IEA Bioenergy
Technology Collaboration Programme

BIOGAS PRODUCTION – AN INTEGRAL PART OF AN EVOLVING INTEGRATED BIOREFINERY COMPLEX IN QUÉBEC

Case Story

IEA Bioenergy: Task 37: 10 2024

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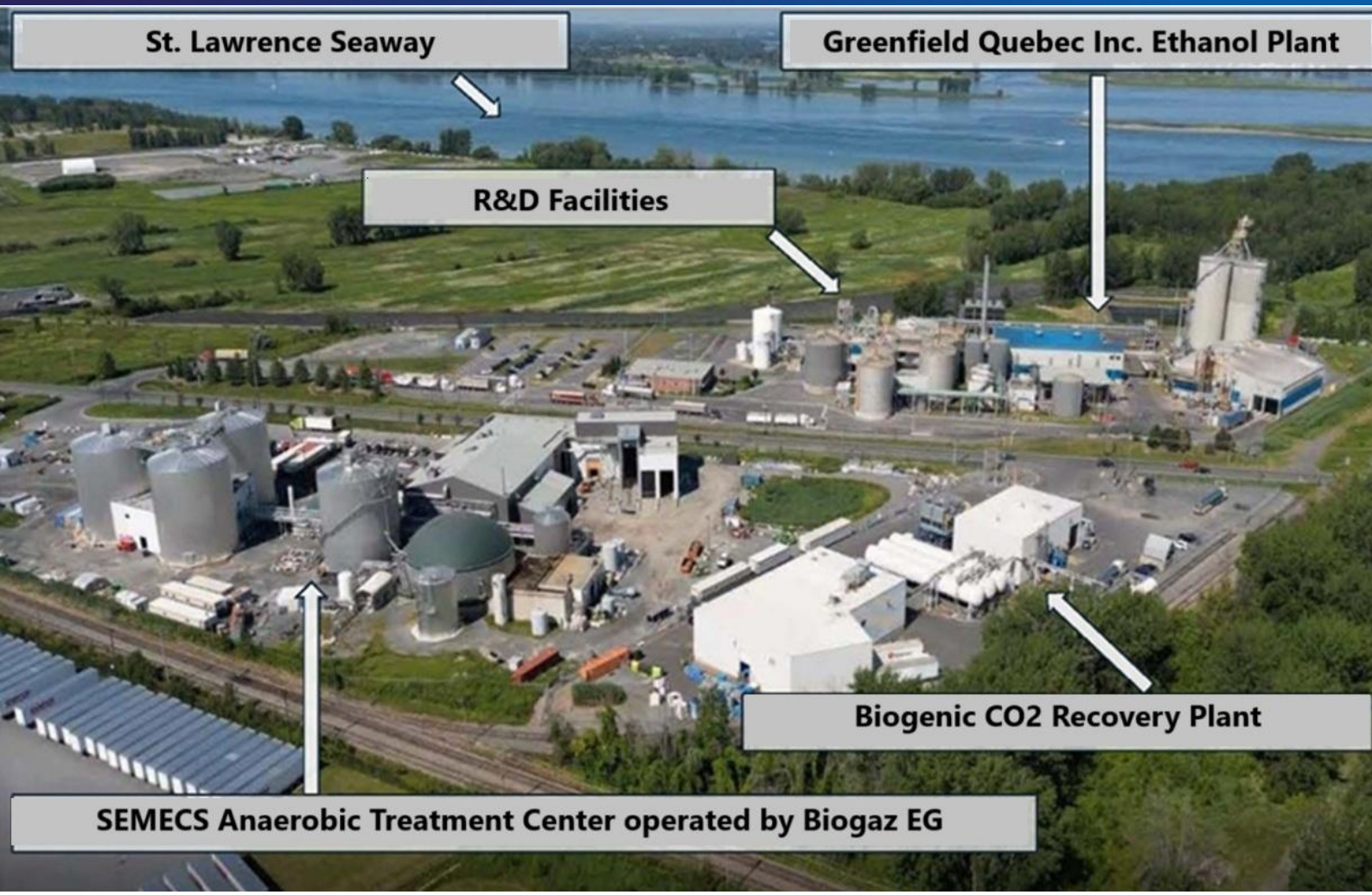

Greenfield Global Biorefinery Complex in Varennes, Québec (Canada)

BACKGROUND

The Province of Québec was the first Canadian province to adopt sustainable development legislation, thereby signaling its clear conviction to embody sustainable development in all government decisions. Since the Act came into force in 2006, numerous policies, strategies and programs have been put in place to guide future development accordingly. More recently, the 2030 Green Economy Plan and the 2030 Québec Green Hydrogen and Bioenergy Strategy included the following ambitious targets for 2030: 15% ethanol content in gasoline, 10% biodiesel in diesel fuel, 10% renewable natural gas in the gas network, 50% increase in bioenergy production, 80% energy supply of off-grid systems from renewable sources, 40% reduction in the consumption of oil products, and achieving carbon neutrality by 2050.

In 2007, Greenfield Québec Inc. (a circular economy company; see https://greenfield.com/about-us/) built the first plant to produce fuel grade ethanol from locally produced grain corn in Varennes, on the south shore of the St. Lawrence River. The facility produces 190,000,000 litres of ethanol, 400 tons biogenic CO_2 sold for liquefaction and the production of dry ice, 170 tons of dried distillers' grains sold as animal protein and 5,500 litres of corn oil from 440,000 tons of grain corn each year. All parts of the grain corn are valued and converted into marketable products, meaning there is no material waste. Hydro-generated electricity, natural gas and biogas are used to operate the facility today, and plans are in place to completely eliminate the use of fossil fuels by 2027.

In 2010, serious discussions began in Québec on progressive banning of the disposal of organic waste in landfills, and new solutions for waste management were required. Anaerobic digestion of the organic fraction of municipal solid waste was identified as a good alternative, and the siting of such a facility next to an industrial user of natural gas in order to replace this energy source with the generated biogas was proposed as an effective solution. Greenfield Global, through its company Biogaz EG, a company dedicated to biogas development, decided to invest in an organic matter treatment Center using anaerobic digestion adjacent to its fuel grade ethanol plant in Varennes and created, in partnership with local municipalities, Société d'économie mixte de l'est de la couronne sud (SÉMECS). The direct use of biogas produced at SÉMECS Center has made it possible to reduce the carbon intensity of the fuel-grade ethanol produced at the Varennes plant.

CENTER FOR ANAEROBIC DIGESTION OF ORGANIC WASTE (SÉMECS Center)

Construction of SÉMECS Center took place between 2016 and 2018 and the facility was commissioned in 2018. Two digesters, with a respective capacity of 5,300 m^3 and 3,500 m^3, were installed to treat 35,000 tons per annum (tpa) of a mixture of 60% source-separated organics, the organic fraction of municipal waste collected from three surrounding regions; 30% organic industrial and commercial waste; and 10% septic waste.

The pretreatment system for an anaerobic digestion facility treating source separated organic residues is critical to ensure successful operation. Care must be taken to prepare a digestible pulp for the digesters but, very importantly, physical contaminants present in the feedstock must be eliminated. Thus, plastics, metal, concrete, rocks, sand, branches, egg shells, crustacean shells, to name a few, are effectively removed prior to digestion.

The Continuous Stirred-Tank Reactor (CSTR) type digesters were operated in mesophilic mode (37^0C) with an average retention time between 18 and 23 days. A temperature maintenance system provided heat to the digesters in the winter.

The biogas production rate was 650 m^3/hour with a methane content of 65%. After removing moisture and hydrogen sulfide, a portion of the biogas was piped under the road to the ethanol plant (distillery). Here, it was used to replace natural gas used in the distillery's thermal oxidizer. The biogas energy replaced approximately 10% of the natural gas consumed in the distillery.

The digestate was dewatered using a Fournier press to a concentration of 30% solids, and the carbon- and nutrient-rich solids were supplied to farmers, located within a 30 km radius, for field application in accordance with the directives for the management of residual fertilizing materials in Québec. Thus, the digestate solids are stored at the farms in the region year-round, and farmers apply the digestate depending on crop production needs and the time of year.

SÉMECS CENTER EXPANSION ALIGNS WITH PROVINCIAL SUSTAINABLE DEVELOPMENT GOALS

The Province of Québec's ambitious sustainable development goals and subsequent climate change policies have encouraged greater diversion of organic waste and created a target for renewable natural gas production, among other actions. Consequently, in 2019, this created new opportunities for SÉMECS to expand its SÉMECS Center to treat more source-separated organics and to install a biogas upgrading plant to produce pipeline-quality methane, thereby contributing to the reduction of greenhouse gas emissions in Québec.

In December 2023, SÉMECS began the commissioning of the expanded facility to reach today's processing capacity of 120,000 tpa of source separated organic materials (50%), organic industrial and commercial waste (49%) and a small quantity of septic waste (1%). The construction work began at the start of 2020 and was completed in early 2024. The work, as for all construction projects during this period of time, was greatly affected by the COVID-19 pandemic disruptions, but the toughest challenge was to construct the expansion while continuing to operate the existing anaerobic digestion plant.

As shown in Figure 1, the expanded SÉMECS Center is divided into 5 major sections which serve as the vital organs of a facility of this scale. They include feedstock pretreatment, digestion, biogas treatment, digestate and water treatment, and treatment of air emissions.

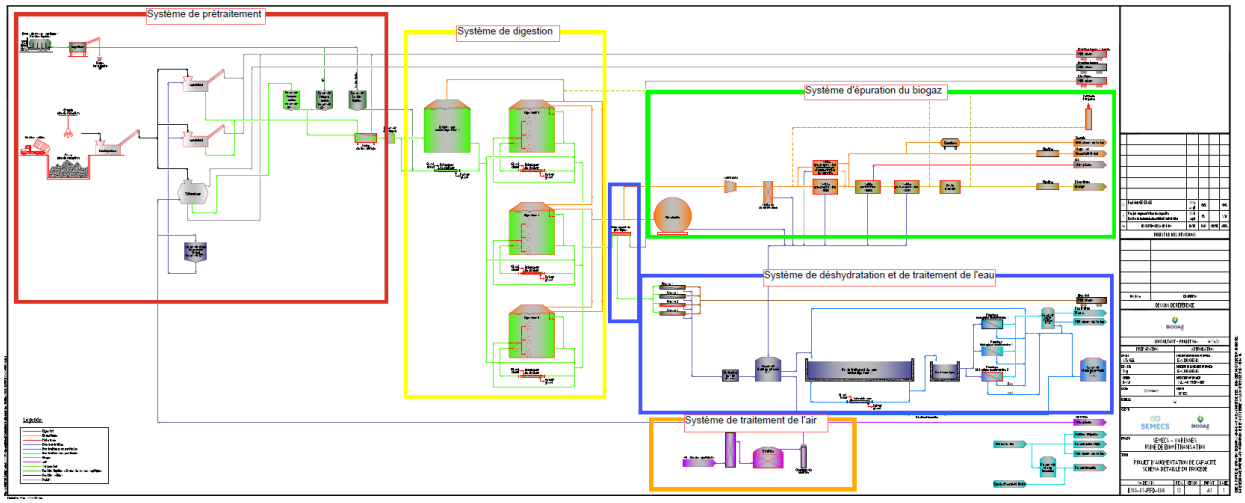

Figure 1. Expanded SÉMECS Center (2024)

Feedstock Pretreatment

The pretreatment system is essential to properly condition the organic matter so that it can be effectively degraded in the digesters. The equipment includes a crusher, depackaging equipment, pulper, screens and sand traps. Great care is taken to remove physical contaminants such as stone, sand, bones, plastics, metal, glass, etc., from the organic slurry that is conveyed to the digestion system.

Digestion

The digestion system consists of a 5,300 m^3 hydrolyzer that also provides some flow equalization, followed by 3 digesters, each 5,300 m^3 in volume, that operate in mesophilic mode (37^{0}C) with an average retention time between 18 and 23 days. A temperature maintenance system allows the contents of the digesters to be heated in winter and, especially, to be cooled in the summer when required.

Treatment and use of biogas

Although the biogas plant consumes approximately 7% of its biogas production to maintain the digesters' temperatures and 800 m^3/hour of biogas is piped to the ethanol plant, the rest of the biogas needs to be upgraded to meet pipeline quality standards and be suitable for injection into the natural gas distribution network. For this, a PSA (Pressure-Swing Adsorption) type gas purification system was selected to treat a volume of 2,060 m^3/hour. This system has a methane recovery rate of around 97.5% with a biomethane content over 98.5%.

The CO_2 separated in the upgrader is of biogenic origin and is not recovered at this time. Plans in preparation aim to capture this CO_2 and create value through biological methanation. That is, biogenic CO_2 combined with renewable hydrogen would make it possible to produce 3rd generation biomethane.

Treatment of digestate and water

Digestate treatment begins with the whole digestate passing through a screw press sieve which captures plastic fragments and other coarse particles, larger than 4 mm in size, that might have escaped the screens of the feedstock pretreatment system. The digestate is sent on to four Fournier rotary presses which dewater the slurry at a rate of 60 m^3/hour. Dewatering makes it possible to obtain a digestate with a solids content between 25% and 37% depending on the season and the types of inputs received. The digestate solids are distributed to local farmers who supply the corn grain for the ethanol plant to nourish their agricultural land with organic matter and soil nutrients.

As a final step, the liquid portion of the digestate is sent to a Membrane Bioreactor (MBR) treatment system which allows the most stringent water quality standards in Québec to be met, i.e. a daily discharge requirement for BOD_5 of 35 mg/L, TSS of 35 mg/L, total phosphorus of 1.3 mg/L and NH_4 of 25 mg/L. As such, close to 550,000 litres of treated water can be discharged into the St. Lawrence River every day.

Treatment of air emissions

Odour emission standards are very stringent, and SÉMECS is required not to exceed the threshold of 1 odour unit (o.u.) at the SÉMECS property boundaries. To do this, the buildings are operated under negative pressure at all times and, given that some areas require more than 6 air changes per hour, an air capture and treatment system was needed. A biofilter was installed that can treat an air volume of 48,000 m^3/hour. It is preceded by an acid wash tower to remove any ammonia in the air. After passing through the biofilter, the cleaned air exits through a 10-metre-long chimney to ensure good dispersion in the atmosphere.

FUTURE PLANS TO EXPAND THE INTEGRATED BIOREFINERY COMPLEX

Always looking for new sustainable development opportunities, Greenfield Québec Inc. plans to increase the ethanol plant's production capacity by 70 million litres per year by 2025, and to add a 60 MW electrolyzer to the site by 2028. The proton exchange membrane (PEM) electrolyzer will produce hydrogen for industrial use and heavy-duty transportation, and will also supply hydrogen as an input for a future methanol plant at the biorefinery complex. Methanol is considered to be an important renewable fuel for the maritime industry and is a key building block in the chemical industry. As shown in Figure 2, CO_2 from the ethanol plant's fermentation tanks and, eventually, from the SÉMECS Center will be combined with renewable hydrogen to produce e-methanol with a very low carbon intensity.

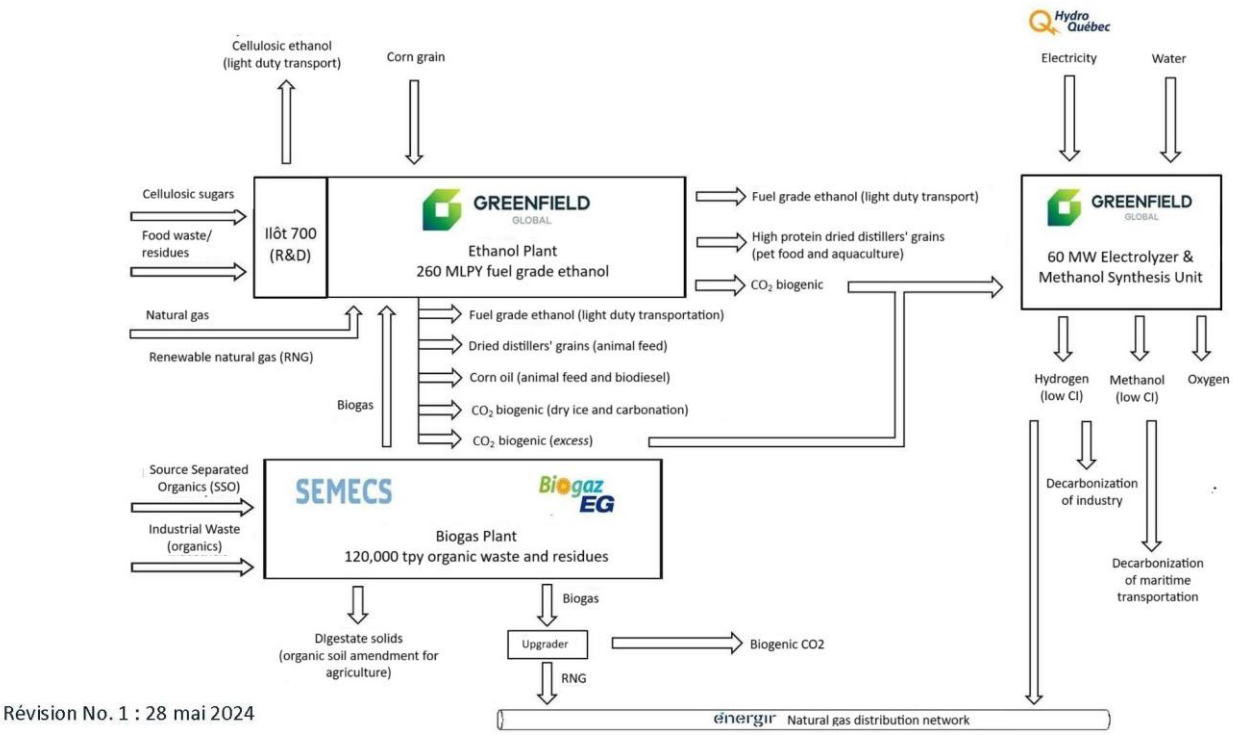

Figure 2. Vision for the Varennes Integrated Biorefinery Complex (May 2024)

As the integrated Varennes biorefinery complex continues to evolve, the co-location of anaerobic treatment of local municipal and industrial waste continues to play a key role. Initially, SÉMECS Center for the treatment of organic waste was a source of renewable energy and recovered valuable nutrients from solid waste, and next it will also supply biogenic CO_2 for methanol production. This biorefinery complex demonstrates how creative industrial design can generate income, create new permanent employment, produce renewable fuels, reduce greenhouse gases, extract value from waste and contribute to the circular economy; bringing Greenfield Global closer to achieving its “below 350 ppm” vision and contributing to Québec’s sustainable development goals.

IEA Bioenergy Task 37 "Energy from Biogas" https://task37.ieabioenergy.com

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