Quantum Ahead

An Overview of Strategic Leverages for Quebec's Leadership in the Quantum Industry

BY VOLUME10

Findings, insights, opinions and recommandations presented in this document are solely those of VOLUME10 and do not necessarily reflect the positions of Distriq and its partners, which implication in this document were limited to its financing and a counselling role.

Quantum

OCTOBER 2025

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Table of contents

Methodological Note

In the context of this study, the quantum industry encompasses all of the players—scientific, manufacturing, financial and governmental—that contribute to the development, structuring and marketability of technologies based on the principles of quantum mechanics and envisioned for computing, communication, sensing and simulation purposes. It includes fundamental research, technological platforms, manufacturing infrastructures, specialized businesses, training resources and coordination instances.

The study looks more particularily at Quebec's stance on the national and international stages. It identifies its specific strengths in the ecosystem (research, talents, infrastructures), underlines the go-to-market hurdles, presents relevant external examples, and suggests possible actionable levers for governments, academia, research centres, businesses and investors.

Data for the study has been garnered from cross-referenced sources. A review of different national strategies from various jurisdictions (in North America, Europe and Asia) enabled the depiction of what would be winning conditions at the international level. Sectoral analyses were conducted with the help of internal documents and publicly available information (research, training, financing). Additionnaly, about 60 semi-supervised interviews were also conducted with researchers, business people, public administrators, investors and final users.

Findings and recommandations were established with the help of a partnership committee, comprised of five governmental ministries and agencies, the city of Sherbrooke, researchers, industry representatives and other key players of the quantum ecosystem. This collaborative effort made possible the validation of study's observations, the adjustment of stated priorities and the outlining of realistic, engaging and actionable guidelines for the future.

Project Partners

The content of this document is based on a previous study mandate (*Étude de positionnement de l'industrie quantique au Québec et plan d'actions gouvernemental*) commissioned by the city of Sherbrooke's Distriq Quantum Innovation Zone, with the financial help of eight other partners involved in the development of Quebec's quantum ecosystem:

- Association de l'industrie électrique du Québec (AIEQ)
- Distriq, Zone Innovation Quantique de Sherbrooke
- Institut National d'Optique (INO)
- Investissement Québec
- Next Generation Manufacturing Canada (NGen)
- PINQ² – Quebec Digital and Quantum Innovation Platform
- PRIMA Québec – Advanced Materials Research and Innovation Hub
- Prompt government agency
- Ville de Sherbrooke

The present study could not have been successfully carried out without the expertise and engagement of many contributing parties. Its in-depth analyses attest to the vitality of Quebec's quantum ecosystem and the collective drive of its shareholders to bring it to future fruition.

A special thanks to Christian Sarra-Bournet, Director, Quantum Strategy, at the Université de Sherbrooke and Executive Director, Institut quantique—who has been instrumental in the guidance of the study's content—, and to the members of the pilot committee for their time and involvment in the project.

These organizations as a whole deserve our heartfelt gratitude for their trust, collaborative spirit and common will to favourably position Quebec as a strategic player in the global quantum arena.

Quebec's Quantum Bet

Every person who has seen the advent of the Internet in their homes, the dissemination of mobile, then smartphones and, more recently, the arrival of artificial intelligence, can vouch for the transformational effect of technologies—in a matter of a few years—on our lives, activities and societies. These revolutionary advances have engendered whole new industries that have reshuffled the global economics and redefined our relationship with our living environment.

And we now see many people speculating on what will be the next big thing to disrupt our future existence. One hopeful candidate for this title is a scientific field which was brought to life in the earlier half of the 20th century, but is just now showing some promising industrial applications: quantum physics.

Albeit representing a major technological leap forward, quantum physics should be seen as a profound thought rupture, capable of reimagining how we comprehend, model and govern our physical world. This revolution articulates itself through three pillars of purpose: in the field of computing—with exponential calculating power to conquer the most complex equations—, the field of communication—through the advent of fully tamper-proofed networks—, and the field of detection and sensing—with a measuring precision previously unimaginable.

And not to mention, a potentially considerable economic impact. This budding industry has the ability to transform a broad spectrum of sectors—health, energy, finance, defence and many more. Quantum computers will enable the design new simulation and optimization tools, predict with accuracy the spreading of epidemics, systemically channel traffic in real time, speed up the development of new drugs and materials, and further new and innovating ways to adapt to climate change.

Admittedly, many major obstacles have yet to be navigated before aspiring to a true industrial deployment. Error correction, qubit stability, system scaling—just a few examples of boulders that will require patience, hefty investments and technological risk tolerance before they can be put aside.

Yet, we can already assert that Quebec has enough aces up its sleeve to become an internationally-envied quantum hotbed. Thanks to its respected scientific leadership, a cluster of startups amounting to more than a third of all Canadian quantum business initiatives, and world-class research infrastructures, Quebec is ahead of the pack.

To transform the quantum postulate into tangible economic results, we must overcome some historical challenges: difficulty to evolve research achievements into commercial successes, tendency to let our talents migrate abroad, and general unease with, and acceptance of technological risk-taking and fails—a essential condition to realizing disruptive innovation.

We must also accept that Quebec cannot go it alone in this global race. The financial and human resources needed far exceed our isolated capacities, yet our unique expertise puts us in a perfect spot to make strategic alliances and define global standards. This does imply some risk-taking when establishing partnerships with Canadian or foreign entities, especially in the current geopolitical turmoil.

Akin to the AI revolution, these endeavours will bring their share of ethical issues, which will obviously need to be dealt with.

The potency of our ecosystem, paired with the will of both provincial and federal governments, can propel us at the forefront of the game, if all involved parties work side by side and have the mettle to implement bold strategic decisions. Some of these may prove to be worthless, but this is a given when you want to explore new frontiers.

Quantum reality is no longer a distant promise; it's a race that's well underway, and where Quebec's favorable position has to be protected and extended. The stake is not only to lead, but not be left behind when others make major strides. Knowing that quantum technology will redefine competitiveness, status quo could spawn lasting dependancy for Quebec. Investing now gives us a strategic shot at technological sovereignty and clout for the coming decades.

VOLUME10 is proud to unveil this position paper on Quebec's quantum industry, the result of eight months of collaborative exchanges between more than 50 subject matter experts. This study, brought about with the steadfast help of Distriq and its partners, delineates a common and daring objective: to make Quebec's quantum know-how a source of prestige and prosperity.

– VOLUME10

Glossary

Fundamental Principles

Superposition
In quantum mechanics, a particle can be perceived in multiple states at the same time (position, energy, polarization).

Entanglement
When one of two linked (or entangled) particles is modified, the other is intantaneously affected, no matter their distance apart.

Coherence
The ability of a quantum system (for instance, a qubit) to maintain its superposition or entanglement without being disturbed by its environment.

Interference
The phenomenon where multiple, superposed quantum states interact with each other, sometimes combining or canceling themselves according to their phases. This fundamental notion in quantum algorithmics enables to amplify or eliminate certains results.

Components and Architecture

Physical Qubit
The physical medium where quantum information is stored, based on two superposed and entangled states.

Logical Qubit
A stable unit of information, established from error-corrected physical qubits.

Connectivity
A series of qubits able to interact together while maintaining coherence.

Algorithms and Computing

NISQ (*Noisy Intermediate-Scale Quantum Computer*)
A quantum gate, noise-affected computer that uses hybrid algorithms and that is not error-corrected.

Quantum Advantage
The advantage provided by a quantum computer (over a standard one) when processing a specific problem,

Quantum Supremacy
The ability of a quantum computer to resolve, within a reasonable amout of time, a problem that is unsolvable for a standard computer

Error Correction
A technique to protect and safeguard quantum information against decoherence and noise.

Error Mitigation
The methods used to reduce partially corrected errors (ex. extrapolation, suppression).

Fidelity / Error Rate
The metric that determines the level of accuracy of a quantum result (99% fidelity indicates a 1% error rate).

High Performance Computing (HPC)
The use of supercomputers or server clusters to perform intensive, high-speed number crunching.

Cybersecurity

Quantum Key Distribution (QKD)
An encryption method that uses quantum mechanics properties to communicate encryption keys in an entirely secure way.

Post-Quantum Cryptography (PQC)
Any cryptographic algorithm operating on a standard computer that can withstand quantum computer attacks.

Applications and Perspectives

Industrial Application
The ability of a quantum-based invention to be used and produced at an industrial level (services, agriculture, etc.).

Fault-Tolerant Quantum Computer (FTQC)
A universal, error correction-enabled quantum computer capable of running complex algorithms.

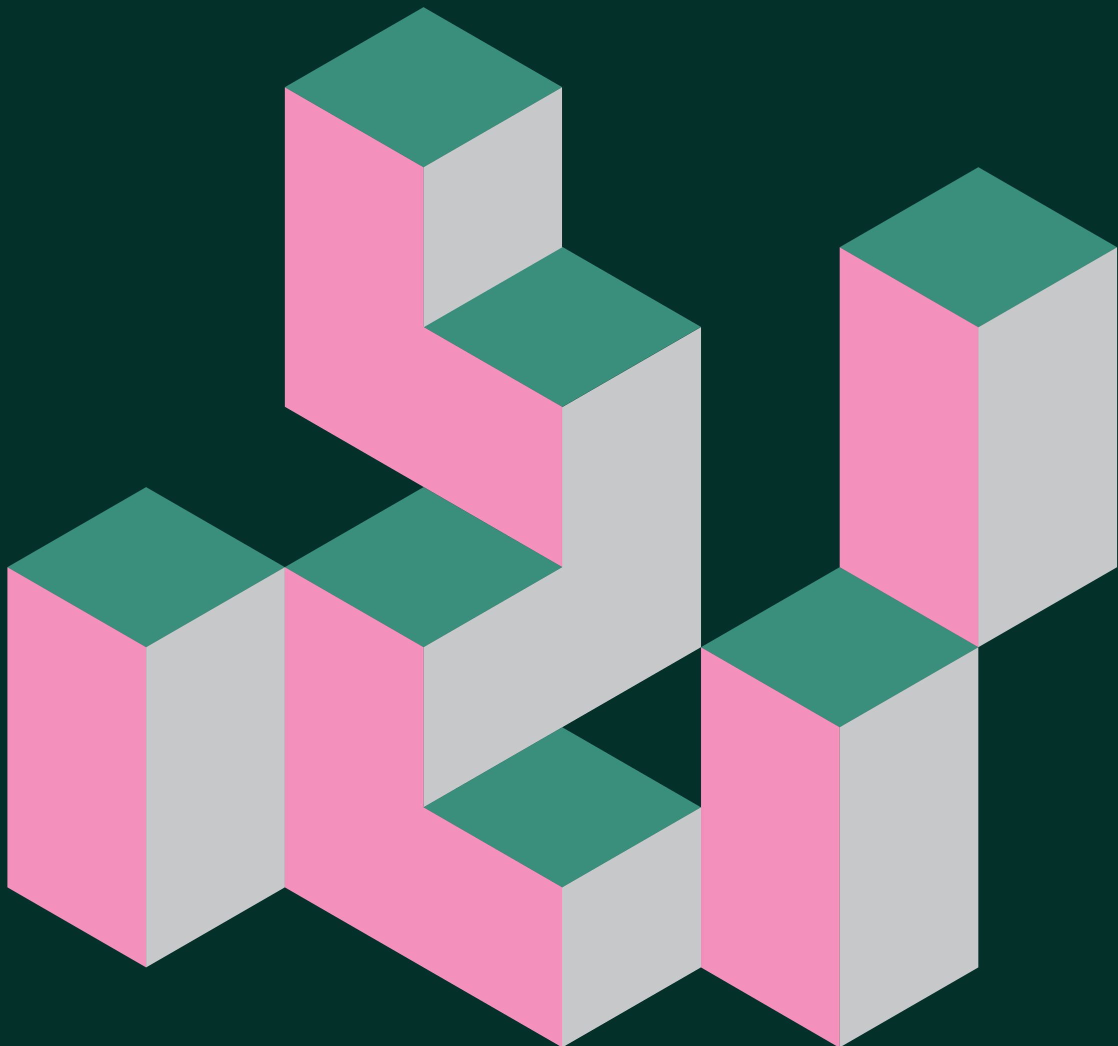
VLSQC (Very Large Scale Quantum Computer)
An FTQC equipped with thousands of logical qubits in order to operate industrially-usable algorithms.

Fundamentals of the Quantum Realm

and Evolution Scenarios

Solvay Conference, Brussels, 1927
This annual conference, which gathered some of the world's most celebrated physicists of the era, marks a key milestone in the history of quantum mechanics. Einstein, Bohr, Heisenberg, Schrödinger, Dirac and Pauli are among the many pioneering scientists debating foundational issues.

Photo from Science & Society Picture Library via Getty Images



Quantum physics describes how matter and energy behave at a scale where normal laws of physics cannot explain what is being observed.

It brings in notions such as superposition, entanglement and interference to illustrate various states and probabilistic dynamics.

This acute understanding of the unfathomably minute universe has already enabled major technological breakthroughs—many already present in our modern realm, such as lasers, GPS, medical imaging devices or graphic processing units.

Today, it constitutes the developmental foundation of a series of arising technologies regrouped around the "quantum sector " designation. These have brought about new ways of observing, computing, transmitting and measuring in the realm of highly-complex scientific conundrums.

The quantum sector encompasses all the technologies that mobilize this new physics for the advent of tangible devices. It includes notably quantum computing—and computers, which exploit the capacities and simultaneity of states of qubits. This approach offers a gateway to complex system simulations and resolution of optimization issues that are presently unattainable.

The improvement of these devices rests on the capacity to achieve stability in qubits. The resulting "logical" qubits start up as noisy physical qubits, which are actively error-corrected to shut out decoherence. At the present time, only a few prototypes have demonstrated this capacity, but progress is steadily speeding up.

The sector also embraces quantum communication, where secure data transmission becomes an intrinsic part of the process. Quantum detection is another promising field, where improved sensing potency will surely be a boon for medical imagery and inertial navigation.

Those three axes—computing, communication and sensing—are evolving at different rates, but share a common requirement in order to access their new possibilities: mastering the quantum behaviour of matter.

Despite the present-day limits in terms of system stability, the costly infrastructures and the varied levels of maturity of applications, the sector is nonetheless progressing rapidly. Industry roadmaps are better defined, investments are multiplying, and many use cases are starting to engender small-scale demonstrators.

The quantum realm is ostensibly governed by a sluggish cycle of innovation, where research progress, establishment of a purpose-built ecosystem and strategic commitment from public and private shareholders have decisive roles.

The quantum prospect goes far beyond the advancement of existing technologies: it puts forth a novel way of contemplating, exploring and acting on our physical world. In this capacity to reinvent our toolbox of understanding and intervention lies its true structuring potential.

Quantum physics has been studied for more than a century and has produced a bevy of current technologies; and it now fosters a wave of radical innovations.

The theoretical bases of quantum physics have been established at the start of the 20th century, when it was discovered that light and matter behave not only as particles, but also as waves. The furthering of research on the latter part of the century brought up the invention of practical tools to exploit these properties—think of lasers, transistors and medical imagery. This is seen as the maiden quantum revolution, with the mastery of its effects, but without direct manipulation of quantum information.

A second revolution got underway in the 1960s, with the ability to control individual quantum systems. Shor's algorithm caused a definite stir by demonstrating that, for instance, factorization of large numbers could be achieved much more rapidly with quantum machines. Since then, various ventures have started to actively develop experimental devices, many of them in Canada.

(1900-1930) **Theoretical Bases of the Quantum Revolution**
Somes Key Discoveries

(1913)	**Planck, Einstein, Bohr, Heisenberg, de Broglie**	Light behaves not only as a wave, but also as a particle.
(1926)	**Schrodinger**	According to the wave equation, an electron's position evolves in time.
(1936)	**Turing (universal computation model)**	Computing operations can be executed according to a mathematical model that sequences the problem in easy steps.

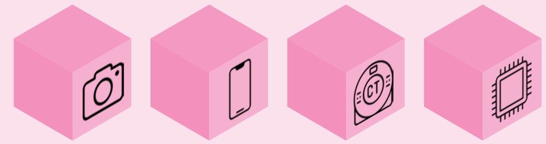
In 2025, the Turing test remains a reliable benchmark in assessing if a machine showcases human-like intelligence. Some yet-to-be validated studies suggest that language models like ChatGPT's have achieved such an ability.

(1930-1980) **First Quantum Revolution**

Development of technologies based on the manipulation of groups of quantum particles

Ex.: Nuclear fission, hard disks, transistors, lasers, optical fibre, GPS, medical imagery, digital photography, etc.

In 2025, a majority of everyday technologies are based on principles originating from quantum physics.



(Since 1980) **Second Quantum Revolution**

(1990) **Shor's Algorithm, sparking a broader interest in quantum computation**

It enable factorization of large numbers, therefore challenging the safety of prevailing encryption systems.

The majority of cybersecurity systems are founded on RSA encryption. It is believed that one day—nicknamed "Q-Day"—, quantum computers will be able to crack this widely-used coding technique. Though a prospective schedule for this day remains fuzzy, anxiety is on the rise, and preparedness levels vary depending on the country or sector.

(2011-2012) **Two Canadian companies have played a pioneering role: D-Wave, with the advent of the first commercialized quantum annealer, and 1Qbit, the first business specializing in quantum softwares.**

(2014-2025) **Arrival and positionning in the quantum arena of the major US tech giants—with noticeable fanfare.**

IBM — IBM Q System One (2019)
Google — Suprématie quantique (2019)
Plateforme Willow (2024)
Microsoft — Processeur quantique Majorana 1 (2025)

W. Hurley, *Quantum Computing for Dummies*; M. Kaku, *Quantum Supremacy*; B. Clegg, *30-Second Quantum Theory*; Cornell University; The Wall Street Journal; VOLUME10 (research, analyses and interviews)

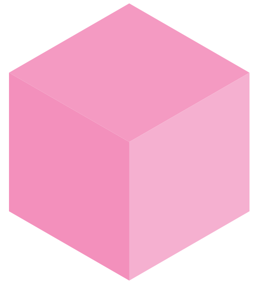
The development of the quantum realm faces scientific, technical and economic limitations. But history has shown that most disruptive technologies eventually manage to reach maturity.

That development is progressing at a steady pace, in spite of unyielding problems such as system stability, error correction and lack of maturity of use cases. Upbeat signs are multiplying: continued improvements of qubits, strenghtening of material platforms, emergence of specialized software tools. And although large-scale applications are few, interest from investors, governments and large technological groups remains high.

In the medium term, the onset of the first usable quantum advantages in targeted scenarios may act as the desired impetus to accelerate industrial efforts and shape up new market segments. Many experts express that immediate disruption of our daily lives is an unlikely scenario, though quantum solutions will have a boosting effect of other disruptive technologies.

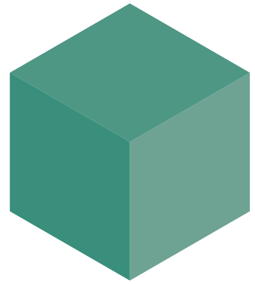
First in line to benefit from this windfall will be applications in the fields of optimization, advanced simulation, high-tech materials and cybersecurity. This evolutive trajectory calls for pragmatism and patience but also eager proactivity, in order to readily establish the bedrock of an ecosystem able to fully reap the future blessings.

Presently, development of the quantum realm is held down by strenuous constraints…



Scientific Challenges

- Qubit instability
- Errror correction still at experimental stage
- Immaturity of quantum algorithms



Technical Challenges

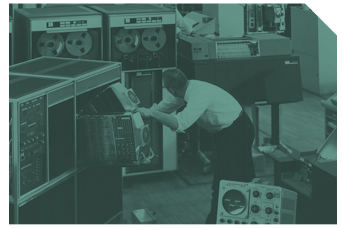
- Scability (number of qubits, cryogenics, control electronics)
- Manufacturing reproducibility of equipment (scarcity of existing standards)
- Hardware-software integration

Financial Challenges

- Sparse use cases, often barely validated
- Steep cost of infrastructures
- Lack of patient capital
- Meager availability of skilled labour

… But history has shown that, sooner or later, we have the capacity to adopt new technologies.

Technological Maturation Assessment –
From Theory to Large-Scale Commercial Distribution



Common computers

~45 years

(Turing → First PC by IBM)

Telecommunications

~120 years

(Maxwell → First commercial cellular network by AT&T)

Artificial Intelligence

~65 years

(Turing → AlexNet)

W. Hurley, *Quantum Computing for Dummies*; *Medium*; Quantum Algorithms Institute (QAI); *Dallas Innovates*; *IEEE Spectrum*; The Boston Consulting Group; *Sciences et Avenir magazine*; VOLUME10 (research, analyses and interviews)

Most of the time, the notion of quantum is symbolically represented through the image of the quantum computer.

Often seen as the poster child of the quantum revolution, the quantum computer is based on the management of qubits and their ability to exist in simultaneous states. This characteristic theoretically allows for more efficient calculations than what a mainstream computer could acheive, notably for the simulation of complex systems or for combinatorial optimization.

Present-day quantum machines remain hindered by digital noise, shortness of coherence and the absence of error correction. Consequential efforts are focused on the realization of logical qubits, which showcase more stability and better fault tolerance.

Further down the road, the goal is to create large-scale quantum computers, capable of running industrial-use algorithms for targeted purposes.

Quantum computers are not supposed to replace mainstream computers; they're meant to work in parallel in differenciated contexts.

For instance, in order to resolve a highly complex problem, the quantum computer can lower the number of possible solutions, then let the standard computer determine the final outcome.

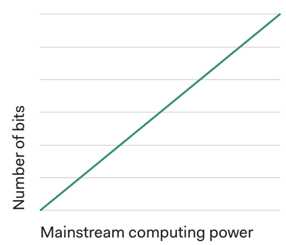
Feature comparison between mainstream and quantum computers

Mainstream computers

- Unit of information: bit
- Bits can either have one of two values, identified as 0 or 1

0 • • 1

A **standard computer**'s computing power is directly related to its number of bits: the higher the bit count, the higher the power.



Fully-matured technology with low error rate

Cost-efficient, low price

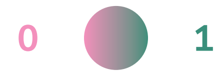
Can operate at room temperature

Competency for general computer applications (e-mails, word processing, graphic design, Web browsing)

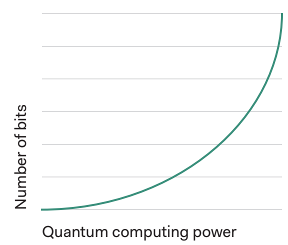
Slow computing speed when dealing with complex/disorganized large data bases

Quantum computers

- Unit of information: qubit
- Qubits may have two values—0 and 1—at the same time, all the time.



Due to the nature of qubits, a **quantum computer**'s computing power is exponential: the higher the qubit count, the higher the multiplying effect on its power.



Newly-appeared technology with error rate still high

Forbidding cost

Requires specific envrionmental conditions (temperature, pressure) to properly operate

Slow and unefficient with simple computing tasks

Drastically quicker in the context of unstructured problems, deep analysis and multiple scenarios

Quantum Computing for Healthcare: A Review (published in *Internet of Things (IoT) for Smart Living and Public Health*); McKinsey & Company; *Sciences et Avenir* magazine; VOLUME10 (research, analyses and interviews)

Five main qubit technologies are being developed concurrently: superconductor, trapped ion, photonic, neutral atom and spin electronics.

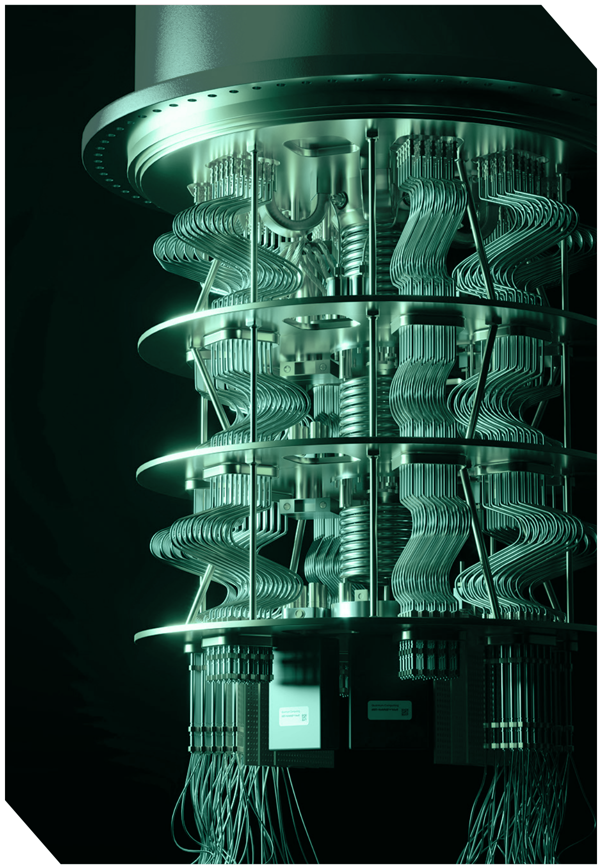


Photo: Planet Volumes

Considering that rivalry dynamically improves the breed, each is competing for universal adoption in the evolution of quantum computers. This said, it is expected that these diverse approaches are likely to combine, rather than exclude each other. The future of quantum computing may well rely on a multi-platform recipe, where various types of qubits will collaborate according to the use case.

(2025) Types of qubits, with respective levels of global investments

Type (Amount in $ US invested in March 2025)	**Description**	**Involved industry players**
Superconducteurs (*including transmons* $ 2,372M	Energy difference between two states of a Cooper-pair in a Josephson junction	IBM, Google, Rigetti, OQC
Trapped Ions $ 1,623M	Internal energy levels of ions trapped by electromagnetic fields	IonQ, Quantinuum, Alpine Quantum
Photonics $ 1,362M	Modal occupation in a photonic waveguide network	PsiQuantum, Xanadu, INRS
Spin Electronics $ 293M	Spin of electrons trapped in a semiconductor dot (ex. silicon dot) with the help of a laser or microwaves	Intel, Quantum Motion, Delft University
Neutral Atoms $ 145M	Internal energy levels of neutral atoms trapped in laser fields	Pasqal, QuEra, ColdQuanta
Topological N/A	Leverage of non-local states of topological excitation,(theoretically resistant to errors)	Microsoft (in R&D), StationQ

W. Hurley, Quantum Computing for Dummies; McKinsey & Company; Crunchbase; PitchBook; VOLUME10 (research, analyses and interviews)

The possibilities offered by quantum mechanics go far beyond the sole field of computing.

The three branches of quantum technologies

Quantum computing

Creating a new blueprint in computer science, based on the laws of quantum physics

In Details

Envisioning **significant performance gains in resolving certain types of problems.**

Ability to produce with enhanced precision **mock-ups of complex systems**, materials, chemical reactions, protein structures, financial portfolios—for an improved comprehension.

Potential Use Cases

- Real-time optimization of distribution / energy storage networks
- Creation of catalysts capable of decarbonizing the production of fertilizers

Quantum communication

Enabling the transmission of quantum informations while preserving their quantum state—making possible the advent of highly-secured communication protocols

In Details

Quantum communication networks
Capacity to transfer quantum information between quantum devices (computers, sensors) in a coherent and secure fashion.

Cybersecurity
Quantum Key Distribution (QKD): use of quantum networks to transmit tamper-proofed keys.

Post-quantum cryptography: upgrade of classic algorithms for protection against quantum attacks without the use of quantum technologies.

Potential Use Cases

- Enhancement of communication security in the financial sector or for critical public infrastructures (ex. hydro dams)
- Upgrading of quantum computers to augment computational performances (interelated data centres)

Quantum sensing

Thanks to the quantum properties of matter, capacity to detect infinitesimal variations in physical systems and their associated environments

In Details

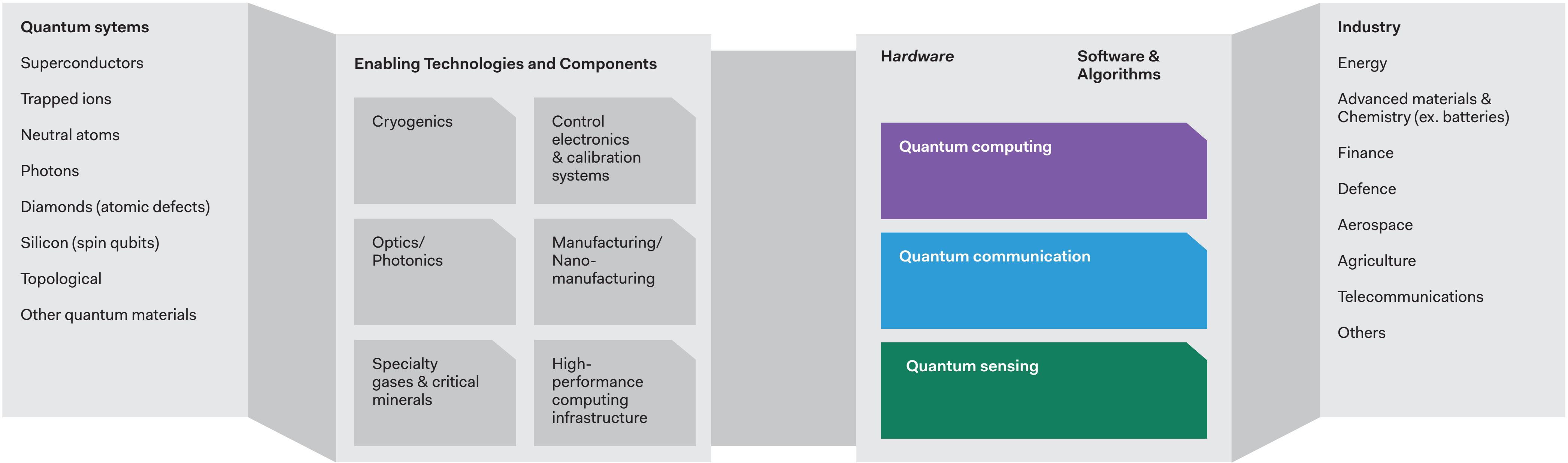
Envisioning through quantum behaviours (such as entanglement and superposition) extreme measurement accuracy for phenomenons such as magnetic fields, gravity and time.

Potential Use Cases

- Quantum magnetometer capable of detecting metal objects from very large distances
- Gravitometer to map underground features (caves systems, water tables, etc.)

W. Hurley, Quantum Computing for Dummies; CEA Y.SPOT; Futuribles; McKinsey & Company; VOLUME10 (research, analyses and interviews)

Development of the quantum industry relies on an extensive value chain, which includes enabling technologies, specialized components and adapted infrastructures.



Good to know: Enabling technologies

The advancement of quantum technologies summons up many knowledges and infrastructures that exist outside of the quantum realm. Cryogenics, photonics, specialized manufacturing, high-performance computing are all enabling technologies positioned at the crossroads of various and strategic value chains. Sustaining these non only promotes the emergence of a true, nationwide quantum capacity, but also fosters the growth of other sectors such as microelectronics, artificial intelligence, health and energy.

And when it comes to investing, this interdependency calls for a cross-sectional vision; quantum-enabling decisions can have a structuring impact on larger technological ecosystems and generate long-term ripple effects.

	Benefit of enabling technologies for the quantum industry	Others domains benefiting from these technologies
Cryogenics	Enables basic stability conditions for qubits	• Energy (ex. liquefied natural gas) • Health/Medical (MRI) • Aerospace (propulsion, fuel storage)
Optics/Photonics	Essential for scaling quantum networks, reducing data loss and miniaturizing components	• Artificial intelligence • Health/Medical (imagery) • Defence
Manufacturing/ Nano-manufacturing	Qubit performance depends directly from purity and structuring of materials (defect = decoherence)	• Microelectronics • Integrated circuits • Biosensors/Embedded sensors
Specialty gases & critical minerals	Required for particular quantum manufacturing processes (ex. qubits, thin layering, etc.)	• Semiconductors • Defence • Energy
High performance computing infrastructure	For simulating, correcting and interfacing hybrid systems (quantum/ non-quantum)	• Data processing / AI • Finance • Climatology

Case study: Netherlands

Through a €615M public investment, Quantum Delta NL is in charge of implementing Netherlands' quantum strategy. It prioritizes the manufacturing branch in order to structure its ecosystem and generate economic value.

Enabling technologies are being **co-developed and tested** through start-up and final user experimentation, supported by a **localized and agile value chain that's focused on industrial needs.**

Quantum Delta NL

Case study: Finland

Bluefors demonstrates how investing in a single, specific element of the quantum value chain can produce strong economic value. By zeroing in on the domain of cryogenics—a key enabling technology—, the Finnish company has become an essential strategic supplier at the international level, with more than 1,250 dilution refrigerators sold and revenues of €200M.

Its niche positioning and expertise has carved out a unique, but also cross-sectional slot in the industrial ecosystem.

BLUE FORS

Quantum Delta NL, Bluefors ; VOLUME10 (research, analyses and interviews)

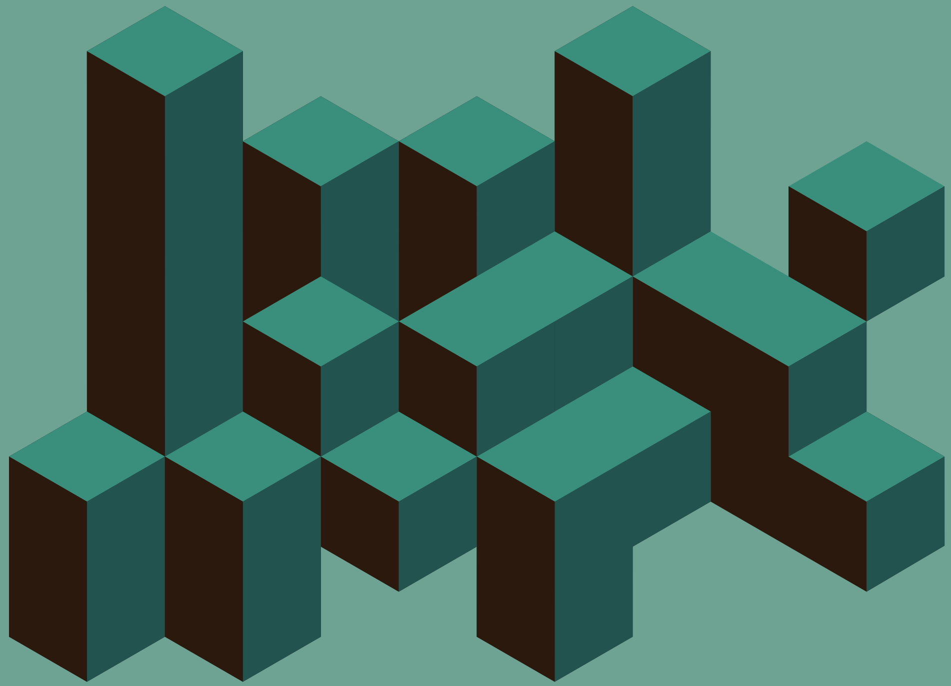
Good to know: Artificial intelligence

Artificial intelligence and the quantum realm may have their own developmental trajectories, but their forecasted intersection is closely followed. AI is enabled by its capacity to process large amounts of data and extract coherent results for modeling and decision-making. Meanwhile, quantum science explore solutions that remain hard to reach with mainstream approaches, notably in the context of molecular simulation, combinatorial optimization and cryptography. Pairing them opens up new and targeted applications, for instance in the field of precision medicine, supply chain management and particular energy systems.

At the present time, this complementarity is at an investigatory level. The current quantum systems are not able to train AI models on a large scale, but could provide some help in the context of complex (but restricted) data sets. Concurrently, AI is being leveraged to boost the efficiency of quantum devices, especially when it comes to calibration, stabilization and pilot experimenting.

The takeaway here is that this joining of forces will not happen overnight. It will rather develop into a technological cohabitation that may, in the long run, contribute to the advent of new computational capacities, accelerate exploratory phases and promote the diversification of usages in strategic domains.

Nuances	Aritificial intelligence	Quantum technologies
Core of the technology	Algorithms driven by standard computers	Material and physical technologies (and softwares)
Foundational sciences	Statistics, probabilities and applies mathematics	Fundamental physics, quantum mechanics, linear algebra
Computing hardware	Depends on traditional HPC for training	Requires specialized hardware (qubits, control systems, etc.)
Uses	Larger number of marketable applications	Experimental or nascent



Myths	Reality
Quantum power will solve AI's big data blockage issue.	Quantum technologies are ill-adapted when processing large sets of data. Their potency lies more in dealing with small volumes of complex structures—more difficult to figure out with traditional computing.
AI and quantum computing are naturally compatible and easily combined.	Quantum computers are not yet capable of training AI models on a large scale. Quantum AI is being experimented on and shows no edge over prior technologies.
AI will take over quantum technologies by optimizing the resolution of comparable inquiries.	Some issues—for instance, with combinatorial optimization and quantum systems simulation—represent a hurdle for present-day AI, which cannot foray into the same areas of exploration as quantum does.

W. Hurley, *Quantum Computing for Dummies*; Quantum Insider; IEEE Spectrum; McKinsey & Company; VOLUME10 (research, analyses and interviews)

At the present time, the quantum sector development is still meandering. But even though its roadmap remains fuzzy, it may still end up being a formidable technological leap forward.

Quantum computing is still at an exploratory stage known as the “NISQ era” (Noisy Intermediate-Scale Quantum). Today’s unstable devices are essentially testbeds for quantum architectures and try to evaluate the potential reach of different use cases. Immediate applications may not crop up at this stage, which more probably serves as a transitional period leading us toward more fault-tolerant machines.

Uncertainty remains as to when fully-reliable quantum computing will materialize, even though recent developments may lead us to believe that this day may come sooner than envisioned. Consequently, the main question is not to predict the when, but to know who’s ready to seize the moment—by staying up-to-date on progress, upscaling competencies and optimizing preparedness and agility when the proverbial push will come to shove.

Good to know: Today’s qubits are easily upset by the variations in their environment (temperatures, vibrations, electromagnetic fields). This “noise” has a destabilizing effect which engenders computing errors; until this nuisance is suppressed, results will have to be monitored and/or deemed as debatable.

A number of experts have been stunned by the recent pace of quantum development

During an interview with Sciences et Avenir magazine, 2022 Nobel prize winner in physics Alain Aspect was asked if he had imagined, when working on quantum phenomenons decades ago, that it would lead to all of this. He answered : “Absolutely not!”

(2024 surveys)

Experts’* views on potential milepost for various quantum accomplishments
% of experts agreeing on indicated milepost date/year

	2032	2042	2050+
Very Large Scale Quantum Computing (VLSQC) > 100 logical qubits Error rate < 10^{-12}	15 %	54 %	93 %
Fault-Tolerant Quantum Computing (FTQC) < 100 logical qubits Error rate < 10^{-12}	50 %	81 %	96 %
Quantum computer able to break RSA encryption	20 %	65 %	79 %

The notion of fault-tolerant quantum computing is associated with “practical” computers and enables industrial use cases.

* Number of experts consulted (from industry and academia, worldwide): 18 for quantum computing accomplishments, 32 for RSA encryption.

50% of interviewees predict the advent of FTQC in 2032

Fault-tolerant quantum computing will enable the dependable operability of complex algorithms, hence revolutionizing molecular simulation (for the discovery of new drugs), new material development, financial portfolio optimization or energy network management.

65% think that a quantum computer will “crack” RSA coding by 2042, followed by the true advent of Large Scale Quantum Computing.

Modern encryption practices are mostly based on RSA cryptography, an asymmetric system where a public key mixes up data and a private key then unscrambles it. Its safety attributes are due to the fact that traditional computers have a hard time factorizing large numbers—something that would prove to be effortless for a quantum computer, thanks to Shor’s algorithm.

Ex.: When shopping online, the buyer’s data is encrypted with a public key, then can only be read by the website’s private key.

Global Risk Institute ; evolutionQ ; CEA/Y.Spot ; Futuribles ; Sciences et Avenir ; M. Kaku, Quantum Supremacy ; VOLUME10 (research, analyses and interviews)

Quantum computing, communication and sensing will evolve at different speeds and unequal levels of unpredictability.

Technology Readiness Level (TRL)

TRL 1-2
Fundamental research

TRL 3
Technological concepts

TRL 4-6
Prototyping, testing, validation, Minimum Viable Product (at TRL 6)

TRL 7
Pre-marketing phase

TRL 8-9
Implementation & Go-to-market

1 2 3 4 5 6 7 8 9

Quantum computing

Quantum computing is presently at the lowest readiness levels, but has potentially the highest disruptive power. Some industry players are betting on the coming of fault-tolerant computers with elevated TRLs by 2030, opening the door to prominent use cases.

Some stakeholders are touting high TRLs by 2030

Note
Each year, the main stakeholders in the quantum realm adjust their game plan toward fault-tolerant computing and communicate their own updates and news. These releases often underline real progress, but their purpose may also be to favorably stir up the market and media interest. One must therefore decipher them accordingly, to determine if their message is truly noteworthy or just a showy spectacle.

Quantum communication

A number of communication use cases have reached noticeably higher TRLs than computing cases.
In the mid- to long term, and despite a fragmented ecosystem, institutional alignment and a clearer roadmap could more rapidly lead to marketability compared to quantum sensing eventualities.

High readiness could be achieved one requirement at a time: quantum securement first, quantum Internet further down the road

Quantum sensing

Apart from a good number of demo cases, a few products have reached high TRLs , but the offer remains fragmented.
Short- to mid term, the lack of alignment with market needs holds back go-to-market feasibility.

Reaching higher TRLs is reined in by the inability to commercialize solutions

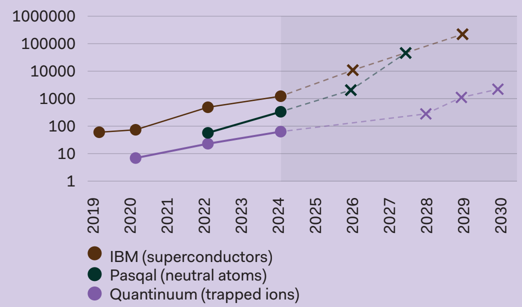
K. Groenland, Introduction to Quantum Computing for Business; O. Ezratty, Understanding Quantum Technologies; VOLUME10 (research, analyses and interviews)

Good to know

When thinking about quantum computing, it is crucial to tell apart true progress from media noise, and to keep an eye on the evolving industrial roadmaps.

(2019-2030) Past and future progression of **physical qubit** count **(uncorrected)** for three industry players

Since 2019, physical qubit counts have doubled every 12-to-24 months; this said, only a handful of parties have reached **logical qubit** capacity and the realization of effective error correction.



Projected capacity of **logical qubits (corrected qubits)**

Some players even predict they'll reach sizable counts of **logical qubits** in the next five years for potentially feasible use cases.

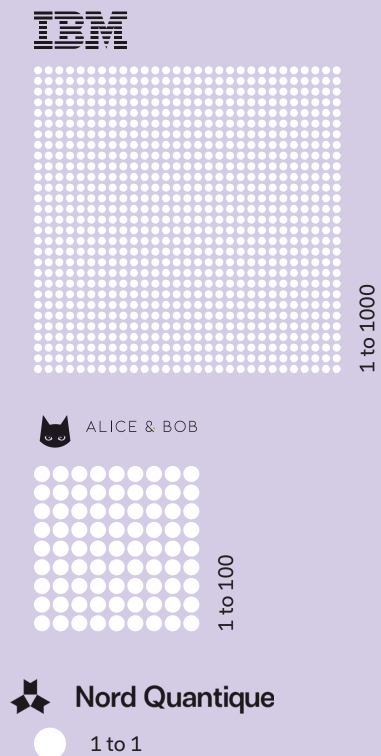

How IBM will build the world's first large-scale, fault-tolerant quantum computer

			Projected number of logical qubits – 2028-2029
Superconductors	**IBM**	United States	200
Superconductors	**Alice & Bob**	France	100
Superconductors	**Nord Quantique**	Canada	100
Neutral atoms	**Pasqal**	France	128
Photons	**Quandela**	France	50
Trapped ions	**IONQ**	United States	1600

Refresher

A **physical qubit** constitutes the basic unit being operated by a quantum computer, though that unit is easily disturbed by digital noise and plagued by errors. To achieve computational reliance, physical qubits are regrouped to form a logical qubit, which will correct errors on an ongoing basis, thus enabling the piloting of complex algorithms without loss of data. Practically speaking, a lone **logical qubit** may require the assembly of tens, if not hundreds of physical qubits. It is such a structure that can bring forth fault-tolerant quantum computing.

Case study



Nord Quantique is working on a totally unique approach: error correcting is embedded directly in each physical qubit. In traditional structures, tens of physical qubits are required to create one logical qubit; but through Nord Quantique's method, it boils down to a 1:1 ratio. Thanks to a multimode bosomic code, every qubit self-corrects itself, drastically reducing material needs and paving the way to the advent of more compact, rapid and efficient machines.

K. Groenland, Introduction to Quantum Computing for Business; publicly published roadmaps (IBM, Alice & Bob, Nord Quantique, PASQAL, Quandela, IONQ); Quantum Computing Report (GQI); VOLUME10 (research, analyses and interviews)

Investments in the various quantum applications—computing, communication and sensing—are on the rise, especially in sectors where planning cycles have long-term visions.

Computing

Communication

Sensing

Sector	Example of potential use cases *(non-extensive)*	Examples of active players
Aerospace and Advanced Navigation	High-precision inertial navigation (without GPS), with the help of quantum sensors.	Canadian Space Agency / Agence spatiale canadienne, Boeing, Airbus
Agriculture	Optimization of inputs (water, fertilizer, pesticides) through soil and cropping simulation enabled by quantum algorithms.	Bayer CropScience
Chemicals and Materials	Complex material simulations for designing more efficient batteries.	Merck, BASF We create chemistry, Boehringer Ingelheim, Mitsubishi Motors
Defence	Gravity sensing and magnetic field detection for locating tunnels or submarines.	U.S. Air Force, Ministry of Defence, Ministère des Armées, Thales
Energy and Critical Infrastructures	Test models to predict microcrack expansion in hydro dams and to improve long-term maintenance planning.	EDF, ExxonMobil, أرامكو السعودية saudi aramco
Finance, Insurance and Risks	Safety strengthening of banking communications against future quantum computer attacks, through Quantum Key Distribution (QKD).	JPMorganChase, Goldman Sachs, BBVA, Crédit Agricole
Mobility, Transport and Logistics	Solving of complex scheduling and routing issues.	Porsche, DB Schenker, Daimler, Maersk

K. Groenland, Introduction to Quantum Computing for Business, M. Kaku, Quantum Supremacy: How the Quantum Computer Revolution Will Change Everything, CEA/Y.Spot, Futuribles, HPCwire, Investors.com, Public releases from stakeholders; VOLUME10 (research, analyses and interviews)

Growing at a rapid rate, the quantum domain presents a significant technological and economic opportunity, with a future potential market valued between US$ 70G and US$ 173G (2040).

Global market assessment for quantum technologies by 2040*
(Amounts in $ US)

Sectorial overview* (as of December 2023)
(Amounts in $ US)

Quantum computing
~$ 88 G

$ 6.7 G invested
261 start-ups

Quantum communication
~$ 30 G

$ 1.2 G invested
96 start-ups

Quantum sensing
~$ 3.5 G

$ 0.7 G invested
48 start-ups

* McKinsey & Company, Quantum, Technology Monitor, April 2024

(2024)

Global market size for other major technology sectors
(Amounts in $ US)

~$ 750 G	~$ 670 G	~$ 280 G
Cloud technology	**Semiconductors**	**Artificial intelligence**

McKinsey & Company; Grand View Research; VOLUME10 (research, analyses and interviews)

To keep in mind

3 complementary tech pillars, 3 different beats

Quantum computing, communication and sensing are progressing towards different horizons: the first one holds mid-term promises of disruptive greatness, but remains in the meantime at an experimental level; the second lays out multiple stages of advancement (QKD, then quantum Internet); the third has already reached commendable TRLs, but has a hard time with its go-to-market ambitions.

Error correction and logical qubit fruition are critical strategic mileposts

Although physical qubit count regularly doubles, very few stakeholders have been able to take full advantage of logical qubits. Focus is now on error correction, an essential condition if we are to achieve fault-tolerant quantum computing and materialize industrial applications.

Enabling technologies as invaluable strategic levers

Photonics, cryogenics, control electronics, specialized manufacturing: these existing technological fields play a fundamental supporting role in the value chain, while having their own tremendous economic potential.

Despite foggy outcomes, a true economic and structuring opportunity

It is estimated that the quantum market could reach US$173G by 2040, but tried-and-true usages remain scarce. This alleged value is mostly based on the impetus it brings to the technological arena. Such leverage could boost innovation in a handful of strategic domains such as energy, defence, finance and advanced materials.

A tech revolution that calls for long-term patience

Like previous transformational technologies—telecoms, AI and even legacy computer sciences—, quantum adoption moves at a slow pace, with irregular yet meaningful breakthroughs. Transition will happen through patient integration and in specialized niches.

Quebec's position on the Global Stage

Canada's and Quebec's forefront position in the quantum race results from the might of their conjoined centres of excellence, an astute vision and foresighted strategic investments.

Canada has been a pioneering player in the development of quantum knowledge, with a will professed in the early 2000s to link up scientific intelligence with industrial capacities. Emerging business endeavours such as D-Wave in Vancouver—with its world's first commercialized quantum annealer—or 1QBit in Victoria—specializing in quantum optimization softwares—have laid the building blocks of a national entrepreneurial ecosystem and shone the spotlight on the practical uses of quantum computing.

This vitality has been amped up by the gradual establishment of a strategic hub in Waterloo, centered around the Institute for Quantum Computing (IQC), the Perimeter Institute and the Quantum Valley Investments. This Ontarian nucleus—shouldered since 2016 by public, private and philanthropic investments—has been the foundational impulse for Canada's National Quantum Strategy, implemented in 2022.

The Strategy is centred on three pillars : world-class scientific research, specialized labour growth and business promotion of quantum innovations.

As an integrated player in this national plan, Quebec has brought up a complementary approach, with a distinctive ecosystem that focuses on advanced materials, photonics and high-performance computing.

The Quebec government has created an industrial zone in the city of Sherbrooke—the Zone d'innovation quantique, mainly financed by the Canada First Research Excellence Fund and supported by a group of industrial, scientific and institutional partners.

This technological hive buzzes around Sherbrooke University's Institut quantique, logically merging and sharing amenities. labs and entrepreneurial coaching.

Though differentiated, this flightpath remains coherent with the broader federal vision and mechanisms. While Ontario has historically established itself as Canada's quantum research epicenter, Quebec wants to be seen as the hot spot for experimentation, industrialization and integrated training.

The goal now is to foster a symbiotic relation between those unique identities, all the while consolidating Quebec's distinctiveness at the international level.

Inauguration of Quantum Space 1, Sherbrooke, 2023

Martin Enault (Interim CEO of Distriq), Geneviève Hébert (Member of the National Assembly for Saint-François), Alain Aspect (Nobel Prize in Physics, 2022), François Legault (Premier of Québec), Pierre Fitzgibbon (Minister of Economy, Innovation and Energy), Sarah Jenna (CEO of Quantum Venture Studio), Martin Laforest (Manager of the Quantacet Fund), Dr. Georges-Olivier Reymond (Co-founder of Pasqal), Donald Martel (Member of the National Assembly for Nicolet-Bécancour)

Photo: Chloé-Anne Touma

Opening of the Mike & Ophelia Lazaridis Quantum-Nano Centre, shared by the Institute for Quantum Computing (IQC), the Waterloo Institute for Nanotechnology (WIN) and the Nanotechnology Engineering Program, Waterloo, 2012.

Raymond Laflamme (first Director of the Institute for Quantum Computing at the University of Waterloo), Doug Fregin (Co-founder of Research In Motion and later Quantum Valley Investments), Mike Lazaridis (Co-founder of Research In Motion and later Quantum Valley Investments), Ophelia Lazaridis, Stephen Hawking (theoretical physicist, cosmologist and author).

Photo: Quantum Valley Investments

Quebec plays its part in Canada's quantum network, where collaboration and complementary capacities are key to strategic success.

Canada has implemented a structured quantum network, underpinned by complementary hubs based in different provinces. In Ontario, organizations such as the le Perimeter Institute, the Institute for Quantum Computing and Quantum Valley have been driving forces in the advent of a national strategy. In British Columbia, pioneering businesses and the Quantum Algorithms Institute steady up the industrial development. Alberta has taken the leadership in cryogenics and advanced materials. National coordination is managed by Quantum Industry Canada, ensuring that public and private efforts remain mutually coherent. In this varied landscape, Quebec has carved its own place by betting on the supplemental value and the ease of integration of its specialized expertises.

Notable players in Canada's quantum ecosystem (limited list)

British Columbia
- University of British Columbia
- Simon Fraser University
- University of Victoria
- Stewart Blusson Quantum Matter Institute (SBQMI)
- Quantum Algorithms Institute

Alberta
- University of Calgary
- University of Alberta
- University of Lethbridge
- Applied Nanotools
- Applied Quantum Materials Inc.
- Quantum Silicon Inc.
- Quantum Alberta
- Zero Point Cryogenics

Ontario
- University of Toronto
- University of Waterloo
- University of Ottawa
- Institute of Quantum Computing
- Perimeter Institute
- National Research Council Canada
- Xanadu
- Honeywell
- ISARA

McKinsey & Company; Quantum Algorithms Institute; Investissement Québec ; VOLUME10 (research, analyses and interviews)

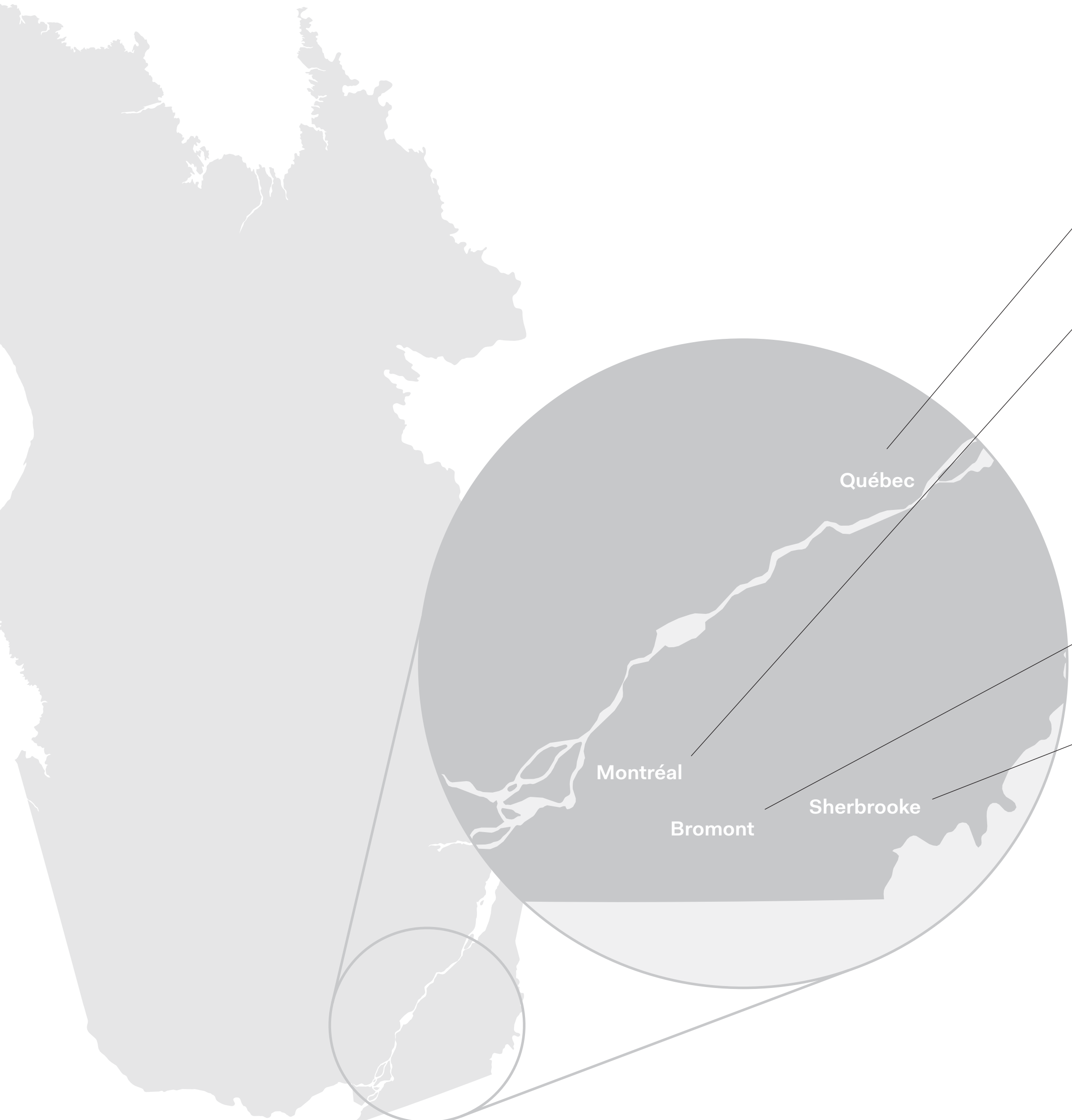
" Building a reliable quantum computer is so difficult that if we don't work at it together, it will never be achieved. "

Alain Aspect
2022 Nobel prize in Physics

Investments in the canadian quantum ecosystem (As of 2024)
(Amounts in $ US)

~ $ 1.4G	**public** investments	*Including $360M in 7 years for a National quantum strategy (compared to $3.8G in the United States)
~ $ 1.3G	**private** investments	(compared to $3.8G in the United States)

Quebec can count on a quantum ecosystem populated by specialized academia, numerous start-ups and support organizations. Its success will depend on the capacity to define clear boundaries between various roles at the provincial level.



Forum IA Québec; Quebec's Ministry of Economy, Innovation and Energy; C2MI; VOLUME10 (research, analyses and interviews)

- Universities & Research Centres
- Support organizations
- Quebecois and Canadian Businesses and Start-ups
- Foreign Businesses and Start-ups

Quebec
- INO
- Quantino
- Université Laval (COPL)

Montreal
- Anyon Systems
- Calcul Québec
- Centech
- CMC Microsystems
- École Polytechnique de Montréal
- Institut Courtois (Université de Montréal)
- Tensor Institute for Quantum Science and Technology (ÉTS)
- Transdisciplinary Institute for Quantum Information (INTRIQ)
- Ki3 Photonics
- Numana
- Prima Québec
- Prompt
- Technologies Nanoacademic
- Quandela
- Concordia University
- McGill University

Bromont
- MIQro Innovation Collaborative Centre (C2MI)
- IBM
- PINQ^2
- Technum Québec

Sherbrooke
- ACET
- Distriq
- Exaion
- Institut quantique (Université de Sherbrooke)
- Nord Quantique
- PASQAL
- Qubic Technologies
- Quantacet
- QV Studio
- SBQuantum
- 1Qbit
- 3IT

Other Notable Stakeholders
C2T3, Chemia Discovery Inc, Entangled Networks, Ericsson, Extropic, FCI, In a Blink, InfinityQ, IREQ, IVADO, MILA, MPB Communication Inc, Optech, Optonique, Productique Québec, Qubit Pharmaceuticals, Quminex, SILQ Connect, SQK, Teraxion, Thorlabs.

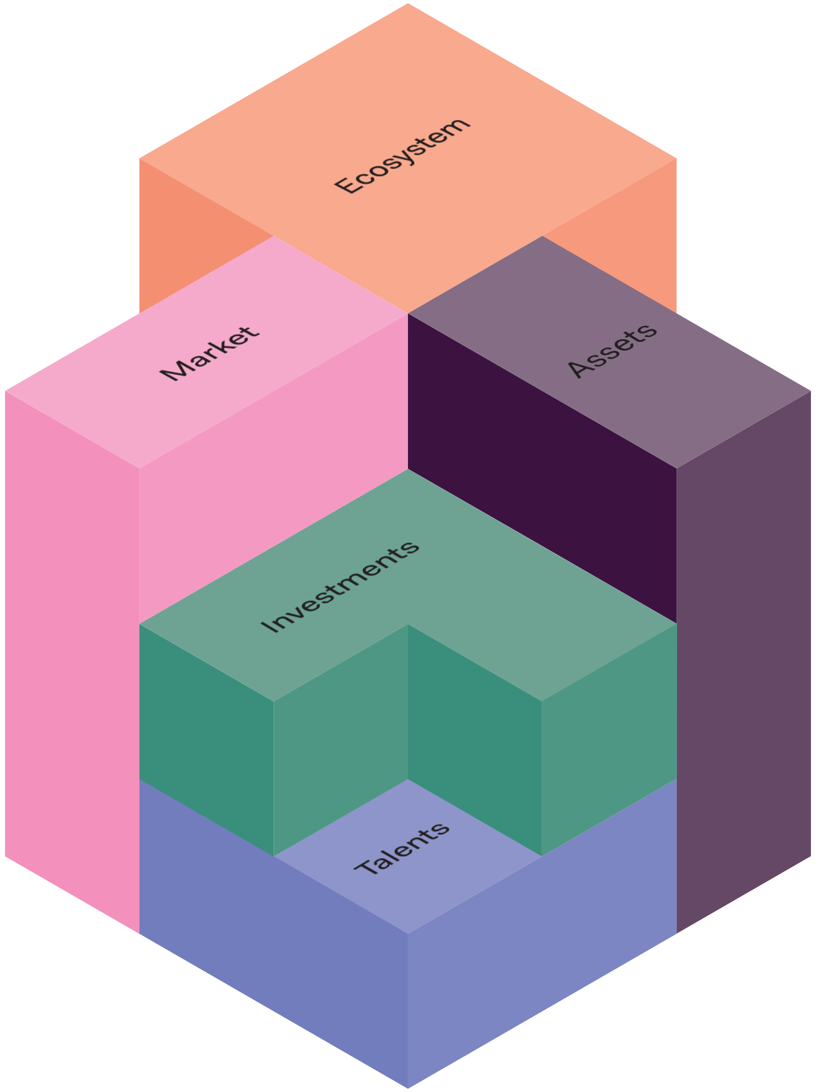
Enabling ecosystems

Artificial Intelligence
Quebec is a major hub in artificial intelligence, with **more than 240 start-ups, 45,000 professionals and 53 research chairs.** Its renowned expertise in algorithms makes it a force to be reckoned with on the international scene.

Optics / Photonics
Quebec's optics and photonics ecosystem regroups **more than 130 businesses and a workforce of 7,500, structured around the Optonique tech cluster** and blessed with strong export capacities. Its fortes include imagery, instrumentation and sensing devices aimed at the aerospace, health and telecom industries.

Integrated Innovation Chain
Through the merging of **research platforms, cutting-edge infrastructures, businesses and training institutions**, development and innovation are sped up, technological transfer is facilitated and skilled labour is expanded.

The speeding up of Quebec's quantum sector development requires to trigger five strategic enablers: investments, talents, assets, market and ecosystemic coordination.



Investments	Private and public funds to strengthen the ecosystem, offer infrastructure support and push forth the development of quantum technologies in Quebec and Canada
Talents (in academia and business)	Training, followed by talent retention and attraction at the international strategic level, to foster technological development and acceleration, applied researching and go-to-market capacities
Assets	Material, technological and infrastructural assets that enable experimentation, inventiveness, testing and validation—all critical to the advent of quantum solutions
Market	Businesses and organizations prepped up for collaborative creation, testing and adoption of quantum technologies
Ecosystem	The weaving of stakeholders, support networks and coordinating structures, in order to combine know-hows, align initiatives and fuse complementary sectors (ex. artificial intelligence), along with national and international partnerships

Quebec has positioned itself quite early and publicly—especially through major investments—, which today gives its expertise an enviable reputation throughout the world.

Public investments in Quebec's quantum sector have intensified in the last 15 years, which speaks of the genuine interest in grounding this strategic field into the local scientific and industrial frameworks. Starting in 2009 with the initial bolstering of the INTRIQ research initiative, many following stepping stones have been laid out: funding from the Canada First program in 2015, creation of Sherbrooke's Distriq in 2022, then a $70M investments from Quebec's Ministry of Economy, Innovation and Energy to lure industrial resources, boost technological progress and consolidate shared platforms.

These efforts are framed into a broader context, shouldered in 2022 by Canada's National Quantum Strategy. With a general budget of $360M spanning a period of seven years, it provides support to fundamental research, talent training and commercialization of innovations.

More recently, the Department of National Defence has announced new investments for the purpose of strategic quantum applications, notably in the fields of communication security, cutting-edge sensors and high-precision computing.

The coming together of provincial and federal initiatives puts Quebec at the core of Canada's quantum roadmap. It upholds its privileged status as a premier testing and deployment ground, where high-potential industrial uses are being perfected and where Canada's scientific sovereignty and authority can assert itself internationally.

Though not specifically targeted at the quantum sector, a number of particular investments and donations—notably a $17M envelope for the expansion of C2MI and another $50M for the inception of a disruptive technology institute at Polytechnique Montréal—also profit directly the quantum ecosystem.

Government of Quebec ; INTRIQ ; University de Sherbrooke ; government of Canada ; VOLUME10 (research, analyses and interviews)

Major investments by the Governments of Canada and Québec and major donations for the advancement of quantum in Québec

- Government of Quebec
- Government of Canada
- Major donations

2009
$2.88M (six-year)
The Fonds de recherche du Québec offers financial support to INTRIQ, a research partnership regrouping the Université de Montréal, Polytechnique Montréal, Université de Sherbrooke and McGill University.

2015
$33.5M (seven-year)
The Université de Sherbrooke acknowledges financial aid from the Canada First Research Excellence Fund, the country's largest federal research funding entity, for the inception of the Institut quantique, specializing in quantum science and technologies.

2022
$159M
The Université de Montréal benefits from an historical donation from the Fondation Jacques Courtois to create the Institut Courtois, aimed at fostering the discovery, development and characterization of novel materials.

$131M
This capital investment from the government of Quebec enables the launching of Distriq, an innovation hub for quantum technologies located in Sherbrooke.

2023
$65,3M
Quebec's ministry of Economy, Innovation and Energy (MEIE) commits monies for five quantum projects: the Espace quantique 1, the arrival of PASQAL at Distriq, the Quantacet Fund, Quantum Venture Studio and the advent of the Institut Quantique.

$6,5M
The MEIE provides funds for quantum communication loop projects managed by Numana.

2024
$5M
Funding from the government of Quebec helps out the École de technologie supérieure (ÉTS) to speed up the advancement of quantum science expertise and research.

2025
$8.1M
Canada Economic Development (CED) announces monetary aid for Sherbrooke's quantum hub.

The aforementioned investments have notably enabled the inception of Distriq, Sherbrooke's quantum innovation zone.

Gaining an official designation in 2022, Distriq is one of four, world-class innovation zones put in place by the Quebec government. Its aim is to attract—within a set perimeter—talents, business people, researchers and decision-makers from here and abroad. It also means to amplify the go-to-market push, alongside exports, local and foreign investments and—supplementarily—the productivity of other Quebec future-tech firms which already offer a key competitive edge.

Distriq seeks to accelerate the development of its high-caliber quantum ecosystem, where talented individuals and organizations can blossom in an attractive, sustainable working-and-living environment. Furthermore, its mission includes promoting Sherbrooke and the Eastern Townships' economic growth.

The hub relies on a series of complementary infrastructures which span the entire innovation cycle, from fundamental research to industrial capacities. This quantum community notably includes the Institut Quantique, 3IT, C2MI, DevTeQ, PINQ^2 (operating IBM's Quantum System One computer), the Exaion data centre, but also projected spaces such as EQ2 (follow-up to EQ1).

This pooling of assets makes for a fertile ground for research, prototyping, performance computing and manufacturing activites—equally easing the welcoming of industrial partners and the growth of local tech businesses.

The technological offsprings of this rich ecosystem hold a transformative potential in many fields of application, namely in aerospace, energy, defence and advanced materials.

VOLUME10 (research, analyses and interviews); Distriq

DistriQ
ZONE INNOVATION QUANTIQUE

ZONES D'INNOVATION QUÉBEC
SHERBROOKE QUANTIQUE

Simplifying access to federal and provincial capitals

Attracting creative and diversified skilled labour

Reducing research costs through the capacities of a world-class innovation hub

Speeding up the development of technological solutions

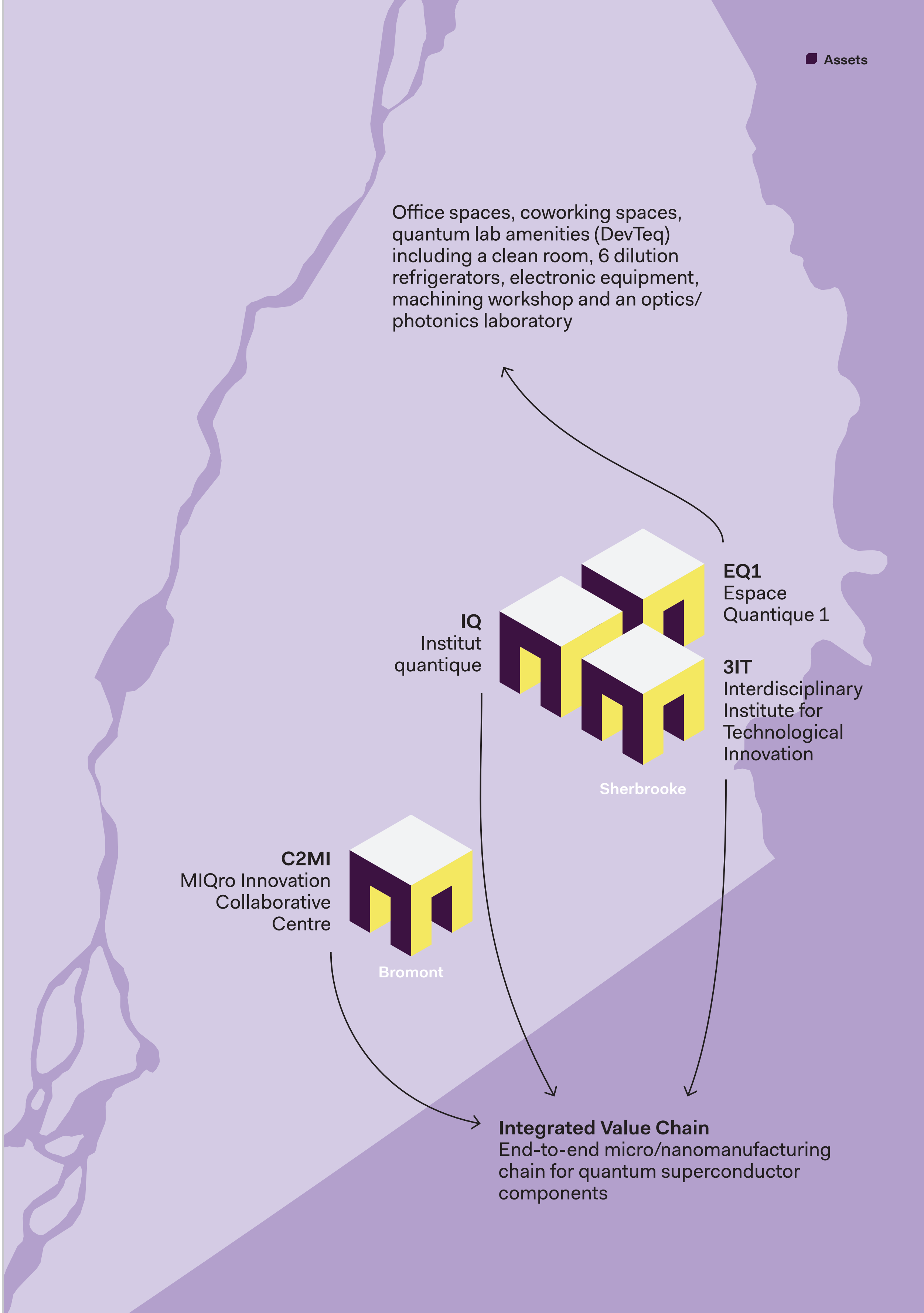
Stimulating growth and international investments

Distriq aims to aggregate high-quality assets in order to bolster the advancement of quantum technologies in Quebec.

Distriq can currently count on an ensemble of complementary infrastructures, covering the whole spectrum of innovation steps, from fundamental research to industrialization.

Its ecosystem encompasses notably the Institut quantique, 3IT and C2MI, specialized installations such as DevTeQ, PINQ² (with the help of IBM's Quantum System One), the Exaion data centre, and future entities like EQ.3IT, CINQ and EQ2 (follow-up to EQ1).

This quantum beehive supports a bevy of research, prototyping, computational and fabrication activities, all the while helping to greet new industrial players and nurturing local endeavours.



Good to know

Canada is seen as a commendable exponent of quantum intellectual property, notably in the communication field where it ranks 4th in the world.

Canada's engagement in quantum technologies is well established on the world scene, especially when it comes to intellectual property. Between 2000 and 2023, it has applied for nearly 3,000 patents relating to quantum capacities—which makes it the seventh most prolific instigator in the world.

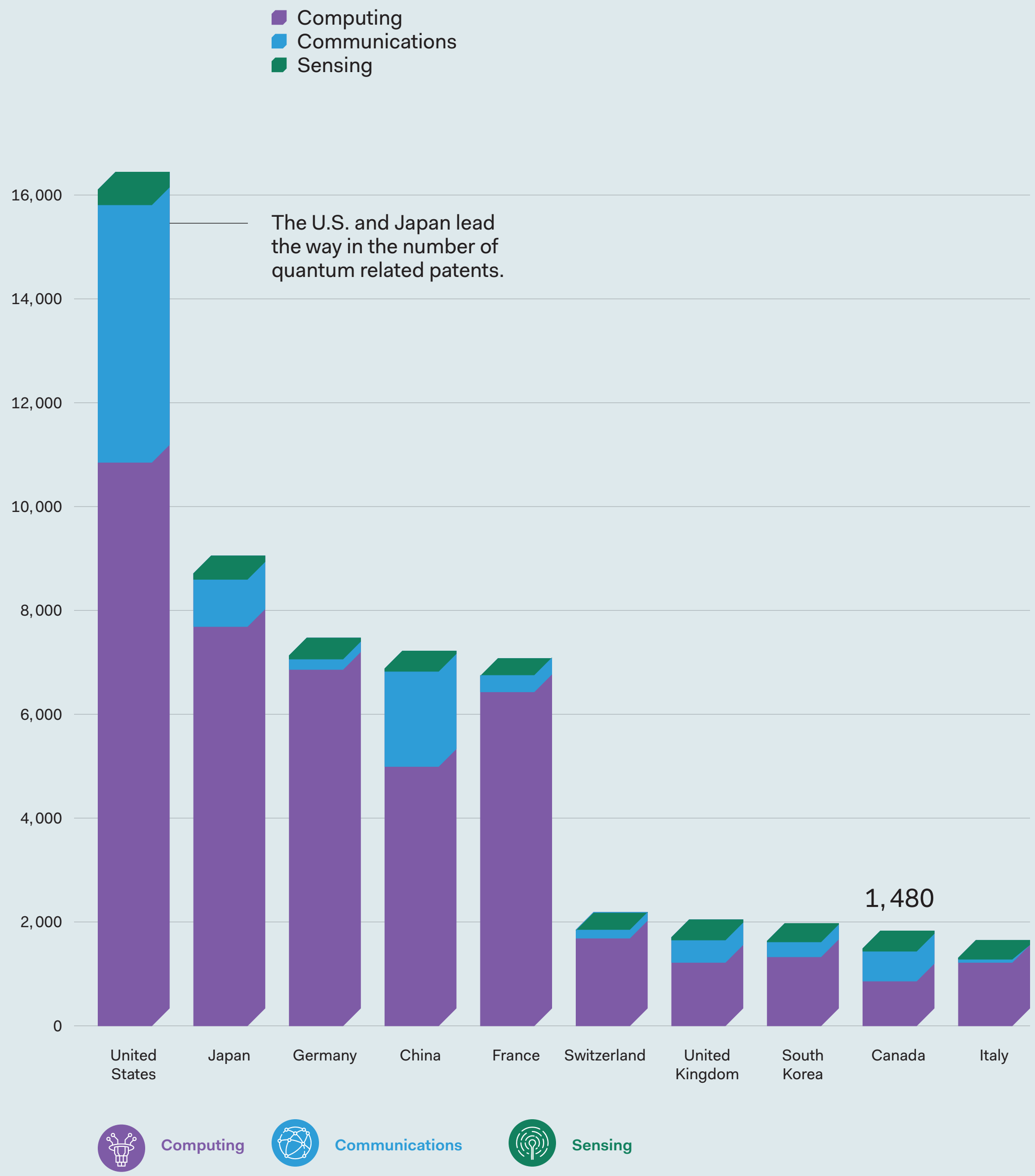
This reputational stance is particularly prominent in the quantum communication sector, which accounts for 38% of all nationally delivered patents. In this regard, Canada is only surpassed by the U.S., China and Japan.

In 2023, patent filing has soared to an all-time, yearly high of 1,300, primarily this time in the field of quantum computing and its associated hardware/software. This sustained vigor showcases the heightened efforts put forth in applied research, technological desirability and strategizing through the quantum chains of value.

McKinsey & Company; Quantum Algorithms Institute (2024); Canadian Intellectual Property Office; VOLUME10 (research, analyses and interviews)

(2000-2023)

Number of patents delivered in relation to quantum technologies
According to patent authority in the country where filing party is headquartered



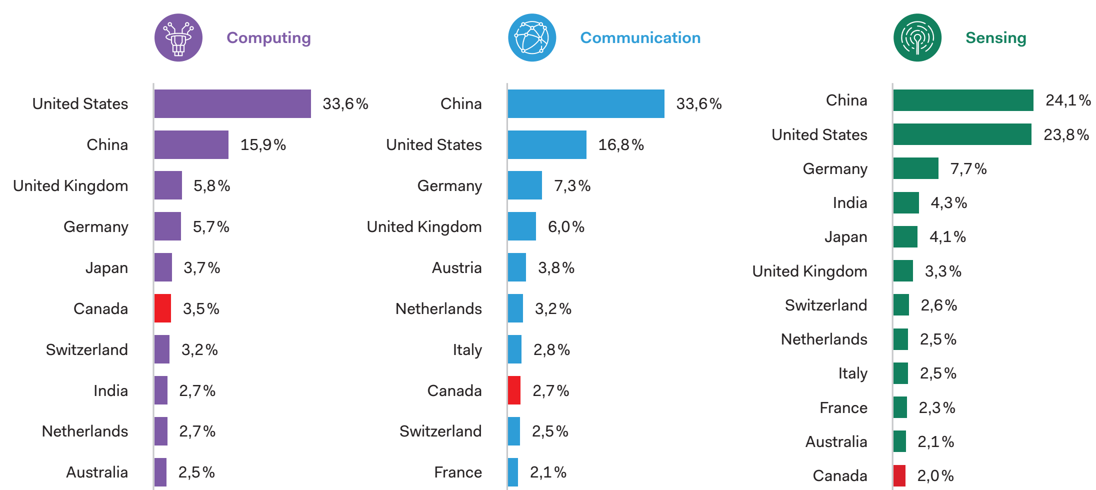
Canada and Quebec's quantum leadership is grounded in an internationally reputed expertise and creditable academic achievements.

Canada's stately poise in the quantum arena results from its scientific stamina, esteemed the world over. Between 2019 and 2023, It has published more than 1,200 papers on quantum subject matters, earning it a place amongst the leading countries in computing, communication and sensing technologies. Notwithstanding the sheer number, this is also due to the impactful quality of the many, oft-cited articles, notably relating to quantum computing.

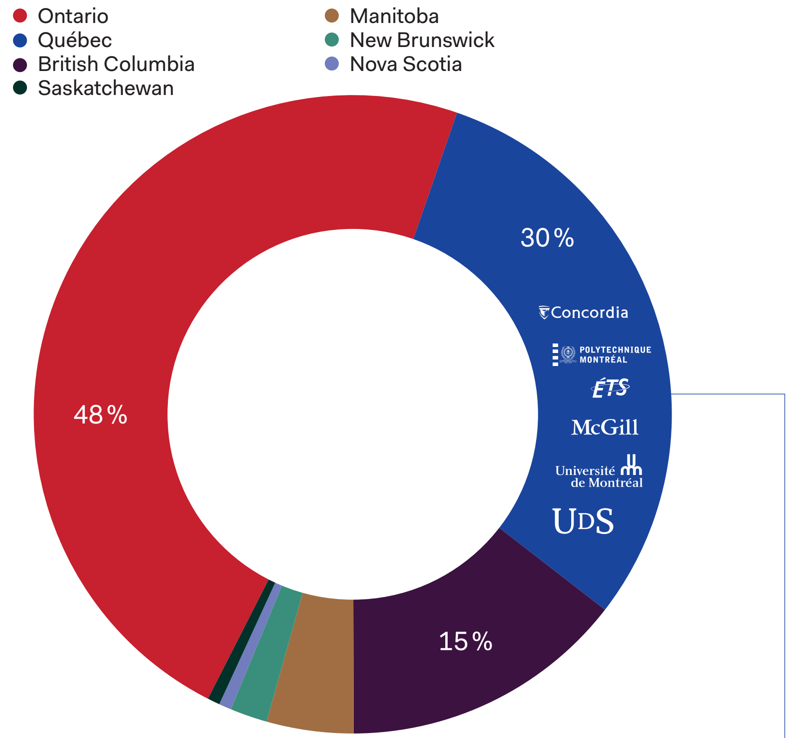
In Quebec's case, this scientific virtue is founded on more than four decades of exploration and the work of illustrious groundbreakers such as Gilles Brassard and Alexandre Blais. Academic resources like INTRIQ's and RQMP's (Quebec Network for Advanced Materials) gravitate around this lively research ecosystem.

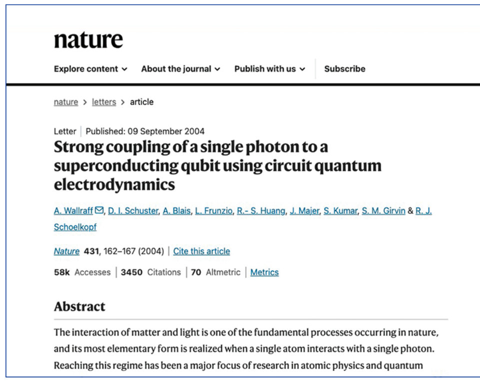
This swarm of networks gathers universities, research centres and technological platforms around a common goal: the mastering of quantum phenomenons and the tutoring of the next generation of talents. This enduring scientific engagement cements Quebec's position in the quantum value chain.

Country rankings in number of oft-cited scientific publications*
2019 to 2023, by sectoral category



(2024) Percentages of quantum researchers
Per Canadian province





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Letter | Published: 09 September 2004

Strong coupling of a single photon to a superconducting qubit using circuit quantum electrodynamics

A. Wallraff, D. I. Schuster, A. Blais, L. Frunzio, R.- S. Huang, J. Majer, S. Kumar, S. M. Girvin & R. J. Schoelkopf

Nature 431, 162–167 (2004) | Cite this article

58k Accesses | 3450 Citations | 70 Altmetric | Metrics

Abstract

The interaction of matter and light is one of the fundamental processes occurring in nature, and its most elementary form is realized when a single atom interacts with a single photon. Reaching this regime has been a major focus of research in atomic physics and quantum

This article established the foundation of circuit QED (quantum electrodynamics), where a superconducting qubit strongly interacts with a resonating circuit's confined electromagnetic field. This enables the precise observation and control of the qubit's state—an approach which has prompted the advent of transmons, a subcategory of superconducting qubits, currently the most used and advanced of their kind (notably chosen by IBM and Google).

* Oft-cited: For articles ranked in the top 10% of cited publications (for a given tech sector and year)

Web of Science; Critical Technology Tracker; VOLUME10 (research, analyses and interviews)

Web of Science; Nature; Critical Technology Tracker; VOLUME10 (research, analyses and interviews)

To maintain its lead, Quebec must attract, train and retain quantum talents throughout their academic course.

Quebec already trains about a quarter of all Canadian graduates in quantum-related programs. This telling fact gives it tremendous leverage to accrue its attractiveness and retaining capacity, and consequently grow its ecosystem. Particularly, the Université de Sherbrooke stands as a pioneer in this field, with the creation of Canada's first Bachelor program in quantum information sciences, proof of its unrelenting will to anchor quantum learning right from the beginning of undergraduate studies.

To keep a leg up on the competition, Quebec must bolster its academic offering by diversifying curriculums, increasing accessibility and enticing the most promising students and researchers worldwide—more than ever, a strategic necessity in the context of other players on the world stage increasingly coveting quantum expertise.

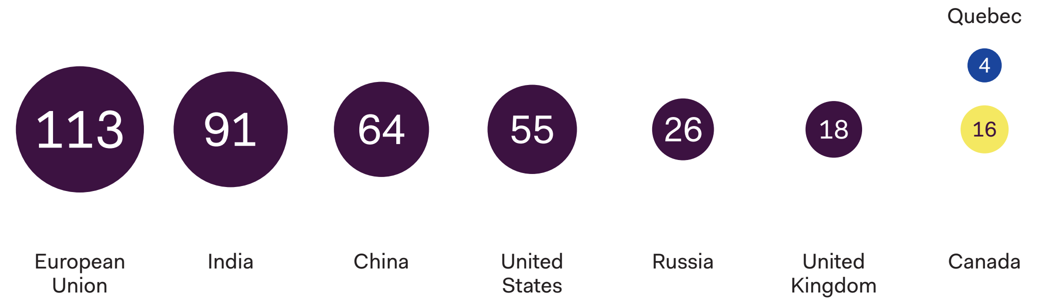
Internationally, we number 87 Masters programs in quantum technologies, with only four being offered on Canadian soil. This meager count, compared to the rest of the world, brings fear of increasing drop-out rates and stresses the need for Quebec to bump up investments if it wants to remain competitive. The European Union currently has the upper hand in quantum science graduates, while Canada, the United Kingdom and other European countries show a high density of fitting student profiles.

87
Masters programs in quantum-related technologies (worldwide, with 4 in Canada)

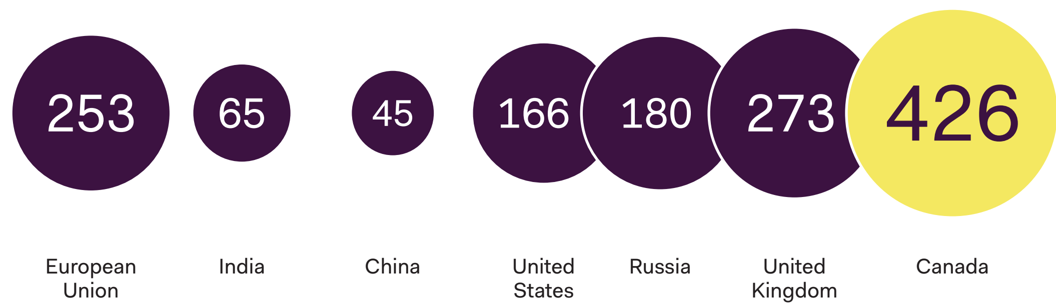
Progress made by a number of competing countries pressures Quebec to strategically consolidate and diversify its academic offering at all levels.

The Université de Sherbrooke leads the way with Canada's first Bachelor program in quantum information sciences.

(2021) Number of graduates* in quantum-relevant fields
X 1,000



Number of graduates* per million inhabitants



* Masters degree or equivalent, in Mathematics, Computer Sciences, Information sciences and Engineering

Governmental websites; McKinsey & Company; Statistics Canada; VOLUME10 (research, analyses and interviews)

Governmental websites; OECD; McKinsey & Company; Statistics Canada; European Quantum Readiness Centre; VOLUME10 (research, analyses and interviews)

To strengthen its ecosystem, Quebec must retain the talent it trains in quantum technologies.

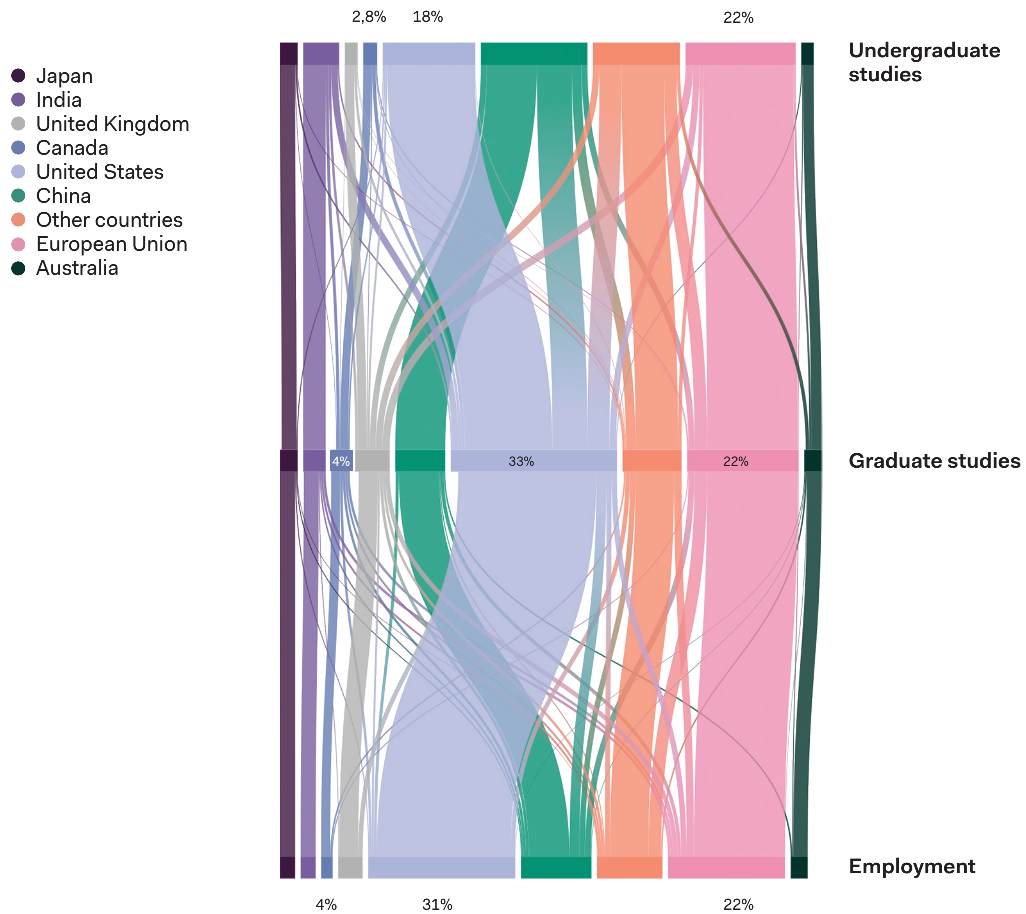
Canada stands out for its ability to attract international talent to graduate studies: 61% of the most cited researchers who've completed their graduate studies there originated from foreign countries. This performance reflects a high level of academic attractiveness, confirmed by the country's regular presence at the top of rankings of the best destinations for studying abroad.

However, this strength in training does not fully translate into sustainable talent retention. Only 43% of these graduates choose to pursue their careers in Canada, a sign of a significant brain drain toward more mature markets with more efficient immigration processes or more aggressive attraction policies. The United States alone accounts for 31% of the researchers authoring the most influential publications in quantum physics, largely thanks to its ability to recruit experts who were trained elsewhere.

This trend poses a strategic challenge: how can Canada's excellence in training be transformed into an enduring competitive advantage? This requires consolidating local industrial value chains, strengthening the links between research and employment, and creating conditions conducive to talent retention in a highly competitive global market.

Share of top-cited researchers (2019–2023)

Itinerary of top-cited researchers in quantum technologies per country*



* Researchers having published a quarter of the most-cited papers on quantum technologies

Web of Science ; Critical Technology Tracker ; VOLUME10 (research, analyses and interviews)

Good to know

Quebec's immigration system is based on a generalist approach designed to meet the overall needs of the labor market. However, this approach has its limitations in highly specialized sectors such as quantum sciences. The path to permanent residency is often longer, more opaque, and less predictable than in other comparable jurisdictions. The two-step process—Quebec Selection Certificate, then federal application—introduces an additional delay that is rarely compatible with the accelerated career trajectories of tech talent.

Learning French as a common language is a legitimate and important goal. That said, a rigid application of this requirement that disregards the linguistic realities of the work environment tends to exclude highly qualified profiles that are already integrated into the ecosystem. In a sector where English predominates as the scientific and operational language, a more progressive approach would facilitate francization without compromising Quebec's attractiveness.

The hiatus on both components of the Quebec Experience Program (or "PEQ"), in effect since the fall of 2024, has heightened this climate of uncertainty. It directly affects Quebecs' foreign graduates and skilled temporary workers—the most sought-after profiles in the quantum sector.

This regulatory instability is in direct contradiction with the clear and bold strategies deployed by other countries to attract scientific talent. In a global competition that now hinges on the ability to mobilize human intelligence, the complexity of migration is becoming a strategic disadvantage.

Case study: Denmark
Targeted messaging and pledge of stability

Under the banner A State of Denmark, Denmark's social media campaign aimed at international university students, doctoral students, and postdoctoral fellows heralds a high-level research environment combined with an attractive quality of life. This positioning highlights a stable, welcoming country that is focused on scientific progress.

Case study: France boosts its scientific attractiveness

During France's AI Summit in 2025, the French launched the third phase of their national strategy on artificial intelligence, supported by the France 2030 plan and focused on structuring research, accelerating innovation, and spreading AI across all sectors.

The country plans to train 100,000 students per year for the AI domain, fund 200 additional research theses, and develop nine centres of excellence in AI, with an investment of $562M.

Choose France™

The creation of the "Choose France for Science" unit, targeted visa schemes (Talent Passport, French Tech Visa) and major investments in data centres (approximately US$ 161G) support this strategy.

Safe Place For Science
Aix Marseille Université

The Université Aix-Marseille has launched the "Safe Place for Science" program to welcome 15 international researchers.

CentraleSupélec and Université Paris Sciences et Lettres have pledged to fund AI research, along with climate and health sciences programs.

Case study: Canada boosts its academic appeal

In reaction to the unstable environment in the US academic sector, some Canadian institutions have begun to take action.

Several Quebec universities have published recommendations to position the province and Canada as leaders in research and innovation. This includes the creation of strategic chairs, support for emerging researchers, and the rapid processing of immigration applications.

Canada Leads

In Toronto, the University Health Network (UHN) aims to recruit 100 leading young researchers through the Canada Leads 100 program, backed by an initial investment of CAD$ 15M.

A State of Denmark (2025); France's AI Strategy; Choose France for Science (2025); Safe Place for Science (2025); Université de Montréal; Newswire UNH (2025); VOLUME10 (research, analyses and interviews)

Good to know

The development of quantum technologies requires a skilled and diverse workforce, with competencies that go far beyond those of candidates with graduate degrees alone.

The development of a quantum ecosystem, including the ability to move from research to industrialization, relies on much more than scientific excellence alone. It requires a shared understanding of the skills needed at each stage of the value chain. This reflection is now underway in Quebec, even as several jurisdictions—including the European Union—have reached an important phase by establishing structured frameworks that organize, describe, and anticipate specialized labour needs.

European Competence Framework for Quantum Technologies

The European Competence Framework for Quantum Technologies identifies three fundamental areas of expertise: quantum concepts (understanding physical phenomenons), engineering (hardware and software), and applications (ability to translate into practical use). These areas correspond to six levels of proficiency, ranging from basic awareness to innovation, enabling a detailed analysis of profiles and career paths that complement each other.

This discriminative approach also applies to the characterization of roles. The quantum ecosystem is not limited to researchers and engineers: it mobilizes a plurality of actors—strategists, decision-makers, communicators, specialized technicians, software developers and integrators—whose expertise is interdependent. Four main categories of roles lay the groundwork for a shared understanding of needs: literates, strategists, technologists, and specialists. This understanding, aligned with emerging international categories (quantum practitioners, quantum scientists, quantum engineers, etc.), helps clarify expectations in terms of training, recruitment, and professional mobility.

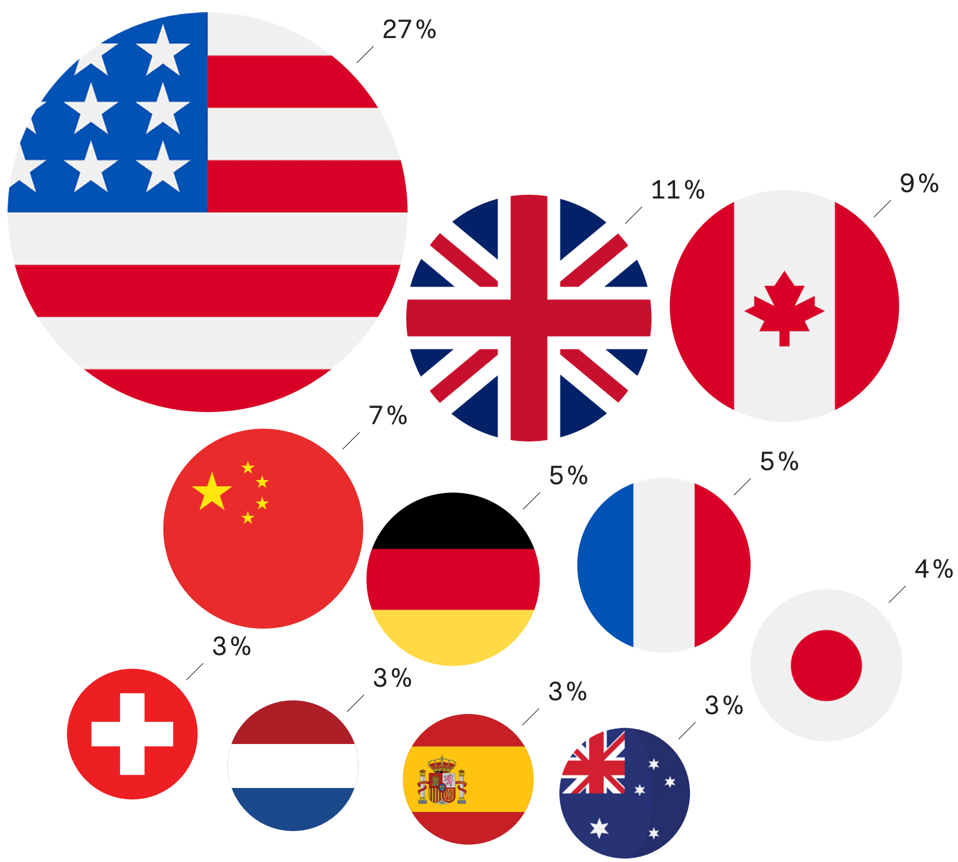
In a context where the sector's growth will depend as much on the quality of research as on the ability to mobilize mixed teams with cross-disciplinary skills, this structuring becomes a strategic necessity. It enables the planning of an alignment of educational pathways with industrial needs, offers new bridges to quantum-related employment, and enhances the visibility of these fields among young people, education institutions, and employers.

Levels of expertise in quantum technology

Type of role		Target audience
Literates	Interested individuals, aware of basic quantum notions and foundational principles.	• Decision-makers • Students • Large corporations
Strategists	Individuals able to grasp the capacities of quantum technologies, figure out interconnected business issues, evaluate use cases and coordinate adoption.	• Tech leaders • Chief technology officers • R&D executives
Technologists & operators	Technical personnel trained for practical applications of quantum capacities, able to manipulate, integrate and adapt sectoral technologies, or partake in their manufacturing.	• Technicians • Technologists • Developers • Tech analysts
Specialists	Individuals able to design, develop or optimize quantum technologies.	• Researchers • Quantum engineers • System architects • Algorithm developers

Talents, assets and Quebec's distinctive ecosystem have prompted the launch of several start-ups, many of them making a splash on the international scene.

(2024) Share of quantum startups worldwide, by country



	United States	United Kingdom	Canada	China	Germany	France
Computing	76	24	28	10	12	11
Communications	20	14	9	16	4	4
Sensing	15	5	1	3	5	4

QUÉBEC

9 4 1

~37 %

of Canadian quantum startups, while Québec accounts for only 20% of the country's GDP

Companies

- Anyon Systems
- Bita Quantum Ai Inc.
- Chemia Discovery
- InfinityQ Technology Inc
- Irréversible
- KI3 Photonics
- Multiverse computing
- Nanoacademics
- Nord Quantique
- Pasqal
- Quandela
- Qubic technologies
- SBQuantum
- t0.technology

McKinsey & Company ; ACET ; Centech ; Dealroom ; Statistique Canada ; VOLUME10 (research, analyses and interviews)

The quantum ecosystem is bolstered by robust affiliated sectors—for instance, manufacturing and photonics.

The development of quantum technologies in Quebec has counted on two historically strong industrial sectors: advanced manufacturing and photonics. Together, they form a sturdy foundation for the quantum value chains, both in terms of hardware and technical expertise.

Quebec is recognized as a production powerhouse in Canada, accounting for 27% of the country's manufacturing companies and contributing CAD$14.1G to Quebec's GDP. This industrial might is based on decades of expertise in mechanics, micro-manufacturing, cryogenics, and electronics. These proficiencies continue to evolve, thanks to sustained investment and the adoption of cutting-edge technologies.

The photonics sector has also experienced rapid growth. Today, there are more than 270 companies and 25,000 jobs in Quebec, with a GDP contribution that could exceed $8G by 2035.

A bona fide cross-sectional technology, photonics plays a key role in strategic sectors such as telecommunications, aerospace, life sciences, and defence. It is also an essential pillar for several quantum technologies, particularly in the fields of sensors, communications, and integrated photonics.

Thanks to the one-two punch of a robust manufacturing base and a rapidly growing photonics ecosystem, Quebec benefits from an environment that can provide comparative advantages in the field of quantum technology. This sectoral alignment calls for close coordination between industries in order to consolidate synergies and maximize industrial benefits.

Investissement Québec ; Statistic Canada ; E&B Data ; Optonique ; VOLUME10 (research, analyses and interviews)

Quebec's manufacturing sector

Amounts in $ CAD

$14.1G contribution to Quebec's GDP, 2021

13 % of Quebec's GDP, 2021

+13 500 companies

27 % of all Canadian manufacturing businesses

Between 2010 and 2021, manufacturing in the province has seen a 12% sustained growth.

Quebec has Canada's highest manufacturing heft in terms of provincial GDP share.

Quebec's photonics sector

Amounts in $ CAD

$3.4G contribution to Quebec's GDP, 2024

+25 000 jobs

+270 businesses

Applications in other impactful sectors

Amounts in $ CAD

Telecommunications	Aerospace	Life sciences
$32.5G PIB (2019)	$15.8G PIB (2020)	$2.1G PIB (2022)

A structured and mobilized ecosystem

Main innovation centres:

INNO
1,350 funded projects ($100M)

C2MI Réinventer l'innovation
$153M for related projects

OPTECH
$20M in mentorship

As quantum technology is increasingly becoming a security issue, the Department of National Defense has the potential to become a driving force for the industry, particularly by injecting patient capital as it is done elsewhere in the world.

The announced increase in Canada's defence budget (to 2% of GDP) marks a strategic turning point for the integration of disruptive technologies, with quantum technology being a priority area. This massive reinvestment, which will mobilize more than CAD$ 9G for 2025–2026, reflects a desire to adapt military capabilities to contemporary technological requirements.

Several of the areas identified in this new defence policy—cybersecurity, secure communications, advanced sensors, data processing—are directly related to quantum applications. These guidelines pave the way for a stronger alignment between military priorities and industrial value chains, creating new opportunities for Canadian businesses.

This course of action is already well wielded internationally, where government-led programs enable armed forces to maintain their technological edge while generating profitable civilian windfalls. In the United States, the Defense Advanced Research Projects Agency (DARPA) has brought to the forefront technologies that are now ubiquitous, such as the Internet and GPS.

DARPA has recently renewed this approach with the Quantum Benchmarking Infrastructure (QBI) initiative, which aims to assess the feasibility of a fault-tolerant and economically viable quantum computer by 2033. Eighteen companies are participating in its first phase, including three Canadian companies: Nord Quantique (Sherbrooke), Xanadu Quantum Technologies (Toronto), and Photonic Inc. (Vancouver). Its initial funding could reach US$1M.

In France, the PROQCIMA program, coordinated by the Ministry of the Armed Forces, pursues similar objectives by focusing on the convergence between military needs and innovation. These examples show that integrating quantum technology into defence strategies can become a powerful lever for industrial innovation and technological sovereignty.

With its scientific and manufacturing expertise, Quebec is well positioned to contribute to this call to action. By mobilizing its academic, industrial, and entrepreneurial abilities, it could play a central role in building an industrial base capable of absorbing and activating quantum technologies, serving both national security and the economy.

Canada's National Defence budget for 2024-2025
Amounts in $ CAD

1.3% of PIB or

$53.4G

National Defence budget for 2025-2025 (forecasted)
Amounts in $ CAD

2% of GDP or

62.7 G$

$9.3G

additional funds, with $560M destined for the strengthening of its digital core.

At the 2025 G7 Summit, Prime Minister Mark Carney announced a specific $22.5M input to speed up development and use of quantum technologies.

Projected percentage of military budget destined for quantum technologies
2025-2030

 0,5 %

 0,1 %

 0,25 %

 0,1 %

 0,2 %

 0,08 %

Beneficial effects of military investments

Easing of aid to local businesses—Sums not subjected to free trade regulations.

Long-term investments, unhindered by administrative cycles.

Affected by the innovation decline in Canada, Quebec must pick up the pace in a rapidly accelerating global technological environment.

Canada seems on a slippery slope when it comes to innovation. Between 2011 and 2024, it was the only G7 country to experience a drop in the Global Innovation Index ranking—retreating from 2nd to 6th place—while France, the United States, and Germany are gaining ground. Despite significant public investment, the country is struggling to transform its knowledge into practical and marketable innovations.

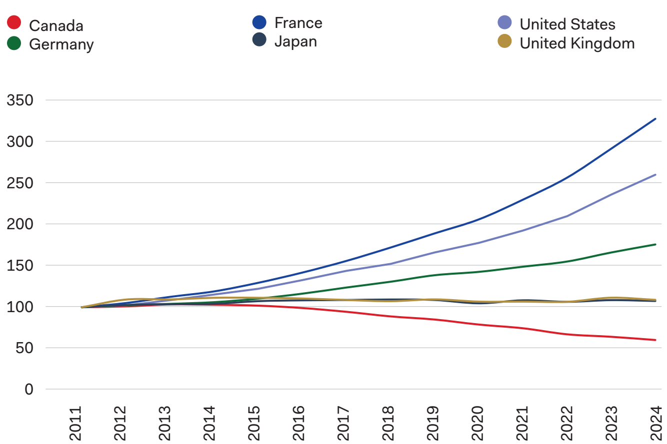
This gap can be attributed to a conservative business culture, closed industrial structures, and often splintered initiatives. The entrepreneurial ecosystem seems also in a slump: business creation is at a standstill, technology adoption remains scarce, and seed venture funding is declining significantly, hindering the emergence of new solutions.

This situation goes against the global trend, where innovation is becoming a strategic lever for sovereignty, security, and competitiveness. Canada continues to take a reactive and compartmentalized approach, with no clear link between public research, industrial ambitions, and commercial strategy. Too often, innovation policy is limited to supporting academic production, without putting in place the conditions to promote its widespread adoption.

For Quebec, the current circumstances call for clear-headed and stern action. It needs to build a coherent and sustainable strategy, focused on impact, value creation, and the local anchoring of innovation capabilities—all fully aligned with tech-intensive, global value chains.

Evolution of the Global Innovation Index*

% variation since 2011 reference year



Global Innovation Index ranking of G7 countries

2011	2024
United States	United States
Canada	United Kingdom
United Kingdom	Germany
Germany	France
Japan	Japan
France	Canada
Italy	Italy

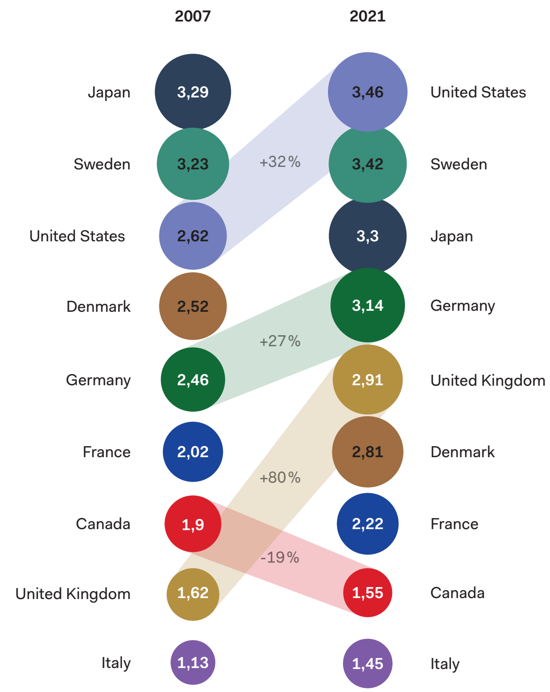
* Established by WIPO, the Global Innovation Index is a global benchmark that measures a country's capacity to innovate, based on 80+ rigorous indicators covering inputs (education, infrastructure, policies) and outputs (patents, publications, products) and using a proven yearly-revised methodology.

Organisation for Economic Co-operation and Development (OECD); The Global Economy; World Intellectual Property Organization (WIPO); Canadian Venture Capital and Private Equity Association; VOLUME10 (research, analyses and interviews)

This lag in innovation is exacerbated by a structural decline in research and development investments in Canada.

Ranking according to level of investments in R&D

% of GDP spent in R&D



Since 2007, Canada has been the only G7 country to reduce its share of gross domestic product (GDP) devoted to research and development—with a marked decline of 20%. This trend is going in the opposite direction of its partners', which R&D investments have grown by an average of 25%, particularly in the United Kingdom, the United States, and Germany.

This partial retreat weakens Canada's innovation capabilities and prevents it from positioning itself favorably in emerging technology value chains. The intensity of R&D in the private sector struggles at 0.93% of GDP—about half the OECD average—demonstrating a persistent inability to mobilize the productive sector around innovation.

In a context of global technological intensification, this decline calls for a considerable push forward if Canada wishes to maintain its economic competitiveness and secure a pleasant berth alongside future flagship innovators.

Organisation for Economic Co-operation and Development (OECD); The Global Economy; World Intellectual Property Organization (WIPO); Canadian Venture Capital and Private Equity Association; VOLUME10 (research, analyses and interviews)

To get back on track, Quebec has to convert its academic prowesses into marketable solutions, something it historically has a hard time achieving.

The path that leads a novel technology from laboratory to market is often long, treacherous and fragmented. The Technology Readiness Level (TRL) scale marks the stages of this journey, from fundamental research (levels 0 to 3) to prototyping (levels 4 to 7), and finally to industrial scale-up (levels 8 and 9).

While Quebec stands out for the merit of its scientific work, it has historically struggled to navigate the critical steps leading to commercialization. Weak links between laboratories and markets, stodgy promotion of intellectual property, and absence of public procurement programs to support early adopters—missing links that delay the transition from invention to innovation.

This handicap is particularly evident in the middle of this development sequence—TRL 4 to 7, known as the "Valley of Death"—, where commercial demonstrations and prototyping support remain underdeveloped. It is at this stage that many innovations fall by the wayside, due to a lack of patient financing, sectoral support, or clear industrial outlets

At this point, overcoming this major obstacle is a prerequisite, requiring an integrated approach to technological development that will align scientific expertise, patient capital, strategic support, and coordinated industrial policies..

In the technology development cycle, the zone between TRL levels 4 to 7 is often referred to as the "Valley of Death." It refers to a critical phase during which many innovations fail in their attempt to make the leap from laboratory to market. At this stage, prototypes do exist, but have not yet been validated in operational or commercially credible environments.

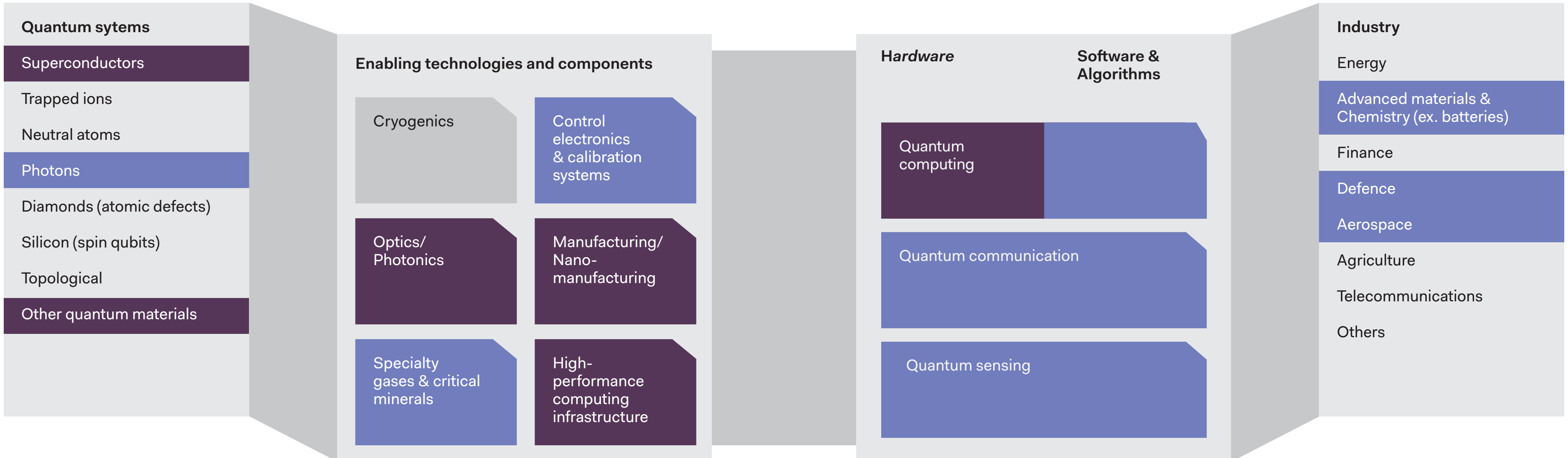
The technological risk remains high and dulls out the interest of private investors, while public mechanisms for early adoption or targeted support are often absent or insufficient. This imbalance creates a funding and support vacuum in which projects, despite their potential, struggle to demonstrate their usefulness, structure their intellectual property strategy, or convince their first customers. It is in this zone that the most promising innovations risk being abandoned due to a lack of conditions conducive to their commercial maturation.

TRL Scale

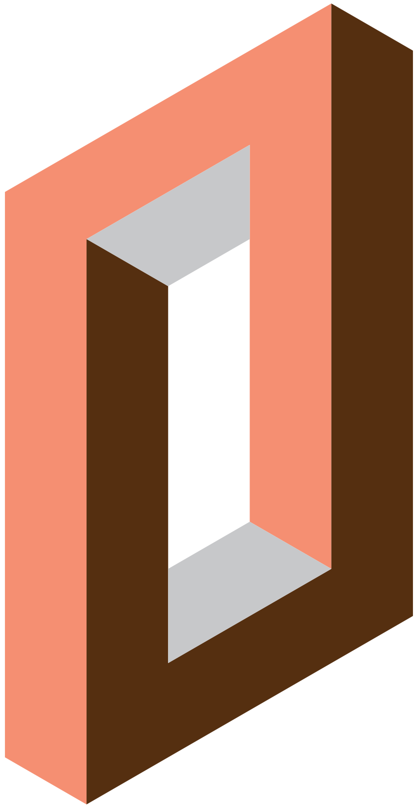
	Fundamental research TRL 0-3	**Prototyping and validation** TRL 4-7	**Manufacturing implementation and scaling** TRL 8-9
Issues related to commercialization	Flawed interconnecting between research and application, due to a lack of structured links between laboratories, transfer experts, and entrepreneurial entities.	Faint capacity to support commercial demonstration, particularly due to limited support for Research and Technology organizations (RTOs) and the absence of early procurement mechanisms to reduce technological risk.	Few public procurement programs to mitigate the risks associated with the market launch phase or to support initial industrial production.
Intellectual property	Lack of support to universities in structuring an intellectual property (IP) strategy rooted in market realities and entrepreneurial dynamics.	Limited acknowledgment of IP importance and the need for standards in the validation phases, limited resources to structure protection, licensing, or spin-off strategies.	Insufficient use of IP as a strategic lever in business models, which hinders negotiations with major decision-makers or foreign manufacturers.

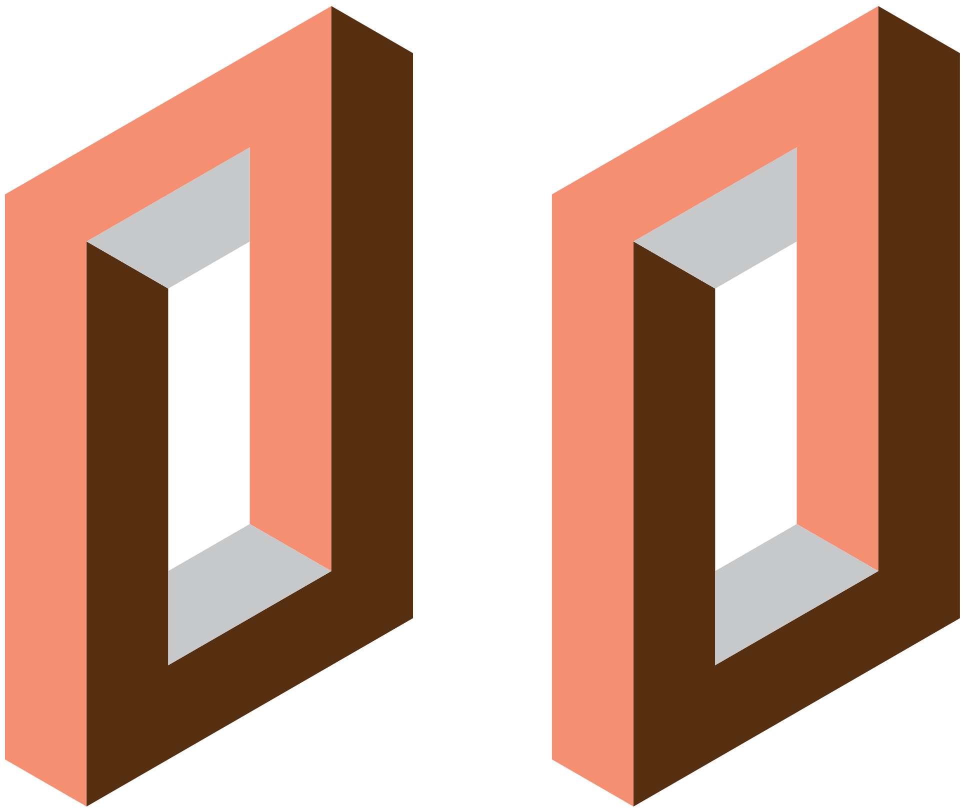
To keep in mind: Quebec’s confirmed strengths and levers of distinction

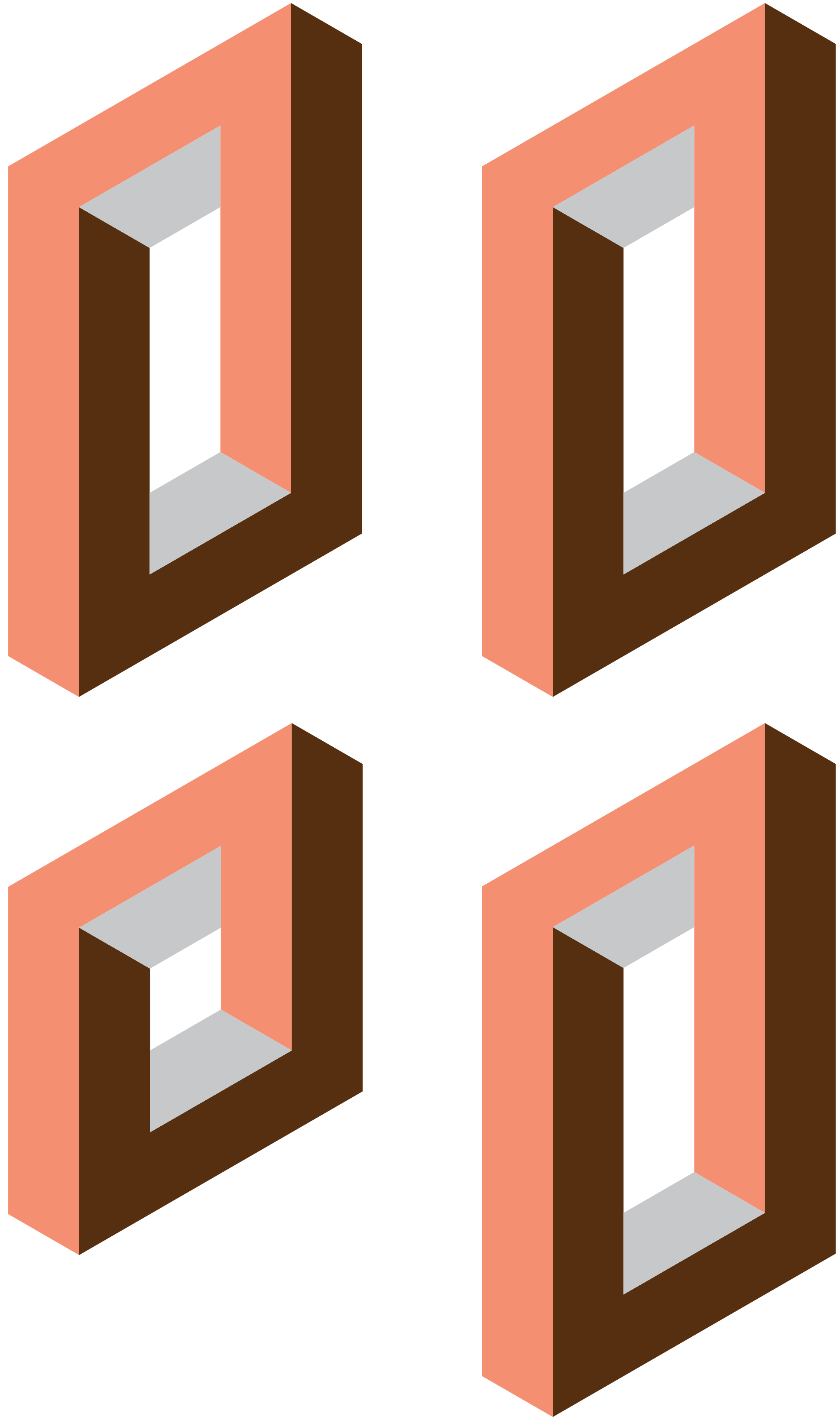
- Quebec is well positioned
- Quebec could stand out



Profiles







ALEXANDRE

Alexandre Blais
Laying the foundations for superconducting qubit architecture

An internationally renowned theoretical physicist, Alexandre Blais is one of the principal architects of the QED circuit, an approach that uses superconducting circuits to manipulate qubits with high precision. His work at the University of Sherbrooke and the Quantum Institute has demonstrated that cavity quantum electrodynamics can be adapted to electronic circuits, paving the way for more stable and scalable quantum computers. This theoretical framework is now at the heart of technologies developed by IBM, Google, and other industry leaders.
In addition to his scientific contributions, Alexandre Blais plays a key role in training the next generation, leading a large research group and collaborating with industrial partners. His influence is measured as much in the advancement of knowledge as in the structuring of the Quebec and Canadian quantum ecosystem, which he is helping to position among the most dynamic hubs in the world.

GILLES

Gilles Brassard
Developing the founding protocol of quantum cryptography

Recognized as one of the fathers of quantum cryptography, Gilles Brassard made history with the BB84 protocol, co-developed with Charles Bennett in 1984. This protocol is based on the laws of quantum mechanics to enable the exchange of unbreakable encryption keys. A professor at the University of Montreal and a member of the Royal Society, he laid the foundations for a field that is now central to cybersecurity in the era of quantum computing. His research has also influenced other fields, including quantum computing and information theory. Brassard has distinguished himself through his ability to anticipate technological challenges and popularize science, helping to raise awareness among decision-makers and the general public about the impacts of quantum technology. His work continues to inspire researchers and guide information security policies in Canada and internationally, positioning the country as a leader in this strategic field.

RAYMOND

Raymond Laflamme
Building world-class Canadian expertise in quantum information

Physicist and co-founder of the Institute for Quantum Computing (IQC) at the University of Waterloo, Raymond Laflamme has played a central role in building world-renowned Canadian expertise. A former collaborator of Stephen Hawking, he focused his research on quantum computing and error correction, becoming an international authority in the field. Under his leadership, the IQC has become a cutting-edge research center, combining scientific excellence with training for the next generation. He has also helped forge strong links between fundamental research and industry, fostering collaborative projects and the creation of technology startups. His commitment to disseminating knowledge and promoting science to the general public has enhanced Canada's visibility and appeal to international talent. Raymond Laflamme has thus firmly established the country in the global quantum race.

MIKE

Mike Lazaridis
Sparking the growth of Waterloo's quantum ecosystem

Mike Lazaridis, founder of Research In Motion (BlackBerry), reinvested part of his fortune in basic science, giving rise to Quantum Valley in Waterloo. By creating the Institute for Quantum Computing (IQC) and the Perimeter Institute for Theoretical Physics, he attracted world-class researchers and put in place the infrastructure needed to develop a center of excellence. His commitment catalyzed the growth of businesses, research programs, and private investment in the region. By launching the Quantum Valley Investment Fund, Lazaridis also supported the commercialization of research-based technologies, linking innovation and the market. His long-term vision, combined with massive investment in talent and equipment, has made Waterloo a model for ecosystem development, inspiring other regions in Canada and around the world to focus on quantum as an engine for growth.

ALIREZA

Alireza Najafi-Yazdi
Designing and manufacturing superconducting quantum computers in Canada, with entrepreneurial boldness

Founder and CEO of Anyon Systems, Alireza Najafi-Yazdi leads one of the few companies in the world capable of designing and manufacturing superconducting quantum computers from start to finish. Based in Quebec, Anyon Systems has control over the entire chain, from qubit design to the integration of cryogenic control systems. This technological autonomy enables the company to deliver complete solutions to institutional and industrial clients, including the Government of Canada. Driven by an ambitious vision and a clear passion for cutting-edge entrepreneurship, Najafi-Yazdi has attracted highly specialized talent and established strategic international collaborations. By demonstrating that a Quebec company can compete with global giants in the sector, he is helping to raise the country's technological profile and put Quebec on the global map of quantum computer manufacturers.

CHRISTIAN

Christian Weedbrook
Envisioning the future of computing with quantum photonics

Christian Weedbrook is the founder and CEO of Canadian company Xanadu, a Toronto-based start-up pioneering quantum photonic computing. With a PhD in quantum information theory (University of Queensland) and postdoctoral experience at MIT and the University of Toronto, he launched the company in 2016 with a radical ambition: to make quantum computers useful and accessible to everyone. Under his leadership, Xanadu has become the only company to have published three times in Nature on fundamental advances: programmable photon circuits, quantum supremacy via Borealis, and modular photonic architectures. With hundreds of millions of dollars in funding, including CAD 40 million from the federal government, the company is developing a fault-tolerant photonic quantum computer. Weedbrook embodies a disruptive vision at the intersection of fundamental research, advanced engineering, and entrepreneurship.

LISA

Lisa Lambert
Uniting the quantum value chain across Canada

Originally from Northern Ontario, Lisa Lambert has always sought to connect science and society. After studying neuroscience and science communication (Western, Laurentian), she contributed to leading organizations such as the Council of Canadian Academies, the Perimeter Institute, and TRIUMF, developing expertise in public policy, strategic partnerships, and international outreach. With this experience and an entrepreneurial background (founder of two consulting firms and co-author of the bestseller The Future is Trust), she was chosen in 2023 as the first CEO of Quantum Industry Canada (QIC). At the helm of this national consortium, she is mobilizing the ecosystem to transform the country's research assets into industrial success and economic prosperity.
For Lisa, quantum is not just a scientific breakthrough: it is a strategic opportunity to position Canada as a world leader in the transition from the laboratory to the marketplace.

DAVID

David Roy-Guay
Deploying quantum magnetometers for space and Earth exploration

Founder of SBQuantum, David Roy-Guay develops quantum magnetometers that exploit the properties of NV centers in diamonds to map magnetic fields with exceptional precision. These sensors have applications in mining exploration, GPS-free navigation, and space observation. The company has collaborated with the Canadian Space Agency to test its sensors in environments simulating space. By combining scientific expertise and entrepreneurial spirit, David Roy-Guay has positioned SBQuantum as a key player in the commercialization of robust, miniaturized quantum sensors. His ability to transform laboratory technology into operational solutions illustrates Quebec's potential to generate high-impact exportable innovations. His work contributes to diversifying the industrial applications of quantum technology and creating concrete bridges between advanced research and the needs of the global market.

ROBERTO

Roberto Morandotti
Harnessing the properties of photonics for quantum technology

A professor at INRS and specialist in integrated photonics, Roberto Morandotti explores how to manipulate light at the quantum scale to develop new communication, computing, and detection technologies. His research covers a broad spectrum, from the generation of quantum states of light to the creation of integrated photonic circuits capable of performing complex operations. By combining nonlinear optics, nanofabrication, and quantum concepts, he is paving the way for more compact, efficient, and environmentally noise-resistant systems. Collaborating with industrial and academic partners around the world, Morandotti is helping to place Quebec and Canada at the forefront of quantum photonics. His work reinforces the complementarity between different technological approaches in quantum computing, offering alternatives to superconducting or ionic architectures and enriching the diversity of solutions under development internationally.

CHRISTIAN

Christian Sarra-Bournet
Mobilizing the ecosystem and ensuring links between fundamental research and industry

As Scientific Director of the Quantum Institute at the University of Sherbrooke, Christian Sarra-Bournet uses his expertise to mobilize the ecosystem and build bridges between research and industry. As a specialist in technology transfer, he works to transform the results of fundamental research into marketable innovations. Under his leadership, the Quantum Institute is strengthening its partnerships with businesses and public organizations, multiplying opportunities for collaboration. His vision emphasizes interdisciplinarity and the ability to bring together expertise in physics, engineering, computer science, and entrepreneurship. By facilitating the transition of discoveries to the market, Christian Sarra-Bournet is helping to position Quebec as a player capable not only of scientific innovation, but also of generating sustainable economic benefits. His actions promote an integrated ecosystem, where science and industry reinforce each other.

FRANCO

Franco Rasetti
Catalyzing the optics-photonics ecosystem in Quebec City

An Italian-born physicist and a leading figure among the first generation of physics researchers in Canada, Franco Rasetti helped establish and structure optics and photonics research at Laval University. His work in the 1940s and 1950s led to the creation of a critical mass of researchers and infrastructure, laying the foundations for a scientific ecosystem that would have a lasting impact on the Quebec City region. Through his academic leadership and ability to attract talent, he helped build an internationally recognized research hub linked to future developments in quantum photonics. His contribution, although predating the current era of quantum computing, paved the way for the region to play a role in this field today. Rasetti's legacy can be seen in the institutional strength and scientific reputation built around optics and photonics in Quebec City.

RICHARD

Richard Bruno
Connecting science, industry, and public policy to build a quantum entrepreneurial ecosystem

Richard Bruno has shaped Quebec's innovation ecosystem by combining science, entrepreneurship, and venture capital. With a PhD in solid-state physics from McMaster University and an Executive MBA, he first taught in Germany and the United States before joining Philips, where he led disruptive innovations such as the Compact Disc and the first Minitel terminals. A serial entrepreneur, he has founded and sold several companies in the video game, videoconferencing, and cybersecurity sectors, making his mark on the consumer and professional technology solutions market. As co-founder and former president of Anges Québec, he helped build a structured network of investors and support the growth of numerous startups. As a mentor, investor, and advisor, he continues to influence innovation policies and pass on his knowledge to new generations of entrepreneurs.

JULIEN

Julien Camirand Lemyre
Integrating error correction into the physical qubit to make quantum computers more reliable

Co-founder and CEO of Nord Quantique, Julien Camirand Lemyre heads a Sherbrooke-based company that is tackling one of the biggest obstacles in quantum computing: error correction. His team is developing superconducting qubits that directly integrate the ability to correct certain errors at the hardware level, thereby reducing the need for software correction resources. This approach could accelerate the arrival of truly useful quantum computers on a large scale. Trained in physics and with solid experience in R&D, Julien Camirand Lemyre combines scientific vision with entrepreneurial acumen, positioning Nord Quantique as a unique player in this niche market. By collaborating with industrial and academic partners, he is helping to strengthen Quebec's position in the global quantum race, while demonstrating that disruptive innovation can emerge from a regional ecosystem and compete with international technology giants.

MICHEL

Michel Pioro-Ladrière
Building Sherbrooke's quantum ecosystem and projecting it globally

A physicist and scientific entrepreneur, Michel Pioro-Ladrière was a professor at the Université de Sherbrooke, where his work on semiconductor qubits helped establish a globally recognized quantum research hub. Until very recently Vice-President of Nord Quantique, he steered the company through its early strategic milestones, notably propelling it to qualify for the DARPA Quantum Benchmarking Initiative, a rare achievement for a Canadian startup. Active in bridging fundamental science and industrial innovation, his career embodies the synergy between academic research and high-tech entrepreneurship. In 2025, appointed CEO of DistriQ, Quebec's quantum innovation zone, he now works to unite scientific, industrial, and institutional stakeholders, strengthening Quebec's standing as a global leader in the quantum revolution.

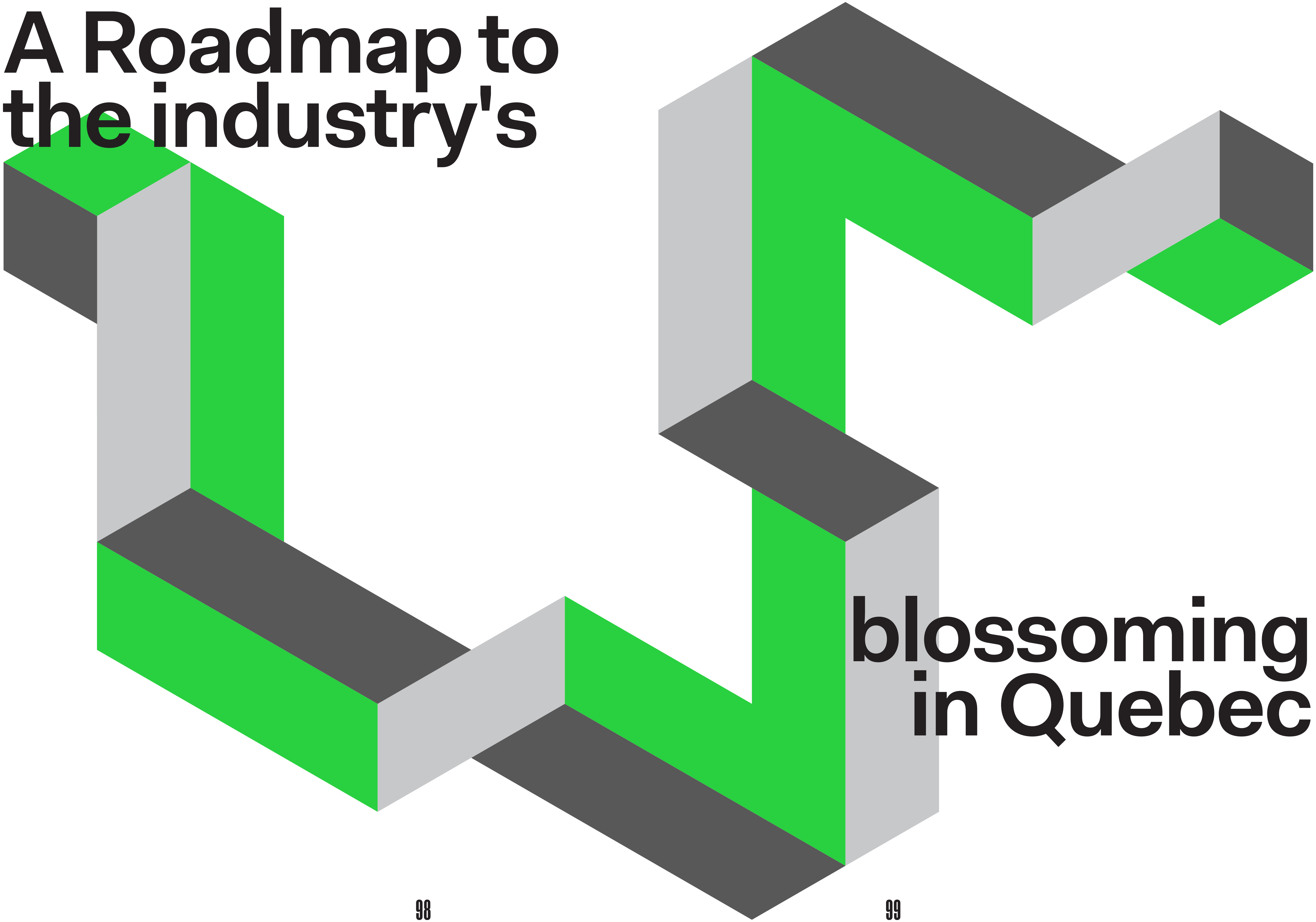
Reinventing the quantum computer through integrated error correction

Founded in 2020 in Sherbrooke, Nord Quantique is tackling one of the greatest bottlenecks in quantum computing: error correction. While giants like IBM and Google rely on architectures requiring several — even thousands — of physical qubits to obtain a single logical qubit, the Quebec-based company is pursuing a radically different approach. Its researchers use bosonic codes to embed redundancy directly within each qubit, thereby reducing hardware requirements by several orders of magnitude. This innovation has earned Nord Quantique international recognition, confirmed by its selection for DARPA's Quantum Benchmarking Initiative, alongside the most advanced players on the planet.

Breakthroughs have followed in rapid succession: the first demonstration of a physical qubit transformed into a logical qubit, the implementation of early fault tolerance, and the creation of the Tesseract Code — a multimode encoding structured as a fouR&Dimensional hypercube, capable of detecting and correcting a broad spectrum of errors while maintaining unprecedented stability. These results pave the way for compact, stable, and energy-efficient machines able to deliver useful power at the scale of data centers.

More than a technological feat, Nord Quantique reflects the vitality of Quebec's ecosystem. By leveraging local academic and industrial strengths, it demonstrates that disruptive innovation can emerge from a regional hub and establish itself on the global stage.

A Roadmap to the industry's blossoming in Quebec



Quebec has what it takes to join in this technological revolution that will invevitably shape the incoming economic and geopolitical era.

The development of quantum technologies remains shrouded in uncertainty, but one thing is clear: the potential for transformation is immense. Computing, communications, sensors—the foreseen applications have the power to reshape entire sectors, open up new markets, and strengthen the sovereignty of nations that master them. Quantum technology is not a distant promise: it is a race that is already underway, and Quebec must consolidate its lead.

This lead is the result of strategic choices implemented over the past decades: academic excellence, recognized innovation hubs, and an interconnected scientific and industrial ecosystem. This said, it is not guaranteed to last forever. Recent history shows that our capacity to transform world-class scientific knowledge into economic activity remains limited. But this is not a gloom and doom situation; Quebec has already reinvented itself many times and adapted to new social, geopolitical, and industrial realities. It can do so again.

Investing now means leveraging strategic sovereignty, competitiveness, and influence for decades to come.
This requires clarity and boldness, by building on our strengths, focusing our investments where they will have the greatest impact, accepting that some of our initiatives will fail, and, above all, opening ourselves fully to international collaborations and talents. Quebec can thus not only participate in this revolution, but also play a leading role in it, by making its quantum ecosystem a driver of innovation, growth, and global influence.

A Roadmap Based on Four Tenets

1

The quantum realm represents a major technological disruption, even though its implementation agenda remains fuzzy.

3

Quebec has a winning hand in this card game, thanks to its scientific know-how and capacity to align local players.

2

Akin to previous, industrial-quake scenarios, its economic worth will coalesce around a limited number of preeminent international hubs.

4

Today's actions will determine Quebec's position for the next twenty years.

Quebec's quantum success depends on six winning conditions

A shared ambition	A common and engaging vision, consistenly shouldered by scientific, industrial and public stakeholders
A continuing alignement between researching and industrial needs, backed by reliable financing	Strategic processes able to generate market interest, guide actions toward practical applications and establish sturdy interconnections
A commited and rallying industry	A clear engagement from investing privates businesses in testing public R&D solutions and actively participating in the structuring of the ecosystem
Patient institutional investments	Durable, multi-cycle funding to realize an ecosystemic framework and nurture budding champions
A higher strategic resilience toward technological risks	Capacity to endorse approaches that are uncertain and accept that they may not give rise to viable outcomes
Keen understanding and sharing of roles that complement each other	Mutual agreement on responsibilities that truly lead stakeholders in the same direction

What's in it for Quebec

Tangible economic returns : job creations, GDP growth, leveraging from homegrown intellectual proprerty

→ Global market for quantum technologies is valued at US$173G by 2040

World-renowned scientific leadership in a strategic field

→ Canada (including Quebec) ranks 6th worldwide in terms of notable publications in quantum computing.

Mastery of critical technologies, developed in-house and usable in defence, cybersecurity and energy

Benefits from a competitive, structured and locally rooted industry

Transformational economic might, able to redefine value chains and attract strategic investements

Productivity gains in fields where traditional ways collapse

What's at risk for Quebec

Loosing to other international players a scientific leadership 40 years in the making

Les talents et entreprises formés ici, faute de perspectives locales à la hauteur de leurs ambitions

→ More than a third of all Canadian start-ups are Quebec-based (representing more than 3% of start-ups worldwide)

25% of the 16,000 Canadians graduatingin quantum-relevant fields are trained in Quebec

Loosing self-reliance and sovereignty over strategic technologies

Not gaining access to markets and value chains established in trailblazing ecosystems

Quebec is setting forth an ambitious agenda to consolidate its posture and increase its clout in the quantum economy.

To guide the development of quantum technologies in Quebec, an ambitious vision—with a quick turnaround time—is needed, while taking into account their novelty and transformational nature. Vision 2030 sets out a clear path for the next five years, based on the strategic mobilization of all stakeholders and the concentration of efforts where they can have the most decisive impact.

Although constantly evolving, the full potential of quantum sciences will call for a patient, structured, and long-term approach. Advances in this field will be measured over several decades, requiring strategic coherence, sustained investment, and governance capable of anticipating innovation cycles.

Vision 2050 seeks to align current decisions with the profound transformations to come, positioning Quebec in a leading role within the quantum economy in order to assert its sovereignty, ensure its competitiveness, and establish its influence on the international stage.

Vision 2030

In the medium term, Quebec's quantum industry will be structured around an ecosystem whose centres of excellence are strategically aligned, closely interconnected, and supported in a coordinated manner by the federal and provincial governments. This holistic network will steer cutting-edge research toward practical usages identified by strategic users—public entities or big tech companies.

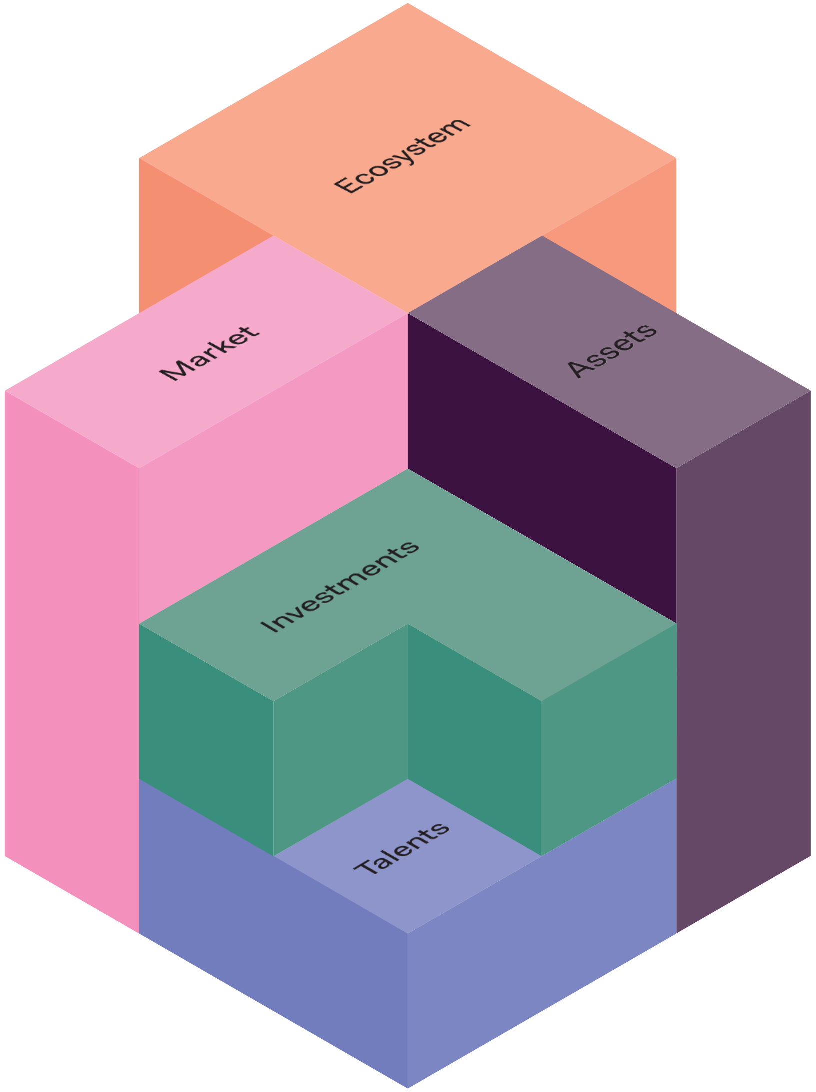
Researchers, industry newcomers and large corporations will play a leading role in intellectual property and technological standardization—two key aspects in a global race where whom sets the norm has the upper hand in the market. Through patient, but unyielding efforts, Quebec can establish itself as a foundational player in the global quantum architecture.

Vision 2050

In the long term, Quebec vies to become a critical link in the quantum supply chain. Local companies will design, produce, and export integrated solutions based on locally developed and internationally valued intellectual property.

This technological sovereignty will strengthen Canada's economic resilience by providing it with a key asset in the context of major industrial transitions. Early investors in Quebec's quantum ecosystem will have not only nurtured a budding sector: they will put their faith in the coming of the greatest paradigm shift of the third millennium.

We submit that Quebec should act on five complementary components to better structure its quantum ecosystem and maximize its return on investment.



Hardware First mindset	Establishing technological **sovereignty** around a strategic **value** chain
Talent as a power broker	Training, attracting and retaining a talent base aligned with **true value chain needs**
Demand as a quantum market igniter	Fostering the emergence of an **open-minded and persuadable market**
Patient and congenial financing	Pushing **readiness forward** to reach marketabilty and lasting economic outcomes
Networking spirit	Furthering interconnections and synergies at provincial and national levels, to enhance coordination and expansion

Appendixes

CONSULTED INDIVIDUALS

** Members of counselling committee

This roadmap is the result of a collective exploration. It presents the vision, expertise, and enthusiasm of a community sold on Quebec's potential at the onset of the next technological revolution. Researchers, entrepreneurs, public decision-makers, investors, and ecosystem builders have assembled their views to inform our analysis and open up new avenues.

Throughout our discourse, something became clear: it is through dialogue and diversity of perspectives that we will be able to transform our scientific lead into sustainable levers for competitiveness and influence.

We would like to express our heartfelt gratitude to all that have graciously spared their time and knowledge in the context of this project—especially those whom we've had the privilege of interviewing.

Visit to Quantum Delta NL and IXCampus

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CEO, Quantum Algorithms Institute

Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis

Strengths

Renowned scientific expertise
Global leadership, driven by leading figures such as Alexandre Blais and Gilles Brassard and resulting from many years of continuous research.

Robust value chain from research to manufacturing
Coherent sequence, from fundamental research to protoyping, manufacturing (C2MI) and shared infrastructures (EQ1), all federated around Distriq's Innovation Hub.

Hardware-rich ecosystem and technological / multi-platform diversity
Variety of approaches (superconductors, photons, neutral atoms), consolidated by local and international players.

Visibility of local start-ups
Quebec accounts for 36% of Canada's quantum startups (while representing 20% of Canada's GDP and population), a strong indicator of its standing-out and market structuring capacities.

Governmental support and international recognition
Tangible support from the provincial government and growing notoriety in Europe's ecosystems.

Foundational optics/photonics ecosystem
Combination of world-class players and solid applied-research core, making Quebec a strategic hot spot for photonic-based quantum technologies integrating photonics.

Leverage from Montreal's AI ecosystem
Synergies with Mila and IVADO institutes, plus other advanced algorithms companies, accelerate software development and platform hybridization.

Weaknesses

Public funds dependency and lack of private capitalization
Timid engagement from family offices and philanthropy, venture capital misaligned with deep-tech cycles.

Weak industrial capacities and limited appreciation of IP
Insufficient push toward TRL 4-7, uneasy transitioning to industry, intellectual property not valued enough.

Lack of ecosystem coordination at the provincial level
Inter-hub tensions (Sherbrooke-Montreal), messaging/narrative in need of clarity.

Shaky strategic messaging and limited industry engagement
Quebec is struggling to articulate a clear and compelling narrative about its strengths in quantum technology, particularly when talking with industry stakeholders. This flawed positioning impedes economic attractiveness and the advent of structuring partnerships.

Opportunities

Structuring of the development cycle, from research to industrial adoption
Mapping the needs for key sectors, customized structuring of readiness levels, enhancing support to RTOs (INO, CRIM research centre) during intermediate phases, launching of pilot program (Qu-Pilot).

Boosting up of enabling technologies for strategic leverage
Bolstering support to stand-out technologies—cryogenics, photonics, specialized chip manufacturing.

Tooling up of promising start-ups, for growth and exports
Mentoring newcomers to accrue business competencies, facilitating inaugural orders and nurturing expansion.

Activation of government pipeline and leveraging of National Defence needs
Considering public sector needs (cybersecurity, critical infrastructures, defence) as a driving force for technological adoption and maturation.

Strengthening of strategic international partnerships
Hiking up exchanges with like-minded countries (notably France, Netherlands, UK) to attract talents and enable large-scale projets and federating events (ex. conferences, summits, etc.).

Threats

Low strategic-purchasing power in Canada/ Quebec
Typically, governments are initiallycautious with new technologies, which translates into a limited number of public contracts in cybersecurity, defense, and critical infrastructure (compared to Europe or the United States).

Difficulty to convince large companies/industrial groups
The Quebec industrial environment is characterized by a limited number of large companies. And across Canada, low tolerance to risk slows down private investment in complex and uncertain technologies.

International jousting for talent and internal migration barriers
Many Nordic and Asian countries are actively recruiting internationally, while in Quebec, restrictive provincial policies (such as Bill 74) are slowing the influx of foreign students in STEM and hindering the renewal of the local ecosystem.

Political uncertainty toward sustainability of innovation zones
Risk of defunding with change of government/ priorities, lack of long-term structuring mechanisms.

Breathing Space for Ideas

Founded in 2015, VOLUME10 is a boutique consulting firm specializing in management and strategy, skillfully melding the agility of a start-up and the expertise of a large international firm. Mainly comprised of engineering minds trained at the world's most prestigious schools—and supported by a network of subject-matter specialists in Economics, Law, Health, and Ethnography—, our team relishes complex projects where solutions are not immediately obvious. This unique mixture of talents allows us to thrive when presented with demanding strategic and operational challenges, delivering tailor-made solutions that are rigorously adapted to our clients' specific needs.

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Content and production by VOLUME10
www.volume10.com

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Layout
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Legal deposit, Bibliothèque et Archives nationales du Québec, 2025

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