

# Catalyzing Innovation

## Bioeconomy in Québec: Innovations to Shift from Fossil-Based to Biobased Industries

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### Introduction

**T**he sustainable bioeconomy, based on the production and transformation of biological resources and wastes into value-added products such as food, animal feed, biobased products, bio-energy and other industrial goods, is an important pillar of economic development in all regions of Québec. The transition from fossil-based to biobased industry is motivated by the deep conviction of Québec stakeholders that the fight against climate change is not only necessary to ensure our well-being and that of future generations, but also represents an opportunity for economic growth. More than a challenge, this fight offers to Québécois an exceptional occasion to reorient their economy towards clean energy and green technologies to reduce carbon footprints and GHG emissions and ensure a healthy and prosperous future.

### The Province with Diversified Economy

Québec is located in northeastern North America and is one of the thirteen provinces and territories of Canada. It is the second-most populous province with a population of 8.2 M. Its economy is diversified and represents 20% of the total gross domestic product (GDP) of Canada.<sup>1</sup> The 1,200-km long St. Lawrence River makes it the natural gateway to North America and affords it preferential access to a market of 460 million consumers. Québec's economy has changed markedly in recent decades. Although Québec has been recognized for many years for the abundance and variety of its natural resources, its economic growth is currently based mainly on new technologies, and the tertiary sector generates 76.2% of Québec's GDP.<sup>2</sup>

### Bioeconomy is Québec's Reality

#### BIOECONOMY DRIVERS

The bioeconomy is firmly anchored in all regions of Québec and already represents a significant economic activity. Its value is estimated at more than \$56 billion of output across the Québec bioeconomy, supporting more than 163,000 jobs.<sup>3-5</sup> The main Québec bioeconomy drivers rely on the excellent quality of its scientific researchers and infrastructure, as well as the strength of its research and innovation ecosystem in all scientific disciplines related to enabling technologies in industrial biotechnology

and process engineering. Other drivers of the bioeconomy are the advances in production of various bioresources (agriculture, forest, and aquatic resources) and their transformation into value-added products such as foods, animal feed, biobased chemicals, biomaterials, and bio-energy.

By relying on its bioresources, human skills, infrastructure, government financial incentive programs, and a diversified industry that is increasingly focused on innovation, Québec aims to become a leader among the world bioeconomy actors.

In recent years, by supporting various consortia, clusters, and funding programs dedicated to life science sectors, federal and Québec governments, with the involvement of industry, have stimulated collaborative research to conduct innovative industrial projects in various bioeconomy sectors to create new bioproducts, processes, and solutions that are economically viable and environmentally sustainable. The Québec government has been implementing various dedicated grant funds including those specialized in the financing of fundamental and applied research in bioeconomy topics that structure institutional research and foster the acquisition of funds granted by federal councils in Canada. Both the Québec consortium for industrial bioprocess research and innovation (CRIBIQ)<sup>6</sup> and advanced materials research and innovations hub (PRIMA)<sup>7</sup> gather more than 300 companies and public research institutions interested in the development of innovation in bioeconomy industrial sectors including agrifood, biomaterials, biofuels, biobased chemicals, and the environment. The collaboration that CRIBIQ and PRIMA catalyze share cost and risk between public research institutes and industries. Other grant funds such as Genome Québec,<sup>8</sup> Innovation Bois,<sup>9</sup> Innov'Action Agrifood program,<sup>10</sup> Maritime Strategy fund<sup>11</sup> and Fond de recherche du Québec-Nature et Technologies<sup>12</sup> are flagship programs that support basic and applied research, as well as innovation in bioeconomy-related research areas.

Many policies have been driving the innovation that is aimed at transforming bioresources into value-added bioproducts. Indeed, the development of the bioeconomy in Québec is consistent with several provincial policies and strategies including the Québec Strategy on Research and Innovation (2017–2022),<sup>13</sup> the Québec residual materials management policy,<sup>14</sup> the Québec government's 2030 Energy Policy,<sup>15</sup> Québec's Maritime Strategy,<sup>16</sup> Energy Transition, Innovation and Efficiency master plan,<sup>17</sup> bio-food policy,<sup>3</sup> Sustainable Forest Management Strategy,<sup>17</sup> Development Strategy for the Québec Forest Products Industry (2018–2023),<sup>4</sup> Climate Change Action Plan (2013–2020),<sup>19</sup> Québec Water Strategy (2018–2030)<sup>20</sup> and Clean Technology Action Plan for Growth (2018–2023).<sup>21</sup>

### QUÉBEC AGRI-FOOD SECTOR: UNIQUE IN THE WORLD

Québec boasts Canada's largest agri-food industry by encompassing farmers, processors, transformers, innovators, academic and industrial researchers, and others in the value chain. The industry generates more than \$21 billion in annual output, exports \$8.3 billion in products each year and employs more than 510,000 people within 66,500 companies.<sup>3</sup> The sector comprises the largest manufacturing sector in terms of value of shipments and employment in Québec, representing 8% of the total Québec GDP (\$25.4 billion).<sup>3</sup> The province is home to well-diversified agriculture production: dairy (29%), pork (18%), grain (14%), poultry (11%), fruit and vegetables (11%), beef (7%), maple syrup (4%), horticulture (3%), and other agriculture products (3%). Furthermore, 70% of agricultural production is transformed in Québec: meat and poultry (22.5%), dairy products (17%), beverages and tobacco (15.3%), bakery products (8.3%), fruit and vegetable (6.8%), feeds (7.4%), sugar and candy (5.4%), marine products (2.3%), and others (11.2%). Québec consumers devote more than 13% of their spending to food.<sup>3</sup> The province also has a global reputation for food quality, safety standards, and processing methods. Leading international and domestic manufacturers for bio-entrants, food, and beverages are located in the province of Québec to take advantage of local market assets. Currently, however, government regulatory constraints limit the development of agricultural crops into non-food products such as bioproducts and bio-energy.

### FORESTRY AND WOOD PRODUCTS INDUSTRY

Today, the forest products industry is one of Québec's most important manufacturing sectors. Québec's annual harvesting potential of forest residual biomass is estimated at 14.86 million wet metric tons (MT) per year notwithstanding 6.56 MT for crown/foilage. In Québec, forest biomass allocation ensures long term supply security due to the new Québec forestry regime that promotes investment, development, and integration of forest biomass transformation technologies to existing infrastructure.<sup>4</sup> Québec forest industry actors, especially pulp and paper manufacturers, have put in place major industrial and financial entities backed by research and innovation to diversify their modes of production and expand their commercial outlets. The accumulation of knowledge and technological change has led to a significant shift in forestry practices. As a result, forestry is now a sustainable activity supporting the Québec economy. The forestry sector accounts for 2% of GDP (\$6.5 billion) and 1.6% of jobs, with nearly 59,000 workers.<sup>4,17</sup> In some parts of Québec's north, home to most of the forest harvest, its economic footprint is much greater. Forestry is a major part of the economy for some 200 Québec municipalities. The heart of the Québec forest sector is traditional forest products, including lumber, other solid wood products, pulp and paper and activities such as forest management and logging. However, with Québec's commitment to clean technology and transition to a low-carbon economy, non-traditional forest products such as advanced bioproducts are growing in importance. A broad range of biobased products from the forest are now either available on the market or under development; notably biobased plastics, biobased adhesives, nanocellulose, cellulose biofilaments, bio-composites,

biochar, bio-inks, biocides, bio-detergent, biofuels, building block molecules, and more.

### ORGANIC WASTE RECOVERY

Québec's residual materials management policy proposes various measures that comply with the principles of sustainable development and the hierarchy of residual materials management methods. The elimination of landfilling of residual organic materials is planned by 2020.<sup>4</sup> This policy has been driving innovative municipal and industrial projects that aim to transform these feedstocks into value-added bioproducts. The great diversity of co-products and residues from the production and transformation of different bioresources and urban organic waste is also being transformed into new commercial applications. The roughly 13 million tons of residual materials produced in Québec annually hold an undeniable potential to be used either for energy or for manufacturing industrial bioproducts including chemicals.<sup>4</sup>

More precisely, several industrial biobased products have now been developed such as: energy in liquid form (ethanol, methanol, bio-kerosene), gas form (bio-hydrogen and bio-methane) and solid form (biochar), building block molecules, biobased plastics, adhesives, detergents, biocides, and fertilizers.

### Strong Research, Innovation and Knowledge Ecosystem

Given the importance of the bioeconomy for Québec's prosperity, research and innovation present a number of major issues for several disciplines and specialties in scientific research including those related to the production and transformation of bioresources. To this end, strong support for scientific and technological progress in areas associated with the bioeconomy is essential to meet the challenge of developing a sustainable economy in Québec as an alternative to the carbon-based economy considered today as a transient. In Québec, more than 65,000 individuals are involved in research and development, equivalent to 9.9 out of every 1,000 active individuals, the highest ratio in Canada.<sup>21</sup> Québec has skilled workers to innovate. The Québec and federal governments are actively funding innovation in Québec. According to the latest data available, Québec allocates 2.32% of its GDP to research and development (R&D),<sup>22</sup> the highest rate of all the Canadian provinces. This indicator ranks Québec 13th among the members of the Organisation for Economic Co-operation and Development (OECD).<sup>23</sup> More specifically, Québec ranks 15th among OECD countries from the standpoint of in-house research and development spending in relation to GDP.<sup>23</sup> Québec's taxation system includes, by way of example, R&D tax assistance for SMEs and tax holidays for foreign researchers and experts in research and development. According to the taxation system's competitiveness index for R&D, Québec ranks 10th among the 40 countries and territories studied for incentives offered to large businesses and ranks first for tax incentives aimed at SMEs.<sup>24</sup> As for research and development spending on higher education in relation to GDP, Québec ranks the equivalent of fourth among OECD countries.<sup>24</sup> The Québec academic research sector is open to international collaborations. Accordingly, Québec produces 1% of worldwide scientific publications, of which 44% involve international collaborations.<sup>25</sup>

## Conclusion

The Canadian province of Québec possesses many assets to boost the development of its bioeconomy. Added to the diversity and abundance of its bioresources, Québec is banking on innovation and benefits from world-class industry-oriented research facilities with advanced technology infrastructure covering most biomass sustainable processing and viable bioproducts production. For logistics and economic reasons, a noticeable trend is emerging towards progressive implementation of regional industrial bioparks and local integrated biorefineries according to the concept of the circular economy. Many collaborative R&D projects involving industries, research institutes, and economic development actors can bear witness to the success of this formula in several Québec regions. Despite all this, the bioeconomy sector is still facing challenges such as transportation cost, feedstock supply cost, innovative process scale-up and new market development.

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## REFERENCES

- Canada, Government of Canada, Statistics. Gross domestic product, expenditure-based, provincial and territorial, annual. Available at: [www150.statcan.gc.ca](http://www150.statcan.gc.ca). (Last accessed November 2018).
- Gouvernement du Québec. Portrait économique des régions du Québec – Edition 2018, 2018, page 41.
- Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ). Politique Bioalimentaire 2018-2025: Alimenter notre monde. 108 pages. ISBN : 978-2-550-80803-9. Available at: [https://cdn-contenu.quebec.ca/cdn-contenu/adm/min/agriculture-pecheries-alimentation/publications-adm/dossier/politique-bioalimentaire/PO\\_politiquebioalimentaire\\_MAPAQ.pdf?1549643501](https://cdn-contenu.quebec.ca/cdn-contenu/adm/min/agriculture-pecheries-alimentation/publications-adm/dossier/politique-bioalimentaire/PO_politiquebioalimentaire_MAPAQ.pdf?1549643501) (Last accessed May 2019).
- Gouvernement du Québec. Les produits forestiers, une richesse à cultiver. Stratégie de développement de l'industrie québécoise des produits forestiers 2018-2023. 76 pages. ISBN: 978-2-550-814418. Available at : <https://mffp.gouv.qc.ca/wp-content/uploads/Strategie-industrie-foret-2018-2023.pdf> (Last accessed May 2019).
- Statistics Canada. Results from the 2015 bioproducts production and development survey, 2017 Edition. Catalogue no. 18-001-x. ISBN: 978-1-100-19260-4. 146 pages. Available at: <https://www150.statcan.gc.ca/n1/en/pub/18-001-x/18-001-x2017001-eng.pdf?st=iqBhYjNp> (Last accessed May 2019).
- CRIBIQ. Available at: [www.cribiq.qc.ca](http://www.cribiq.qc.ca) (Last accessed May 2019).
- PRIMA Québec. Available at: [www.prima.ca](http://www.prima.ca) (Last accessed May 2019).
- Génome Québec. Available at: [www.genomeQuebec.com](http://www.genomeQuebec.com) (Last accessed May 2019).
- Programme Innovation Bois. Available at: <https://mffp.gouv.qc.ca/les-forets/transformation-du-bois/programme-innovation-bois/> (Last accessed May 2019).
- Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ). Programme INNOV'ACTION Agroalimentaire 2018-2023. 23 pages. ISBN: 978-2-550-81726-0. Available at : <https://mapaq.gouv.qc.ca/SiteCollectionDocuments/Formulaires/ProgrammeInnov%27action2018-2023.pdf> (Last accessed May 2019).
- Maritime Strategy. Available at: <https://strategiemaritime.gouv.qc.ca/en/> (Last accessed May 2019).
- Available at: <http://frqnt.gouv.qc.ca> (Last accessed May 2019).
- Ministère de l'Économie et de l'innovation (MEI). Stratégie québécoise de la recherche et de l'innovation 2017-2022. 126 pages. ISBN: 978-2-550-78390-9. Available at: [https://economie.gouv.qc.ca/fileadmin/contenu/documents\\_soutien/strategies/recherche\\_innovation/SQRI/sqri\\_complet\\_fr.pdf](https://economie.gouv.qc.ca/fileadmin/contenu/documents_soutien/strategies/recherche_innovation/SQRI/sqri_complet_fr.pdf) (Last accessed May 2019).
- Gouvernement du Québec. Politique Québécoise de gestion de matières résiduelles. Plan d'action 2011-2015. 34 pages. ISBN: 978-2-550-61105-9. Available at: <http://environnement.gouv.qc.ca/matieres/pgmr/presentation.pdf> (Last accessed May 2019).
- Gouvernement du Québec. Politique énergétique 2030. L'énergie des Québécois, source de croissance. 66 pages. ISBN : 978-2-550-75053-6. Available at: <https://mern.gouv.qc.ca/wp-content/uploads/2016/04/Politique-energetique-2030.pdf> (Last accessed May 2019).
- Gouvernement du Québec. Stratégie maritime: Le Québec, un partenaire essentiel en Amérique du Nord. 8 pages. Available at: [https://mrif.gouv.qc.ca/content/documents/fr/Brochure\\_Strat\\_maritime\\_FR\\_LR.pdf](https://mrif.gouv.qc.ca/content/documents/fr/Brochure_Strat_maritime_FR_LR.pdf) (Last accessed May 2019).
- Gouvernement du Québec. Joining forces for a sustainable energy future. 2018-2023 energy transition, innovation and efficiency master plan: Objectives and roadmaps. 110 pages. ISBN : 978-2-550-81318-7. Available at: [http://transitionenergetique.gouv.qc.ca/fileadmin/medias/pdf/plan-directeur/PAP\\_TEQ\\_PlanDirecteur\\_Web\\_ANG.pdf](http://transitionenergetique.gouv.qc.ca/fileadmin/medias/pdf/plan-directeur/PAP_TEQ_PlanDirecteur_Web_ANG.pdf) (Last accessed May 2019).
- Ministère des Forêts, Faune et Parcs (MFFP). Sustainable forest management strategy. 54 pages. ISBN: 978-2-550-71493-4. Available at: <https://mffp.gouv.qc.ca/english/publications/forest/sustainable-forest-management-strategy.pdf> (Last accessed May 2019).
- Gouvernement du Québec. Québec in action: Greener by 2020. 2013-2020 Climate Change Action plan. 66 pages. ISBN: 978-2-550-65192-5. Available at: [http://environnement.gouv.qc.ca/changements/plan\\_action/pacc2020-en.pdf](http://environnement.gouv.qc.ca/changements/plan_action/pacc2020-en.pdf) (Last accessed May 2019).
- Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques. A source of wealth and pride for us all: Québec Water strategy 2018-2030. 80 pages. ISBN: 978-2-550-82346-9. Available at: <http://environnement.gouv.qc.ca/eau/strategie-Quebecoise/strategie2018-2030-en.pdf> (Last accessed May 2019).
- Plan d'action pour la croissance et les technologies propres: Vers une économie plus verte et prospère. 51 pages. ISBN: 978-2-550-82120-5. Available at: [https://economie.gouv.qc.ca/fileadmin/contenu/documents\\_soutien/secteur\\_activites/environnement/pactp\\_document\\_complet.pdf](https://economie.gouv.qc.ca/fileadmin/contenu/documents_soutien/secteur_activites/environnement/pactp_document_complet.pdf) (Last accessed May 2019).
- Statistics Canada, Table 27-10-0023-01, 2013.
- Statistics Canada, Tables 27-10-0273-01 and 36-10-0222-01, 2016 and Stat OCDE, Base des données PIST, 2016.
- Organisation de coopération et de développement économiques. Indicateur relatif à la générosité des mesures fiscales en faveur de la R&D, November 2018.
- Observatoire des sciences et des technologies (Clarivate Analytics - Web of Science).