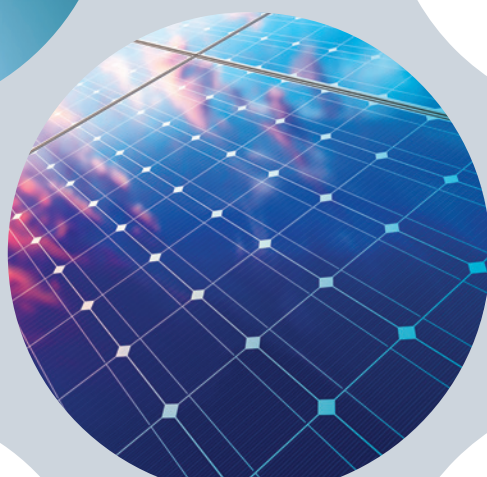
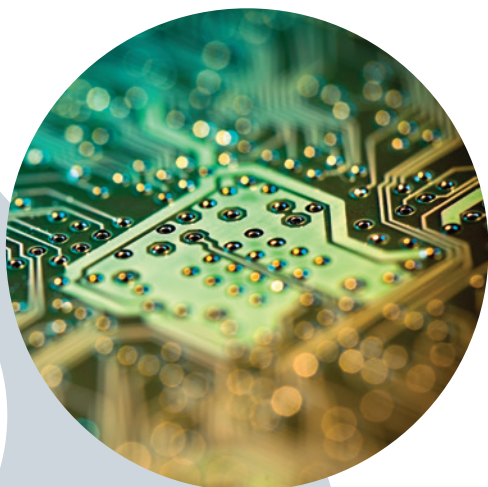


ADVANCED MATERIALS

AN INDUSTRY
OF **INNOVATION**
AND **PROSPERITY**



PRIMA



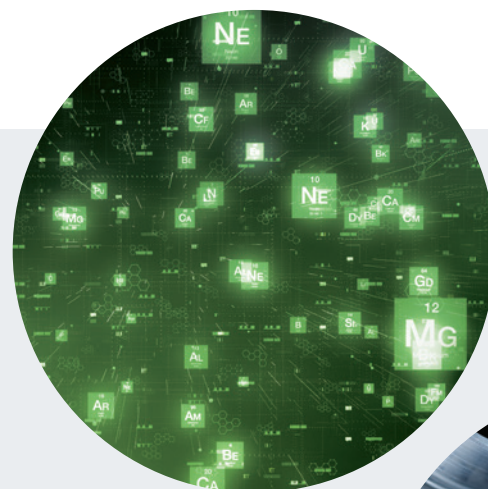
Advanced Materials Moving Forward

PRIMA QUÉBEC, QUEBEC'S ADVANCED MATERIALS **RESEARCH** AND **INNOVATION** HUB



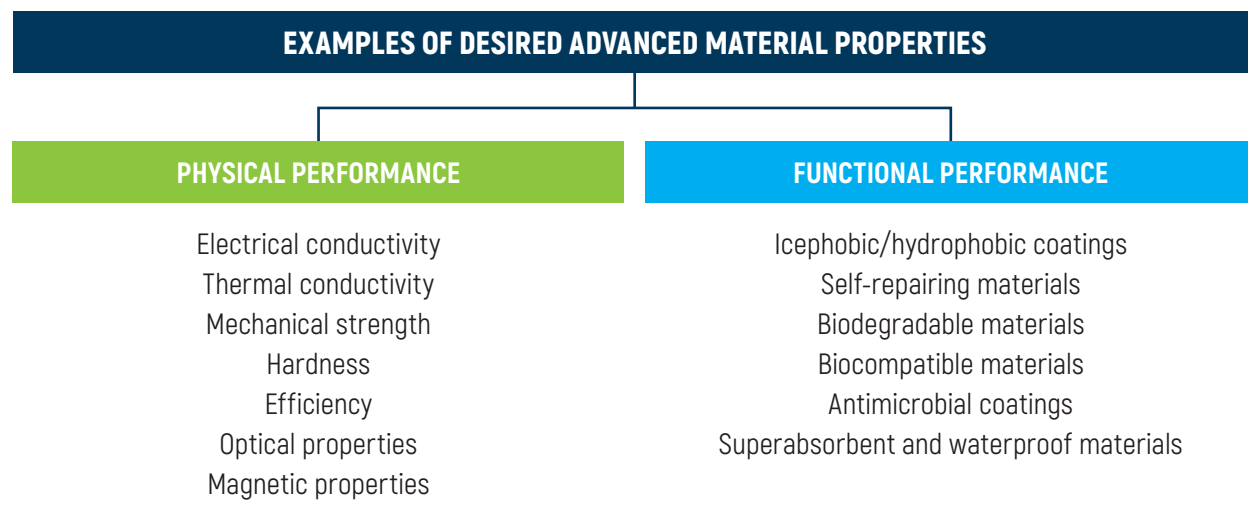
QUEBEC, TOMORROW'S SOCIETY FOR A CHANGING WORLD

Quebec is a renewable energy powerhouse, a leader in transport electrification and clean technologies, North America's largest aluminum producer, Canada's leading aerospace hub, a global force in artificial intelligence research, and host to a large community of health and life sciences researchers and clinicians. All of these future niches share a common thread: Advanced materials. Advanced alloys, polymers, nanomaterials and membranes often reveal extraordinary properties. **PRIMA Québec** brings together a number of stakeholders from this little-known industry, which continues to push the boundaries of the possible.



TOMORROW'S MATERIALS, TODAY'S ENGINEERING

Advanced materials are new and improved materials that offer superior performance over previous ones. They can resist unparalleled temperature variations, recreate skin and replace polluting materials. Among other things, they can be superconductive, hyper-light, and invisible.





ENERGY



TRANSPORT

UNLIMITED FIELDS OF APPLICATION

Advanced materials
are the driving force behind
a multitude of innovations.
They can be found in almost
every sphere of activity.

They are especially
present in a dozen
fields of application.



MANUFACTURING



ENVIRONMENT



CONSTRUCTION/
HOUSING



DEFENCE/
SECURITY



HEALTH AND
BIOTECHNOLOGY



INSTRUMENTATION
AND EQUIPMENT



TELECOMMUNICATIONS/
MICROELECTRONICS



MINING AND
METALLURGY



AGRI-FOOD



TEXTILES/
CLOTHING

AN IMMENSE VARIETY OF PRODUCTS AND SOLUTIONS

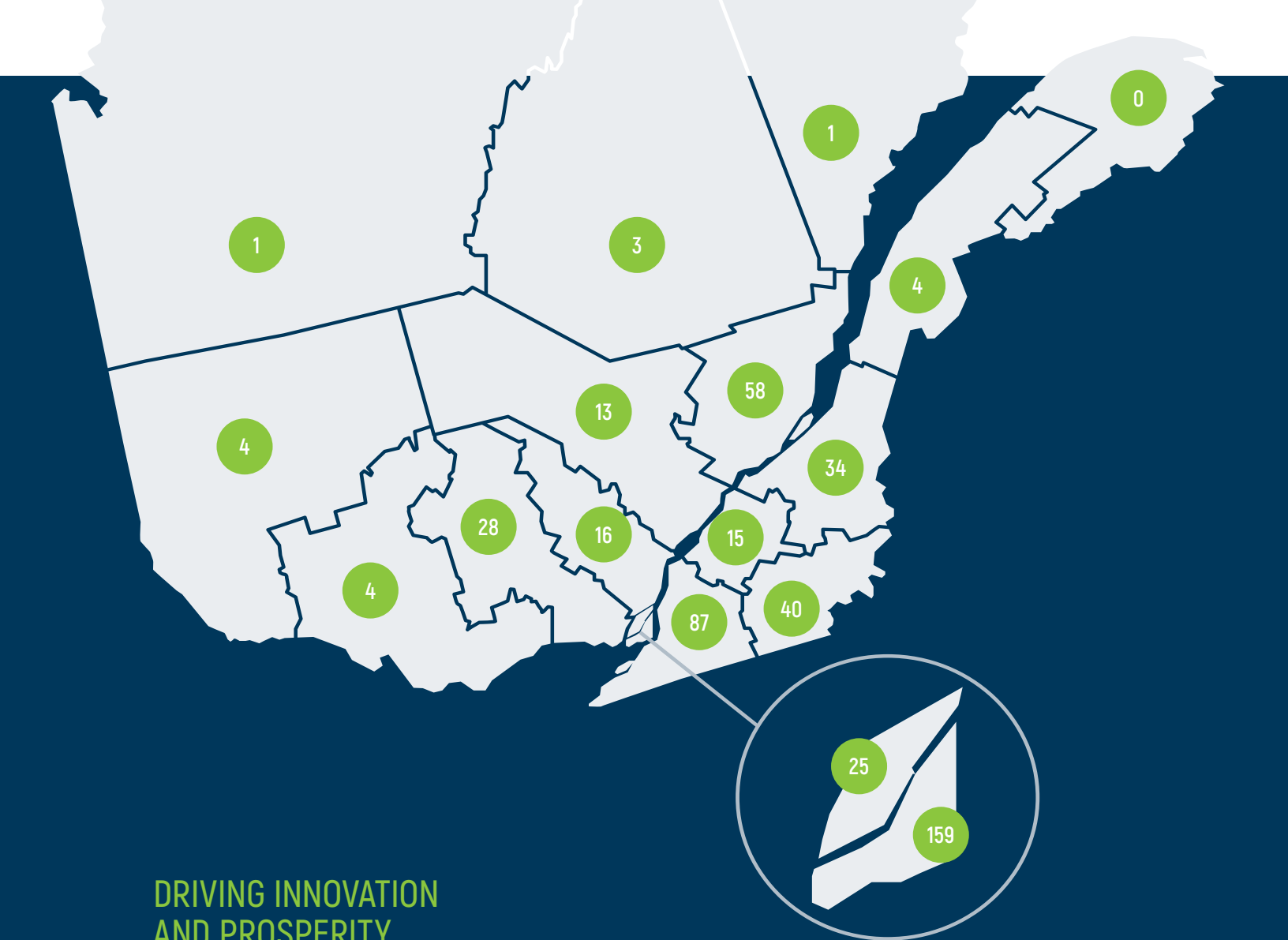
The companies that make up the advanced materials industry work at three levels: Advanced materials **production**, finished and semi-finished product **integration**, along with process and instrumentation **development**. The industry offers a considerable range of products and services¹.

ADVANCED MATERIALS PRODUCTION	
Categories	% of companies
Polymers/Membranes	41%
Metals/Alloys/ Metal powders	32%
Nanomaterials	21%
Composites	21%
Semiconductors	19%
Coatings/Thin layers	16%
Biomaterials	13%
Glass	8%
Fibres/Textiles	8%
Ceramics	5%
Engineered wood	4%
Concrete	4%
Biocompatible materials	2%
Other	2%

FINISHED AND SEMI-FINISHED PRODUCT INTEGRATION	
Categories	% of companies
Composites/Other	36%
Electronic, electrical and optical components	16%
Component-sensors	13%
Systems/Other	13%
Imaging/Optical (laser)/ Optical characterization systems	9%
Materials	6%
Components, systems and subsystems/Energy	6%
Biocompatible components	6%
Non-optical characterization systems	4%
Technical, intelligent textiles	4%
Packaging	4%
Coatings	3%
Advanced chemicals	3%
3D printing systems, software and components	2%
Components/Transportation	2%
Quantum technology	1%
3D-printed part	1%
Components/Energy-transportation	1%
Other finished and semi-finished products	11%

PROCESS AND INSTRUMENTATION DEVELOPMENT	
Categories	% of companies
Surface modification and treatment/Machining/ Shaping	64%
Additive manufacturing	26%
Modelling/Simulation/ Quantum computing/ AI applied to materials	23%
Formulation/Synthesis/ Recycling/Electrochemistry	22%
Characterization instruments	16%
Micro/Nanofabrication	9%
Other processes	3%

¹ The data contained in this document primarily stems from a survey conducted in 2018 and updated in 2021 using a sample of 121 companies that represent Quebec's advanced materials ecosystem.



DRIVING INNOVATION AND PROSPERITY

The advanced materials industry is a driving force in Quebec, with companies in almost every region.

- **More than 470 companies** actively develop, produce and integrate advanced materials, or develop and produce equipment associated with advanced materials;
- Companies that work in advanced materials represent **more than 45,000 jobs in Quebec** and some **\$14 billion in revenues**;
- **Polymers and membranes** (1), along with **metals, alloys and metal powders** (2), make up the two largest categories of advanced materials handled by Quebec companies;

• **Transportation, construction, housing and energy** represent the **primary end-markets** for Quebec's advanced materials sector;

• **Eighty percent of the industry's companies export** outside Canada, with international sales providing **64% of their revenues** on average;

• The sector continues to grow and innovate: **Roughly half of all companies invested over \$1 million in the last three years** and this percentage will continue to rise. **Nearly 60% of companies plan to invest more than \$1 million over the next three years.**

PRIMA QUÉBEC, DEVELOPING THE ADVANCED MATERIALS ECOSYSTEM

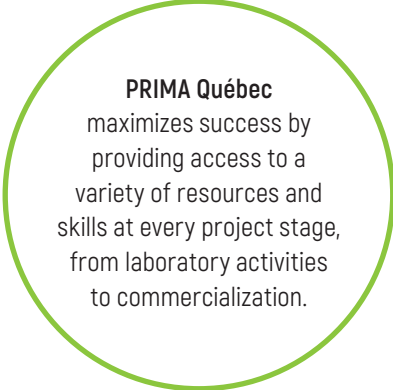
PRIMA Québec was created by the Quebec government in 2014 to stimulate the advanced materials ecosystem and to promote collaborative research between public research centres and companies while offering various economic sectors a range of innovative, high-performance and environmentally friendly solutions that generate benefits for society as a whole.



PRIMA Québec
manages funding programs
for innovative projects
involving advanced materials.



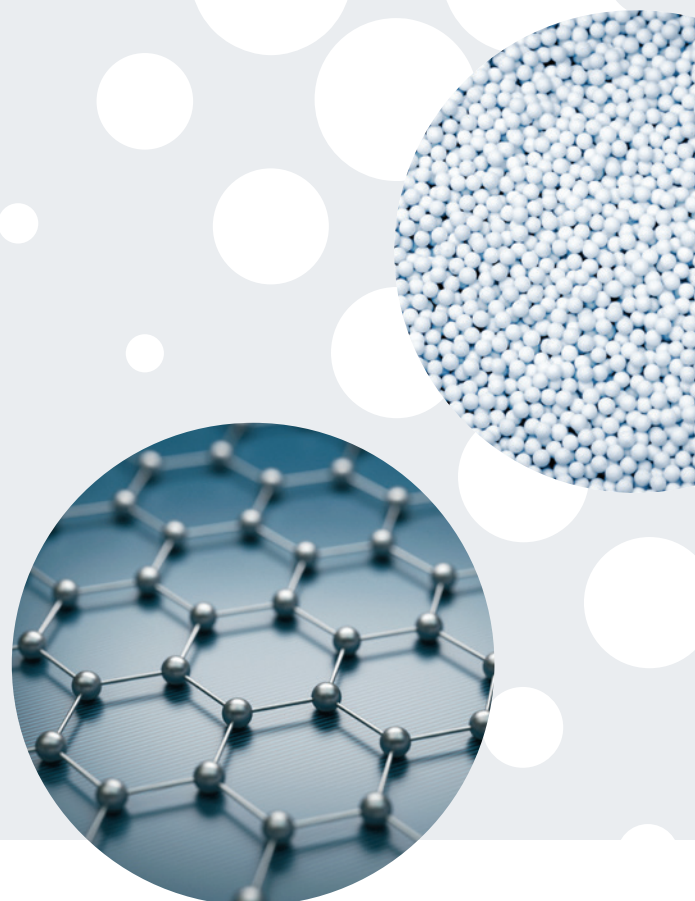
PRIMA Québec
facilitates partnerships by
supporting companies and
research centres in their
innovation projects.



PRIMA Québec
maximizes success by
providing access to a
variety of resources and
skills at every project stage,
from laboratory activities
to commercialization.



Ninety-one innovative projects were made possible through PRIMA Québec's involvement over the 2016-2021 period, including two international consortium projects, for **a combined value of \$82.4 million**. Through its **direct contribution of \$24.2 million**, **along with \$23.4 million from other public partners** (NSERC, MITACS), PRIMA Québec was able to leverage some **\$34.8 million in private investments for innovation**. These projects brought together **190 industrial partners** under a collaborative research approach, 20% of which came from companies outside Quebec, along with **26 public research centres**. These fertile collaborations went on to generate **130 scientific publications**, **15 invention declarations** and **10 patents**. They also helped **124 master's students** and **277 doctoral and post-doctoral students** further their education while contributing to the advancement of knowledge. Several projects involving College Technology Transfer Centres (CTTCs) also helped train dozens of highly qualified technicians.



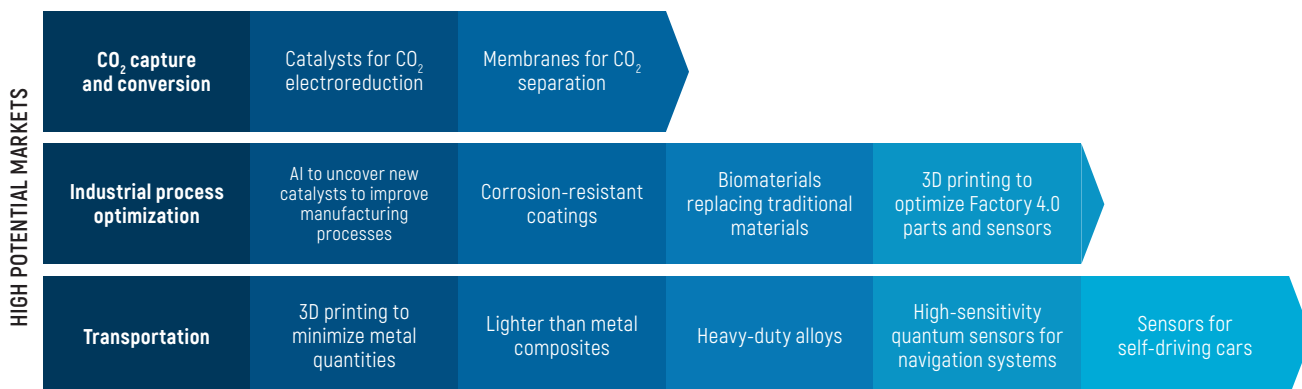
KNOWLEDGE TO CREATE A SUSTAINABLE ECONOMY AND A BETTER WORLD

The demand for advanced materials is growing steadily, and for good reason. Advanced materials belong to the solutions and tools that will help resolve the most significant challenges of our time.

SEVEN OF SOCIETY'S MOST PRESSING ISSUES CALL UPON ADVANCED MATERIALS.

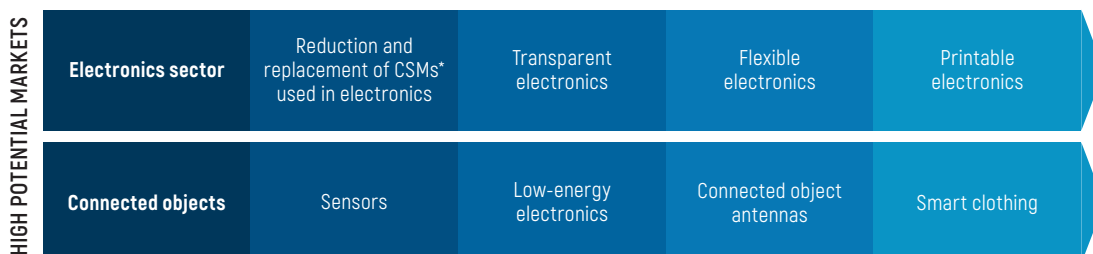
1 FIGHTING CLIMATE CHANGE AND DECARBONIZING THE ECONOMY

Advanced materials offer technological solutions to reduce CO₂ emissions while adapting infrastructures to climate change. For example, the adoption of technologies powered by advanced materials can optimize energy performance and develop new and environmentally responsible manufacturing techniques for a variety of industries.



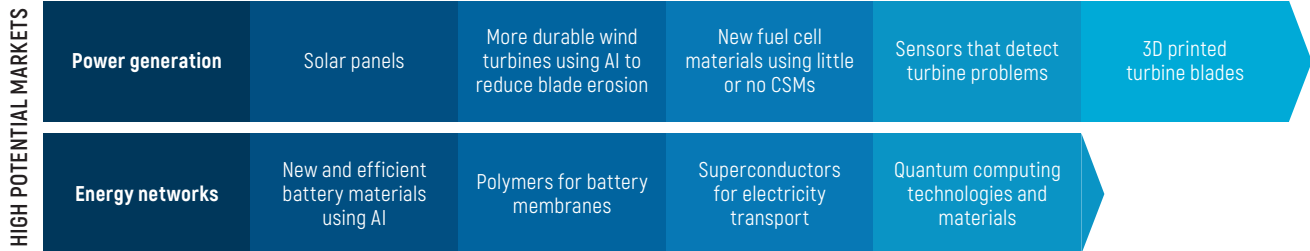
2 ACCELERATION OF THE DIGITAL REVOLUTION

The digital revolution will continue to spread under an increasingly connected population, widespread use of the Internet of Things, new phenomena like telework and 5G connectivity, along with the upcoming emergence of self-driving cars. Other significant developments are on the horizon and the revolution is showing no signs of slowing. The rise of artificial intelligence, virtual reality applications and quantum processors will usher in a new chapter for the digital age. Advanced materials are inextricably linked to all of these cutting-edge technologies, from the most significant breakthroughs to the solutions that reduce and replace toxic elements in semiconductors. Moreover, the tools used in quantum computers are typically built using quantum materials.



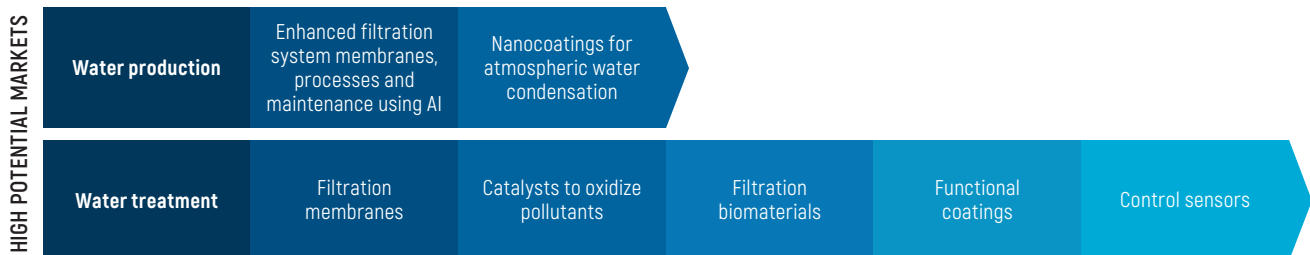
3 INCREASED ENERGY DEMANDS

Growing energy demands and our need to fight climate change will lead to major innovations in energy production and network management. The challenges that surround renewable energy, energy efficiency and energy recovery call for the use of advanced materials; these challenges will be explored to meet industrial, housing and transportation demands without failing to protect the environment.



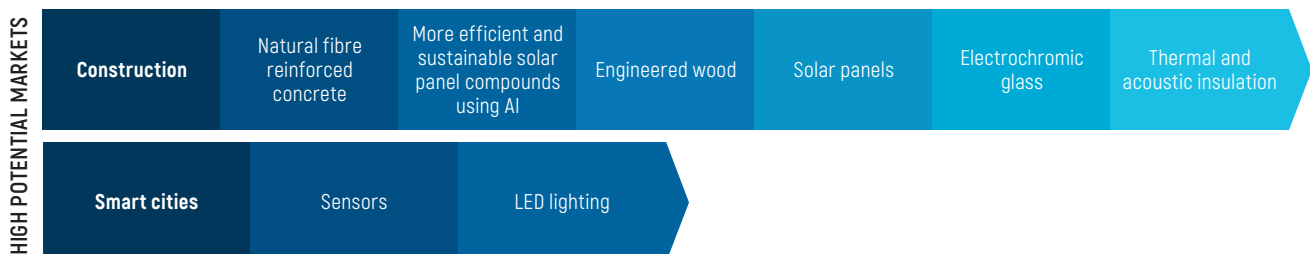
4 WATER RESOURCE DEMANDS

Water availability, drinking water quality, wastewater management and the protection of fisheries are of tremendous concern. Advanced materials offer new technological solutions that can improve the production and treatment of drinking water while optimizing consumption.



5 POPULATION GROWTH

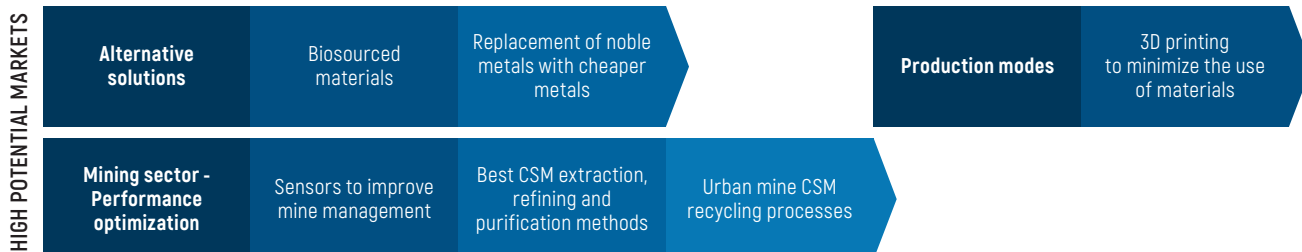
The world's population is set to reach 9.5 billion by 2050. This population growth will lead to an increase in basic needs, including food and water, while increasing our demand for resources. Population growth will also lead to the acceleration of urbanization. Housing construction and public infrastructure, building heating and maintenance, and mobility management are already fermenting innovation. Advanced materials can help reduce the cost and the environmental footprint of buildings and cities while improving quality of life for their inhabitants.



6

NATURAL RESOURCE SUPPLIES

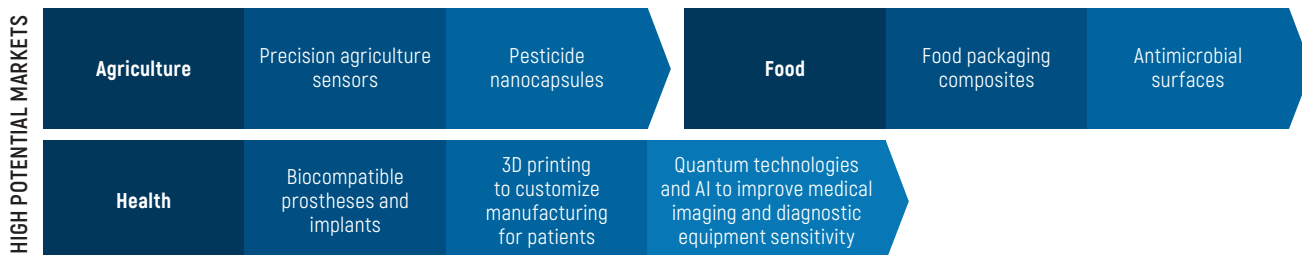
Increasing energy needs and population growth, along with economic and technological developments, continue to drive our demand for resources. In addition, new technologies often require critical and strategic minerals (CSMs). Occasionally, these minerals can be found upstream of certain advanced materials. In the coming years, major efforts will be made to curb the consumption of non-renewable resources. Reuse, substitution, recycling, recovery and remanufacturing will become an integral part of industrial practices thanks to new, more environmentally responsible methods. For CSMs in particular, the recycling of old electronic devices – veritable urban mines – will become essential to reduce virgin resource extraction. These methods will lead to greater responsibility when using natural resources thanks to solutions developed by the advanced materials industry.



7

FOOD AND HEALTH

Food and health represent societal priorities and these essential functions continue to face complex challenges. By 2050, our demand for food will increase by 60%, yet food and agri-food systems are already struggling to keep up. Meanwhile, the COVID-19 pandemic highlighted the many gaps that exist in our health systems while raising new concerns regarding public health, among other issues. Advanced materials are already being used to minimize the environmental impact of agriculture and reduce food waste. These materials are also being used in a growing number of health care services and research projects to develop new drugs, reduce side effects and improve therapeutic performance.



A DIVERSE AND ROBUST ECOSYSTEM...

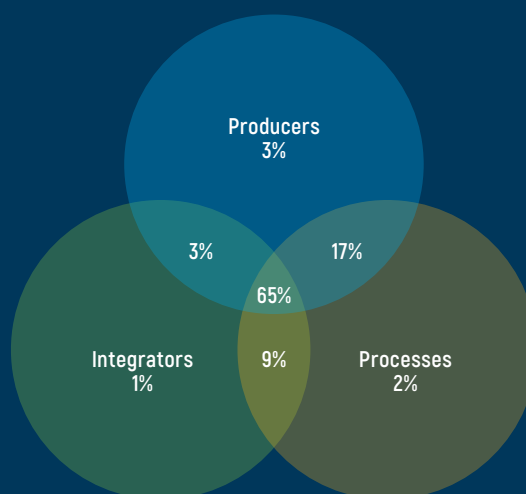
Quebec's advanced materials industry represents a diverse and robust ecosystem. Some 470 large, medium, small and very small enterprises focus their efforts on advanced materials through production, integration and process development. This core ecosystem is home to some 45,000 skilled employees. The industry includes roughly 20 very large enterprises employing more than 80,000 workers. These companies mainly work in the aerospace, energy, transport and primary processing sectors while using advanced materials in their broader activities, not their primary ones. The cohabitation of companies that target advanced materials in their primary mission and strategic function speaks of a dynamic industry that has firmly established itself in Quebec's economy.

QUEBEC'S ADVANCED MATERIALS INDUSTRY COMPANY SIZE AND EMPLOYMENT INDICATORS				
Company size	Companies		Jobs	
	N	%	N	%
Very large enterprises (1000+ jobs)	23	5	80,300	64
Large and medium enterprises (100-999 jobs)	133	27	37,640	30
Small enterprises (10-99 jobs)	203	41	6,912	6
Very small enterprises (1-9 jobs)	135	27	530	0.4
Total	494	100	125,382	100

...A HIGH LEVEL OF COMPETENCE...

Companies that work in this industry often target the production and integration of advanced materials, or the development of manufacturing processes. Two thirds of these companies focus on all three functions. This points to high levels of competence.

COMPANY PROFILE
(% BY NUMBER OF ESTABLISHMENTS)



...A STRONG CULTURE OF RESEARCH AND INNOVATION

The advanced materials industry carries out intensive research and development activities. Innovation is the very essence of the industry. All companies, regardless of their size, invest in R&D.

RESEARCH INTENSITY INDICATORS				
Company Size	Intramural Research		Extramural Research	
	Share of Companies Active in R&D ¹	Share of Employment Dedicated to R&D	Share of Companies Active in R&D ¹	Scope of Partnerships
Very large enterprises (1000+ jobs)	100%	4%	100%	4
Other (1-999 jobs)	100%	11%	98%	2
Large and medium enterprises (100-999 jobs)	100%	7%	100%	3
Small enterprises (10-99 jobs)	100%	26%	96%	2
Very small enterprises (1-9 jobs)	100%	65%	100%	2
Total	100%	9%	98%	2

¹ The data contained in this document primarily stems from a survey conducted in 2018 and updated in 2021 using a sample of 121 companies that represent Quebec's advanced materials ecosystem.

THE PRIMA QUÉBEC METHOD: COLLABORATIVE RESEARCH

PRIMA Québec helps develop the advanced materials ecosystem through its collaborative research approach. This approach is unique in Quebec and is built on close partnerships between academia and industry. It is a co-creation between public and private organizations, which stimulates innovation and helps develop more growth-generating projects while de-risking technological development, optimizing returns on investment and increasing positive spin-offs for both the economy and society. Companies that seek collaborative research tend to partner with external resources like universities and public research centres (e.g., the NRC, Corem, IQ-CRIQ), along with CTTCs to access resources that were not previously available. PRIMA Québec provides a bridge between these companies and external resources.

EXTRAMURAL R&D PARTNERSHIP DISTRIBUTION					
Partner	% of respondents	% by company size			
		% VLE	% LME	% SE	% VSE
Universities	83%	100%	86%	76%	90%
Research centres (e.g., NRC, Corem, IQ-CRIQ)	51%	100%	64%	56%	26%
College Technology Transfer Centres (CTTC)	45%	60%	43%	51%	35%
Testing laboratories	37%	80%	50%	36%	19%
Vocational Training Centres (VTC)	4%	20%	7%	2%	0%
Other	8%	0%	0%	16%	6%
Average number of partnership types	2	4	3	2	2

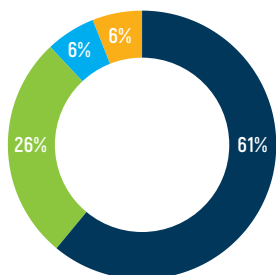


KEY GROWTH CHALLENGES

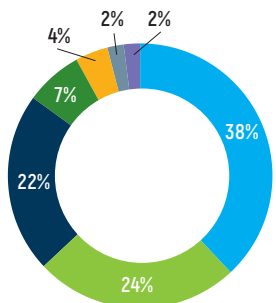
The advanced materials industry has the wind in its sails. It cultivates knowledge that leads to significant economic, environmental and social progress. It is a community that imagines the future. Nevertheless, developing this strategic industry involves challenges. Some concerns emerged among entrepreneurs when asked to comment on their development prospects.

As the following graphs illustrate, **challenges vary by company size**. Of particular note, funding access can become problematic for smaller companies when compared to larger ones. Obtaining capital in the early stages of a business project presents many challenges, which can be significant in a field that involves such high levels of innovation.

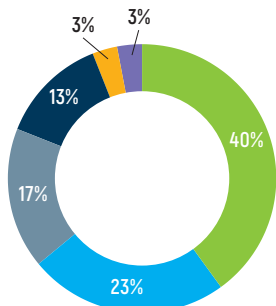
MAIN OBSTACLES FOR THE GROWTH OF VERY SMALL ENTERPRISES



MAIN OBSTACLES FOR THE GROWTH OF SMALL ENTERPRISES



MAIN OBSTACLES FOR THE GROWTH OF LARGE AND MEDIUM ENTERPRISES



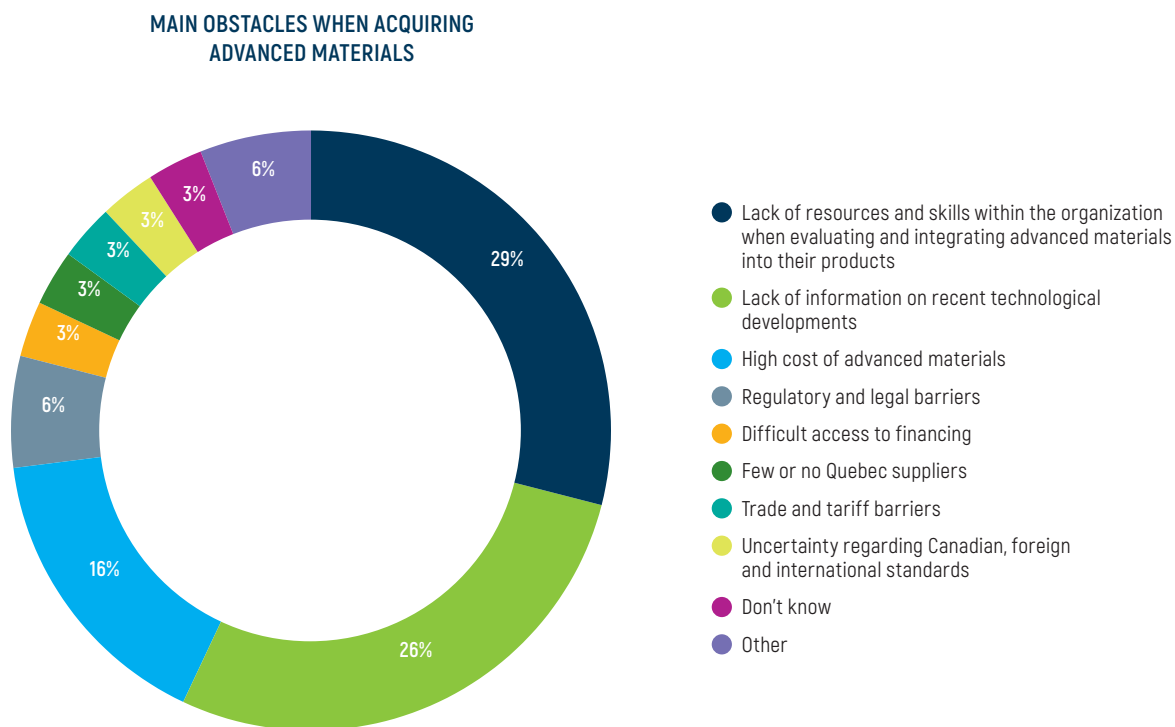
Small and medium enterprises also face labour issues. Scarcity is especially felt in production jobs, which often require uncommon skills. **It is therefore essential that companies establish dynamic partnerships with training centres** while obtaining access to equipment that will develop the skills of their workers internally.

Regulatory and marketing issues, along with international competition, also represent important challenges for a number of medium enterprises. Because the advanced materials industry innovates by definition, companies must regularly obtain authorizations and certifications when commercializing their latest products in various markets. The complexity and weight of these procedures can create significant barriers and hinder the company's development. Expert collaborators from the marketing and regulatory sectors can help simplify these procedures.



COMMUNICATING INNOVATION AND ENSURING THE TRANSFER OF TECHNOLOGY

The advanced materials industry generates innovation at a rapid pace. Customer communication must be adapted to this reality. Companies must first develop an informative and even pedagogical communication method that can explain to potential customers the solutions offered by advanced materials. Customer relations must then be expanded to include tailor-made support that ensures a flawless transfer of technology so that buyers can make the most of the advanced material's potential. This targeted communication method becomes necessary upon realizing that more than half of the industry's customers (55%) have identified a lack of in-house expertise or supplier information as a primary obstacle when acquiring advanced materials.





PROJECTS THAT PROTECT THE ENVIRONMENT, IMPROVE QUALITY OF LIFE AND GENERATE ECONOMIC BENEFITS



ENERGY – CRITICAL AND STRATEGIC MATERIALS

QUEBEC SILICON FOR HIGH-PERFORMANCE LITHIUM BATTERIES

INRS EMT – Prof. Lionel Roué

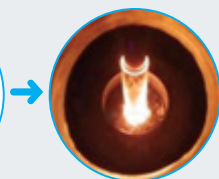
By optimizing Pyrogenesis' PUREVAP plasma process, HPQ Silicon will be able to recover materials that primarily contain a mixture of silicon, silicon carbide and carbon. These compounds will be used in the formulation of high-capacity anodes (INRS) for integration into the new Li-ion battery prototypes (NRC) primarily used in electric vehicles. This project will train two master's students, two post-doctoral trainees and four undergraduate trainees.

Quartz SiO_2 to MG Si (2N+)

The PUREVAP™ QRR, a proprietary (patent pending) 2.0
carbothermic process:



SiO_2 98.8%
92.1% Total Carbon



A one Step
Process



2N+ Si @ 17.9%
Conversion Yield
4N+ Si @ 90.0%
Conversion Yield

Source: HPQ Silicon



ENVIRONMENT-HEALTH

DECONTAMINATING SNOW USING CLAY!

McGill University – Prof. Parisa Ariya

In partnership with McGill University, two Quebec companies (Alserna and PO-Laboratories) are developing and testing a new decontamination technology using a natural clay mineral. This effective and inexpensive approach will make it possible to instantly eliminate and recycle several emerging contaminants found in waste snow (mercury, arsenic, lead, cobalt, etc.). This project will train a doctoral student and a post-doctoral trainee.



Discussion between Oleg Nepotchaykh from
PO-Laboratories and three students at the McGill laboratory.

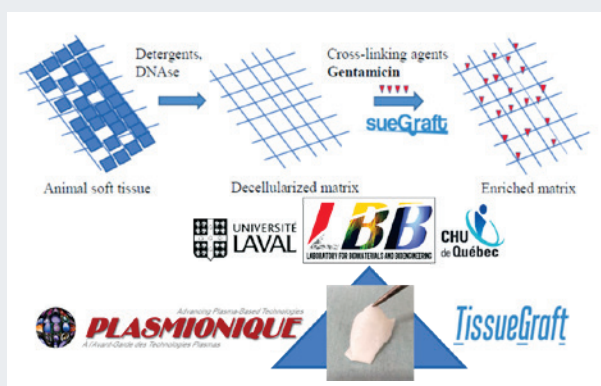


HEALTH

BIOMATERIALS FOR TISSUE REGENERATION

Laval University – Prof. Diego Mantovani

A team centred around Laval University's Biomaterials and Bioengineering Laboratory will develop new treatments for tissue regeneration in humans in collaboration with two industrial partners (Plasmionique Inc. and TissueGraft). The applied plasma and collagen-based matrix approach will include multiple applications. The project will train four post-doctoral trainees, one doctoral student, two master's students and eight undergraduate students.



Source: Image provided by Prof. Diego Mantovani, Laval University



TEXTILE

100% MADE-IN-QUEBEC HOCKEY STICKS!

Polytechnique Montréal – Prof. Louis Laberge-Lebel

In collaboration with Bauer Hockey, the world's largest hockey stick manufacturer, along with FilSpec Inc., a global specialist in textile yarns, and Pultrusion Technique Inc., an expert in composite laminates, Polytechnique Montréal is developing a new automated production line for carbon fibre composite hockey sticks. This new and 100% made-in-Quebec value chain will eliminate the need for manual hockey stick manufacturing outside the country. This project will train two master's students, three doctoral students and two post-doctoral trainees.



Photo credit: Caroline Perron, Photographer



CONSTRUCTION

SUSTAINABILITY AT THE END OF THE TUNNEL

Université de Sherbrooke – Prof. Brahim Benmokrane

How to integrate reinforced and more durable structures when building road, metro and railway tunnels? In partnership with the Université de Sherbrooke, two Quebec companies (PULTRALL Inc. and SYM-TECH) are developing and testing pre-cast concrete tunnel segments that include fibre-reinforced polymers (FRPs). This project will train four doctoral students, two master's students and three post-doctoral trainees.

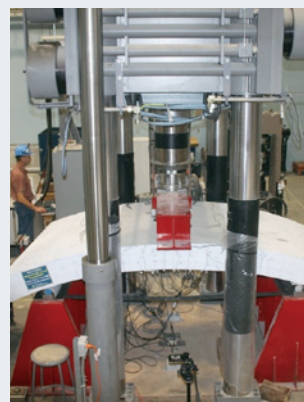


Photo credit: Prof. Brahim Benmokrane, Université de Sherbrooke



CONSTRUCTION

GREEN CONCRETE TO REPAIR AGING STRUCTURES

Laval University – Prof. Luca Sorelli

Laval University is developing low-carbon, ultra-high-performance composite concrete (UHPC) to rehabilitate aging and damaged reinforced concrete structures in Hydro-Québec's vast network by recycling a granite industry by-product supplied by Polycor. This three-year project will also help develop quantitative methods to monitor and inspect aging reinforced concrete structures, digital tools to predict their remaining service life, along with reinforcement techniques using eco-friendly UHPC. This collaboration will help train twelve highly qualified workers.



ENVIRONMENT

CAPTURING ATMOSPHERIC WATER FOR EVERYONE

Polytechnique Montréal – Prof. Jason Tavares

AWN Nanotech, Polytechnique Montréal and McGill University will jointly deploy new Canadian technology to capture atmospheric water and revolutionize the supply of fresh water. Two master's students, one undergraduate student, four supervisory trainees, two post-doctoral trainees and two research associates will contribute by combining surface engineering and nanomaterials. A new nanoporous sponge material has been developed to improve capturing performance while making the process more stable and energy efficient.

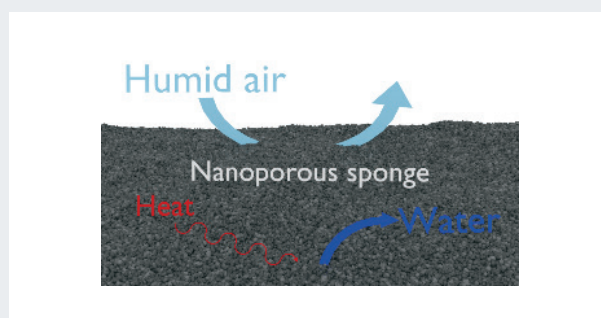


Photo credit: Prof. Jason Tavares, Polytechnique Montréal



T.I.C

QUEBEC MICROCHIPS FOR CLOUD COMPUTING

INRS – Prof. Mohamed Chaker

AEPONYX is collaborating with the INRS and the UQAM to develop prototypes for more affordable, compact and energy efficient switches that are compatible with microelectronics industry standards. A doctoral student, three undergraduate students, two post-doctoral trainees and a research associate will participate by combining innovations in lithography and nanofabrication.

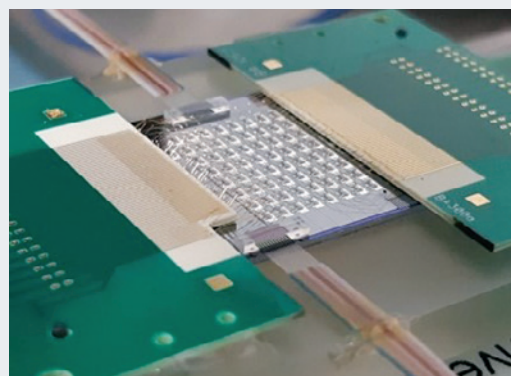


Photo credit: AEPONYX



ADVANCED MANUFACTURING

POWDERS OF THE FUTURE

ÉTS Montréal – Prof. Vladimir Brailovski

Rio Tinto Metal Powders commissioned ÉTS Montréal to improve the properties of its water atomized metal powders and mixtures, providing more control over the manufacturing of high performance products for the transportation and energy sectors. These metal powders are the raw materials used for innovative metallurgy, additive manufacturing and injection moulding processes. During this three-year collaborative project, two doctoral students, one master's student, three undergraduate students and two post-doctoral trainees will receive training at ÉTS Montréal.

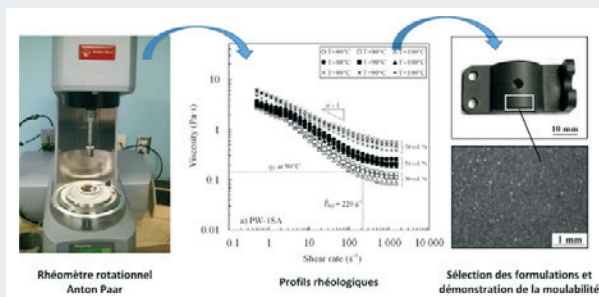


Photo credit: Prof. Vladimir Brailovski, ÉTS Montréal



AERONAUTICS

A SUPER VARNISH FOR AIRPLANES

McGill University – Prof. Milan Maric

An aircraft varnish tested under extreme conditions. C&D Aerospace Canada (Zodiac Aerospace) is collaborating with McGill University and three doctoral students to develop a non-flammable, high-crack resistant varnish with strong levels of adhesion. This complex product will accommodate spray applications without shrinking and provide a long service life. It will also self-repair!



Photo credit: Prof. Milan Maric (McGill University)



ENERGY

PROTECTING POWER LINES FROM ICE

UQAC – Prof. Gelareh Momen

Hydro-Québec is collaborating with the UQAC to develop icephobic coatings for power lines and insulators. These coatings will significantly reduce the risk and frequency of power outages, along with the financial impact of severe ice and snow storms. The project is supported by PRIMA Québec and will help train two post-doctoral trainees, two doctoral students, one master's student and three undergraduate students, creating a hiring pool that will be second to none.

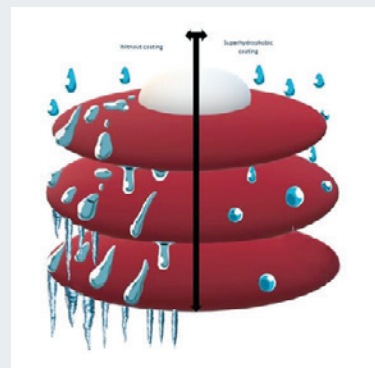


Photo credit: UQAC



WOMEN AND MEN WHO IMAGINE THE FUTURE

"Our business focuses on the microfabrication of integrated circuits using innovative materials. Collaborative R&D has been and remains essential to our development. We greatly appreciate the work that was done by PRIMA Québec to facilitate this collaboration as it continues to drive this high-potential industrial sector."

- Philippe Babin, CEO, AEPONYX

"PRIMA Québec is an excellent technological resource for e2ip. We have successfully integrated the NRC's Molecular Ink process (MINK) into overmoulded components for printable electronics through a collaborative research project."

- Eric Saint-Jacques, CEO, e2ip

"Almost everything that can be produced from fossil fuel can be produced from renewable biomass. That is the principle of the research we conducted with the assistance of PRIMA Quebec. Wood can be transformed into high quality lignin and sugars which can be used in sustainable construction, food, packaging and other applications."

- Helen Lentzakis, Biomass Conversion Manager, FPInnovations

"Our hyperspectral platforms are used around the world to help promote research into advanced materials, including the latest generation of photovoltaic materials. PRIMA Québec's support helped us validate our technologies. We continue to work with the academic sector to develop new solutions that will meet the market's needs. None of this would have been possible without PRIMA Québec's funding and support."

- Photon etc.

"Making sustainable advanced materials, such as graphene, more affordable and available is key to a better future. PRIMA Quebec has been a great partner to NanoXplore on this journey."

- Nima Moghimian, Global Director of Research and Development, NanoXplore

"Thanks to the support we received from PRIMA Québec, Polycontrols was able to significantly accelerate the development of functional coating applications based on advanced materials. Our work involves antiviral, anti-corrosion and wear-resistant coatings."

- Luc Pouliot, Chief Operations Officer and Chief Technology Officer, Co-owner, Polycontrols





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PRIMA Québec is an advanced materials research and innovation hub that supports and promotes the advanced materials ecosystem and acts as an engine of innovation and growth in Quebec. Through support and funding, it stimulates the competitiveness of Quebec companies by facilitating access to research expertise. Acting as a Sectoral Industrial Research Group (SIRG), PRIMA Québec relies on financial support from the Quebec government as well as the private sector when promoting research-industry relations.

A list of industrial and academic members and partners can be found on the PRIMA Québec website.

www.prima.ca