs
Quantum Communication

1. Performance

Number of complementary subsystems, advancing the state of the art, necessary for Quantum Communications networks enabling security or quantum internet applications.

2021 value	2
2022 value	5
2023 value	11
2024 value	12
progression/year	x1.2
2030 target	20

2. European technical leadership

Comm2a – Quantum Information Networks: Quantum Information Networks: Physical distance (km) for entanglement generation, or teleportation of a data qubit, with fidelity and rate.
Distance for entanglement generation refers to heralded entanglement generation between quantum processing nodes.

2021 value	1.3 km
2022 value	1.3* km
2023 value	1.3* km
2024 value	10** km
progression/year	x2
2030 target	500 km

***Remark**: 33km on a fibre spool between buildings 400m apart.
****Remark**: via 25 km deployed fibre. Fidelity: 0.534; maximum key rate: 0.48 Hz.

Comm2b – Quantum Secure Networks:

- Physical distance and key rate of Prepare & Measure quantum key exchange;
- Number of new realized protocols beyond P&M QKD.

2021 value	-
2022 value	-
2023 value	248 km @1.4 bits/s***; 1 new realized protocol (BBM92)
2024 value	248 km @1.4 bits/s***; 1 new realized protocol (BBM92)
progression/year	-
2030 target	n/a

*****Remark**: Achieved with an entanglement-based protocol (BBM92).

3. Deployment

Number of QKD connected European metropolitan areas (and nodes) integrated with a commercial telecom infrastructure, including both terrestrial and satellite links with a secure key rate of at least 100 bit/s.

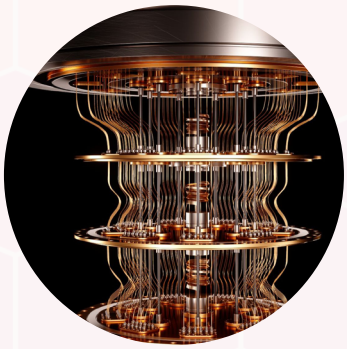
2021 value	1 metropolitan area; 8 nodes
2022 value	15 metropolitan areas; 10 nodes
2023 value	16 metropolitan areas; 10 nodes
2024 value	20 metropolitan areas; 10 nodes
progression/year	x1.5 (metropolitan areas); x1.3 (nodes)
2030 target	25 metropolitan areas; 75 nodes

4. Adoption

Number of Quantum Communication services and/or use-cases that enable commercial adoption for the public as well as private sector.

2021 value	5
2022 value	9
2023 value	10
2024 value	10
progression/year	+2.7
2030 target	30

KPIs
Quantum Computing



1. Performance

The number of unique European quantum computing hardware stack systems/services demonstrating quantum advantage (i.e., outperforming a non-quantum hardware system/service in the solution of the same problem) by an ad-hoc benchmark created for proof.

2021 value	0
2022 value	0
2023 value	0
2024 value	0
progression/year	-
2030 target	3

2. European technical leadership

Largest quantum computing capacity of an EU computing system, based on a European (or alternatively a widely adopted global) benchmark.

a. Circuit size: The largest random N-qubit Clifford unitary gate that can be reliably executed
b. Entanglement: The largest GHZ state successfully prepared and verified by a quantum computer.
c. Factoring: Largest reliable instance of Shor's algorithm.
d. Error correction: Relative reduction of the memory error rate.

	2021 value	*2022 value*	*2023 value*	*2024 value*	*Progression/ year*	*2030 value*
Circuit size:	-	-	*20*	*20*[f]	-	*n/a**
Entanglement:	-	-	*24*	*24*[f]	-	*n/a**
Factoring:	-	-	*15*	*15*[f]	-	*n/a**
Error Correction:	-	-	-	-	-	*n/a**

***Remark**: These KPIs were recently elaborated and work is ongoing to define the targets.

[f] In 2024 a benchmarking method to measure these KPIs was proposed. The values of these KPIs were not ready for the time of the KPI publication.

3. European impact leadership

Quantum algorithms and use cases created with clear impact orientation in basic science, applied science, industries, and the public sector (aligned with the UN and EU 2030 goals).

2021 value	70
2022 value	70
2023 value	97
2024 value	102
progression/year	x1.3
2030 target	500

Remark: Data from QuIC use cases database.

4. Accessibility

a. Compt4a. Number of entities providing public or private access from fully European quantum computing facilities (also based on fully European computing stack) to institutions, academia, research centres and companies.
b. Compt4b. Number of access through the HPC/QCS network, according to the Digital Decade KPI: "Quantum computing measured as the number of operational quantum computers or quantum simulators, inc. as accelerators of HPC supercomputers, deployed and accessible to the user communities."

	4a	4b
2021 value	0	0
2022 value	4	0
2023 value	6	0
2024 value	9	2
progression/year	-	-
2030 target	10	5

KPIs
Quantum Simulation

1. Performance

Number of unique EU quantum simulators (services) outperforming the best-known algorithm running on the best classical computer on at least one relevant real-life computational problem.

2021 value	0
2022 value	0
2023 value	0
2024 value	0
progression/year	+1.5
2030 target	8

2. Increase market adoption

New unique industrial or societal real-life applications (products & services) introduced by EU companies, based on any quantum simulation.

2021 value	0
2022 value	0
2023 value	0
2024 value	0
progression/year	+ 1 by 2026; +3/year thereafter
2030 target	12

3. Performance

Number of available EU quantum simulators (QPU's) providing results that cannot be obtained on available classical computers, about any problem, whose solution creates a clear benefit to academy or industry.

2021 value	-
2022 value	-
2023 value	-
2024 value	4
progression/year	-
2030 target	n/a*

4. Increase market adoption

Number of use cases of relevance for industrial or societal applications, which have been realized on EU quantum simulators. Use cases with no quantum advantage yet but with clear arguments about scalability and quantum advantage of the scaled version are also counted.

2021 value	-
2022 value	-
2023 value	-
2024 value	1
progression/year	-
2030 target	n/a*

5. European technical leadership

The number of qubits or simulated particles of Europe's EU27 most advanced non-gate-based quantum simulator.

2021 value	-
2022 value	100
2023 value	100
2024 value	100
progression/year	x1.9
2030 target	5000

***Remark**: These KPIs were recently elaborated and work is ongoing to define the targets.

KPIs Quantum Sensing and Metrology

1. Market readiness

Number of different (publicly known) product classes or service classes (or use cases) based on quantum sensors developed, implemented and sold by European companies or deployed in the EU.

2021 value	3
2022 value	5
2023 value	6
2024 value	8
progression/year	+2
2030 target	20

2. Next-generation technologies

Number of demonstrated sensing technologies exploiting advanced quantum effects (entanglement, collective coherence etc.)

2021 value	0
2022 value	2
2023 value	5
2024 value	6
progression/year	+0.7
2030 target	7

KPIs
Education

1. Outreach

Establish a successful communication and outreach program to raise awareness of quantum technologies: Number of outreach and training events promoted on the Quantum Flagship website (following the continually updated criteria laid out by the running Flagship Coordination and Support Action (CSA)).

2021 value	7
2022 value	33
2023 value	38
2024 value	122
progression/year	+10
2030 target	100

2. Education

Developing an open-source ecosystem of validated and scalable QT education and training modules: Number of open source, curated (didactically validated) QT education modules accessible via the Quantum Flagship repository.

2021 value	0 (0 validated)
2022 value	20 (12 validated)
2023 value	45 (21)
2024 value	56 (32)
progression/year	+20 (+10 validated)
2030 target	180 (90 validated)

3. Adoption

Pan-European institutional adoption of the competence framework for planning, conducting and evaluating QT educational and training efforts: Number of entities (companies, universities and training institutions such as corporate training and vocational) actively using the competence framework in their workforce development and curriculum development efforts.

2021 value	1
2022 value	17
2023 value	43
2024 value	47
progression/year	+25
2030 target	225

4. Diversity and equity

Fostering structural integration of equity and diversity initiatives into QT education and training: Number of entities (companies and educational institutions) contributing to the coordinated Quantum Flagship efforts following the guidelines developed in the CSAs, reported into the European Quantum Readiness Center (EQRC).

2021 value	0
2022 value	10
2023 value	15
2024 value	18
progression/year	+10
2030 target	90

References

As outlined above, the 2024 values were obtained via survey of the SAB, QCB, QCN and QuIC members. Below we give explanation and reference behind the respective results.

Ecosystem

1. Source: European Commission. See also https://qt.eu/funding-opportunities/.
2. Defined as number of SMEs with QuIC membership.
3. Source: open online KPI survey. Facilities: 1) Quantum Information Technology Testing Facility (QITT), TNO, NL; 2) Istituto Nazionale di Ricerca Metrologica (INRIM); 3) Quantum Technology Competence Center (QTZ); 4) Kavli Nanolab, TU Delft; 5) Nanofabrication lab, MC2, Chalmers University of Technology; 6) CSIC open facility for quantum circuit testing; 7) Commissariat à l'énergie atomique et aux énergies alternatives - Information and Electronics technologies Lab (CEA-Leti, FR); 8) Imec (BE); 9) VTT, Finland; 10) LNE-SYRTE; 11) Centre National d'Etudes Spatiales (CNES) Laboratoire Temps/Fréquence - DTN/TPI/STR; 12) European Space Research & Technology Centre (ESTEC); 13) Münster Nanofabrication Facility (MNF); 14) Paris Saclay – C2N; 15) Fraunhofer Institute for Applied Optics and Precision Engineering; 16) Fraunhofer IAF; 17) Fraunhofer IPM; 18) OtaNano; 19) FinnLight; 20) LENS, Firenze, Italy; 21) Quantum Application Lab (QAL); 22) PSI Zuerich (attached to ETH); 23) Fondazione Bruno Kessler (FBK, IT); 24) Tecnalia (ES); 25) Silicon Austria Labs (AT); 26) International Iberian Nanotechnology Laboratory (INL, PT); 27) Austrian Institute of Technology (AIT); 28) Danish National Metrology Institute (DFM); 29) PITC (Photonic Integration Technology Center, Eindhoven); 30) Fraunhofer IISB, Erlangen (Germany).
4. Data obtained from a survey conducted by QuIC. Target for 2030 derived from the expected growth of the number of companies, see target for KPI Eco2. Also see McKinsey Quantum Technology Monitor, April 2023, section "Global technology progress", p. 50.
5. Data source: QuIC study "A Portrait of the Global Patent Landscape in Quantum Technologies" (Jan 2025), section 2. Percentage of International Patent Families by country of origin: 17% (EU/Total). USA is at 49%.
6. For year 2021, the value is zero by definition. Subsequent values represent the progress with respect to year 2021. Source: open online KPI survey.

Communication

1. Consensus of open online KPI survey for the 2024 value.
2. Comm2A: A. J. Stolk et al., "Metropolitan-scale heralded entanglement of solid-state qubit", Science Advances, vol. 10, issue 44. Comm2B: Achieved with an entanglement-based protocol (BBM92).
3. Consensus of survey for the 2022 value. Connected metropolitan areas: Bristol, Vienna, Graz, Geneva, Cambridge, Cambridge-London, Delft, Poznan-Warsaw, Poznan, Berlin, Madrid, Barcelona, Ostrava, Paris, Padua, Trieste/Rijeka/Postojna/Ljubljana, Madrid, Vienna, Paris, Berlin, Utrecht/Amsterdam, Nice, Padova.
4. IDQuantique, Toshiba & BT, Airbus, Thales, Q-Bird, QO Jena, ThinkQuantum, LuxQuanta (all these entities were partners in the OpenQKD H2020 project), TIM.

Computing

1. Consensus of survey.
2. Quantum Volume: AQTION: 10.1103/PRXQuantum.2.020343. GHZ-state: https://www.aqt.eu/24-qubit-entanglement/. Quantum error correction: arXiv:2312.09745. Shor's algorithm: Science Vol 351, Issue 6277 pp. 1068-1070.
3. QuIC database for Computing and Simulation use-cases.
4. Consensus of KPI survey. Compt4A: EU entities offering access to full-stack systems: PASQAL, Quantum Inspire, LUMI supercomputing centre, AQT, Forschungszentrum Jülich, University of Innsbruck, University of Mainz, IQM, XeedQ. Compt4B: AQT + LRZ, Forschungszentrum Jülich.

Simulation

1. Current examples only work 'in principle', with no real-life problems solved yet.
2. Consensus of the KPI survey.
3. Adler, Wei, ..., Bloch, Zeiher, "Observation of Hilbert-space fragmentation and fractonic excitations in two-dimensional Hubbard systems" arXiv:2404.14896; Wienand, Karch, ..., Aidelsburger, Bloch, "Emergence of fluctuating hydrodynamics in chaotic quantum systems", Nature Physics, 1-6 (2024); M. Ringbauer, M. Hinsche, T. Feldker, P. K. Faehrmann, J. BermejoVega, C. Edmunds, L. Postler, R. Stricker, C. D. Marciniak, M. Meth, I. Pogorelov, R. Blatt, P. Schindler, J. Eisert, T. Monz, D. Hangleiter, "Verifiable measurement-based quantum random sampling with trapped ions", Nature Comm. 16, 106 (2025); Joshi, Kokail, van Bijnen, Kranzl, Zache, Blatt, Roos, Zoller, "Exploring large-scale entanglement in quantum simulation", Nature 624, 539 (2023).
4. L. Leclerc at al., "Implementing transferable annealing protocols for combinatorial optimisation on neutral atom quantum processors: a case study on smart-charging of electric vehicles", https://arxiv.org/abs/2411.16656.
5. PASQAL / MPQ-LMU Munich for the 2022, 2023 and 2024 value.

Sensing & Metrology

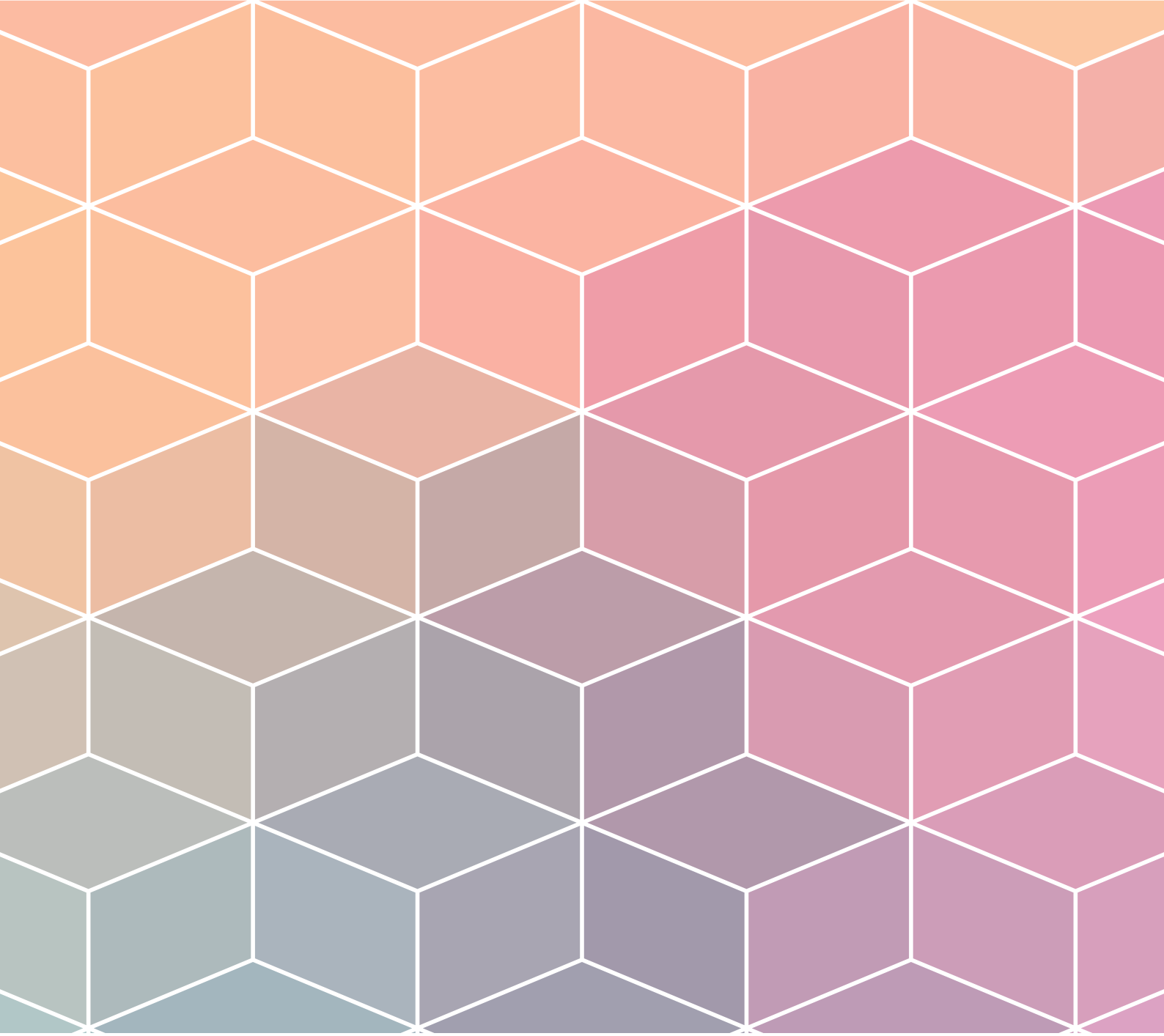
1. Optical atomic clocks; cold-atom gravimeters; NV-centre magnetometers; superconducting single photon detectors; NV-centre in diamond for signal frequency measurements; Non-destructive testing for metal defect detection; quantum gravimeter for archaeology; quantum gravimeter for volcanology.
2. Consensus of survey: Subshot-noise imaging, NV Centres, Quantum Optical Coherence Tomography, Quantum Imaging, Laser threshold magnetometry, hyperpolarisation of natural metabolites for MRI.

Education

1. QTEdu (https://qt.eu/events/?q=&tags%5B%5D=education-outreach).
2. QTEdu (https://qt.eu/events/?q=&tags%5B%5D=education-outreach) and QURECA (https://platform.qureca.com/courses/).
3. TU Delft; U Helsinki; TU Braunschweig; PTB; Qureca; Airbus Space and Defense; Auantum Investor Mentorship Programme; Aarhus University; ICFO; CTU Prague; Science Melting Pot; University of Pisa; Quarks Interactive; University of Barcelona; Instituto Superior Técnico; RWTH Aachen; University of Strasbourg; Copenhagen University; Danish Technical University; Utrecht University; FAU Erlangen-Nürnberg; TU Dresden; University of Pavia; CNR; University of Ljubljiana; UC Limburg; The Hebrew University of Jerusalem; Copenhagen University; University of Twente; ICN2; Heidelberg University; U. Paris Saclay; Centrale Supelec; Ecole Normale Superieure; Barcelona University; LMU Munich; TU Munich; University of Troyes; Sorbonne University; PQI - Portuguese Quantum Institute; Deloitte; IST Lisbon; QTLabs.
4. ICFO; CNR; Switzerland; QURECA; University of Paderborn; CSIC; University of York; Forschungszentrum Jülich; PQI – Portuguese Quantum Institute; Spanish Foundation for Science and Technology; Technical University Braunschweig; Leibniz University Hannover; University of Barcelona; RWTH Aachen University; Science Melting Pot; University of Amsterdam; VDI; TU Delft.

Notes

The 2030 targets for the KPIs Quantum Communication 2B, Quantum Computing 2, Quantum Simulation 3 and 4 are currently under review.



QUANTUM FLAGSHIP

European Commission

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