How Industries and Cities Are Seizing the Opportunity of the Bioeconomy to Enable Prosperous and Sustainable Regions: Cases from Quebec

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Abstract

Quebec, a province in Canada, is well positioned in the global bioeconomy. Its regions are overflowing with forest, agricultural crops or other organic residues that can be recovered and converted into bioproducts and bioenergy. Quebec's strength has long been in the forest products industry and municipal solid waste recycling. Product diversification is now targeted by many companies and municipalities. Value chains for bioproducts and bioenergy are set in practically all of Quebec's regions. In fact, most of them have their own ''community-scale'' bioeconomy project, even if the province of Quebec itself does not have yet its own bioproducts or bioeconomy roadmap. In this paper, various community-scale bioeconomy projects are presented and discussed. The role of cities and other local stakeholders in the deployment of these projects and the focus on getting products or coproducts for local uses are also elaborated. A framework involving the positive involvement of national and regional institutions and the development of a network with local stakeholders is proposed to increase the chance of success of community-scale bioeconomy projects.

Introduction

Bioeconomy can be defined as all economic activities related to the development of bioresources production and processing. The current Canadian market for bioproducts is estimated at more than CAD 230 billion, and the industries that support it employ many Canadians. Quebec, a 1.5 million km^2 province of Canada, is an important player, with diversity and abundance of bioresources. For instance, Quebec's annual harvesting potential of forest residues is estimated at 4.9 million metric tons (MT) per year.[1]

Forest biomass is mostly government-owned, thus allowing strategic biomass allocation that ensures long-term supply security. In particular, the new Quebec forestry regime promotes investment, development, and integration of forest biomass valorization technologies to existing infrastructures. In addition, there are other bioresource supply sources such as agricultural crop residues, recycled wood-based products, urban organic waste, stranded seaweed, etc.

Today, a few major industrial players contribute to the Quebec bioeconomy. Enerkem (Montreal), with its worldwide reputation in waste gasification is one of the major players with and operates a demonstration plant in Windsor. Greenfield Global (Toronto) is also a notable actor in the space. It is the only major producer of first-generation ethanol in the province, with a plant at Varennes. Furthermore, the Quebec forest product industry has always been very active in diversifying its products portfolio. Up to 2017, the pulp and paper facility of Tembec in La Sarre used to be a biorefining model where ethanol and lignosulfonates were produced. Now, Domtar in Windsor is taking over the lead with the Celluforce pilot plant for nanocellulose production as they gradually position themselves in new markets, extending the reach and market share of innovative bioproducts.[2] The Fortress Global Enterprises mill in Thurso is producing specialty cellulose (or dissolving pulp) for the rayon/viscose industry and plans to produce food-grade xylitol shortly.

However, the bioeconomy in Quebec is not only driven by private companies, but also by regional and city authorities, local economic development organizations, and industrial park managers. The bioeconomy in most regions of Quebec involves many stakeholders, including the public, private and academic sectors. It is what we can call the ''community-scale bioeconomy.'' This paper reports case studies of community-scale bioeconomy in Quebec's administrative regions and discusses their tenets and outcomes. The conditions necessary to create successful community-scale bioeconomy projects are also discussed.

Community-Scale Bioeconomy Case Studies in Quebec

Community-scale bioeconomy refers to activities related to the development of bioresources production and processing supported actively by local private and public stakeholders in a

delimited geographic area or territory. In these projects, the community is involved for diverse reasons, including to redefine itself economically and mobilize around unifying projects sources of pride among the regional participants. Local concerns (e.g., plant closures or reduced activities, job losses, single-industry culture) and local assets (e.g., expertise in biomass harvest, preparation and supply; leading companies that could become potential users of bioproducts) must especially be considered in the implementation of bioeconomy activities. To exemplify this, the next sections report regional case studies in Quebec where the bioeconomy is growing and thriving.

CENTRE-DU-QUÉBEC

The Centre-du-Québec is a primarily agricultural region with the presence of other major industries in manufacturing, transportation, timber and wood products, and recycling. This region benefits from its central location. Being halfway between the two province metropolitan areas of Montreal and Quebec cities, the Parc industriel et portuaire de Bécancour (PIPB) is a provincial government-owned industrial park with a commercial deep-water port located on the shore of the St. Lawrence River in Bécancour. With nearly 7,000 hectares of flat land, this industrial park is one of the largest in Canada and can accommodate the needs of high-capacity industries (e.g., low-cost energy, maritime-inland, intermodal connection). The PIPB has chemical and electro-chemical industry facilities that can help the development of a local and circular bioeconomy. In fact, this park is similar in several ways to the City of Sarnia industrial park in the Canadian province of Ontario, which became some years ago a bio-industrial park with the arrival of a biobased succinic acid production facility supplied with cellulosic biomass by local farmers.[3,4]

Since 2015, there is an ongoing project to transition PIPB to a bio-industrial park, driven by local research institutions and local economic development organizations in partnership with Bioindustrial Innovation Canada, the Société du parc industriel et portuaire de Bécancour, farmer cooperatives and Greenfield Global.[5] The project is looking to implement a regional biomass processing depot that should reduce the supply cost of corn crop residues for further processing into cellulosic sugars and coproducts. Like the Sarnia industrial park, it could attract a new biorefinery in the PIPB and create new industrial synergies in the park and its surroundings. In addition to this new biorefinery project, there is a scenario where the depot will supply an existing biorefinery, the Greenfield Global plant in Varennes.

MONTÉRÉGIE

Greenfield Global is a major player in the Quebec bioeconomy with a biorefinery located in the Montérégie region. Greenfield Global is a privately held company specializing in the distillation of industrial alcohol and fuel ethanol in Canada.[6] This company operates four distilleries and four packaging plants in Canada and the United States. It is highly involved in the circular economy through the commercialization of biofuels and modern technologies to produce energy from renewable resources and residual materials such as urban organic waste. Greenfield Global's biorefinery in Varennes is the only fuel-grade ethanol plant in Quebec. It uses grain corn produced in Quebec as a raw material. The required supply represents a minor portion of Quebec's average annual grain corn production surplus. The plant produces about 175 million L/year of fuel ethanol used in the transport sector and coproducts that are used locally: (i) a food-grade CO_2 used in the production of dry ice and soft drinks by the Praxair plant in colocation; (ii) protein feed (spent grains) and grain corn oil for animal feed (dairy cattle, beef, sheep, pigs, and poultry) sent back to the farmers supplying the biorefinery. This way, it contributes significantly to the regional economy by emphasizing industrial symbiosis with local farmers and other facilities. Recently, the City of Varennes and neighboring cities installed a biogas plant co-located with Greenfield Global's biorefinery. The biodigester unit of the Société d'Économie Mixte de l'Est de la Couronne Sud (SEMECS) treats the organic waste generated by the 275,000 inhabitants of 27 cities and municipalities in area.[1] This initiative boosts the industrial symbiosis and the overall bioeconomy around Greenfield Global's biorefinery. With its strong leadership in biofuels and bioeconomy, the company has decided to expand its activities and contribute to the development of various renewable energy sources.

MAURICIE

Mauricie is one of the most productive forest region in Quebec with active sawmills and pulp and paper plants. In the northwest of this region, the City of La Tuque, with 15,000 inhabitants, is highly dependent on the forest products industry. Since 2012, La Tuque, along with many local and international collaborators, has been looking to build Canada's first forest residues biorefinery. The promotors started a non-profit organization called Bioénergie La Tuque (BELT) to lead the project.[8–10] Its objective is to convert forest logging residues into drop-in fuels for diesel users in Quebec, mainly in the freight transport and aviation sectors. About 600,000 dried metric tons/year will be available to produce around 200 million L of renewable fuels per year by using a mature thermal conversion technology. It is expected that the future biofuel plant can produce 4.3–7.0% of Quebec diesel consumption from the transportation sector. As the forest residues are spread over a territory of 10,000 km^2, a biomass densification approach is required to reduce cost of transportation.

There is also a modern wood charcoal factory that stimulates the bioeconomy in the industrial park of the City of St-Tite in Mauricie. Xylo-Carbone built the factory with minimal environmental footprint.[11] They are specialized in the transformation of wood into charcoal for the barbeque industry, char in agriculture, and activated carbon for water and air purification. The company also manages a log cutting and sorting operation on its production site that separates many wood parts into grades for wood veneer, furniture, pulp and paper applications and firewood prior to shipping to customers, some of which are local. The waste heat of the charcoal factory is now shared with newcomers in the industrial park that are also processing biomass to get valuable products. Their product diversification and waste-recovery strategy is creating significant synergies with local businesses.

OUTAOUAIS

The Outaouais region is located in the south of Quebec, bordering Ontario. The industrial structure of the Outaouais reflects the vocation of the region, focused on government services. The economy of the latter is therefore strongly oriented towards the service sector. However, this region retains several pulp and paper companies that have survived its economic transformation.

The City of Thurso in Outaouais owns a pulp and paper mill of Fortress Papers Ltd (a subsidiary of Fortress Global Enterprises), which is a major player in Quebec's bioeconomy.[12] The mill produces dissolving pulp (specialty cellulose) from wood as a substitute for cotton for the textile industry. This process separates cellulose from lignin and hemicelluloses, which are used to produce renewable electricity through biomass cogeneration. To maximize beneficial uses of wastes, Fortress Global Enterprises bought in 2018 S2G Biochemicals to produce xylitol from their hemicelluloses stream. Xylitol is extensively used in a variety of confectionary products such as gums and candies. In partnership with Mondelēz International—one of the world's largest snacking companies—a demonstration plant of food-grade xylitol production is being built at the Thurso mill. This investment will create more jobs in the region and further optimize use of wood fiber.

The BELT project, described previously, has inspired one bioeconomy initiative in Outaouais. At Pontiac, a pulp and paper mill closed in 2008 and left tons of unexploited forest biomass, principally yellow birch. Local stakeholders have taken charge of reviving the regional economy by creating a non-profit organization called Fibre Pontiac. Its mission is to conduct local biomass inventory and perform a technological review for production of cellulosic sugars and coproducts to prospect for investors or attract a foreign biorefining company in the Pontiac's area.[13]

CÔTE-NORD

The region of Côte-Nord is Quebec's most northeastern territory. Its population is essentially living on the St. Lawrence coast. The regional economy is based on natural resources, namely fishing, forestry and mining. Recently, a 10.5 million gallons/year biocrude production facility was built in this region at Port-Cartier. This project, called Bioénergie AE Côte-Nord, is being developed by Ensyn, Arbec Forest Products, and Groupe Rémabec. It is located adjacent to Arbec's sawmill on the north shore of the St. Lawrence River.[14] Ensyn has produced and commercialized biocrude for over 25 years. Arbec Forest Products Inc. and Groupe Rémabec are leading, privately-held forest products company operating in Eastern Canada. Together, they built a facility that can convert approximately 65,000 dry metric tons per year of woody biomass from local sources to biocrude used for heating, cooling and refinery applications. The facility uses the RTP™ technology of Honeywell UOP for the biomass conversion. It was planned first to sell the biocrude to customers in the U.S. Northeast and in Eastern Canada for heating purposes and as a renewable feedstock for petroleum refineries to produce low-carbon transportation fuels. But there has been a delay in the beginning of plant operations and the Bioénergie AE Côte-Nord. Nevertheless, this project has mobilized local expertise and many regional subcontractors, and Bioénergie AE Côte-Nord is now looking for local uses of the biocrude and the attainment of higher-value products from it. However, in this particular case, the city and other local stakeholders (others than Arbec) were not directly involved in helping to implement the project.

SAGUENAY-LAC-ST-JEAN

Saguenay-Lac-St-Jean is located in southeastern Quebec and north of the St. Lawrence River. The economy of this region is particularly dependent on the forest products industry. To ensure the sustainability of the forest products industry in Saguenay-Lac-St-Jean, several initiatives have recently been launched, particularly for the beneficial use of forest residues. For example, the St-Félicien Cogeneration Power Plant, located in St-Félicien, became a good place to centralize forest residues processing and generate a new bioeconomy around them.[15] Indeed, it is a cogeneration facility that uses an average of 250,000 dried metric tons per year of bark for electricity production. This facility generates 22 MW of electricity production. A potential of more than 57 MW of thermal energy from different sources in the facility can also be recovered. For this reason, an agro-thermal park has been set up by the City of St-Félicien to attract companies in the agri-food sector.[16] They successfully attracted Toundra Greenhouse in 2013, which is now the largest producer of cucumbers in Quebec. They are also looking to extract valuable molecules from barks before using them for electricity production. The forest extractables have a lot of applications and could attract other companies in the agro-thermal park looking for such biobased molecules.

ESTRIE

Estrie is located in the eastern part of the province along the border with the United States in southeastern of Quebec. The town of Windsor hosts two of the most important players in the Quebec bioeconomy—Enerkem and Domtar. Enerkem produces clean fuels and green chemicals from non-recyclable municipal solid waste, but they are targeting cellulosic wastes.[17] Domtar is a pulp and paper company that targets biorefining activities, especially in their facility in Windsor.[18] Valoris's eco-industrial park with the company Englobe, also in this region, operates a regional biomass processing center, and the company CRB Innovations is developing and marketing technologies in the field of residual biomass conversion.[19] Since 2010, the Ville de Sherbrooke and the MRC du Haut-Saint-François have pooled their resources to become co-owners of the site. In doing so, they created the Régie intermunicipale du centre de valorisation des matières résiduelles du Haut-Saint-François et de Sherbrooke, now known as Valoris, whose mission is to recover the region's waste materials. With Enerkem and Domtar, Valoris reunites many companies to transform a wide range of waste into high value-added compounds.

GASPÉSIE-ÎLE-DE-LA-MADELEINE

Gaspésie-Îles-de-la-Madeleine is an administrative region of Quebec that lies in the Gulf of Saint Lawrence at the eastern

extreme of southern Quebec. Its predominant economic activities are fishing, forestry and tourism, but the cement industry has gained ground since McInnis Cement built a cement plant in 2017 at Port-Daniel. This state-of-the-art cement plant consumes 33% less fuel and 40% less energy than other plants in North America. Nevertheless, the plant remains the largest industrial emitter of greenhouse gases (GHG) in Quebec, with 1.76 million tons per year, or about 2% of total emissions in Quebec. The Government of Quebec's energy policy has set very important GHG reduction targets in the province, and McInnis Cement must join the collective effort to try to achieve them. At the same time, the economic development actors in the region are working to multiply the business opportunities on its territory linked to the presence of the cement plant. This situation led to the idea of developing this ''deposit'' of carbon dioxide (CO_2) to attract companies specialized in CO_2 capture and recovery and renewable fuel to settle in the outskirts of McInnis Cement. To coordinate the deployment of this initiative, the Pôle des technologies propres de la Gaspésie (PTPG) was created with the help of local economic development organizations and McInnis Cement. The cluster aims to deploy an ecologically and financially efficient industrial network; develop a proactive approach and value chain management; stimulate industrial investment in the region; and optimize access to clean technology investment programs by local companies. With expertise from university and technical college institutions and collaboration with other local companies, it has been proposed to develop a plan for the implementation of a bio-industrial park involving CO_2 capture/recovery and biofuel production technologies, including the production of microalgae and algal biomass, in synergy with McInnis Cement, to reduce GHG emissions and maximize economic and social impacts on the region. The implementation of a CO_2 industrial park will significantly contribute to the reduction of GHG in Quebec and is expected to transpose the model in other regions.

The Particular Case of Microalgae Production

Most of regional bioeconomy case studies in Quebec involve forest and agricultural biomass. Another source of biomass is increasing for emerging bioeconomy projects: algae. In Quebec, seaweed of St-Lawrence River is already generating local economic benefit in some coastal regions. However, algae biomass can also be constituted of microalgae that are known to grow well in nutrient-rich wastewater. Indeed, microalgae can be used for the tertiary treatment of municipal or industrial wastewater, but culture conditions can be changed to increase biomass productivity and obtain valuable products. This approach is behind one particular case of a regional bioeconomy project in Quebec called the VERTECH I project. The project started in 2014 and consists of studying microalgae production using a mixture of wastewaters from the Victoriaville City industrial park, especially the wastewater from Parmalat Victoriaville, a dairy factory; Canlac Group-Abbott Laboratories, a lactulose production facility; and Sani-Marc,[20] a manufacturer of household and industrial cleaning products, to produce a lipid-rich algae biomass. The lipids were then extracted and converted into biosurfactants to replace petrochemical-based compounds in industrial cleaning product formulations of Sani-Marc. Post-extraction residues were in turn converted into biocrude using hydrothermal liquefaction for, once refined, local municipal use in heavy vehicles. This project showed that biomass integration in an industrial park can create unexpected synergies between companies from different sectors.

Discussion

This brief introduction to community-scale projects in the province of Quebec shows that significant effort has been made, but much work remains. The challenge of developing a thriving community-scale bioeconomy depends on the efficient use of biomass, long-term availability, profitability, and sustainability. Based on the case studies presented, the benefits of bringing together a set of conditions to ensure the success of the community-scale bioeconomy projects can be seen. Inspired by the models of Zhang et al.[21] and Walls and Paquin[22] on organizational perspectives in industrial ecology, we suggest some considerations as key success factors in the implementation of such projects.

First, the conditions for success concern the compatibility of physical flows, i.e., the capacity for the exchange of material resources between actors (complementarity, proximity, diversity, and synchronization). The availability, accessibility, characteristics and cost of the biomass resources, and the presence of a market for final products and coproducts are crucial considerations. For instance, a successful model of a community-scale biorefining project would involve a well-designed strategy where the companies and local stakeholders target high-value niche products and coproducts commodities for local markets that are anchored in the community. This two-fold strategy allows profitability with a well-established core business and a diversification strategy through the development of the coproducts for local use.

Second, it is essential that sustainable community-scale bioeconomy projects are based on robust market analysis, viable business models, and mature technological platforms. One way to make community-scale bioeconomy projects economically viable is through a mechanism of internalization of externalities that diversifies cash inflows and offsets environmental impacts. This allows the development of a lower-carbon economic growth and environmentally responsible as, for example, integrating carbon pricing into the company's business model, because biomass products are almost carbon-neutral and can substitute fossil fuels.

Third, a sustainable community-scale biorefining project must have a well-structured contract and governance where national and regional institutions are inclined toward such projects. Financial support to launch these projects is a concrete sign of commitment and present in each case. Also, all case studies presented in this paper have a stakeholder network with strong ties to the community. This willingness to cooperate among stakeholders provides many economic and sustainable benefits. But how does the common vision co-construct itself between the stakeholders? Relations between actors are based on mutual trust and alignment of values. These notions are very close to what some authors refer as the ''short mental distance.''[23] Social innovation could be a way of bringing stakeholders together to create a common shared vision based on how biomass should be used in an optimal and sustainable way.

Dialogue and mutual understanding among stakeholders are essential to building a shared vision and a common future toward the bioeconomy. By organizing dialogue and collaboration between stakeholders, the common vision can emerge and thus influence change by choosing innovations that are in line with the shared vision. As a result, the project to be implemented becomes more efficient, transparent and governable. This has already happened to a certain extent with the Pomacle-Bazancourt biorefinery in France.[24,25] Clearly, with its numerous community-scale bioeconomy cases, the province of Quebec is well-positioned to be an active and strong player in the global bioeconomy.

Conclusion

The Canadian province of Quebec is rich in diverse biomass that can contribute to the establishment of the bioeconomy in its regions. There are a few biomass processing factories strongly related to the bioeconomy itself (i.e., Greenfield Global, Domtar, Xylo-Carbone). Other projects are under development and provide a promising outlook to the Quebec bioeconomy. Local stakeholders help in the implantation of the bioeconomy, while industrial parks are good places to start. When thinking locally, local uses of coproducts can be identified that contribute to the establishment of a circular bioeconomy. These are major considerations that can provide success in the implementation of community-scale bioeconomy projects. Industrial ecology, combined with robust market analysis, viable business models, mature technological platforms, and the support of national and regional institutions, can increase the chance for successful stories.

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