

## PERSPECTIVE



# Advanced Materials: The Future Is Now

Advanced materials (AMs) are a bit like information technology and communications—they are just about everywhere. They outperform traditional materials from a physical standpoint (e.g. conductivity, resistance, optical properties) and functionally (e.g. hydrophobic, biodegradable). The market for AMs is in full swing around the world. Quebec has a stake in this market, with more than 300 companies that have jumped on board this fast-moving train. This issue of Perspective offers an overview of a world that may seem futuristic but is squarely in the here and now. At a time when innovation is every economy's pathway to prosperity, this is one train Quebec cannot afford to miss.

### Advanced Materials in a Nutshell

According to the Advanced Material Research and Innovation Hub (PRIMA Québec), "Advanced materials can be described as any new or significantly improved material that provides a distinct physical or functional performance advantage when compared to commonly used conventional materials, which they replace."

Let's look at a few examples to get a better idea of what AMs are all about. In the textile industry, consider clothing that helps keep people cool and refreshed. In the construction sector, researchers have developed cement that can withstand shocks measuring 9.0 to 9.1 on the Richter scale. In the food industry, a biodegradable material was developed to package pasta and cheese that protects food from oxygen and humidity, and leaves behind a smaller footprint than conventional materials. For the environment, think of the carbon nanotubes that could help desalinate sea water, or processes designed to increase energy efficiency. These are just a few of the myriad examples available.

AMs are a reflection of our era: the fruit of collaboration and increasing cross-fertilization. Boundaries are being obliterated and hurdles that used to exist between different disciplines like chemistry, biology, physics and the environment and their sub-components are disappearing. This level of cooperation is creating a merging of technologies that would have been considered improbable not too long ago, and this has led to what we now call AMs.

### Advanced Materials: Not a 21<sup>st</sup> Century Innovation

AMs are not a new phenomenon. A [study](#) released in 1992 on this topic for the committee on the Bilan de l'activité scientifique et technologique de la région de Montréal touched on their

"ubiquity, versatility and competitiveness." At the time, Quebec's AM industry consisted of about 20 companies, with that number estimated to have exploded at least 15-fold in 2017–2018.

While AMs are not exactly new, the industry is creating a buzz at the moment. A flurry of events are being held in Quebec and elsewhere around the world, with many conferences, forums, symposiums and seminars being held. To continue to move forward and keep developing materials that will create solutions to ongoing problems, we have to pool our knowledge and share new developments. We also have to combine saving energy, reducing our environmental footprint and cutting costs to make sure these innovations can be adopted quickly.

PRIMA Québec divides these materials into three categories: basic materials, finished and semi-finished products and lastly, processes and instrumentation (box on page 2). Polymers, elastomers and membranes are seen as basic materials, which also includes nanomaterials (e.g. nano-objects that can be used in liquid, powder or gel form), followed by metals, alloys and metal powders. Composites and ceramics also fall under this heading, as do biomaterials, i.e. bioplastics and bacteriophages, to name a few.

Transportation components make up the bulk of the semi-finished products category (e.g. landing gear), electronic, optical and electrical systems and subsystems (e.g. pinhole cameras), biocompatible materials (tissue repair devices), smart textiles and packaging (uniforms with RFID (Radio Frequency Identification) chips, heated coats, etc.).

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NOTE TO READERS: The letters k, M and B are used in texts and tables to refer to thousands, millions and billions respectively.

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## CATEGORIES OF ADVANCED MATERIALS, ACCORDING TO PRIMA QUÉBEC

### Basic materials:

- ▶ Polymers, elastomers and membranes
- ▶ Nanomaterials
- ▶ Metals, alloys and metal powders
- ▶ Composites and ceramics
- ▶ Functional coatings, sealants and thin layers
- ▶ Biomaterials
- ▶ Semi-conductors
- ▶ Cement and engineered wood
- ▶ Glass
- ▶ Natural and high-performance fibres

### Semi-finished products:

- ▶ Transportation components
- ▶ Electronic, optical and electrical systems and subsystems
- ▶ Electronic, optical and electrical components
- ▶ Biocompatible materials
- ▶ Packaging
- ▶ Smart textiles
- ▶ Other semi-finished products

### Processes and instrumentation:

- ▶ Additive manufacturing
- ▶ Characterization instruments
- ▶ Modelling and simulations
- ▶ Nanomanufacturing

Sources: E&B Data and PRIMA Québec

Additive manufacturing (3D), characterization instruments (e.g. biomedical technologies and microbiological tests), modelling and simulations as well as nanomanufacturing fall under processes and instrumentation.

### Why Choose Advanced Materials?

Why look toward AMs? These materials and processes have properties that are highly sought-after, in fact. In terms of physical performance, some materials are better electrical conductors, while others offer superior mechanical resistance, are much harder or offer increased efficiency. Still others have optical or magnetic properties. These qualities are not mutually exclusive, and may sometimes overlap.

AMs are useful primarily due to their “functional performance.” When used as a coating, AMs can create hydrophobic

membranes. Some materials self-repair, others are biodegradable, while others can be used as an antimicrobial coating, to name a few uses.

AMs tend to wade into every area of human and economic activity, much like we experienced with IT and communications.

### Quebec and Advanced Materials

In June 2018, PRIMA Québec presented its most recent *snapshot* of AMs in Québec.<sup>1</sup> About 340 companies in Québec were active in the AM space in 2017–2018. These companies develop, produce or incorporate AMs into their production lines, while others focus on designing and producing “systems or equipment related to AM production and/or characterization.” The breakdown is as follows, based on company size: about 30% have between 1 and 9 employees, 36% have between 10 and 99 employees, 29% have between 100 and 999, while the remainder have 1,000 or more employees.

Québec has about 33,000 workers in this industry, with most employed in companies that have between 100 and 999 employees. Between 2015 and 2017, job growth was 1%. Last year, the business volume of companies in the AM industry reached \$10.6B. This data also accounts for other company activities that are not necessarily directly related to AMs.

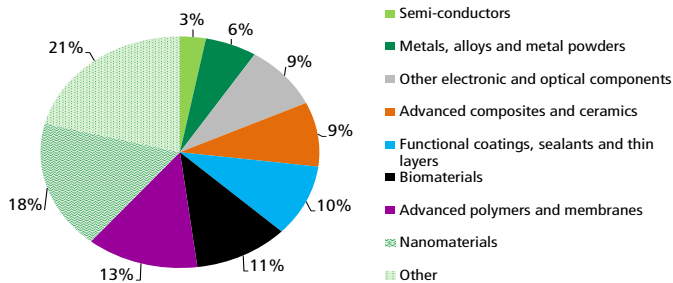
AM development is not driven by companies alone. Québec has about 500 researchers working on AMs in research centres across the province. PRIMA Québec’s survey of small-to-medium businesses helped shed some light on what drove companies to tap Québec’s research centres. 71% of respondents highlighted their need for precision equipment. And a majority of SMEs, or 56%, explained that what they needed most was focused expertise. Among the respondents, 44% pointed to a lack of financial resources to purchase much needed equipment, which prompted them to turn to public research centres. Lastly, 36% of SMEs cited another compelling reason: the absence of in-house laboratories.

How did the researchers’ efforts help? Based on the PRIMA Québec survey, 73% of industrial clients found a solution to a problem, 71% developed a new product, and 58% created a new process.

A question for the researchers in public research centres: what areas tied to AMs are the most active right now? Graph 1 on page 3 illustrates the diversity of current research activities. The biggest category is the one that encompasses a set of products (21%), followed by nanomaterials (18%), advanced polymers and membranes (13%), biomaterials (11%), functional coatings,

<sup>1</sup> PRIMA Québec, in collaboration with le Ministère de l’Économie, de la Science et de l’Innovation (MÉSI) et Innovation, Science and Economic Development (ISED) Canada.

**GRAPH 1**  
**Research into advanced materials at public research centres covers a broad range of industries**



Sources: E&B Data and PRIMA Québec

sealants and thin layers (10%), and other areas with a less than 10% share.

### Expanding Needs

Nothing suggests this focus on AMs will fade anytime soon, on the contrary. Several trends seem to be extending the movement to all four corners of the Earth. Energy—an issue that is at the core of economic and human development, stands out as one of the primary trends. On one hand, global demand for energy is ever-increasing. On the other, calls for clean and renewable energy production are getting louder. With this in mind, fresh ideas are being brought to the table, such as manufacturing new types of solar panels, creating alloys to reduce the weight of vehicles on the road, in the air, on the sea and rails, or developing superconductors for the transmission of electricity. Rising environmental concerns are among the many challenges that AMs may help resolve. Water quality and scarcity, for example, has led to the development of biomaterials for filtration and membranes that can desalinate sea water.

In keeping with these environmental concerns, a more reasonable and respectful use of non-renewable energy resources calls for action. It also requires that we develop replacement materials, and use less damaging processes to extract raw materials. Climate change has also been a catalyst in creating solutions to these problems. This is how innovations like CO<sub>2</sub> separation membranes were created, and how the range of processes developed to characterize air quality came to be. However, much work has to be done and the battle is far from over. This is why the creation of new AMs will help support the processes and materials that have been developed thus far.

Demographic growth, exploding urbanization, urban densification and the need to keep people healthy are just a few of the pressing issues that have to be solved around the world. As such, we are looking to AMs to create solutions that will help us deal with these trends. For example, newly developed antimicrobial surfaces and building materials with greater resistance.

Increased security needs, whether for food (quality, hygiene, quantity), people (e.g. citizens, police officers, firefighters, the military), corporations (e.g. industrial secrets, sensitive data, physical access), or governments (e.g. citizen information, decision processes, public finances and management), all require solutions that might feature AMs. The development of detection and traceability tools is key. Consider printable or flexible electrical components, medical imaging equipment, or sensors, as just a few examples.

These trends are all interrelated, and they all require solutions. AMs can respond to these needs more efficiently than more conventional materials, often getting the job done faster, and sometimes even for a longer period.

### Demand in Quebec for AMs

Based on PRIMA Québec's snapshot of the situation, demand for AMs at home is also strong. What's more, the prospects for the future look bright. Just think about the potential in the following areas: energy, transportation, the environment, healthcare, construction, information technology and communications, defence, security and many other fields.

Sensors, metals, alloys and polymers seem to be the front-runners at the moment. According to the companies that responded to the 2017 survey, defence, advanced manufacturing and transportation are the sectors that offer the greatest potential for AMs.

Though demand for AMs exists in Quebec, the companies in Quebec's AM industry export 85% of the products and services they develop, according to the survey of enterprises in the advanced materials sector. "Quebec is not a major player on a global scale, but in terms of its outputs and the inroads made in certain international networks (high export level), Quebec's industry is indeed competitive," according to PRIMA Québec.

Could anything derail the growth of Quebec's companies? In terms of demand, a lack of knowledge about AMs could slow their introduction in companies, across all areas of activity. The absence of information and the high cost of some AMs present additional obstacles.

On the supply side, access to financing was raised by about one third of the businesses surveyed. Labour can also be an issue, due to the knowledge and education required to be part of the teams that are developing AMs. As mentioned earlier, the lack of information could also be holding back some buyers from taking the plunge. This goes hand in hand with the marketing difficulties of Quebec-based producers. Opening Quebec's AM market to the world exposes our home-grown companies to foreign competitors, many of whom have deep pockets that allow them to grab a leading market share. We only have to think about industry giants like 3M to illustrate the kind of battle that to be fought.

The recognition of intellectual property through patents is another challenge facing companies that develop AMs. On the manufacturing side, the difficulties of passing from the prototype phase to industrial-scale production must be tackled.

**Betting on the Future**

The prospects for the AM market look bright. The forecasts for the global market are very optimistic, even if they differ depending on the source (table 1). According to market researchers Transparency Market Research and Research Nester, the global market will more than double by 2024, reaching more than US\$100B. For its part, BCC Research expects the market to reach about US\$128B by 2022, less than four years away. Regardless of the benchmark used, the global AM market is expected to rise by more than 10% each year for the next few years. This pace is considerably faster than GDP growth in the manufacturing industry and the projected growth for the services industry in advanced economies.

**TABLE 1**  
Global market for advanced materials: a few estimates

SOURCE	CURRENT MARKET (US\$B)	FUTURE MARKET (US\$B)	AVERAGE ANNUAL GROWTH RATE (%)
Transparency Market Research (April 2018)	2015: 42.8	2024: 102.5	10.4
BCC Research (August 2017)	2017: 68.4	2022: 128.1	13.3
Research Nester (July 2018)	2016: 42.9	2024: 101.0	11.6

Sources: Transparency Market Research, BCC Research, Research Nester and Desjardins, Economic Studies

AMs are generating a lot of interest at the moment. All in all, they are very promising for the future. Given the considerable strides AMs have made over the years, the possibilities are almost endless. The demand is there, and so is the supply. Quebec has already jumped aboard this moving train. We have the researchers, and Quebec companies already enjoy a foothold in foreign markets. Quebec must make the most of this asset.

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