PRIMA

Les matériaux pour avancer

2035 ROADMAP

DECARBONIZING THE ECONOMY THROUGH ADVANCED MATERIALS AND ASSOCIATED PROCESSES

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FOREWORD

The impacts of climate change are increasingly being felt throughout society. To tackle these major societal challenges, many countries and regions around the world have committed to achieving carbon neutrality by 2050. For this purpose, researchers, manufacturers, governments, and consumers must mobilize and take action. Achieving net zero emissions in Quebec and Canada will require more than one strategy.

In this race to decarbonize, all nations are currently positioning themselves. A nation's relative position is typically gauged by its finished products (electric vehicles, wind turbines, solar panels, clean technologies, etc.), but the most important battle must be fought upstream.

Materials are at the very heart of industrial innovation processes. Quebec, like Canada, must invest in the development and marketing of a new generation of advanced, eco-responsible materials that provide rapid and effective solutions to the many challenges that underlie industrial and process-related decarbonization efforts, as well as our efforts to decarbonize the economy as a whole.

FINANCIAL PARTNERS

PRIMA Québec served as the main funding body for this structuring project, while additional funding came from the Ministère de l'Économie, de l'Innovation et de l'Énergie (MEIE), Innovation, Science and Economic Development Canada (ISED), and Canada Economic Development for Quebec Regions (CED).*

Économie Innovation et Énergie Québec

Développement économique Canada pour les régions du Québec

Innovation, Sciences et Développement économique Canada

STEERING COMMITTEE

This initiative received commitment and guidance from a steering committee throughout the process. The committee's active engagement at every stage ensured diligence and relevance for both the approach and the Roadmap.

Maxime Duval - Industrial Development Advisor, Ministère de l'Économie, de l'Innovation et de l'Énergie (MEIE)
Mario Vendittoli - Director of Economic Intelligence, Canada Economic Development (CED)
René Poirier - Regional Manager, Quebec - Innovation, Science and Economic Development Canada (ISED)
Denis Geoffroy - Chief Commercialization Officer, Nano One
Luc Pouliot - CEO, Polycontrols
Simon Thibault - EV Critical Materials Leader, General Motors
Audrey Laventure - Assistant Professor, Institut Courtois, Université de Montréal
Caroline Cloutier - Director of R&D, National Research Council Canada (NRC)
Jean-François Morin - Professor, Institut des matériaux durables
Valérie Boissonneault - Director, Innovation Zones, Investissement Québec (IQ)
Pascal Lanctôt - Associate, Climate Tech Fund, Business Development Bank of Canada (BDC)
Daniel Normandin - Director of CERIEC (ÉTS)
Maude Lizaire - Doctoral student, Mila - Quebec AI Institute
Liza Abid - Doctoral student, Université Laval

STRATEGIC PARTNER

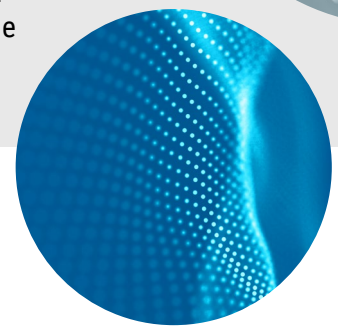
PRIMA Québec commissioned the firm of Sia Partners in support of its activities.

*The content of this document in no way binds the government organizations who helped fund the initiative or any of its analyses and activities.

SUMMARY

The Roadmap for advanced materials and associated processes is the first of its kind in Canada. Its objective is to help resolve **three major societal challenges**:

1. Complete the energy transition and decarbonize industry to achieve net zero by 2050 through collaboration with the innovation zones;
2. Increase productivity with a digital transition to help maintain and improve our standard of living;
3. Secure the country's strategic supply chains by reducing its dependence on the foreign minerals, materials, components, and services needed to fuel the energy and digital transitions.



This mobilizing approach rallied more than 150 stakeholders and experts around **a common vision:**

"By 2035, Quebec will have developed and marketed a new generation of advanced materials, along with sustainable and competitive processes through its committed and collaborative ecosystem."

Seven key guidelines were drafted to support this vision. Various objectives stem from the first six, while the seventh objective provides a series of recommendations that seek to improve the conditions in which companies will eventually operate.

Guideline 1
Increasing the circularity of advanced materials within supply chains

Guideline 2
Becoming a leader in research

Guideline 3
Boosting the emergence of start-ups

Guideline 4
Promoting growth for small and medium-sized enterprises

Guideline 5
Developing the next generation of skilled workers

Guideline 6
Providing companies with more patient capital

Guideline 7
Modernizing public procurement and regulatory frameworks

A WORD FROM THE PRESIDENT & CEO

Proudly speaking on behalf of the entire advanced materials ecosystem, PRIMA Québec is pleased to introduce the 2035 Roadmap, an ambitious document designed to meet one of the greatest challenges of our time: decarbonizing the economy.

"Every day, the fascinating world of advanced materials propels Quebec towards a greener, more sustainable future. Like critical and strategic minerals, advanced materials provide an essential pillar for a decarbonized energy transition while promoting the ever-expanding role of a circular economy in our society."

Marie-Pierre Ippersiel, Ph.D.
President and CEO
PRIMA Québec

Following an inspiring and unifying mobilization exercise that brought together more than 275 participants through surveys, workshops, and discussion groups, the creation of the Roadmap helped us clarify our vision while establishing new connections and partnerships centred around our shared goals and outcomes.

While the guidelines that appear in the Roadmap are the end result of a process that began in the spring, they nonetheless herald the start of an ongoing mission that will incorporate new measures intended to position Quebec within the international market while reinforcing the strategic significance of advanced materials for the future of our planet.

I offer my sincere gratitude to every member of the steering committee for its participation in this collective and collaborative effort. I wish to thank the PRIMA Québec team, our Board of Directors, and René Poirier for their unfailing support throughout the project.

I also wish to thank every company, research community and organization that was consulted while developing the Roadmap. All have contributed their heart and passion, and my fondest wish is that they will be the first to benefit.

THE APPROACH

Roadmaps provide strategic plans that define the various actions put in place by sectors to achieve pre-established goals and outcomes. They maximize benefits by providing a vision and a set of objectives while uniting stakeholders under a common initiative across the entire value chain and market.

LAUNCHED IN MARCH 2024, THE APPROACH REFLECTS PRIMA QUÉBEC'S COMMITMENT TO THE FOLLOWING:

- To undertake a significant mobilization exercise targeting the advanced materials ecosystem in the context of decarbonization;
- To further promote ties between industry and researchers to help position Quebec in the marketplace;
- To further position the advanced materials sector as a pillar for Quebec's decarbonization and biodiversity preservation objectives.

THE APPROACH (CONTINUED)

THE ROADMAP WAS DEVELOPED IN FOUR KEY PHASES:

Updates on global trends and the ecosystem

The first phase involved bringing together all strategic content from the advanced materials sector and associated processes. This included a study on supply and demand, research into scientific publications and patents, a survey for industrialists and researchers, along with interviews with experts in the field.

Identification of strategic sectors and themes

The first version of the Roadmap consolidated these results to prioritize four of Quebec's application sectors: energy, transport, electronics, and the environment.*

The exercise also led to three transversal themes that merit further investigation: funding, start-ups and commercialization, technology adoption, and the workforce.

Vision 2035 workshop and preliminary definition of guidelines

In April of 2024, a vision workshop was held for researchers, business representatives, and economic development organizations to help lay the groundwork for a sector-wide outlook targeting 2035.

Co-drafting of objectives and actions

Between May and July, seven working groups met to take part in a co-drafting exercise that sought to translate this vision into concrete objectives and actions.**

THE NUMBERS:

125+ respondents

for a survey targeting organizations and businesses regarding their perceptions of technological trends with regard to the four application sectors and their outlook for 2035.

15+ interviews

with experts in the field to create a profile of Quebec's advanced materials sector.

40+ collaborative workshop participants

to define Vision 2035 and create a basis for its guidelines.

100+ participants

within sectoral and thematic working groups to define a set of objectives and actions.

*See Appendix A
**See Ambition 2035 section

A WORLD IN TRANSITION

Advanced materials play a key role in the energy transition while providing significant business opportunities. Demand for these products continues to grow significantly as countries position themselves and strategies begin to take shape.

AN EVOLVING GLOBAL CONTEXT

The advanced materials sector is increasingly faced with a rising tide of trade protectionism. These new barriers are adding complexity to international trade while increasing the risks associated with the supply of raw materials and essential components. For example, China requires export licenses for gallium and germanium, which are intended for use in electronics and optical fibers. In this context, strategies must be reconsidered when securing supply chains.[2]

Furthermore, any withdrawal or significant alteration involving the Canada - United States - Mexico Agreement (CUSMA), set for renewal in 2026, is likely to have substantial implications for the Canadian economy. Almost two thirds of Canadian products are destined for the United States as supply chains remain highly integrated.[2]

Thus, stakeholders remain bound to a geopolitical context that is constantly evolving, making it essential to implement strategies that can maintain their competitiveness.

THE ENERGY TRANSITION IS WELL UNDERWAY

Global investments in electric vehicles, renewable energy, and smart electricity grids reached US$1.8 trillion in 2023.[12]

These investments provide a considerable boost to research and development (R&D) while increasing the demand for advanced materials which, in turn, generates new commercial opportunities.

In 2023, global demand in the advanced materials market was estimated at US$68.9 billion and is expected to reach US$147 billion by 2032. It is a booming market, with a compound annual growth rate (CAGR) estimated at 8.8% between now and 2032.[1]

STRATEGIES UNDER DEVELOPMENT

With the transition currently underway, several countries have defined their strategies around advanced materials. These include the European Union, the United Kingdom, Sweden, and Ireland, which have developed strategies that typically focus on supporting innovation, strengthening production capacity, and reducing dependence for critical minerals.

Quebec has everything it needs to develop its own strategy and position itself globally while transforming its advanced materials sector into a pillar for the energy transition.

BUSINESS OPPORTUNITIES IN A DYNAMIC MARKET

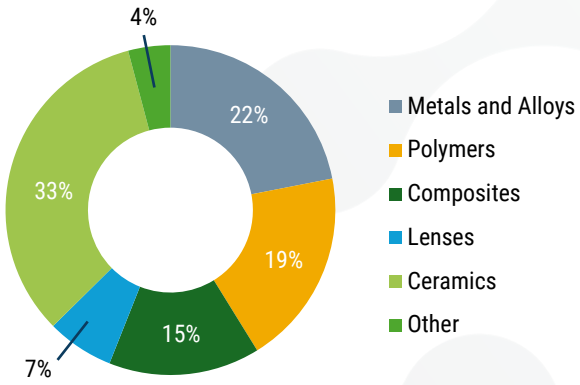
Global demand is set to double in 10 years, providing a strong stimulus to growth in the advanced materials market[1] while generating a number of business opportunities for both Canada and Quebec.

North America is expected to generate the largest share of revenues by 2032 through its considerable R&D capabilities, its robust manufacturing infrastructure, and its direct access to a large consumer market. The demand for advanced materials will also increase in sectors like aerospace, automotive, electronics, healthcare, and energy, all of which will be driven by innovation, infrastructure investments, and favourable government policies.[1]

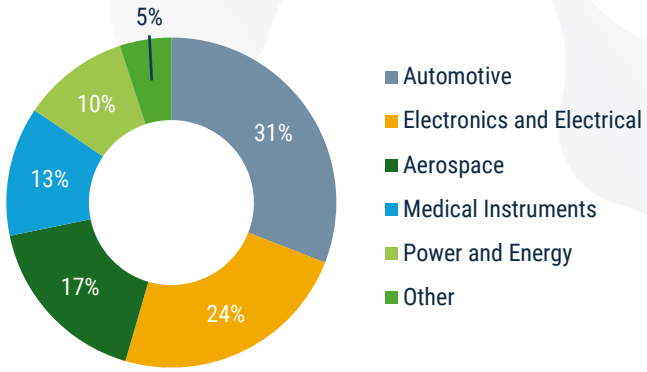
Canada stands out for its attractiveness, with direct foreign investment flows that outperformed global averages between 2015 and 2022.[3] Significant investments have also been made in various strategic sectors like automotive, aerospace, and energy in response to an anticipated worldwide growth in revenues between now and 2032[1] and the ability of Canadian companies to specialize and innovate within these areas. In terms of the number of patent families, Canada ranks ninth in the world in the field of advanced materials.

Quebec ranks 2nd in Canada for its share of patent families (2,130).[3] Thanks to its world-renowned research centres and dynamic business ecosystem, Quebec is equally well positioned to capitalize on growth opportunities through several types of materials. These include metals, alloys, and composites, whose share of revenues is expected to rise between now and 2032.[1]

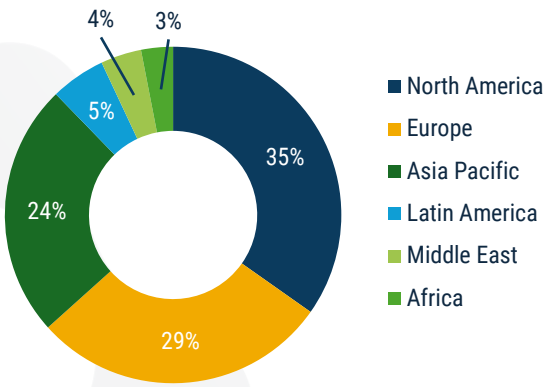
GLOBAL REVENUE DISTRIBUTION BY MATERIAL TYPE, 2032[1]



GLOBAL REVENUE DISTRIBUTION BY APPLICATION SECTOR, 2032[1]



GLOBAL REVENUE DISTRIBUTION BY GEOGRAPHY, 2032[1]



QUEBEC'S ADVANCED MATERIALS ECOSYSTEM

AT A GLANCE[5]

570 active companies in Quebec

A large number of companies are involved in the development, production and integration of advanced materials, as well as the development and production of associated equipment and processes.

US$15 billion in sales by 2024

Significant investments are currently underway. More than 70% of large and medium-sized companies (100-999 employees) have already invested, or plan to invest, over $1 million between 2021 and 2026.

49,000 jobs

The number of jobs in the advanced materials sector continues to rise. Most of the companies surveyed (65%) are currently undergoing a growth phase, particularly small businesses (10-99 employees), which have grown by 6.6% since 2021.

70% of revenues attributed to exports

The advanced materials sector in Quebec has a strong tendency towards export and a significant presence in international markets. Indeed, 70% of revenues associated with almost every business category stems from exports, and over 85% of companies with more than 10 employees are active in foreign markets.

99% research participation rate

Companies in this sector lean strongly towards R&D: almost 99% of these are involved in both internal and external research. On average, approximately 7% of jobs in large and medium-sized companies are devoted to R&D activities.

WHAT ARE ADVANCED MATERIALS?

Advanced materials include any new or significantly improved material that offers a marked advantage in performance (physical or functional) over the conventional materials currently in use, thus providing a substitute. They include lightweight composites, nanomaterials, high-performance alloys, and specialized polymers, among other things. This definition stems from a documentation exercise conducted by PRIMA Québec in 2018.

These materials play a key role in various application sectors, where their unique properties can, for example, improve efficiency or biodegradability.

Advanced materials can be divided into three categories:

BASIC MATERIALS

Materials that have undergone little or no transformation and are used upstream in the manufacturing chain (e.g., materials production).

FINISHED AND SEMI-FINISHED PRODUCTS

Products intended for an intermediate or end user (e.g., material integration).

ASSOCIATED PROCESSES AND INSTRUMENTATION

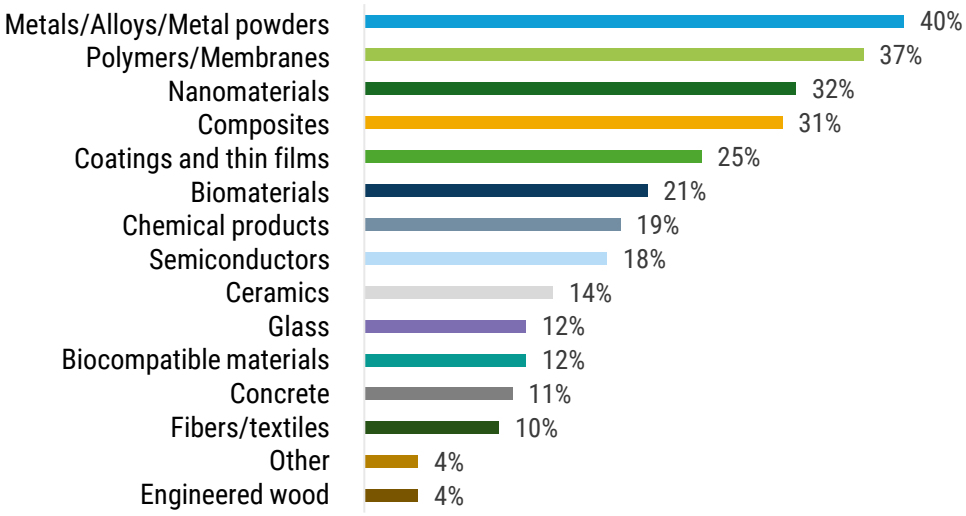
Any innovative process involving advanced materials (e.g., nanomanufacturing, additive manufacturing, surface treatment, shaping, etc.).

A WIDE RANGE OF PRODUCTS AND SOLUTIONS

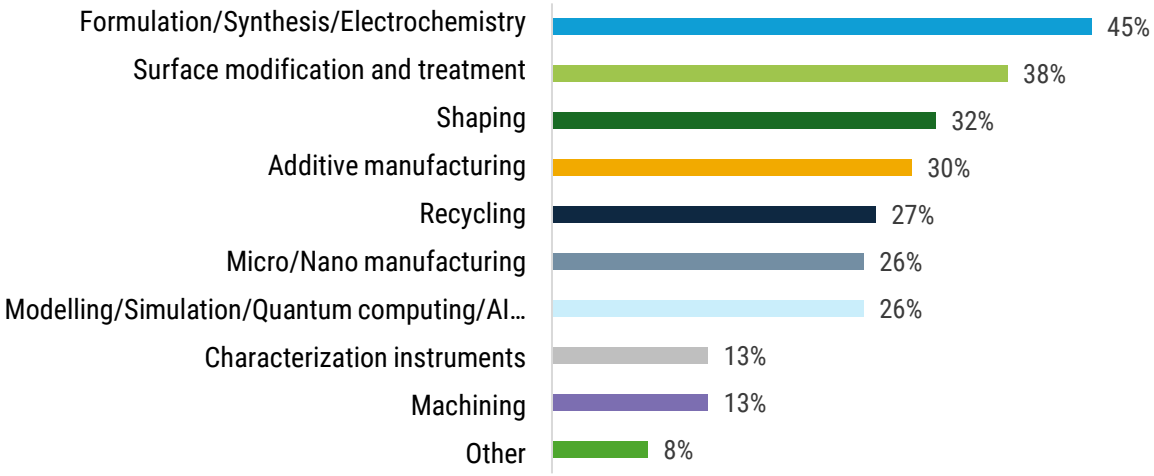
Quebec's advanced materials sector is home to a wide range of products and services that can respond to an equally wide range of industrial and technological requirements, thus strengthening the province's adaptability and growth in an evolving global market.

PRODUCT AND SERVICE RANGE COVERED BY THE COMPANIES SURVEYED[5]

ADVANCED MATERIALS



ASSOCIATED PROCESSES AND INSTRUMENTATION



The vast majority of Quebec companies operate in several areas, which speaks to their considerable level of skill. Over 90% of companies that use advanced materials classify themselves as producers, 91% as developers, and 81% as integrators.

A significant percentage of companies operate within two categories (25%), and within all three categories (68%),[5] helping them position themselves and compete effectively in various market segments.

A STRONG PROPENSITY TO INNOVATE BASED ON R&D…

R&D activities in Quebec's advanced materials sector have gained considerable international recognition. The province is able to reliably develop international partnerships while promoting collaboration between private and public sectors. It is home to several organizations that conduct research involving various topics while publishing their findings in scientific journals. Quebec ranks second in Canada for its number of publications–roughly 25% of the national total.[3]

Quebec's research activities focus primarily on nano/metamaterials like graphene, nanoparticles, nanotubes, and plasmons, as well as electric batteries, composites like polymers and concrete, along with photocatalysts and solar cells.[3]

This helps Quebec tackle the challenge associated with the energy transition and decarbonization through its commercialization of innovations.

MAIN RESEARCH THEMES FOR ADVANCED MATERIALS IN QUEBEC[3]

Research Themes (by publication volume)	**Publication Volume (%)**		
	QC	**CAN**	**World**
Graphene, carbon nanotubes, nanotubes	4.30	4.00	5.30
Secondary batteries, electric batteries, lithium alloys	3.40	3.50	4.30
Polypropylenes, lactic acid, mixture	2.60	1.70	1.20
Reinforced concrete, concrete, steel	2.40	2.00	0.80
Photocatalysis, photocatalysts, solar cells	2.00	2.20	4.90
Fiber laser, fibers, optical fibers	1.90	1.10	1.10
Composite materials, laminates, fiber-reinforced plastics	1.90	1.10	0.80
Quantum optics, quantum computers, quantum theory	1.90	3.20	1.40
Organic light-emitting diodes, solar cells, conjugated polymers	1.70	1.50	1.70

...AND INGENUITY

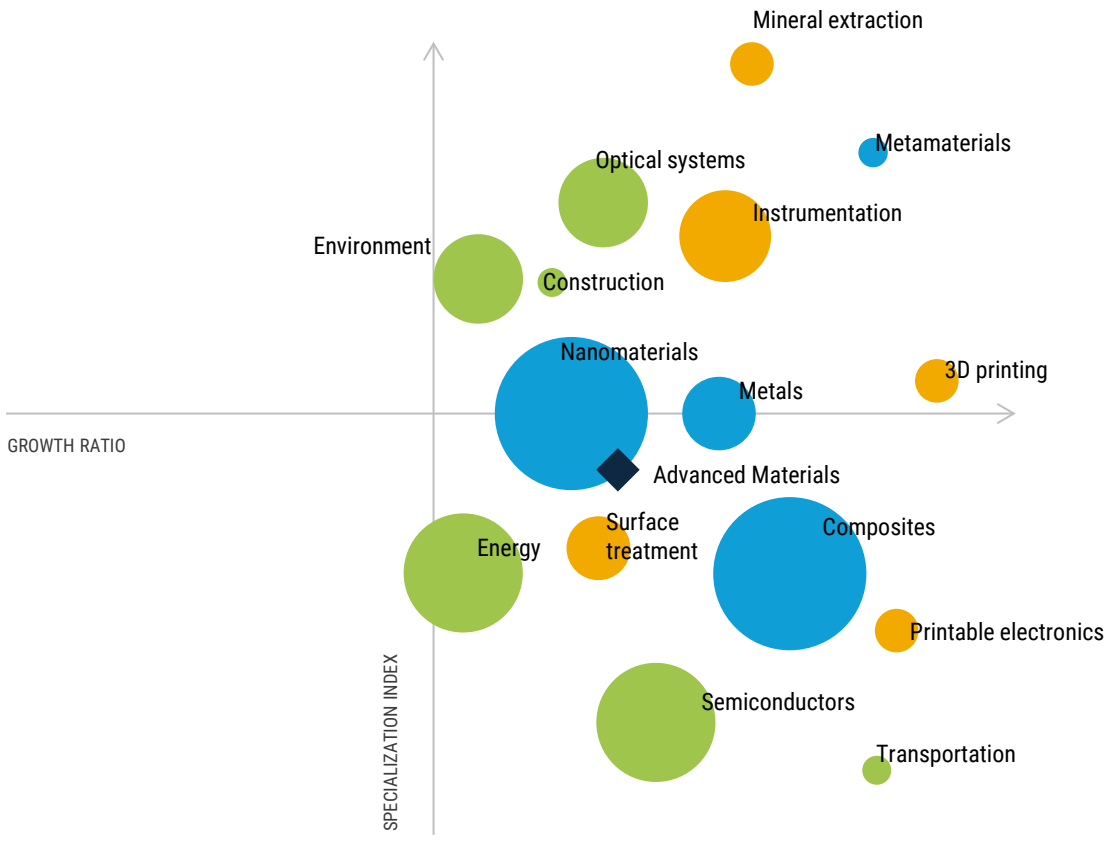
Quebec stands out for its ability to invent and its considerable rate of growth.

This dynamic helps companies develop various intellectual property (IP) protection strategies. In fact, more than 75% of stakeholders use trade secrets and patents.[5]

Quebec is home to a number of sub-sectors that work with nanomaterials, semiconductors, composites, and metals, along with a significant number of patents in these areas.

These assets provide Quebec with a strong position when marketing its inventions in various application sectors linked to the energy transition.

GROWTH BY INGENUITY SPECIALIZATION IN QUEBEC SUB-SECTORS (2003-2020)



How to read this figure

The Quebec-based sub-sectors that appear in the top right quadrant represent specializations (specialization index (SI) > 1) with a positive trend (growth ratio > 1). The sub-sectors in the bottom right quadrant represent non-specializations for the organization involved (specialization index (SI) = 1). The size of the bubbles illustrates the number of patent families.

Legend

- Types of materials
- Areas of Application
- Processes

AMBITION 2035

The Roadmap is intended to help solve some of the most significant challenges facing society (energy transition, digital transition, securing strategic supply chains) by implementing concrete measures in line with Vision 2035.

"By 2035, Quebec will have developed and marketed a new generation of advanced materials, along with sustainable and competitive processes through its committed and collaborative ecosystem."

THE GUIDELINES

1. **Increasing the circularity of advanced materials within supply chains**
2. **Becoming a leader in research**
3. **Boosting the emergence of start-ups**
4. **Promoting growth for small and medium-sized enterprises**
5. **Developing the next generation of skilled workers**
6. **Providing companies with more patient capital**
7. **Modernizing public procurement and regulatory frameworks**

GUIDELINE 1

INCREASING THE CIRCULARITY OF ADVANCED MATERIALS WITHIN SUPPLY CHAINS

1

Optimizing the production and use of resources will be essential, considering the growing demand for advanced materials targeting the energy and digital transitions, along with ever-increasing stocks of end products, which represent exploitable resources, not industrial and domestic waste. Thus, the goal is to significantly reduce the number of materials used[8] while increasing the resilience and circularity of supply chains through improved and recycled materials, optimized designs, and efficient manufacturing processes.

OBJECTIVE 1.1

To promote eco-design when developing new advanced materials and processes.

- As of 2025, include the concept of a circular economy within the evaluation criterion used in calls for projects launched by PRIMA Québec.
  – *Sponsor: PRIMA Québec*
- Integrate the life cycle analysis concept as an evaluation criterion for projects that specifically target the development of advanced materials and processes and receive support from PRIMA Québec.
  – *Sponsor: PRIMA Québec*

OBJECTIVE 1.2

To deploy traceability and environmental transparency solutions within supply chains.

- Raise awareness among companies in the ecosystem of the Écoleader program, intended to finance environmentally responsible support initiatives.
  – *Sponsor: Fonds d'action québécois pour le développement durable (FAQDD)*
- Encourage companies to assess their own degree of material circularity.
  – *Sponsor: Centre de Transfert Technologique en Écologie Industrielle (CTTÉI)*
- Implement a traceability pilot project that brings together a large number of stakeholders in the battery sector.
  – *Sponsor: Propulsion Québec*
- Map incoming and outgoing material flows in Quebec's industries while identifying potential synergies.

OBJECTIVE 1.3

To increase advanced materials recycling and reuse within the four application sectors.

- Launch the Circular Innovation Challenge, an initiative designed to support companies that develop and implement innovative and practical solutions in the wind turbine and electric battery sectors. This challenge will encourage new eco-design methods, along with the reuse and recycling of materials within these sectors.
  – *Sponsor: RECYC-QUÉBEC and Cycle Momentum*

- Launch a circular economy accelerator laboratory for advanced materials.
  – *Sponsor: CERIEC*

CIRCULARITY

A digital platform for the reuse of composite products

The Pyrofibre Platform

Drawing on its expertise in composites, the Centre de Développement des Composites du Quebec (CDQC) has developed a digital resource exchange platform to help reuse, recycle and recover composite products. The CDCQ and the Regroupement des Industries des Composites du Québec (RICQ) share a resource that gathers information regarding deposits.

As the number of registrations on the Pyrofibre platform increases, so will the opportunities to locate deposits. This increase will provide greater support for companies and start-ups, helping them develop solid business plans for the creation of pyrolysis and recovery centres.

GUIDELINE 2

BECOMING A LEADER IN RESEARCH

2

Quebec's advanced materials ecosystem is home to a wide range of world-class research centres and renowned experts. This guideline seeks to transform this competitive advantage into a lever of growth to help them seize the opportunities offered by the latest technological advances and the growing demand for sustainable materials. By adopting the best practices in research and collaboration, and by placing sustainability at the heart of its projects, Quebec is positioning itself to become a world leader in this rapidly expanding field.

OBJECTIVE 2.1

To accelerate the development of new, sustainable materials and processes using digital technologies, including artificial intelligence and quantum technologies.

- Increase or maintain budgets allocated to programs that support business investments in new technologies, like artificial intelligence and quantum technologies.
- Support the development of new materials with innovative properties and functionalities using tools like the Partenar-IA program and Scale-AI, as well as collaborations with organizations like IVADO, or programs like Quantum Technologies or PSO.
  – *Sponsor: PRIMA Québec*

OBJECTIVE 2.2

To use the opportunities created by international agreements when promoting collaborative research.

- Raise awareness and support companies when responding to calls for projects while actively participating in consortia involving international agreements like the ERA.NET and Horizon Europe.
  – *Sponsor: PRIMA Québec*

COLLABORATIVE R&D

Transforming graphite by-products into active materials for battery anodes

Graphite is used to manufacture active materials for Li-ion battery anodes. Some manufacturing stages generate by-products that make up roughly 50% of the initial graphite, thus increasing production and transport costs, as well as the environmental impact.

This project will convert the finer graphite particles into active materials using a process developed by NanoXplore. This falls in line with the company's objective to create a 16-tonne anode production plant in Quebec by 2026.

COLLABORATIVE R&D

High-performance engines manufactured through cold spraying for the aerospace industry

The aviation industry must be electrified to reduce its carbon footprint. This project seeks to manufacture engines with high power density for the aerospace industry by expanding the limits associated with cold spray processes for electric machine rotors. The initiative will strengthen Quebec's expertise in cold spray additive manufacturing.

The newly acquired knowledge will help Polycontrols (a Quebec SME working in the field of cold spraying) position itself in the growing transport electrification market. Safran, for its part, will be able to market new products (aircraft engines).

Finally, the project will provide Altair with an opportunity to generalize and improve the capabilities of its electric engine design software tools with direct feedback from a multidisciplinary team.

OBJECTIVE 2.3

To use the research and development opportunities that come with large North American investments in energy, electronics, electric vehicles, and batteries.

- Work closely with innovation zones to support collaborative innovation projects involving advanced materials and processes.
  – *Sponsor: PRIMA Québec*
- Contact large companies operating in Quebec's strategic sectors to define their specific needs and launch calls for projects and dedicated contests.

OBJECTIVE 2.4

To apply the results of publicly funded research to advanced materials and processes.

- Identify and promote patents involving the advanced materials and associated processes developed by public/parapublic research organizations in Quebec and Canada.
  – *Sponsors: Axelys and ExplorerPI*

OBJECTIVE 2.5

To help increase private research investments.

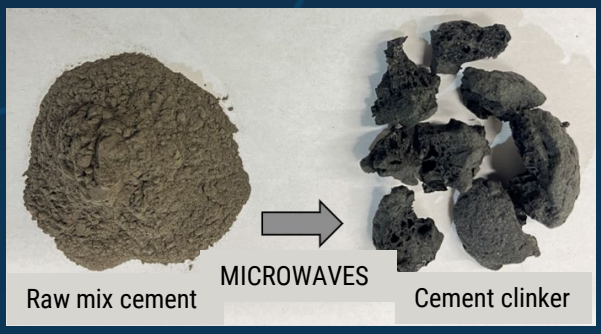
- Maintain and increase calls for collaborative research projects based on the needs of private companies via Quebec's Sector-Based Industrial Research Clusters (RSRIs).
- Familiarize companies with the use cases and successful business models that have generated commercial spin-offs through private research investments.

OBJECTIVE 2.6

To help position advanced materials companies at the forefront of standards.

- Encourage companies and organizations at the forefront of advanced materials and associated processes to participate in standards committees at the Bureau de normalisation du Québec (BNQ) and the CSA Group to help align their research efforts with emerging standards.

COLLABORATIVE R&D



Revolutionizing the cement industry with an electrified and CO_2-free process

Developing a zero CO_2 emission Portland cement production process using Pyrowave's microwave technology and the expertise of the Université de Sherbrooke.

This project intends to electrify the process on an industrial scale, thereby replacing fossil fuels with renewable electricity while producing a pure CO_2 gas that is ready for sequestration.

This microwave technology will produce a Portland cement that complies with Canadian standards, thus facilitating the industry's adoption.

The project has already created interest within the industry; the Holcim Maqer Ventures accelerator selected the initiative to speed up its commercialization.

GUIDELINE 3

BOOSTING THE EMERGENCE OF START-UPS

3

The emergence of advanced materials start-ups remains essential when promoting innovation and economic growth in Quebec. Targeted measures will be implemented to complement those already in place within existing incubators and accelerators and to help them overcome challenges like funding, marketing, and human resources management while supporting their growth from inception to supply chain integration.

OBJECTIVE 3.1

To support and accelerate development for innovative start-ups.

- Support Quebec's Cleantech Consortium, with its twofold objective:
  - Expand the start-up pipeline in key climate technology sectors (particularly advanced materials) based on the academic and industrial research;
  - Accelerate the commercialization of cleantech start-ups at the incubation and acceleration stages.

  – *Sponsors: 2 Degrés, Cycle Momentum and IVÉO*

- Support start-ups in their applications to Investissement Québec's Impulsion PME.
  – *Sponsor: PRIMA Québec*

OBJECTIVE 3.2

To launch calls for solutions that stimulate innovation and attract first buyers.

- Encourage the use of programs like PRIMO-Adoptant from the Ministère de l'Économie, de l'Innovation et de l'Énergie (MEIE), which provides support for technology companies with high growth potential

- Launch calls for solutions like Innovative Solutions Canada, and the federal government's IDEaS challenge.

GUIDELINE 4

PROMOTING GROWTH FOR SMALL AND MEDIUM-SIZED ENTERPRISES

4

Promoting growth for small and medium-sized enterprises (SMEs) in the materials sector is crucial when stimulating innovation, diversifying the economy, and promoting the local development of high-quality jobs. A range of initiatives will be used to further promote the integration of small and medium-sized enterprises (SMEs) into supply chains, notably by facilitating access to financing, raising awareness towards international expansion opportunities and existing regulations, and focusing on upgrading digital and technological infrastructures.

OBJECTIVE 4.1

To promote the personalized support-consultations currently available to those who produce advanced materials and their associated processes.

- Support and organize activities to promote the use of support services provided by Investissement Québec, Innovation, Science and Economic Development Canada (ISED) – Accelerated Growth Service, Business Development Bank of Canada, and PRIMA Québec, among others.

OBJECTIVE 4.2

To raise awareness among SMEs of foreign regulations in matters of decarbonization (e.g., digital product passports, carbon adjustment mechanisms at the border, etc.).

- Propose and develop a section titled “Circular Advanced Materials” on the Québec Circulaire website.
  – *Sponsor: CERIEC*

PROMOTING GROWTH FOR SMALL AND MEDIUM-SIZED ENTERPRISES

4

OBJECTIVE 4.3

To accelerate manufacturing processes by promoting the use of artificial intelligence.

- Familiarize advanced materials companies with the funding opportunities provided by the Offensive de Transformation Numérique (OTN), Investissement Québec, along with the upcoming Canada Economic Development for Quebec Regions' project, which targets the adoption and commercialization of artificial intelligence (AI).

OBJECTIVE 4.4

To help SMEs integrate supply chains.

- Clarify the nature of the advanced materials and associated processes that are essential to the development of innovation zones.
  – *Sponsor: Current study by Propulsion Québec on advanced materials for LFP batteries*
- Set up a simplified and accelerated referencing process to help with exports and financing.
  – *Sponsors: Investissement Québec and collaborators*
- Identify and invite dynamic firms to work with a cohort in advanced materials and associated processes in order to assist their supply chain integration.

PARTNERSHIPS AND SUPPLY CHAINS

Positioning companies in the battery industry through strategic alliances

Start-ups face many difficulties when seeking to integrate battery and automotive sectors dominated by industrial giants. Nano One realized early on that its survival and credibility depended on its ability to work with key players.

Active cathode materials represent the halfway point between the mine and the battery. Multinationals like Rio Tinto, Sumitomo Metal Mining, Umicore, and BASF developed strategic partnerships with Nano One after realizing that the company's competitive and environmentally friendly process could address a number of supply chain security issues.

More recently, Nano One formed an alliance with the global engineering firm Worley to market and deploy its technology worldwide.

GUIDELINE 5

DEVELOPING THE NEXT GENERATION OF SKILLED WORKERS

5

The shortage of a qualified workforce and skills development represent significant challenges for technology-intensive sectors.[10] By strengthening the training received by the next generation of fundamental scientists while aligning academic curricula with industry requirements, this guideline will prepare a new generation of highly qualified personnel who can support innovation and growth in the advanced materials sector.

OBJECTIVE 5.1

To promote career opportunities in advanced materials and processes for young people.

- Launch the Création d'Étincelles project.
  – *Sponsors: PRIMA Québec and Réseau TechnoSciences*
- Organize summer camps to promote the advanced materials sector among youths.
  – *Sponsor: Réseau de la Transformation Métallique du Québec (RTMQ)*

WORKFORCE

Training tomorrow's engineers: Key skills in materials science

Faced with rapidly evolving needs regarding materials skills, Quebec universities are reassessing their training needs. Led by Professor Nadi Braidy, a materials science and engineering training committee at the Université de Sherbrooke has identified key skills for engineers and scientists.

These are:

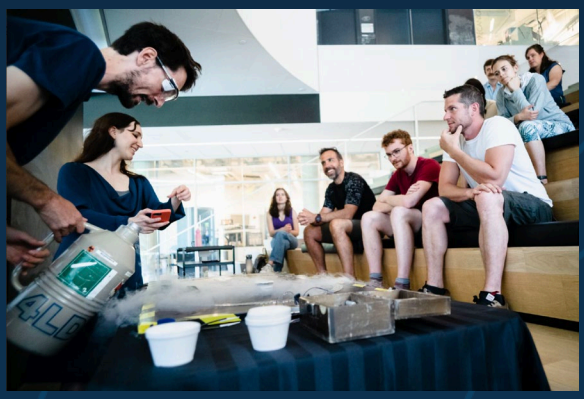
1. Identifying and solving applied problems involving materials, along with their microstructure and properties, using the appropriate measurement tools.
2. Controlling the properties of various materials to optimize their selection and integration into systems with a given function under potentially extreme usage conditions.
3. Optimizing the production costs and yields associated with a variety of materials according to their intended application.
4. Designing durable materials, tools and devices equipped with the most effective replacement and repair properties (cost, complexity, repeatability, etc.).
5. Providing leadership for a multidisciplinary team, particularly through knowledge of the social and environmental impacts associated with the life cycle of materials.

GUIDELINE 5 (continued)

DEVELOPING THE NEXT GENERATION OF SKILLED WORKERS

5

WORKFORCE



Demystifying quantum physics

Curieux quantiques is an initiative dedicated to promoting and disseminating knowledge of quantum physics among the general public, secondary and CEGEP students and teaching staff, along with companies interested in developing their understanding of the subject.

Curieux quantiques' activities have expanded over the years to include quarterly newsletters, lectures, animated videos, classroom workshops, and large-scale popularization events. It also provides adapted teaching materials for teachers, like explanation sheets and interactive learning modules.

Since its creation in 2020, the Curieux quantiques team has organized or taken part in more than 180 activities, reaching over 15,000 individuals. The initiative plays an important role in public awareness by demystifying quantum physics, getting young people interested in the subject, and promoting scientific careers.

OBJECTIVE 5.2

To help create training opportunities that correspond to the sector's industrial needs.

- Conduct a survey of companies working with advanced materials and associated processes regarding the skills required from graduates. Survey results will be shared among every university and college in Quebec.
  – *Sponsor: PRIMA Québec*

- Mapping key skills and training needs to support the advanced materials sector.

OBJECTIVE 5.3

To promote the use of company programs that strengthen workers' technical skills, numeracy and literacy.

- Familiarize the ecosystem with programs like those offered by the sectoral workforce committees (Commission des partenaires du marché du travail - needs identified by sectors), the Fédération des Chambres de Commerce du Québec/Chamber of Commerce of Metropolitan Montréal, and the ISED program (Upskilling for Industry Initiative (UII) - needs identified by companies).

GUIDELINE 6

PROVIDING COMPANIES WITH GREATER ACCESS TO PATIENT CAPITAL

6

The specific and innovative nature of the advanced materials sector requires longer-term investments, often with extended maturation periods before it can generate substantial returns. The sector is characterized by long and costly technological maturity cycles (10 to 20 years);[11] scaling up requires significant investments in infrastructure and process optimization.

To meet these challenges, the current financial tools must be reimagined while developing mechanisms that bring together every stakeholder in the financing chain (investors, financial institutions, government agencies, etc.) in support of high-potential businesses.

OBJECTIVE 6.1

To support high-potential businesses by creating a unit that brings together stakeholders from the financing chain.

- Prepare and introduce start-ups with high growth potential to stakeholders in the financing chain, with consideration for their specific investment criteria.
  – *Sponsors: PRIMA Québec and stakeholders in the financing chain*

OBJECTIVE 6.2

To develop and provide a financial tool adapted to the particularities of advanced materials.

- Prepare a business case that justifies the tool's relevance and development.
  – *Sponsors: PRIMA Québec and stakeholders in the financing chain*

CIRCULARITY

WattByWatt: Towards more efficient and affordable solar panels

WattByWatt is the fruit of two decades of research into perovskite. The initiative brought together scientists, engineers and business people to provide environmentally friendly energy solutions. They developed a revolutionary ink that extends the life of silicon solar panels, increasing their efficiency by at least 25%.

This innovation improves energy efficiency and reduces costs, making solar energy more sustainable. Made from predominantly recyclable materials, perovskite panels are sustainable and compatible with future regulations that promote circularity and fewer environmental impacts.

GUIDELINE 7

MODERNIZING PUBLIC PROCUREMENT AND REGULATORY FRAMEWORKS

7

The modernization of public procurement and regulatory frameworks represents an important aspect that can foster innovation and competition, accelerate the transition to more sustainable processes, and facilitate the commercialization of new materials.
After clarifying the concerns of those in the ecosystem, this guideline developed **three recommendations:**

RECOMMENDATION 7.1

To modernize regulatory frameworks, particularly with regard to the life cycle and recycling of advanced materials.

Regulatory frameworks must consider the entire life cycle of materials in order to facilitate and accelerate the energy and digital transitions while promoting the development of environmentally responsible materials and circularity.

This includes the assessment of environmental impacts at the design stage, along with criteria targeting recyclability and end-of-life waste management. Integrating these considerations into the regulatory framework would ensure that advanced materials meet sustainability objectives while facilitating their inclusion into recycling and reuse loops. This approach would help generate practices that reduce the ecological footprint while aligning them with a circular economy.

RECOMMENDATION 7.2

To revise the criteria for public procurement contracts by emphasizing the anticipated functional and environmental performance of materials and products.

Public procurement plays a key role in driving demand for advanced materials. By revising the tender evaluation criteria to further emphasize functional and environmental performance, public procurement could be steered towards solutions that are more sustainable and innovative.

The new criteria could include specific requirements like energy efficiency, emissions reduction, and material sustainability, along with other ESG factors (environmental, social, and governance). The revised criteria would encourage the integration of advanced materials that not only enhance performance but provide environmental benefits as well, thereby stimulating demand for these technologies in both the public and private sectors.

RECOMMENDATION 7.3

To promote the adoption and commercialization of advanced materials and associated processes by simplifying and accelerating the approval and certification processes.

Approval and certification processes must be simplified and accelerated to promote the commercialization of advanced materials. Current processes increase the time-to-market period, as well as the costs involved. One potential alternative could involve simultaneous development and prototyping certification, reflecting the current approach used by C2MI for electrical components. This would reduce lead times and the associated costs, facilitating market access for advanced materials while stimulating their adoption. Non-regulatory sandboxes could also encourage innovation while updating regulatory frameworks. The Unmanned Aerial System Centre of Excellence in Alma provides a good example.[4]

Modernizing public procurement and regulatory frameworks represents a key step towards the effective integration of advanced and sustainable materials into a decarbonized Quebec economy. By revising regulatory standards, adapting public procurement criteria and optimizing approval processes, Quebec would not only support innovation and sustainability but strengthen its position as a pioneer in the field of advanced materials. These measures would create an environment that is conducive to the emergence of new technologies while promoting a successful transition to greener, more responsible practices.

PARTNERSHIPS AND SUPPLY CHAINS

Towards a Canadian quantum computer supply chain

Anyon Systems has been working to build and deliver quantum computers with commercial utility since 2014. Early on, the team decided to produce vertically integrated quantum computers by assuming control over the manufacturing of chips, cryogenic systems, and control electronics.

This approach reduces the risks associated with supply chains while providing control over scaling. A network of local partners helped the company produce the very first all-Canadian universal quantum computer.

Anyon's most important partners–the clients–are part of its continuous improvement cycle, enabling it to successfully evolve its technology while growing its business.

FINAL THOUGHTS

The 2035 Roadmap for Advanced Materials and Associated Processes represents a key milestone that can transform the advanced materials sector into a pillar of Quebec's decarbonization strategy.

Its evolution is based on progress and changing external factors, along with the integration of new measures within the ecosystem.

Investment in research and development and the strengthening of strategic partnerships between research institutions, businesses, and governments are essential if we are to turn this vision into a reality.

The road to 2035 is paved with business and research opportunities. The resilience, creativity and commitment of the scientific and industrial communities will drive this transformation, and governments will play a role. It is imperative that we expand the boundaries of materials science for all initiatives while optimizing processes and integrating the principles associated with circular economies and life cycle analyses.

We offer our sincerest gratitude to all of our collaborators, partners and stakeholders for their commitment. This close and ongoing collaboration will help build a prosperous and sustainable future for Quebec, as well as future generations.

THE MOVEMENT IS UNDERWAY.
ONWARDS TO 2035!

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Albatal, Fadi, COO and Partner, Innovobot

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Bassila, Christian, President, Anyon

Beaudoin, Serge, Director, Université de Sherbrooke

Belisle, Gary, Chief Operating Officer, Carbicrete

Benmokrane, Brahim, Professor, Université de Sherbrooke

Bergeron-Vachon, Amélie, Senior Director - Partnerships and Networking, Écotech Québec

Berrouard, Nicholas, Deputy CEO and Director of Operations, CNETE (Centre National en Électrochimie et en Technologies Environnementales)

Berthiaume, David, Managing Director, Kemitek

Nohair, Bendaoud, Project Manager, CDCQ (Centre de Développement des Composites du Québec)

Bérubé, Catherine, Partner, Cycle Capital

Boisvert, Daniel, Business Development Director, C-Mac Microcircuits ULC

Bonenfant, Stéphane, Senior Software Manager, LeddarTech

Bourbonnais, Normand, President and CEO, Technum Québec

Braidy, Nadi, Professor, Eng., Ph.D., Université de Sherbrooke

Brassard, Martin, R&D Director, Nouveau Monde Graphite

Bureau, Martin, Vice-President of Innovation and Director of the PFAS Centre of Excellence, ALTRA Sanexen

Bussières, Virginie, Vice-President - External Relations and Partnerships, Polystyvert

Carabin, Pierre, Chief Technology Officer and Chief Strategist, PyroGenesis Canada Inc.

Carrier, Renaud, Engineering Director, Demers manufacturiers

Chaker, Mohamed, Professor, INRS-EMT (Institut national de la recherche scientifique - Énergie Matériaux Télécommunications)

Champagne-Gélinas, Alex, Director of Strategic Development, InnovÉÉ

Chénier, Richard, CEO, Québec Tech

Chevalier, Frédéric, CEO, RTMQ (Réseau de la Transformation Métallique du Québec)

Chrétien, Simon, CEO, Alliance Polymères Québec

Cloutier, Caroline, Director of R&D, NRC (National Research Council Canada)

Côté, Guillaume, President and CEO, CRIAQ (Consortium for Research and Innovation in Aerospace in Quebec)

Coulombe, Sylvain, Professor, McGill University

Dakin, Sébastien, Director of Stakeholder Mobilization, Nano One

Daoud, Alexandra, Vice-President - Intellectual Property and Regulatory Affairs, Anyon

De Sousa, Isabel, Senior Hardware Development Engineer, IBM (International Business Machines)

Delisle, Jean-Philippe, Investment Analyst, AXELYS

Desaulniers, Eric, Founder, President and CEO, Nouveau Monde Graphite

Desgagniers, Anne, Ecosystem Manager, SDTC (Sustainable Development Technology Canada)

Després, Mélissa, Director of R&D, Materials and Processes, NRC (National Research Council Canada)

Desrosiers, Quentin Abraham, CEO, Plasticompétences

Déziel, Nancy, CEO, CNETE (Centre National en Électrochimie et en Technologies Environnementales)

Diez, Carl, Vice-President, R&D, Soleno

Doucet, Jocelyn, Co-Founder and CEO, Pyrowave

Dubé, Martine, Professor, ÉTS (École de Technologie Supérieure)

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Ducharme, Edith, Innovation and Collaboration Specialist, Optonique (Pôle d'excellence en optique-photonique du Québec)

Fillon, Tiphaine, Director of Partnerships and Corporate Affairs, Technum Québec

Fournier, René, Head of Innovation, Liberty Springs

Fradette, Louis, Co-founder and Technical Director, Cycle Carbone

Gagnon, Jean-Philippe, Chief Technology Officer, Exterra

Gordon, Sébastien, Structural Analysis Project Manager, Eng, Ph.D., CTA (Centre Technologique en Aérospatiale)

Guestier, Martin, Investment Director - Private Equity and Impact Investments, Energy and Environment, Fonds de solidarité des travailleurs et travailleuses (FTQ)

Guindon, Alexandre, CEO and Co-Founder, 2 Degrés

Hovan, Luc, Vice-President, Integration and Infrastructure, Northvolt

Henry, Schaer, Business Analyst, WattByWatt

Johnson, Michael, Combustion Analyst - New Technologies, Hydrogen, Fuel Flexibility and Carbon Capture, Siemens Energy

Ka, Ibrahima, Co-founder, WattByWatt

Khoun, Loleï, Research Officer, NRC- Automation and Surface Transportation

Kroeger, Jens, R&D Manager, AP&C Powder Metallurgy|GE Additive

Lanctôt, Pascal, Partner, Climate Technologies Fund, BDC Capital

Lapierre, Dominic, Account Manager, ABB

Lauzon, Janic, CEO, CDCQ (Centre de Développement des Composites du Québec)

Lefèvre, Florent, Chairman, Kynze

Lequin, François, CTO Office, Technology Initiatives, E2ip

Levasseur, Annie, Scientific Director, Centre d'études et de recherches intersectorielles en économie circulaire, CERIEC

Levesque, Rodrick, Vice-President, Engineering, Manac Inc.

Lévesque, Sylvie, Deputy General Manager, Corem

Lizaire, Maude, Doctoral student, Mila - Quebec AI Institute

Maghoul, Pooneh, Professor, Polytechnique Montréal

Mailloux, Nicolas, R&D and Government Grants Coordinator, Sayona

Marin, Gheorghe, CEO, CMQ (Centre de Métallurgie du Québec)

Marion, Frédéric, Head of Customer Experience and Material Expertise, AP&C Powder Metallurgy|GE Additive

Marques, Cristina, Vice-President - Management of Innovation programs, CRIBIQ (Consortium for Research and Innovation in Industrial Bioprocesses in Quebec)

Marquis, Josiane, Senior Advisor - Hydrogen Development and CCUS, Énergir

Martin, Manuel, Technical Lead for Additive Manufacturing, METALTec Industrial R&D Group

Moghimian, Nima, Director of R&D, NanoXplore

Mottola, Laura, Vice President - Supply Chain, Northvolt

Mousseau, Normand, Scientific Director, Institut Trottier

Normandin, Daniel, Director, CERIEC (Centre d'études et de recherches intersectorielles en économie circulaire)

Olsen, Caroline, Director of R&D, SGS Canada (Société Générale de Surveillance)

Parenteau, Guillaume, Vice-President - Business Development, Vallée de la transition énergétique

Perineau, Fabien, Technology Transfer and Innovation Advisor, IVADO

Perron, Christian, President and Chief Operating Officer, CEIM (Centre d'entreprizes et d'innovation de Montréal)

Poirier, René, Regional Manager (Quebec), Policy, Analysis and Intelligence, Innovation, Science and Economic Development Canada (ISED)

Pomerleau, Guy, Consultant - Strategic Planning, Blue Solutions

Pouliot, Jean-François, CEO, CRITM (Consortium de recherche et d'innovation en transformation métallique)

Quenneville, Olivier, President and CEO, Réseau Capital

Rego De Vasconcelos, Bruna, Assistant Professor, Université de Sherbrooke

Renaudin, Alan, Director - Business Development, Strategic Partnerships and Marketing, C2MI (MiQro Innovation Collaborative Centre)

Rilling, Madison, CEO, Optonique (Pôle d'excellence en optique-photonique du Québec)

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Robitaille, Myrielle, Senior Director, Eng. - Energy and Environment, Sia Partners Inc.

Rolnick, David, Research Professor, Mila - Quebec AI Institute

Rossetto, Daniela, Researcher, Geomega

Sarra-Bournet, Christian, Scientific Director, DistriQ

Santato, Clara, Professor, Polytechnique Montréal

Sarazin, Pierre, Vice President, R&D and Sustainable Development, PolyExpert

Sasseville, Mathieu, Senior Advisor, FondAction

Schaer, Henry, Business Analyst, WattByWatt

Schiettekatte, Francois, Deputy Director, RQMP (Regroupement québécois sur les matériaux de pointe)

Shchupak, Zoya, Managing Partner, Innovobot Resonance

Siaj, Mohamed, Director, CQMF (Centre Québécois sur les Matériaux Fonctionnels)

Stafford, Luc, Professor and Associate Vice-Rector, Research, Université de Montréal

Stateikina, Irina, Senior Scientist - Design and fabrication of MEMS, C2MI (MiQro Innovation Collaborative Centre)

Tanguay, Geneviève, President and CEO, Anges Québec

Tolza, Alexandra, CEO, ISEQ (Industrie des Systèmes Électroniques du Québec)

Valois, Steve, Head of Expertise - Asset Performance, Evolution and Characterization - Generation, Hydro-Québec

Vendittoli, Mario, Director of Economic Intelligence, CED (Canada Economic Development)

Villemont Clément, Vice-President - Development of the Knowledge Environment and the Innovation Ecosystem, Vallée de la transition énergétique

Zaghib, Karim, President and CEO, Volt-Age and Professor, Chemical and Materials Engineering, Concordia University

Zwarts, Franck, Senior Director - Investments, CDPQ (Caisse de Dépôt et Placement du Québec)

APPENDIX A – THE FOUR PRIORITY APPLICATION SECTORS

Four of Quebec's application sectors have been identified according to four criteria:

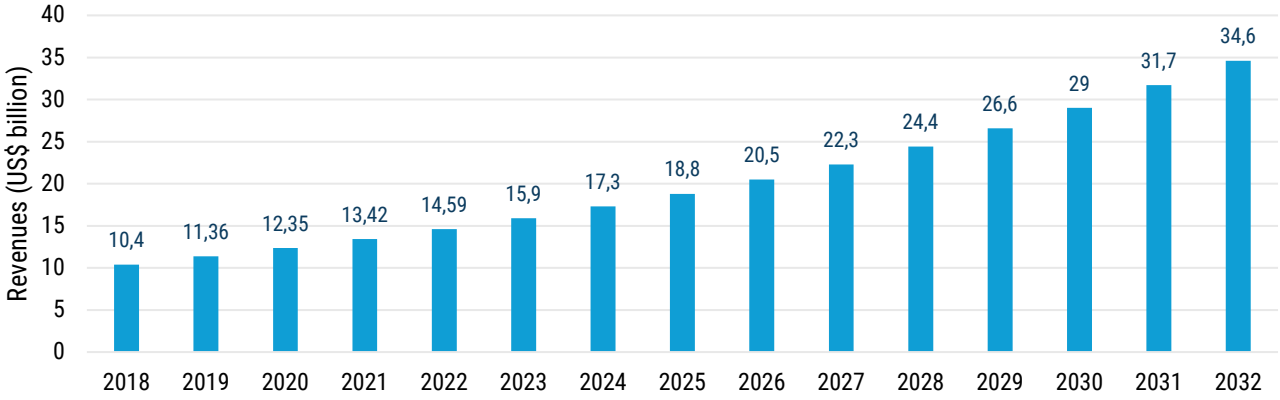
- **MARKET OUTLOOK:** Assessed by Zion Market Research[1] and E&B Data.[5]
- **THE CRITICAL MASS OF COMPANIES:** Defined as the number of Quebec firms manufacturing advanced materials for the various application sectors, assessed by E&B Data.[5]
- **PROPENSITY TO INNOVATE:** Assessed according to the Science-Metrix analysis regarding patents and scientific publications, as well as the Survey of Innovation and Business Strategies (2023) from Statistics Canada and the Institut de la Statistique du Québec.
- **ECONOMIC DECARBONIZATION CONTRIBUTION:** Assessed by decarbonization contributions within the company's own sector, as well as other application sectors and supply chains.

ELECTRONICS SECTOR

MARKET OUTLOOK

Materials with superior thermal and electrical properties are driving innovation and strengthening demand in the electrical and electronics market.[1] Revenues from this sector could reach $34.6 billion by 2032, with the largest share ($5.8 billion) expected for North America.

Figure 12: 2032 GLOBAL REVENUES IN THE MICROELECTRONICS/ELECTRONICS SECTOR[1]



Geopolitical tensions between the United States, China and Taiwan, as well as supply chain disruptions in the wake of the pandemic, have prompted Europe and North America to invest massively, increasing their semiconductor manufacturing capacity.

Lucrative business opportunities are opening up for Canadian advanced materials and associated processes while the CHIPS and Science Act (2022-2026) has invested $74 billion to repatriate microelectronics manufacturing from Asia to North America. Meanwhile, an integrated North American value chain is growing rapidly, including minerals that are critical to electric vehicle mega-manufacturing, all of which is being fuelled by the Inflation Reduction Act.[2]

Global semiconductor manufacturing capacity will increase by 6.4% in 2024, reaching a record rate of 30 million wafers per month.[26]

CRITICAL MASS IN QUEBEC

Quebec has a significant critical mass in the microelectronics/electronics sector. The core of the Quebec ecosystem includes companies like IBM-Bromont, Teledyne Dalsa, Matrox, Esterline, MPB and Aeponyx, along with world-class research centres like C2MI and the Institut national d'optique (INO). Another key initiative includes the creation of the Technum innovation zone. This zone brings together a number of companies, academic institutions and research centres to promote collaboration and innovation in key sectors that include microelectronics, artificial intelligence and advanced materials. By 2024, 19% of companies working in advanced materials and associated processes will focus on microelectronics and telecommunications technologies.[5]

Quebec is home to a critical mass of world-renowned expertise in research and development, microelectronic/electronic component design and assembly, optics-photonics, along with artificial and quantum intelligence. In 2023, electronics manufacturing accounted for $3.2 billion of Quebec's gross domestic product (GDP) and roughly 36,500 jobs across 730 companies.[28]

Did you know?

The Bromont innovation zone is home to a number of microelectronics companies and research centres. Among them, IBM, one of the world's largest semiconductor manufacturers, owns a major manufacturing facility.[27]

Table 2: PATENTS BY SECTOR OF APPLICATION IN QUÉBEC[3]

Sector and Sub-Sectors	Patent Families	Growth Ratio (GR)	Relative GR	Specialization Index (SI)
Advanced Materials	2,130	1.54	1.11	0.94
Nanomaterials	331	1.45	1.07	1.03
Composites, ceramics and polymers	326	1.94	1.46	0.82
Semiconductors	248	1.61	1.53	0.65
Energy	270	1.05	0.68	0.83
Environment	186	1.04	0.76	1.28
Optical systems	206	1.48	1.30	1.44
Instrumentation	198	1.61	1.31	1.2
Surface treatment	148	1.31	1.14	0.85
3D printing	113	4.38	0.64	1.06
Metals	129	1.8	1.12	1
Printable/flexible electronics	**100**	**3.76**	**1.69**	**0.76**
Mineral extraction and processing	117	1.92	1.67	2.99
Construction	51	1.13	0.99	1.29
Transportation	54	2.38	1.17	0.57
Metamaterials	34	3.86	2.54	1.94

The electronics sector in Quebec is also characterized by a research and development capacity that is known throughout the world for its assets.[28]

- **Several research centres**, including C2MI, Institut National d'Optique, 3IT and CMC Microsystems, along with the Centre d'Innovation en Microélectronique du Québec, provide a range of electronics specializations that help diversify innovation.
- **Umbrella organizations** like Technum Québec ensure sectoral development and collaboration between various stakeholders in the ecosystem, while the Industrie des systèmes électroniques du Québec represents a cluster of excellence in Quebec-based electronics.
- **Recent investments** by the Quebec Government totalled CAD$255 million in 2022 to support innovation in the Technum Québec innovation zone. In 2024, investments reached CAD$39.8 million for C2MI and IBM in the same zone. The Government of Canada also invested CAD$24.9 million in 2024 to support the production of components at IBM and C2MI, along with CAD$35 million to upgrade IBM's semiconductor plant in a joint investment with the Government of Quebec.

Did you know?

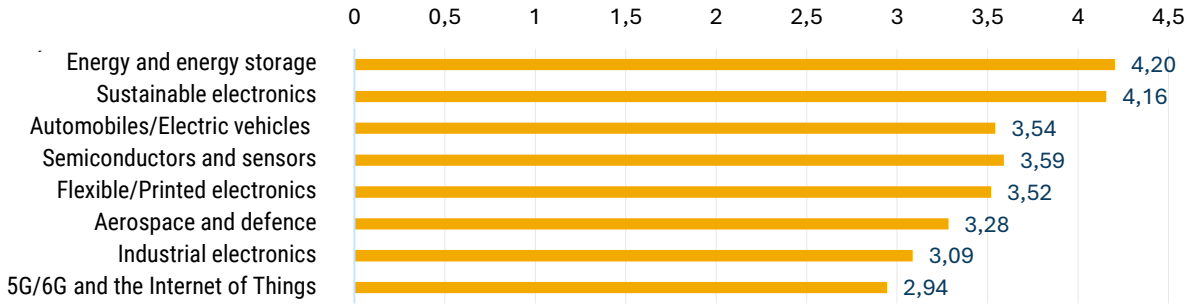
The C2MI (MiQro Innovation Collaborative Centre) is recognized as one of Canada's leading research and development centres in the field of electronics systems. Located in Bromont, Quebec, it focuses on microelectronics and microsystems, providing state-of-the-art facilities that develop and commercialize advanced technologies. C2MI plays a key role in facilitating collaboration between companies, universities and research organizations to accelerate innovation and technology transfers.[28]

ECONOMIC DECARBONIZATION CONTRIBUTION

Several application sectors rely on microelectronics/electronics technologies in the form of sensors, semiconductors, control units, and LEDs. These materials and components are essential for decarbonization and industrial process automation, along with energy use management and network distribution optimization.

The organizations and companies surveyed by PRIMA Québec identified three priority applications in the electronics sector: energy and energy storage, sustainable electronics, and automobiles and electric vehicles (Figure 13).

Figure 13: PRIMA QUÉBEC SURVEY RESULTS ON PRIORITY APPLICATIONS IN QUEBEC'S ELECTRONICS SECTOR (n=127)



ENERGY SECTOR

MARKET OUTLOOK

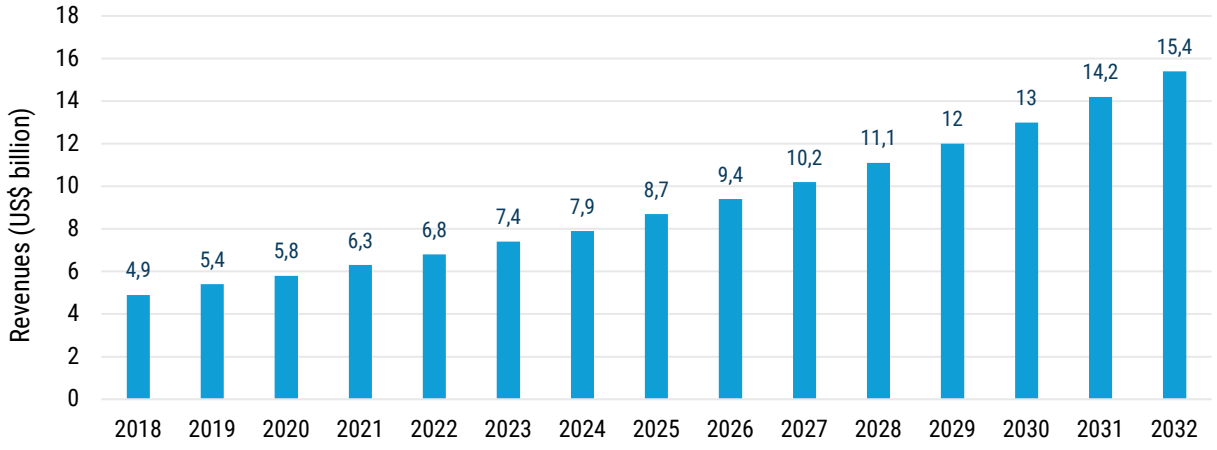
The energy transition is well underway, with global investments totalling $1.8 trillion in 2023.[12] Renewable energies continue to account for a large portion of these investments, totalling $800 billion between 2023 and 2024. The average CAPEX for renewable energies is expected to decline by 15-20% between now and 2030. By 2024, solar energy will lead the way, accounting for 55% of total global investments, followed by onshore wind power.[2] This dynamic market significantly drives demand for advanced materials and components. In the advanced materials market, energy sector revenues could reach $15.4 billion by 2032 (Figure 7). According to PRIMA Québec's 2024 report and the companies surveyed, the energy application sector shows the greatest market potential.[5]

Several factors will drive development in this market, including:

- Hydro-Québec's 2022-2026 strategic plan and the forthcoming bill on the private production of renewable energy, which will pave the way to lucrative business opportunities for Quebec companies that successfully integrate the supply chain. Similarly, the United States continues to be Quebec's largest market for the export and manufacturing of advanced materials and components involving solar and wind power, despite its protectionist policies.[2]

- Multiple roadmaps that prioritize potential technical solutions to reduce or decarbonize the processes used within energy-intensive industries. Typically, these involve the electrification of heat, the use of green hydrogen, the use of biomass as a fuel, along with carbon capture, storage and use.[2]

Figure 7: 2032 GLOBAL REVENUES IN THE ENERGY SECTOR[1]



Did you know?

According to a Radio-Canada report in July 2024, Hydro-Québec's first mega-wind farm will be built in the Saguenay-Lac-Saint-Jean region. This project will be the second largest in the world, covering an area 13 times the size of the island of Montréal.[13]

CRITICAL MASS IN QUEBEC

Quebec is home to a large critical mass of energy companies supported by major investments and strategic initiatives. Twenty-nine percent (29%) of advanced materials companies in Quebec focus on energy as their main area of application.[5] Advanced materials play a key role in several applications, including power line protection, hydrogen production and storage, along with electrolysis and characterization technologies.[3]

The province is also home to a world-renowned research and development expertise, particularly in electricity transmission superconductors and new battery materials, along with artificial intelligence that generates clean energy (solar and wind). In addition, favourable public policies and regulatory frameworks, supported by stakeholders like Hydro-Québec, Propulsion Québec, and the Vallée de la Transition Énergétique, continue to promote structuring initiatives in the energy sector.

PROPENSITY TO INNOVATE

Our propensity to innovate in the field of advanced materials for the energy sector is remarkable. Quebec's leadership is built upon a robust innovation ecosystem, academic and industrial collaborations, and favourable public policies.

Patents involving advanced materials cover 270 patent families, ranking Quebec third in terms of ingenuity in Canada's energy sector (Table 2). The study also indicates that Quebec holds research and development expertise in electricity transmission superconductors, new battery materials that use artificial intelligence, clean energy generation materials (solar and wind), power line protection using advanced materials, along with hydrogen production and storage.[3]

Table 2: PATENTS BY APPLICATION SECTOR IN QUEBEC [3]

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3D printing	113	4.38	0.64	1.06
Metals	129	1.8	1.12	1
Printable/flexible electronics	100	3.76	1.69	0.76
Mineral extraction and processing	117	1.92	1.67	2.99
Construction	51	1.13	0.99	1.29
Transportation	54	2.38	1.17	0.57
Metamaterials	34	3.86	2.54	1.94

Did you know?

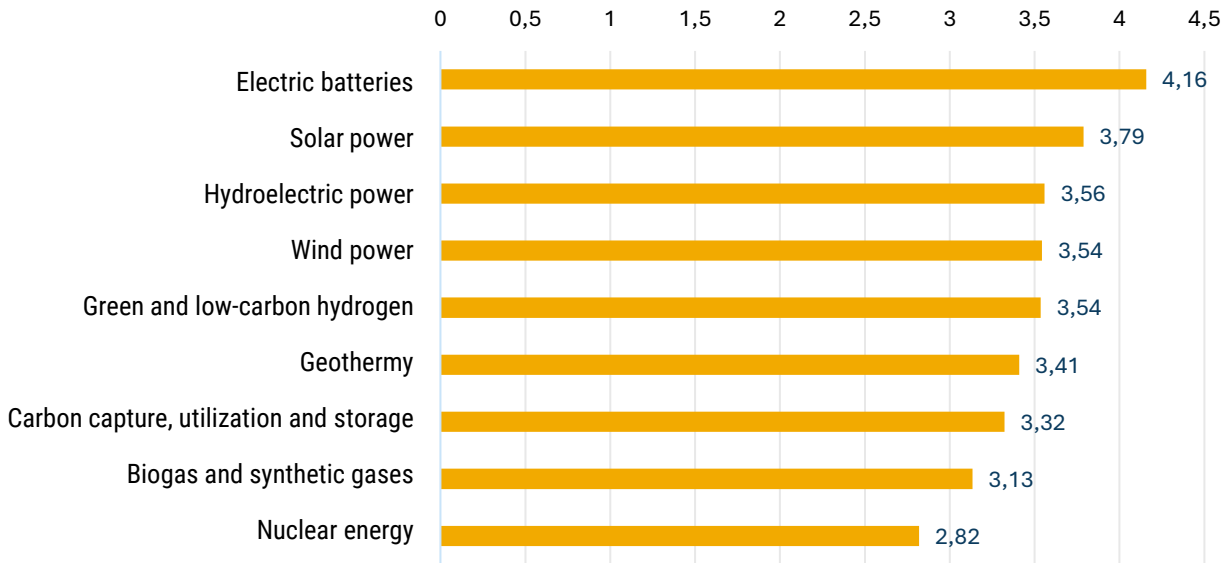
A joint project between industrial and academic partners led to the creation of next-generation super capacitors that significantly improve energy storage and distribution. The initiative involves the super capacitor development project at the Hydro-Québec Research Institute (IREQ). These super capacitors are used to stabilize electricity grids by integrating renewable energy sources like solar and wind power, and by improving energy efficiency in electricity transmission systems.

ECONOMIC DECARBONIZATION CONTRIBUTION

Virtually every technology used in Quebec's energy sector reduces dependence on fossil fuels, improves energy efficiency in industrial processes, and contributes to decarbonization. Advanced materials and components for energy storage, turbines, wind turbines and solar panels provide essential contributions.

When developing the Roadmap, PRIMA Québec surveyed companies and organizations that work with advanced materials and associated processes to identify priority applications within the four strategic sectors. For the energy sector, electric batteries were at the forefront.

Figure 8: PRIMA QUÉBEC SURVEY RESULTS ON PRIORITY APPLICATIONS IN QUEBEC'S ENERGY SECTOR (n=127)



ENVIRONMENT SECTOR (next page)

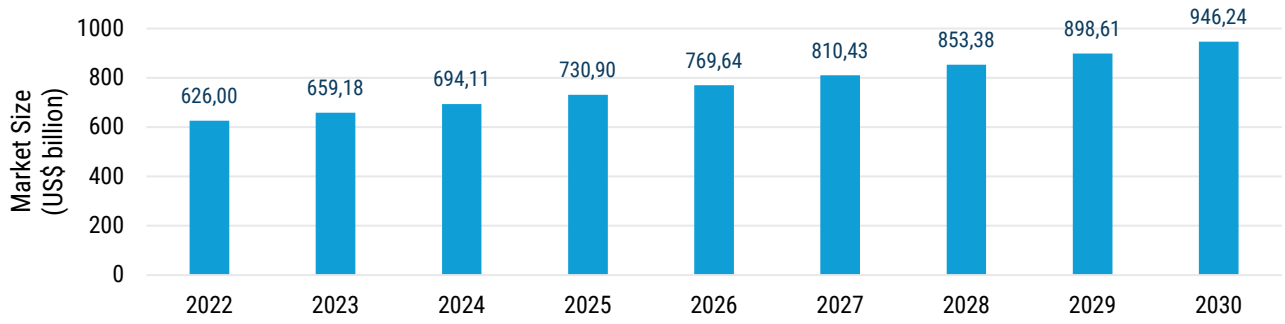
ENVIRONMENT SECTOR

MARKET OUTLOOK

Global demand in the environment sector is being driven by the growing need for sustainability and preoccupations regarding the energy transition. Climate change awareness and a recognition of the impacts of environmental technologies represent key levers that drive the advanced materials market.[1]

The environmental technology sector will be worth $946 billion by 2030; North America will be its largest market, and the water treatment technology segment will be its largest source of revenue.[15]

Figure 9: 2030 GLOBAL REVENUES IN THE ENVIRONMENTAL TECHNOLOGY SECTOR[15]



Several levers promote the development and growth of Quebec's environment sector:

- Policies on sustainable development, energy efficiency, waste, soil and wastewater management, along with a commitment to reduce greenhouse gas (GHG) emissions to 37.5% below 1990 levels by 2030.[2]
- A framework that includes a number of structuring laws tackling environmental issues in Quebec, including regulations that will increase the number of zero-emission motor vehicles while improving environmental quality, as well as water management and treatment, all of which will require enabling environmental technologies that rely on advanced materials and associated processes.[16]
- Quebec's involvement in the Western Climate Initiative in 2008 and its commitment to reduce GHG emissions through a cap-and-trade system. This has attracted investments in clean technologies while stimulating innovation in emissions reduction.[17]

CRITICAL MASS IN QUEBEC

Quebec companies hold extensive expertise in the treatment of emissions and effluents, as well as in the 4R principles (reduce, reuse, recycle and recover). Several innovative firms in Quebec are working to resolve the challenges associated with reduction at source, reuse, recycling, and recovery. These include Géoméga, Pyrowave, and Polystyvert, among others. The strength of Quebec's environmental consultancy is also recognized on the world stage. The province is home to a large pool of companies that specialize in environmental engineering, system and equipment manufacturing, along with process design and usage involving air, water, soil and waste treatment, all of which requires advanced materials and associated processes.[18] In addition, 22% of companies that work with advanced materials and associated processes focus on the environment.[5]

Did you know?

Quebec's sizable critical mass in the environment sector promotes effective collaborations. One example involves the Réseau Environnement, a group of over 200 companies and institutions that specialize in resource management and environmental technologies. Together, these companies are designing innovative projects, like wastewater treatment and advanced materials recycling technologies.[19]

PROPENSITY TO INNOVATE

Quebec is home to some of Canada's most prolific inventors in the environment sector. The propensity to innovate in the field of advanced materials for the environment sector is evidenced by the large number of patent families within this sector. As a major specialist in the environment, Quebec holds186 patent families.[3]

Did you know?

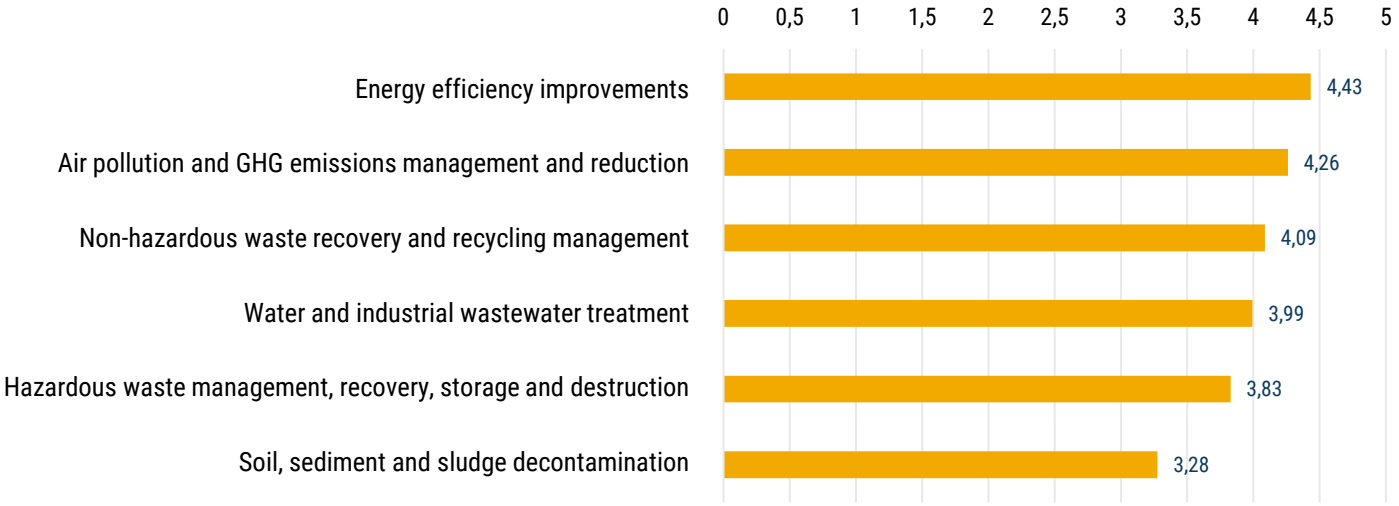
One project at the École de technologie supérieure (ÉTS) involves developing biodegradable and functionalized fibres to improve water treatment. These innovative fibres are designed to provide effective and environmentally friendly filtration. By integrating contaminant absorption and adsorption properties, they help purify water in a sustainable manner. Thanks to their biodegradable nature, these fibres reduce the environmental impact of filtration systems, thus meeting the increasing demand for environmentally friendly water treatment technologies.[20]

ECONOMIC DECARBONIZATION CONTRIBUTION

Enabling technologies in the environment sector, which rely heavily on materials and processes, reduce carbon intensity and environmental impacts.

The organizations and companies surveyed by PRIMA Québec identified three priority applications in the environment sector: energy efficiency improvements, air pollution and GHG emissions management and reduction, and non-hazardous waste recovery and recycling management.

Figure 10: PRIMA QUÉBEC SURVEY RESULTS ON PRIORITY APPLICATIONS IN QUEBEC'S ENVIRONMENT SECTOR (n=127)[15]



Did you know?

In some sectors, environmental technologies can reduce GHG emissions by up to 70%.[21]

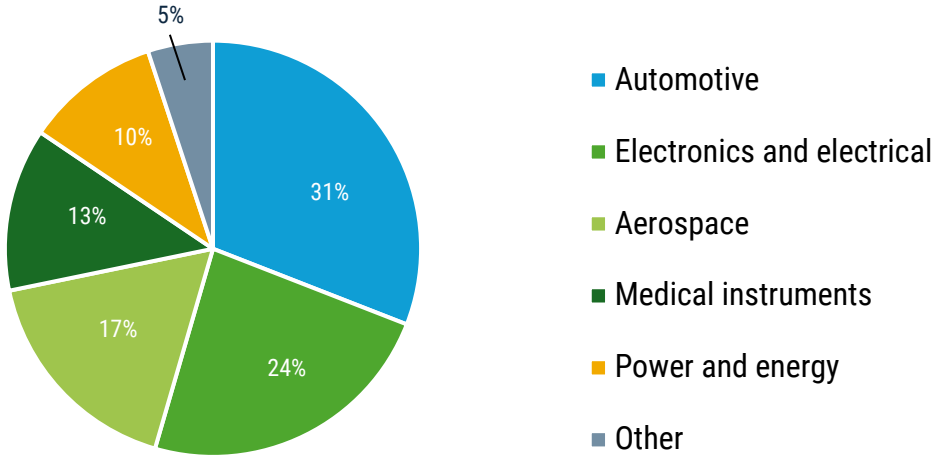
TRANSPORT SECTOR (next page)

TRANSPORT SECTOR

MARKET OUTLOOK

The growing need for lighter components, energy efficiency and lower emissions is a significant factor that drives the demand for advanced materials in the transport sector. Several market segments are experiencing rapid and dynamic growth. According to forecasts, the automotive sector will make up the largest portion of revenues in the advanced materials market by 2032.[1]

Figure 11: 2032 GLOBAL REVENUES IN THE TRANSPORT SECTOR[15]



According to International Energy Agency (IEA) estimates, the United States will lead the way in meeting the global demand for electric batteries between now and 2032. Canada, however, continues to invest, having completed 66 investment projects between 2014 and 2023, with capital expenditure totalling $33 billion for automotive transport equipment.[2]

In addition, a number of provincial and federal government initiatives have led to significant investments in the electric vehicle/battery sector, the introduction of the Vallée de la transition énergétique, and the decarbonization of transport.

Did you know?

Three quarters of the $1.8 trillion in global investments for the energy transition in 2023 targeted the transport sector, more specifically electric vehicles.[12]

CRITICAL MASS IN QUEBEC

Forty-eight percent (48%) of companies working in advanced materials and associated processes focus on transport.[5] Quebec is home to an emerging electric battery industry, with a number of major industrial projects under construction. Their impact will be felt over the coming decade. According to Bloomberg, Canada has surpassed China as the world's premier destination for lithium-ion battery manufacturing.[12] Quebec has everything it needs to produce the cleanest batteries in North America: natural resources, cutting-edge know-how, a thriving industrial ecosystem, along with a state-of-the-art CSM research network with more than 850 battery-related patents.[22]

Did you know?

Quebec is Canada's largest aerospace manufacturing centre. The province is home to 61% of all aerospace manufacturing jobs. Quebec is also a pioneer in various market segments that involve, among other technologies, flight simulators and helicopter engines.[23] In 2023, the aerospace industry accounted for $4.9 billion of Quebec's GDP, employing 28,000 workers[31] across 81 companies.[32] It is a growth industry driven by increasing defence spending.[29] In Quebec, Montréal is a major global aerospace hub, housing a variety of international aviation agencies like the International Civil Aviation Organization and the International Air Transport Association, along with companies like Bombardier, Bell Textron, Pratt & Whitney Canada, CAE and Airbus.[29,30]

PROPENSITY TO INNOVATE

Quebec holds 54 patent families in the transport sector. The province's research and development expertise focuses on lightweight composites, alloys, high-sensitivity sensors, 3D printing, and battery materials. Quebec's ingenuity in advanced materials for the transport sector showed a noticeable growth between 2003 and 2020, with one of the highest patent family growth ratios across 16 sectors and sub-sectors.[3]

Did you know?

Lithium iron phosphate (LFP) battery technology has strong roots in Quebec. Recognized for its safety, longevity and energy efficiency, this technology was partly developed by Quebec researchers and companies. Originating in Quebec, this technology is contributing to the global energy transition by offering safer and more sustainable energy storage solutions.[24]

ECONOMIC DECARBONIZATION CONTRIBUTION

Advanced materials and associated processes like batteries and light alloys offer enormous potential when decarbonization transportation through the manufacturing of lighter, more efficient vehicles that are less dependent on fossil fuels.

Several examples of enabling technologies are making sizable contributions to a decarbonized economy. These include faster-charging batteries, engines that are more resistant to high temperatures and pressures, new and lighter alloys, and conductive materials.

The use of composite materials in vehicles will also significantly reduce GHG emissions. A study by the Automotive and Surface Transportation Research Centre indicates that the use of lightweight composites in car manufacturing can reduce CO_2 emissions by up to 20% per vehicle. Materials like carbon fibre composites allow for the manufacturing of lighter vehicles, thus improving their energy efficiency while reducing fuel consumption.[25]

APPENDIX B - GLOSSARY

APPENDIX B - GLOSSARY

C

Certification

The process of validating and approving new materials for specific applications, ensuring compliance with strict performance, safety and quality standards.

D

Decarbonization

The process of reducing carbon dioxide (CO_2) emissions and, more broadly, reducing the GHG emissions resulting from human activities.

E

Eco-design

An approach to product and service design that seeks to minimize environmental impacts throughout their life cycle, from the extraction of raw materials to their end-of-life. This approach incorporates environmental considerations from the earliest stages of design and continues throughout the product's development.

Emissions

Refers to greenhouse gas (GHG) emissions that are released into the atmosphere by industry, transport, etc.

Environmental transparency

The accessibility of information regarding the product's environmental impact.

P

Patient capital

Capital investments committed over an extended period of time for projects and companies that require time to reach maturity and generate returns.

Public procurement

Contracts between public agencies (including governments, municipalities, and public establishments) and private companies for the purchase of goods, the performance of work, or the provision of services.

T

Traceability

The ability to track and record the progress of a product, material or process throughout its production and distribution chain, from its origins to its final destination. It provides information regarding the history, use and transformation of a given product.

Trade protectionism

Economic policies and measures designed to protect domestic industries from foreign competition by limiting imports and promoting local products.

APPENDIX C - REFERENCES

APPENDIX C - REFERENCES

1. Zion Market Research (2024). Global Advanced Materials Market Analysis, 2018-2032.
2. René Poirier (2024). Transition énergétique et matériaux avancés : une lecture de l'environnement, Innovation, Sciences et Développement économique Canada.
3. Science-Metrix (2024). Étude bibliométrique et technométrique sur la recherche et l'innovation sur les matériaux avancés au Québec, on behalf of PRIMA Québec.
4. Unmanned Aerial System Centre of Excellence (2024). Civil and Commercial RPAS Niche of Excellence.
5. E&B Data (2024). Mise à jour des indicateurs statistiques de l'offre et de la demande de matériaux avancés au Québec, on behalf of PRIMA Québec.
6. Experts in the field (2024). Expert interviews conducted under the roadmap's development.
7. Stantec (2024). Matériaux de la transition énergétique: État de la situation et pistes de solutions.
8. Harvey, J. (2024). Guide sur la décarbonation industrielle compétitive, produced for the CRITM and PRIMA Québec.
9. European Commission (2020). Proposition de règlement du Parlement européen et du Conseil relatif aux batteries et aux déchets de batteries.
10. Plasticompétences (2022). Analyse de besoins de formation.
11. Argonne National Laboratory (2024). Advanced Materials and Manufacturing.
12. Bloomberg NEF (2024). Global Clean Energy Investment Jumps 17%, Hits $1.8 Trillion in 2023.
13. Radio-Canada (2024). Hydro-Québec annonce un premier grand projet éolien de 9 milliards $.
14. Hydro-Québec (2015). Scientific Breakthrough in Rechargeable Batteries.
15. Grand View Research (2023). Environmental Technology Market Size.
16. Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (2024), Zero-Emission Vehicle (ZEV) Standard.
17. Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (2024). Western Climate Initiative.
18. Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (2024). Residual Materials Management.
19. Réseau Environnement (2024). À propos.
20. École de Technologie Supérieure (2024). Des fibres fonctionnalisées biodégradables pour mieux traiter l'eau.
21. IPCC (2019). Climate Change and Land.
22. Government of Quebec (2024). Critical and Strategic Minerals.
23. Montréal International (2024). Aerospace.
24. Le Devoir (2015). L'IREQ met au point une batterie qui dure 50 ans.
25. Government of Canada (2021). Leading the way to high-speed and cost-effective manufacturing of lightweight automotive parts.