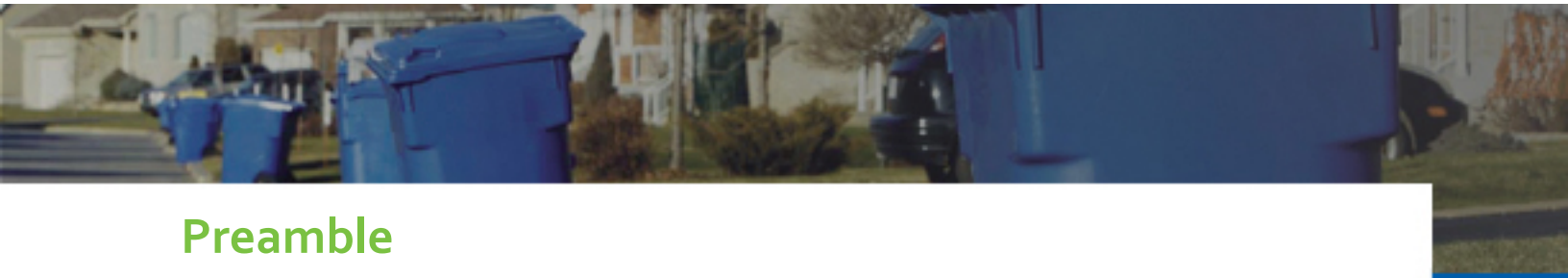
Éco Entreprises Québec

Recycling is our business

Report on the *Innovative Glass Works* Plan: The solution to recycling 100% of the glass collected via curbside recycling in Québec

February 2019



Preamble

In 2013, the closure of the main glass processing plant in Québec highlighted the necessity to develop and diversify recycling markets on the territory. Moreover, little investment in materials recovery facilities to process glass further mitigated the benefits of developing glass recycling. In the following years, legitimate concerns were voiced and a broad public debate started to determine the best ways to carry out the collection and recycling of glass. Launched in 2016, Éco Entreprises Québec's *Innovative Glass Works Plan* is first and foremost an initiative devised to modernize Québec materials recovery facilities and support growth of markets to give glass a new life, with the goal of recycling 100% of glass collected from curbside bins.

This document presents a detailed and technical report on all operations, as well as findings and recommendations regarding the recycling of glass collected via curbside recycling in Québec.

The document is organized as follows:

- Following the introduction, the first two sections present the state of things regarding collecting, sorting and recycling prior to the implementation of the *Innovative Glass Works* Plan
- The next two sections are dedicated to the carrying out of materials recovery facility projects, as well as findings and recommendations
- Two further sections deal in similar fashion with the development of recycling markets.
- The deployment strategy for glass sorting and recycling in Québec for the next few years is discussed in the seventh section, followed by the conclusion.

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Development of the *Innovative Glass Works* Plan

Éco Entreprises Québec (ÉEQ) is a private non-profit organization that represents companies who market containers, packaging and printed matter in Québec in their responsibility to finance the costs of effective and efficient municipal curbside recycling services. As an expert, ÉEQ optimizes the curbside recycling value chain and implements innovative approaches with a view to sustainable development and circular economy.

In its efforts to optimize curbside recycling, ÉEQ created a multidisciplinary team in 2015 pursuant to the Forum "Solution matters" with the mandate of identifying a solution to sort and recycle 100% of the glass collected from curbside recycling in Québec. And so, the *Innovative Glass Works* Plan (the "**Plan**") was developed and launched by ÉEQ in January, 2016. In this North American first, ÉEQ's role is that of catalyzer for an unprecedented mobilization of the recycling industry in order to give a second life to recovered glass and, ultimately, to renew its value.

During 2015, the ÉEQ team met with various players in the glass value chain, including materials recovery facilities or MRFs, processing plants and recyclers, as well as equipment suppliers. The contacts enabled us to better understand the needs of those players, to learn about the state of things regarding technologies available or being developed, and to identify the expectations of stakeholders. In addition to the meetings, ÉEQ's team directed several studies by independent experts in the field and conducted site visits outside Québec to identify and select innovative glass processing technologies in materials recovery facilities. Additionally, research was carried out to identify and quantify existing and emerging markets for recycled glass, particularly on the Eastern seaboard of Canada and the U.S.

The results of the research and analysis revealed the following findings on the glass situation in Québec:

1. The decision to invest in new equipment lays mainly on the ability to generate more revenue, not on increasing the rate of recycling.
2. Little has been invested in materials recovery facilities to improve the quality of glass and provide it with a resale value.
3. In 2013, the closure of the main glass processing plant in Québec, who processed almost all the glass from curbside recycling, highlighted the various issues due to poor quality glass in our materials recovery facilities and the importance of developing and diversifying glass markets.

These conclusions lead ÉEQ to develop the *Innovative Glass Works* Plan. The Plan's main objectives are the following:

- Test glass processing equipment in order to improve the quality of glass from curbside recycling and issue recommendations in order to provide Québec's materials recovery facilities with more adequate equipment.
- Modernize Québec's materials recovery facilities to sort and process glass.
- Develop and diversify curbside recycling glass markets in order to avoid all forms of landfilling glass, including daily cover, in the near future (3 to 5 years).
- Ultimately, to enable recycling of 100% of the glass from curbside recycling.

Announced in 2016, the Plan comprises two components, thanks to an investment of $12.2M: the modernization of Québec materials recovery facilities through pilot projects in order to enable them to produce better quality glass, as well as support measures for companies who wish to develop new eco-materials (and new opportunities) using glass from curbside recycling. These investments are outlined in the table below:

Table 1 ***Innovative Glass Works*** **Plan Investments**

Innovative Glass Works **Plan Components**	**Invested Sums**
Modernization of materials recovery facilities	
▪ Testing pilot projects: provided glass sorting and processing equipment in five Québec materials recovery facilities.	$8M
▪ Provided glass sorting and processing equipment for the future recyclable materials MRF in Montreal.	$2.5M
Support measures to develop markets	$1.7M
Total	**$12.2M**

Communications support

To support its team of experts and its partners in materials recovery facilities, ÉEQ's communications department worked to promote and raise awareness about the Plan through various initiatives that were deployed throughout the course of the project, including the following:

- Disclosure of the results of a survey conducted by Léger on the habits of Quebecers regarding glass recovery
- Press operations, including visits to materials recovery facilities, the launch of the Plan, the inauguration of pilot projects (with ministerial presence), the publication of numerous press releases and fact sheets, etc.
- Distribution of virtual communication tools (website, videos, social media, newsletters to contributing companies, etc.)
- Installation of a kiosk showcasing glass processing during conventions and conferences
- Team member conferences at various forums
- Distribution of treated glass samples to elected officials and partners during inaugurations

1. Management of recyclable materials recovery facilities in Québec

The Plan falls within the context of operating Québec's 22 curbside recycling materials recovery facilities. It is therefore important to understand their management methods, configuration and operational models.

1.1. Management methods in Québec's materials recovery facilities

Québec has three main materials recovery facility operator categories regarding curbside recycling materials. Sorting operations can be managed by a private, for-profit company, by an non-profit organization (NPO) or by an organization controlled by one or several municipalities. Each management model is defined by specific characteristics described in the table below.

Table 2: Definition of materials recovery facility management methods

Management models	Definition	Operators
Management by a private, for-profit company	▪ A privately-owned business with one or several owners ▪ There are 4 main types of private companies: proprietorships, partnerships, limited liability companies and joint-stock companies. Each has its own rules regarding shareholders, members and taxation.	Gaudreau Environnement Groupe Bouffard EBI Environnement Sani-Éco Tiru (Recyclage Papiers MD)
Management by a non-profit private organization	▪ Association or company whose members receive no financial benefit ▪ Profits used for non-profit purposes, very often reinvested in infrastructures and communities ▪ In several cases, integration of employees with functional limitations	Société V.I.A. Groupe RCM Récupération Frontenac Récupéraction Centre-du-Québec Ressource de Réinsertion Le Phare Récupération des Basques
Management by a municipal utility	▪ Public organization made up of several municipalities or MRCs who provide one common organization with their competencies regarding the management of residual materials ▪ Profits used for non-profit purposes, very often reinvested in infrastructures and communities	RMR Lac-Saint-Jean RITMRG (Gaspésie) Récup Estrie
Management by a non-profit organization made up of municipalities or municipal organizations	▪ Association or company made up of a group of municipalities, whose members receive no financial benefit ▪ Profits used for non-profit purposes, very often reinvested in infrastructures and communities ▪ Board of Directors made up of member municipalities	Tricentris

1.2. Configuration of Québec's materials recovery facilities

Figure 1: Reception of recyclable materials in materials recovery facilities

In Québec, the commingled collection method means that all recyclable materials from the general public are collected together, printed matter being mixed in with containers and packaging to be sorted later in materials recovery facilities. These are set up to receive and separate materials.

In materials recovery facilities, recyclables are unloaded on the ground and transferred to pre-sorting stations for removal of non-compliant materials. These are then conveyed to sorting tables and specialized equipment, were materials are separated, as explained in the figure below.

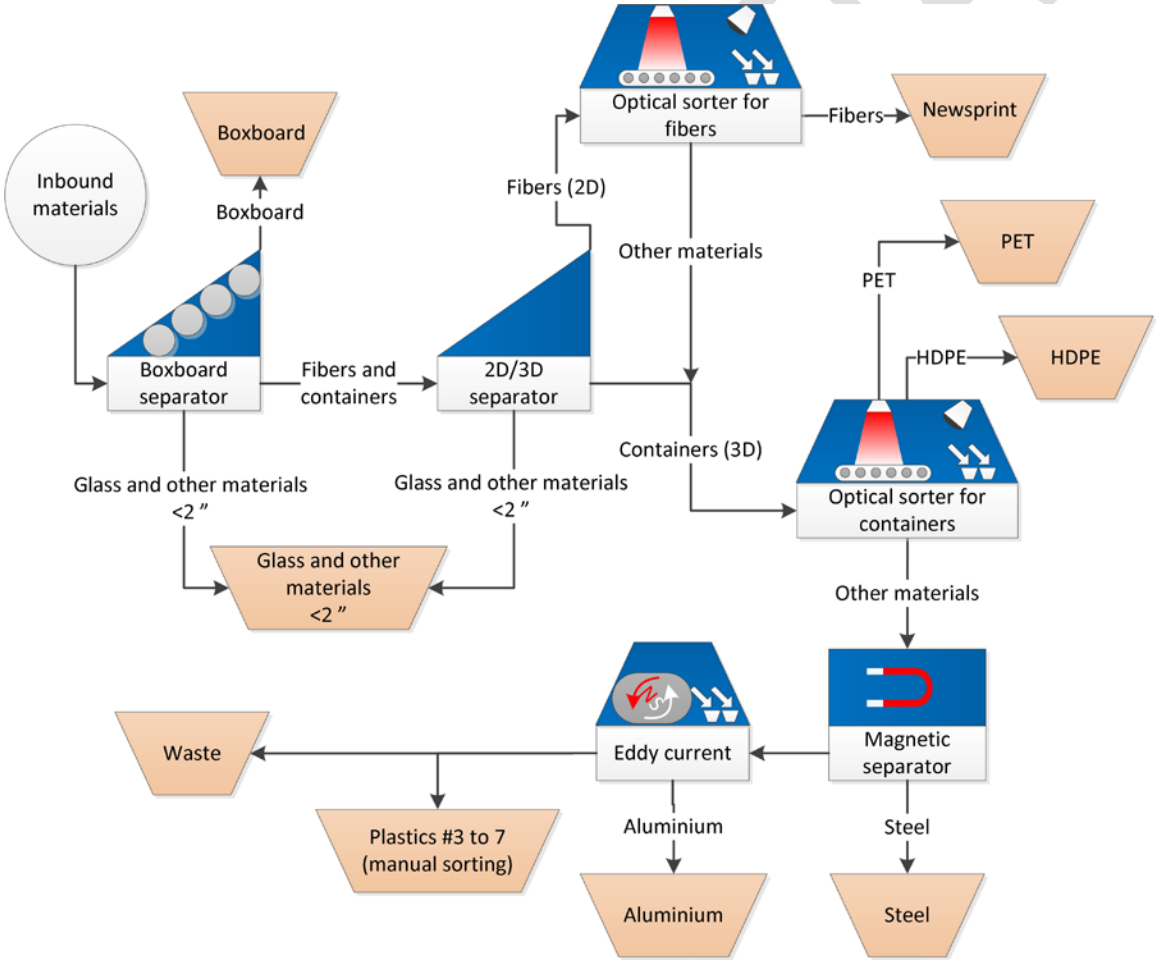


Figure 2: Schematic representation of a general materials recovery facility configuration

Some materials recovery facilities with small capacities and in remote locations do manual or semi-mechanized sorting. In the first case, only sorters separate materials that pass on conveyors, whereas in semi-mechanized materials recovery facilities, the sorting process can be partially completed by some equipment (cardboard separator, magnetic separator, etc.).

Mechanized materials recovery facilities are equipped with separators to sort cardboard, separate containers (3D) from fibers (2D) and sort recyclable materials with equipment that is adapted to the materials' properties (optical sorting, magnetic separator, eddy current).

Most materials recovery facilities have fine materials separation equipment (fine material separator, glass breaker, ballistic separator, rotary sieve, etc.), where glass ends up. These allow the glass to be removed the glass during the sorting process. Some small-capacity materials recovery facilities manually separate glass containers. Glass is also collected towards the end of the process, i.e. on the last conveyor unit, mixed with all the other unsorted materials.

The mechanical separation of containers and fibers is done using disc screen separators or ballistic separators. Disk screen separators are equipped with high throughput rubber discs whose angle and openings determine the direction of separated materials. As for ballistic separators, they are equipped with parallel tracks with elliptical movement that agitate materials to segregate them in two or three fractions. In ballistic separators, glass breaks more easily. The materials then converge towards sorting tables or towards optical or mechanical sorting equipment.

Figure 3 Ballistic Separator

Figure 4 Disk Screen Separator
(Source: CP group)

Quality control staff are posted at the output end of the equipment in order to ensure purity of materials or to perform more detailed sorting. The sorted materials are then stored in stockpiles before being conveyed into containers or to a press to be compressed into bundles.

1.3. Operational management of materials recovery facilities

1.3.1. Operating models

In Québec, materials recovery facilities are generally managed according to two main types of operating models. Either production based on the maximum tonnage processing or on end-product quality-oriented sorting.

The first model consists in sorting a maximum volume of recyclable materials. Due to a lack of capacity or for purely economic reasons, sorting is organized in such a way to process a maximum volume of material in a given period. This method can lead to lower sort quality.

Conversely, operations that are geared towards better quality sorting of recyclable materials mean higher operating costs (preventive maintenance and servicing, training, quality control, performance monitoring, etc.) and require significant investment in the acquisition of high-performance technologies. The choice of operating models can also be influenced by a materials recovery facility's desire to create suitable jobs, develop local industries, etc.

The closure of Asian markets in 2017 highlights the benefits of quality-oriented sorting. Materials recovery facilities that implemented this operational philosophy before the recycling crisis were able to cope and find buyers for sorted materials more easily.

1.3.2. Equipment Maintenance

Regarding equipment maintenance, two strategies prevail. In the first, materials recovery facilities choose to minimize maintenance and equipment improvement. In their view, it is preferable and more cost-efficient to simply replace equipment or important parts that reach the end of their service life. One of the consequences of this approach is the progressive degradation of performance or quality and increased wear of equipment.

Other materials recovery facilities prioritize ongoing improvement and preventive maintenance of equipment. Preventive maintenance programs are set up, in collaboration with equipment manufacturers. Routine equipment inspection and maintenance periods are scheduled in the materials recovery facilities' production calendar, and standstill periods are reserved so the maintenance can be carried out. One of the benefits of this strategy is prolonged life of the equipment, steady performance of sorting activity as well as reduced and/or anticipated major breakages that could cause extended periods of standstill.

In this respect, too, the closure of Asian markets shows us that it is preferable to favour the method of preventive and ongoing equipment maintenance to promote the best possible sorting quality.

1.3.3. Labour and Working Conditions

Some materials recovery facilities deploy efforts to improve the work environment for sorters: temperate workspaces or heated sorting booths, independent ventilation, personal protective equipment, training, ergonomic assessment of workstations, appropriate lighting, etc. Other materials recovery facilities emphasize the specialization of the position, giving sorters greater responsibilities. This way, sorters are responsible for procurement, quality monitoring, etc.

The task of quality control by sorters highlights the quantity of not-accepted or even dangerous materials found in curbside bins: syringes, lightbulbs, organic materials, electronic devices, ammunition, etc. However, handling of such materials carries risks that must be eliminated directly in the materials recovery facilities thanks to adequate training, monitoring compliance with safety procedures and providing appropriate protective equipment.

It is possible to draw a link between workforce performance and the applied resource allocation method. Sorting quality and equipment performance are improved when sorters are permanently assigned to a sorting station with specific responsibilities. In the case of materials recovery facilities that rotate staff or have a high turnover rate, the learning curve is longer, and sorting is often not done according to the established protocols.

2. Recycling of glass recovered via curbside recycling

In Quebec, glass containers are collected all together, or commingled, in curbside recycling bins. The materials go through a materials recovery facility in order to be sorted and shipped to a processing plant/recycler or a waste management centre.

2.1. Glass recovered via curbside recycling in Québec

For several years, contradictory data have been circulating concerning glass tonnage from waste collection. RECYC-QUÉBEC and ÉEQ have undertaken to clarify the situation so that all stakeholders can work on common ground.

In Québec, the glass deposit in curbside recycling amounts to approximately 120,000 t/year, based on residual characterization data for 2012-2013 in the residential sector as published by RECYC-QUÉBEC and ÉEQ in 2015. That figure represents the quantity of containers and glass bottles placed in recycling bins, whether they are refundable or not. Two-thirds (62%) of the clear glass found in recycling bins comes from food containers and not wine or spirit bottles.

2.2. Glass market situation before the *Innovative Glass Works* Plan

Until 2013, almost all of Québec's waste collected glass ended up at Klareco, a glass processor. Klareco's main market was mineral wool, whose plants were located mainly in the United States.

In 2012, the economic recession in the United States strongly affected the construction market, bringing down the demand for mineral wool. As Klareco lost its main market, the plant had to close in 2013, leaving the glass without a buyer.

For its part, Groupe Bellemare took a portion of the glass to meet the demand for the manufacturing of abrasives and filtration media for swimming pools. In 2013, these markets represented approximately 10,000 tonnes per year. In addition, Tricentris recycled part of its glass for the production of Verrox glass powder. Lastly, 2M Ressources received a small quantity of glass from certain materials recovery facilities.

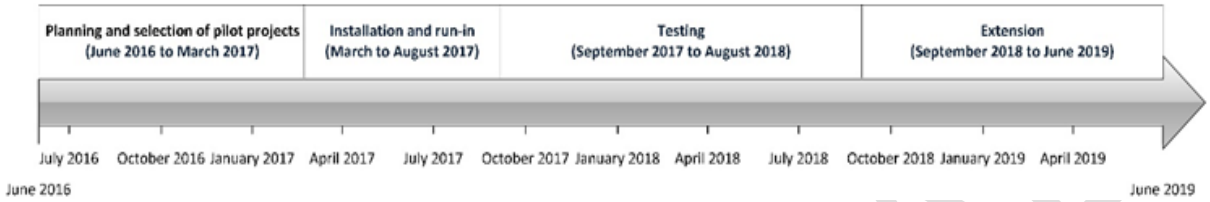
After the closure of Klareco, in the absence of local markets, the majority of glass collected from curbside bins ended up in engineered landfills to be used as access road construction material or as alternative daily cover, in accordance with the *Regulation respecting the landfilling and incineration of residual materials* of the EQA.

It is important to remember that, given the exceptional nature of this situation, the Union des municipalités du Québec (UMQ) had asked the Ministry of Municipal Affairs and Land Occupancy (MAMOT) to allow municipalities to reopen contracts with materials recovery facilities that traded on the mixed glass market. The order issued by the MAMOT granted general permission to all municipalities and intermunicipal management boards of Québec to modify certain contracts with MRF administrators, adding an additional amount to the price paid for the glass in order to compensate for the increase in landfill entry fees. This fee increase has been considered eligible for the compensation plan financed by ÉEQ.

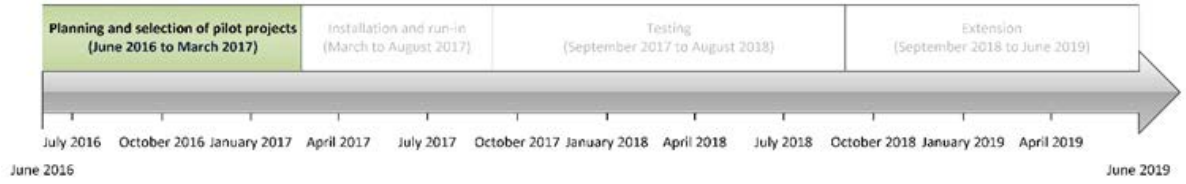
Note that the exemption was effective only for the period of July 9 to December 31, 2014. Contract amendments made during this period could, however, apply for the remainder of a contract.

3. Testing Pilot Projects in Materials recovery facilities

Including the planning period, the Plan's timeline runs from June 2016 to June 2019. This third section further details the Plan's execution stages, from its initial planning to the extension of the testing period.



3.1. Planning and Selecting Pilot Projects



Planning testing pilot projects

The Plan began to take shape after an overall diagnosis was made regarding the curbside recycling glass value chain. Prior to this, not much equipment was installed in materials recovery facilities. The most common pieces were blowers, glass breakers or rotary drum screens, but their performance remained unsatisfactory. With the exception of a few materials recovery facilities, output glass was, in many cases, mixed with MRF waste, such as organic matter, fine particles and shredded paper. The Plan was developed in order to meet the specific needs of materials recovery facilities and the growth of recycled glass markets. Defined as technical and financial support effort, it enables us to test existing technologies identified by ÉEQ in materials recovery facilities via testing pilot projects.

External expertise

Along each step of the Plan's development, ÉEQ worked closely with external experts and benefited from the technical support of ten specialized organizations.

Organizations	Origin	Types of expertise provided
Gestion Valoris		Supporting ÉEQ in developing the terms of the Plan
NovAxia		Supporting ÉEQ, materials recovery facilities and equipment manufacturers in the execution of testing pilot projects
Miller Thomson, Daigneault Avocats		Validating legal issues
SECOR-KPMG		Analysis of the Plan's terms and parameters

For Sustainability Too		Analysis of North American MRF glass sorting equipment
Naturallis		Analysis of sorting equipment in materials recovery facilities with commingled curbside recycling and of North American markets.
Product Stewardship Institute		Situation of glass recovery and glass consignment systems in North America
Farel		Calculation of transportation costs
NI Environnement, Chamard Stratégies environnementales		Characterization of glass from materials recovery facilities
Groupe Agéco		GHG balance of the Innovative Glass Works Plan

Consultations and visits

In addition to visiting factories in Europe equipped with glass sorting and processing machinery and where curbside recycling is commingled, ÉEQ contacted more than 20 equipment manufacturers to better understand the specificities of technologies developed by each for separating and cleaning glass. After these meetings, ÉEQ selected technologies from the United Kingdom, Germany and Australia. They were selected as promising to improve the quality of curbside recycling glass being processed at materials recovery facilities. In addition, ÉEQ commissioned Machinex, a Québec company, to integrate all the equipment into a materials recovery facility.
Thus, equipment selected by ÉEQ can perform fragmentation by implosion and cleaning. This machinery includes metal separation, fiber and light materials vacuuming or blowing, implosion and sizing equipment.

The testing pilot projects included multiple goals:

- Learning about the proper functioning and operation of the equipment
- Optimal equipment performance according to seasonal variations
- Producing qualitative glass as uniformly as possible
- Validating glass quality with various processors and recyclers
- Knowledge acquisition and dissemination of best practices

In this context, ÉEQ aimed to implement specific equipment pieces in small, medium and large capacity materials recovery facilities across the Québec territory.

Call for applications

The call for applications launched in January, 2016, included a description of the technical and financial conditions applicable to the implementation of the pilot projects for the materials recovery facilities that would be selected. In addition, this call described the expected conditions of participation from the materials recovery facilities in order to ensure the viability of all elements of the value chain during testing pilot projects. The pilot project had an initial term of fifteen (15) months as of start of operations of the equipment.

To be eligible, materials recovery facilities were required to submit technical data that would allow the ÉEQ team to better take into account the realities of the field and adequately assess the feasibility of the pilot projects.

A precise portrait of the conditions of the glass routing in materials recovery facilities was required before proceeding to the final selection of candidates. For this purpose, materials recovery facilities were asked to provide the diagram of the glass routing, indicating:

- The various points where glass was separated from other materials
- The approximate quantities of glass from these different points
- Whether the glass had been processed (sifted, crushed, etc.)
- The way in which the materials recovery facility intended to bring the entire glass to the desired location for a possible processing system while describing the equipment that would be needed to achieve it.

In addition, materials recovery facilities were required to:

- Provide and submit glass samples at the end of the process according to the sampling protocol proposed by ÉEQ
- Submit samples to the characterization firm designated by ÉEQ
- Disclose their glass tonnage for the last year of operation
- Disclose due dates and duration of the sorting contracts with their municipalities
- Indicate the destination(s) of the glass during the last year.

In April and May, 2016, a team made up of equipment manufacturer and ÉEQ representatives visited the 18 materials recovery facilities that had applied. By the end of these visits, files were submitted to ÉEQ, outlining the strengths of each application and confirming the technical feasibility of the projects.

Selecting testing pilot projects

The selection of pilot projects by an internal committee comprising members of the ÉEQ Board of Directors and ÉEQ employees in June 2016 was based on the analysis of application documents. It should be noted that one of the application file elements, i.e. the results of sample characterization leaving the materials recovery facility, was not considered to be a selection criterion. This element was used to adapt the equipment arrangement to the quality of the glass to be processed.

ÉEQ wanted to implement testing pilot projects in three categories of materials recovery facilities:

- Small-capacity materials recovery facilities (<10 kt of recyclable materials/yr.) .
- Medium-capacity materials recovery facilities (10-35 kt of recyclable materials/yr.)
- Large-capacity materials recovery facilities (>35 kt of recyclable materials/yr.)

In order to better represent the particularities of selective collection, attention has been paid to the regional presence. Thus, materials recovery facilities located both in remote areas and in densely populated urban areas were selected. Consideration has also been given to the representation of different management modes. For this purpose, the selected materials recovery facilities are operated by an intermunicipal board, a non-profit sheltered work organization, a municipal non-profit organization or a private company. These materials recovery facilities are presented in the following table:

Table 3: Materials recovery facilities selected for the *Innovative Glass Works* Plan pilot projects

Small capacity	Medium capacity	Large capacity
Régie intermunicipale de traitement des matières résiduelles de la Gaspésie (Grande-Rivière)	EBI Environnement Inc. (St-Paul) Récupération Frontenac (Thetford Mines)	Tricentris (Terrebonne) Centre de tri de Québec (Québec)

Figure 5: Materials recovery facilities selected for the *Innovative Glass Works* Plan pilot projects

Contractual agreement with selected materials recovery facilities

Materials recovery facilities selected for the testing pilot projects were contractually bound to work in partnership with the ÉEQ team to ensure the successful implementation of the Plan. The commitment of materials recovery facilities and the collaborative mode of operation with ÉEQ were formalized through a contractual agreement between the two parties in August 2016. A project management plan was also defined with each participating materials recovery facility following the final selection.

Management Plan

As part of the contractual agreement with materials recovery facilities taking part in the pilot projects, ÉEQ has developed a management plan intended to define business processes for the testing pilot projects. The plan is specific to each materials recovery facility and includes all elements listed below:

1) Pre-installation phase

- Identify and train the testing pilot project team
- Describe the work required before the installation of glass sorting and processing equipment and executing parties (building, electricity, civil engineering, logistics, etc.)
- Develop a schedule of work required before the installation of equipment
- Execute the work required before the installation of equipment
- Prepare an area to install and operate characterization equipment

2) Equipment installation and staff training phase
- Health and safety measures during equipment installation
  - Cleanliness of premises before and during the installation
  - Worksite supervision
  - Protective equipment
- Training on the sampling and characterization program
- Training for the proper functioning of equipment

3) Demonstration phase - 15 months
- Visits from the ÉEQ project leader
- Visits from media and various other stakeholders
- Media communications and public relations
- Cleanliness of premises
- Table of communication processes between materials recovery facilities, ÉEQ and equipment manufacturers (by situation type)
- Targeted materials
- Operation of equipment in compliance with manufacturer standards and regulations
- Roles and responsibilities of the sorter – quality controller
- Health and safety measures during equipment operation
- Maintenance and servicing program
- Management of contaminants
- Storage and handling of glass
- Execution of the sampling and characterization program
- Destination (purpose) of glass and development of market opportunities
- Glass recycling goals
- Payment terms regarding support provided for participation and other administrative processes

4) Post-demonstration phase
- Management at the end of the demonstration project
- Meetings and follow-up

Technical and financial support

In addition to receiving glass processing equipment, the selected materials recovery facilities also received technical assistance from ÉEQ in several forms, including:
- Engineering and equipment installation costs
- Development of a spare parts flowchart and a list of emergency parts for effective inventory management
- Providing sampling and characterization equipment
- Staff training on equipment operation and maintenance, glass sampling and characterization campaigns during the testing period and the use of computerized management tools.
- Technical monitoring for equipment performance measurement during the testing period.

These testing pilot projects required considerable commitment on the part of materials recovery facilities. As compensation for taking part in the pilot projects, ÉEQ provided support, in the form of a contribution of $28 per tonne sorted and sold to a processing plant or recycler, on presentation of valid weight tickets and supporting documents over the entire testing period. It should be noted that

no compensation was given for glass sent to landfills to be used as daily cover or road foundation material.

Development of a glass characterization protocol

The Plan was the ideal vehicle for initiating the implementation of a glass characterization process in order to objectively assess the performance of the installed systems. Consultations carried out at materials recovery facilities showed that most facilities do not include such performance measures as part of their processes.

The large-scale characterization protocol dedicated to materials recovery facility glass as developed by ÉEQ was a first in Québec. To ensure a successful implementation, ÉEQ made full use of the experience it acquired during the call for applications in January 2016, when more than 90 glass samples were characterized. For this purpose, ÉEQ also called on external statistics and methodology experts.

The program's aim was to measure performance of the testing pilot projects and, more specifically, to:

- Measure the quantity and composition of inbound and outbound glass flows to and from testing systems in order to calculate glass purity rates
- Monitor the performance of testing systems over 12 months and measure seasonal variations
- Enable the application of guarantees by monitoring parameters indicated in the contract between ÉEQ and Industries Machinex, as well as in the contracts between ÉEQ and materials recovery facilities
- Compare performances of testing pilot projects, in particular by comparing small-, medium- and large-capacity systems
- Optimize the operation of testing systems in materials recovery facilities
- Measure performance for each individual piece of equipment in order to maximize machine settings
- Prevent premature wear of equipment and ducts (e.g. characterization of materials collected under the cyclone)
- Assess the quality of outbound glass from testing pilot projects with regard to requirements defined by processing plants (opportunities).

This program enabled ÉEQ to:

- Gather information on curbside recycling to update the allocation study by activity.
- Develop important technical knowledge regarding glass sampling and characterization.
- Develop glass sampling and characterization protocols that can be replicated in subsequent studies (e.g. for the on-site characterization study).

Under the supervision of the ÉEQ team, materials recovery facilities carried out sampling and characterization activities on inbound materials entering the systems and on the outbound glass. These activities were designed to measure the following parameters: moisture, composition and density of glass. In total, more than 300 samples were analyzed, allowing for a correlative analysis of results with observations made in the field.

3.2. Equipment Installed at Materials recovery facilities

Equipment installed at materials recovery facilities was selected according to each centre's specific configuration and the contamination rate of the glass.

Glass purity and the role of the materials recovery facility

Characterizations of glass from the 18 materials recovery facilities that submitted their application for the Plan have shown that glass can contain up to 30% of other materials, mainly paper, plastic and organic materials.

Therefore, 30% of the quantities of glass declared by materials recovery facilities and transported are in fact materials other than glass and should not be recorded in this manner.

Characterization data as carried out by ÉEQ, based on the results from more than 100 samples of inbound glass in the pilot projects as part of the Plan, support these observations and are presented in the table below.

Table 4 – Average composition of inbound glass in the pilot projects

Material	%
1. Any colour glass from containers	70.6%
2. Paper and paperboard	7.2%
3. Plastic containers and packaging	1.5%
4. Ferrous and non-ferrous metal containers and packaging	0.8%
5. Ceramic / stone / brick / porcelain	1.5%
6. Organic materials	1.0%
7. Non-recyclable containers and packaging	0.2%
8. All other waste	3.5%
9. Fine particles	13.7%

The goal of combining equipment and systems is to produce glass with a purity rate higher than 95% using glass that is initially up to 30% contaminated. Although achieving this purity rate enables us to greatly reduce transporting contaminants to processing plants, it should be noted that the role of the materials recovery facility is not to be a substitute for processing plants. Processors must meet the quality criteria required by markets, such as colour separation or removal of infusibles. Figure 6 presents the potential markets for glass and the types of processing plants required, indicating the role of materials recovery facilities in the recycling chain.

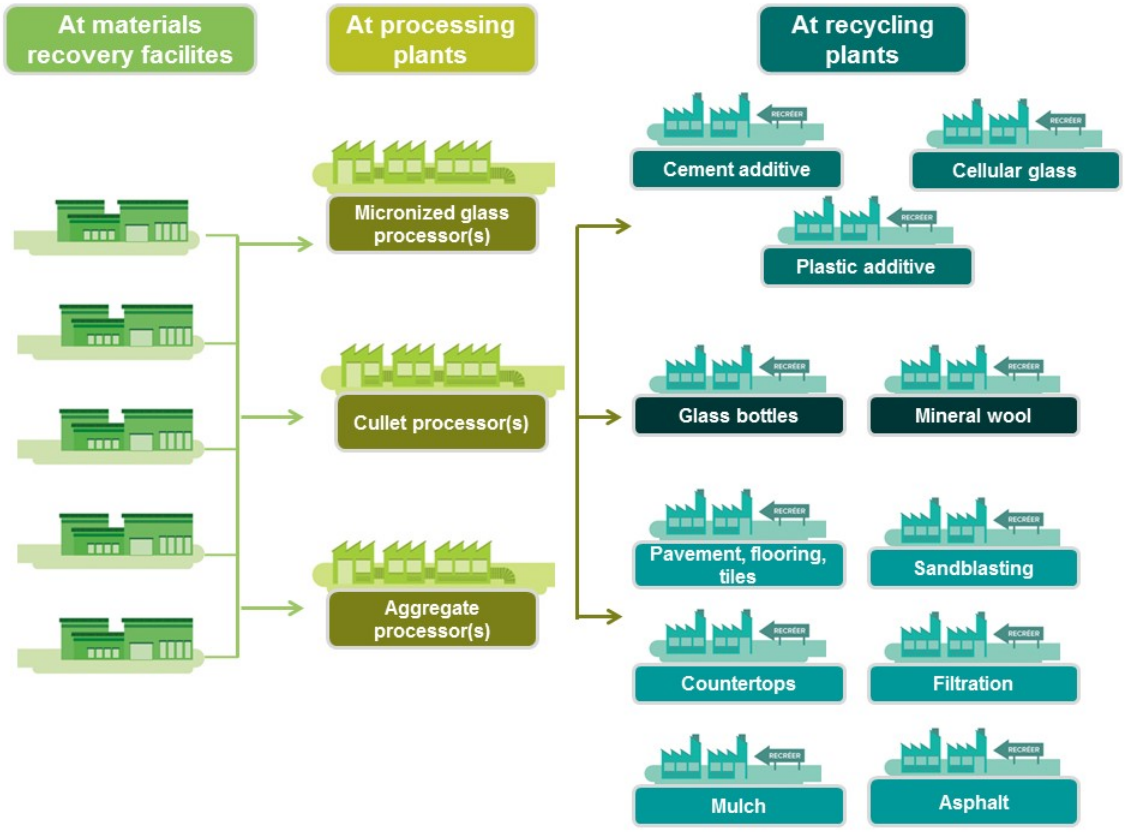


Figure 6: Schematic representation of materials recovery facilities, processing plants and recyclers

Design efforts were concentrated on the key equipment presented in the table below, as it was anticipated that combining them would enable the achievement of the desired purity level.

Table 5: Key equipment installed as part of the pilot projects

Equipment	Description	Origin
Flip-Flow type screen	Particle size separation	Australia
Imploder	Breaks glass into smaller pieces	United Kingdom
Zig Zag	Removal of lightweight materials	Germany
Air Lift Channel Feeder (ALCF)	Removal of lightweight materials	United Kingdom

Contract with equipment manufacturer Machinex

A 9-month design and engineering process was devised by ÉEQ in collaboration with Machinex and its partner, Krysteline, supplier of the four key equipment pieces presented in Table 5. As a result of this process, a contract for the purchase, installation and commissioning of the Plan's equipment was signed in September 2016 with Machinex. The latter was responsible for the integration and installation of all equipment. This type of contract was a first in North America, as it laid the foundations for a tripartite collaboration involving materials recovery facilities, ÉEQ and Machinex.

The contract included warranty commitments covering the entire testing period, inspection visits, terms for technical support, training and the list of spare parts. Detailed engineering and equipment manufacturing took place from September 2016 to January 2017.

The diagrams below show the glass sorting and processing process for each of the five pilot projects.

3.2.1. Small-capacity pilot project: Materials recovery facility of the Régie intermunicipale de traitement des matières résiduelles de la Gaspésie, Grande-Rivière

The design of the glass processing system of the Gaspésie intermunicipal waste management board (RITMRG) is based on a local use of glass, particularly for use in the construction of road or trail infrastructures, or for horticultural use. Given that the equipment is installed in a separate building, a feed hopper must be added. By using this hopper, the RITMRG can process glass that has already passed through the equipment and thus reduce particle size more than once if the market demands it.

As part of this project, the RITMRG was able to rely on additional financial support from RECYC-QUÉBEC in order to erect the building for the glass processing system as well as to acquire vacuum machinery to remove fibers contained in the glass.

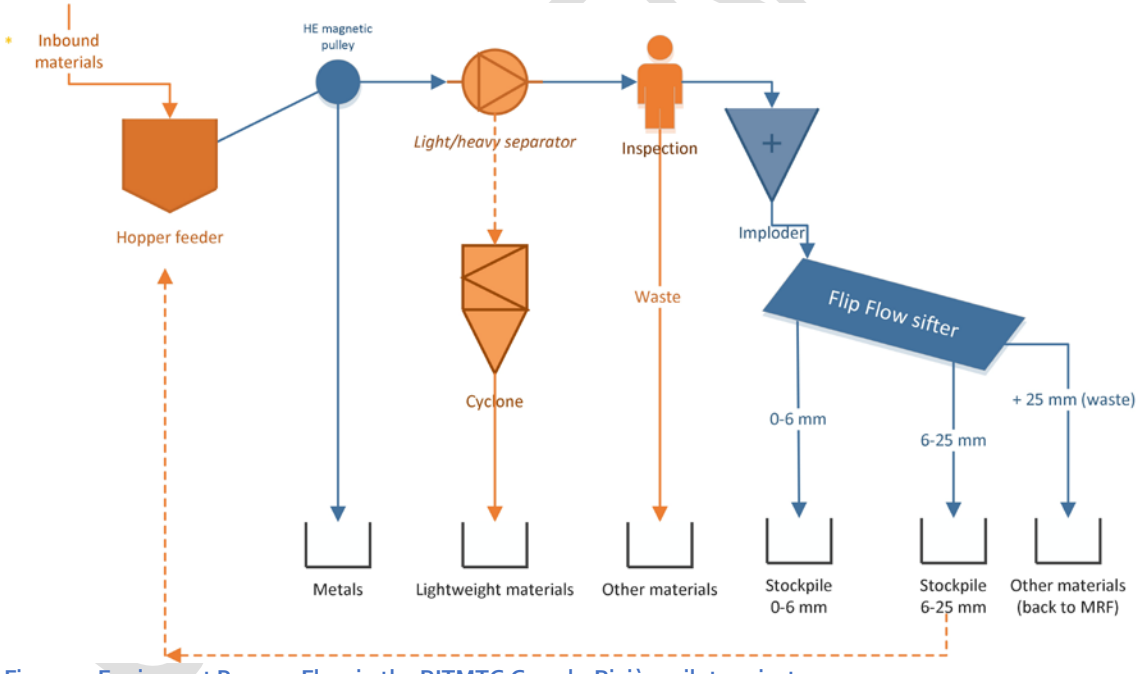


Figure 7: Equipment Process Flow in the RITMTG Grande-Rivière pilot project

3.2.2. Medium-capacity pilot projects Récupération Frontenac and EBI Environnement Materials recovery facilities

The design of glass processing systems for medium-sized materials recovery facilities is based on the desire to offer the versatility required to produce glass that meets market requirements. Thanks to the installed equipment, medium-sized materials recovery facilities can opt for maximum production of fine glass or large-particle glass by modifying equipment parameters.

These two pilot projects have a two-way conveyor ahead of the glass processing system so that the glass can be diverted in the event of breakage or shutdown. This bypass system is also useful when inbound glass is highly contaminated and sorting is difficult, either due to significant amounts of snow, organic matter or shredded paper. In addition, at EBI Environnement, a second bypass was positioned ahead of the imploder, which allows them to sort and process the glass without imploding it, according to market demands.

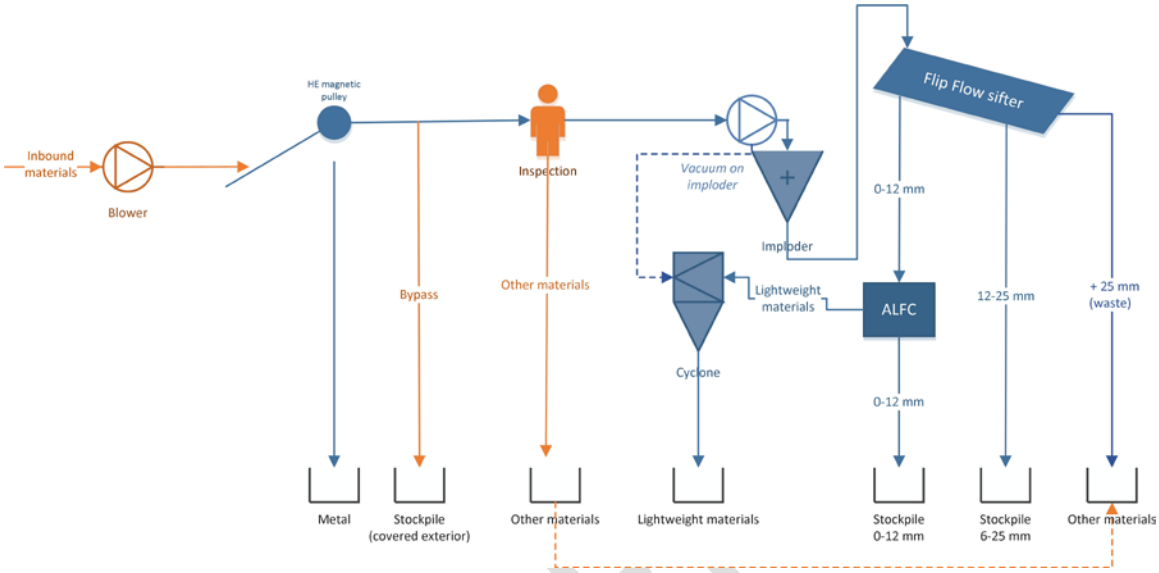


Figure 8: Equipment Process Flow in the Récupération Frontenac, Thetford Mines pilot project

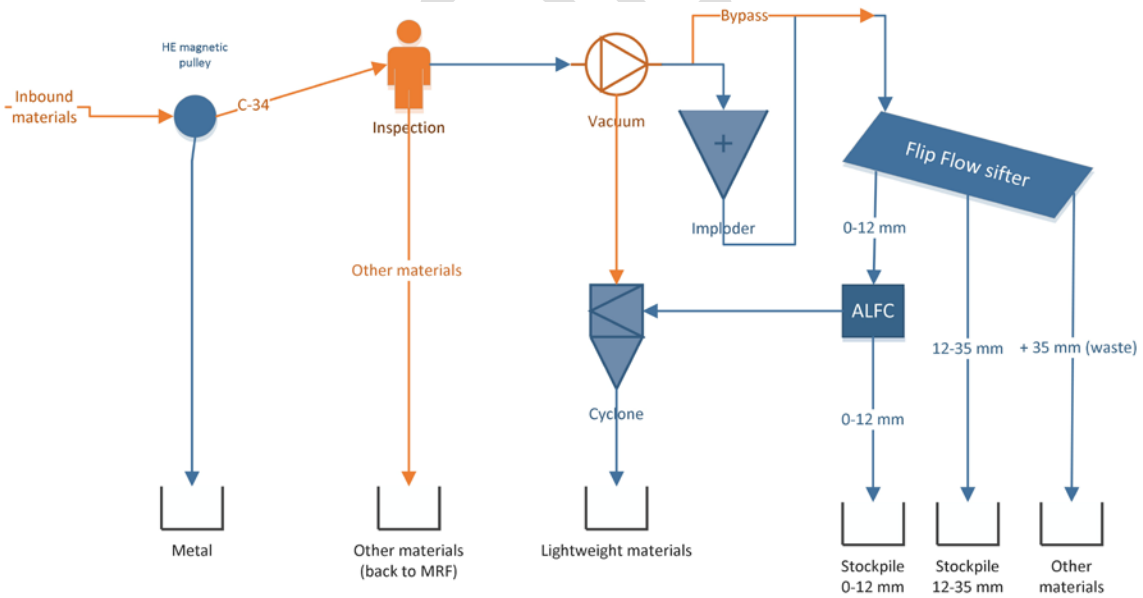


Figure 9: Equipment Process Flow in the EBI Environnement, Saint-Paul pilot project

3.2.3. Large-capacity pilot projects: Québec (Québec) and Tricentris (Terrebonne) materials recovery facilities

The two systems at the Quebec City and Tricentris materials recovery facilities are identical, except for their feeding system:

- The system of the Québec City materials recovery facility, operated by Société V.I.A., is located in a building adjacent to the materials recovery facility. The glass is loaded using an external feed hopper.
- The Tricentris system does not have a feed hopper. The glass comes directly from the materials recovery facility and is loaded in a continuous feed.

The rest of the glass processing is identical for both systems. At first, inbound glass is sieved; thin glass (less than 12 mm) is separated from the batch and directed to a cleaning system and a stockpile. Materials larger than 50 mm are also removed by the sieve and directed to the appropriate stockpile. The rest of the glass goes through quality control before the removal of light contaminants using a vacuum system. The operator then has the choice to implode the glass or leave it in its current form. In the latter case, the glass will be routed directly to the stockpile. If the glass is imploded, it will be sieved again and cleaned of light contaminants before being transferred to a stockpile.

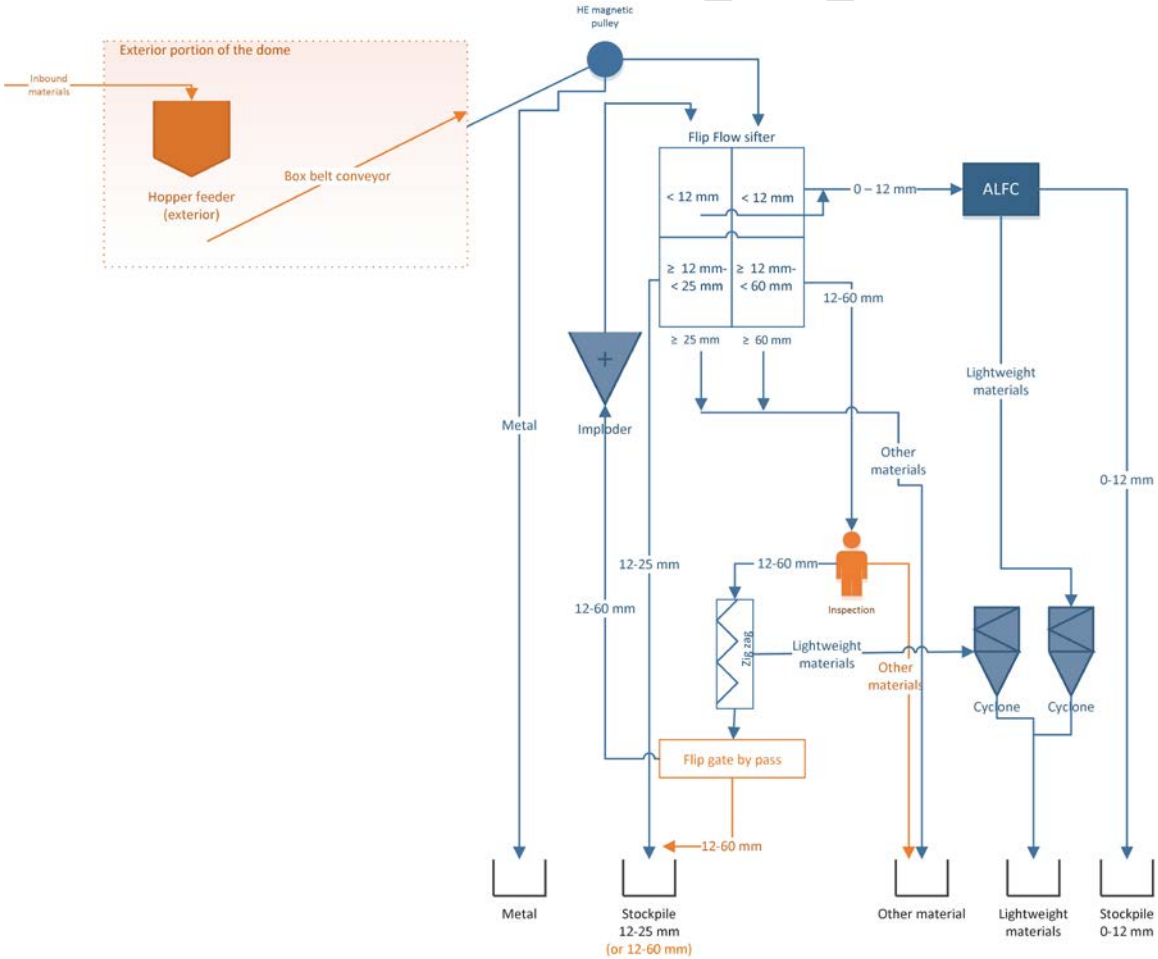


Figure 10: Equipment Process Flow in the Québec City, Québec materials recovery facility pilot project

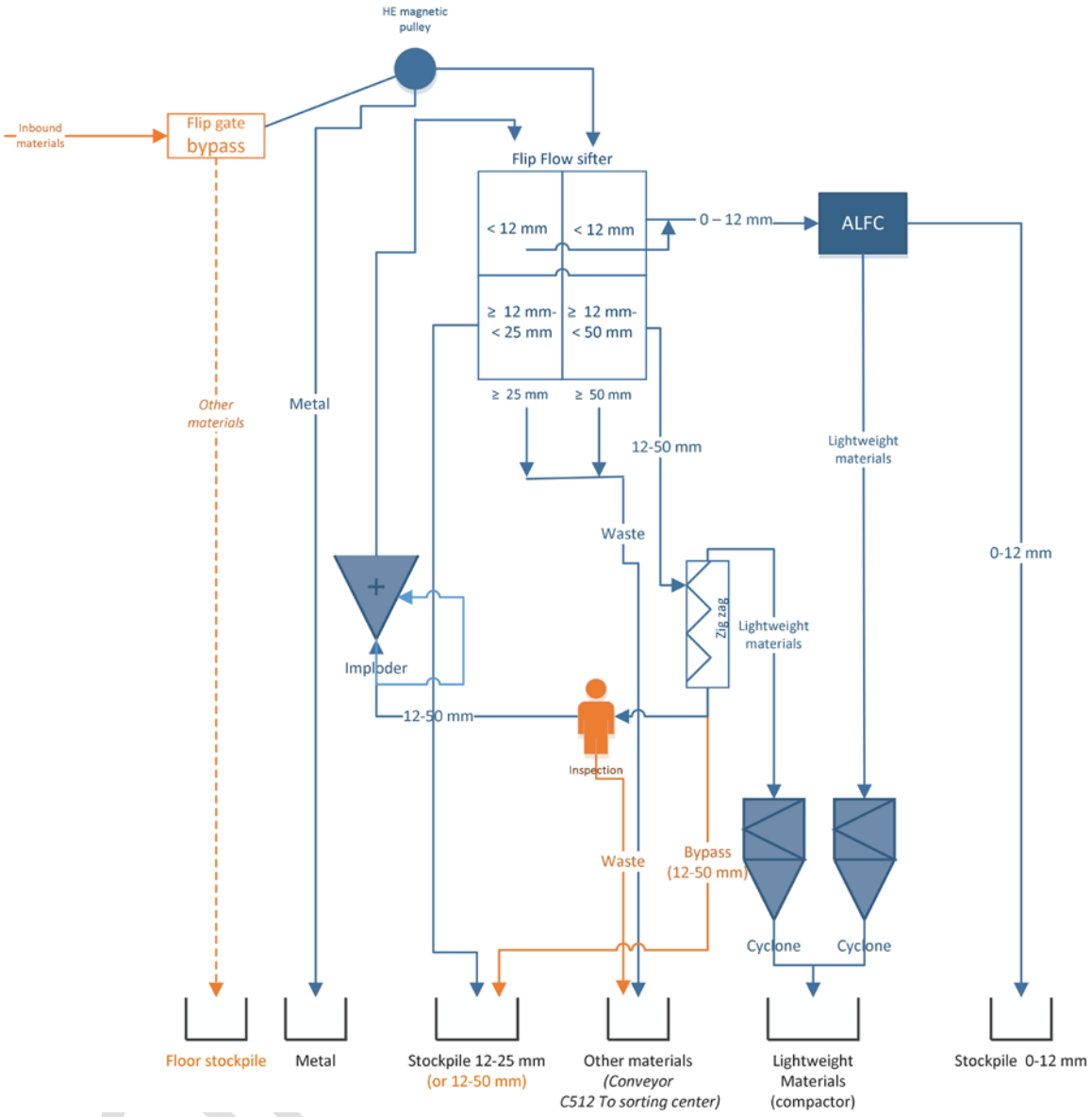
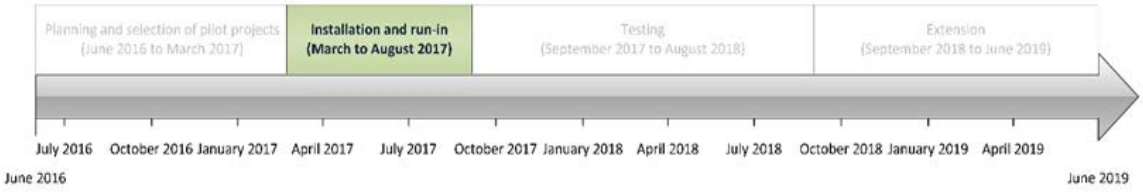


Figure 11: Equipment Process Flow in the Tricentris, Terrebonne materials recovery facility pilot project

3.3. Installation and run-in periods: March to August, 2017



Machinex delivered the equipment during the months of February and March, 2017. Installation of all equipment began in early March, 2017, at the RITMRG materials recovery facility in Grande-Rivière. Following a rigorous work schedule, the installation teams then moved on to the Récupération Frontenac materials recovery facility, then to those of the Ville de Québec (Québec City materials recovery facility) and Tricentris (Terrebonne), and finally, to the EBI Environnement materials recovery facility, where they completed the system launch at the end of April, 2017.

One of the more innovative aspects of the Plan was bringing together high-performance equipment that had never been integrated into a single system. In doing so, the 6-month installation and run-in periods required many adjustments due to the heterogeneity of inbound materials and equipment's performance. These adjustments made it possible to appropriately synchronize the system's operation.

During the run-in period, some equipment required significant modifications to meet performance criteria set out in the contract. These changes were made during the summer and fall of 2017. Significant work was done on the Flip Flow screen and the imploder, which required numerous modifications and improvements to allow proper separation of the curbside bin glass. In addition to the financial contribution required for these modifications, ÉEQ provided more than 1,000 hours of technical support during this single run-in period.

ÉEQ's training program

In accordance with the management plan, ÉEQ has set up a customized training program adapted to the context of Québec materials recovery facilities to facilitate the integration and operation of new equipment dedicated to glass processing. The following table presents the various components of the training program.

Table 6 ÉEQ's Training Program

	Period	Duration	Clientele	Trainer(s)	Training Summary
Implementation of the glass sampling and characterization program	Pre-installation phase	1 day	MRF project team	ÉEQ	• Sampling methodology • Characterization methods • Use and maintenance of characterization equipment • Data management and compilation process • Interpretation of results and actions to be taken, etc.
Management and preparation processes for project follow-up documents	Pre-installation phase	0.5 day	MRF project team	ÉEQ	• Presentation of the information and data management process between the materials recovery facility and ÉEQ • Presentation of forms and a form submission schedule
Operation, adjustment and maintenance of equipment	Pre-installation phase	2 days	MRF project team	ÉEQ and equipment manufacturer	• Review of equipment operation principles (sequences, start-ups, stops, etc.) • Adjustment and adaptation principles for equipment and effects on operations • Equipment maintenance, including a preventive maintenance schedule • Problem-solving principles for equipment operation problems • Management of information pertaining to equipment operation and maintenance • Refresher on the sampling and characterization program training
Health and safety, communications and visit management terms	Pre-installation phase	0.5 day	MRF project team	ÉEQ and equipment manufacturer	• Health and safety principles regarding operations • Communications management • Definition of roles and logistics regarding public events

3.4. Guidance and support to materials recovery facilities during the testing period: September, 2017 to August, 2018

The testing period began on September 1, 2017 and ran for 12 months. The pivotal period was undoubtedly the winter of 2017. During the month of December, 2017, marked by temperatures dropping below -30°C, some components in materials recovery facilities were extensively exposed to snow, ice and frost. From January to March, 2018, heavy snow and ice accumulations on conveyors and equipment caused blockages and breakage. Some pilot projects occasionally had to be operated in bypass mode during these periods. Under these circumstances, mechanical modifications were made to the imploder in order to ensure adequate operation. Adjustments were also made to other equipment in order to restore their expected level of performance.

Technical support

In the spring of 2018, due to the negative impact of a mixture of snow, ice and fibers in materials recovery facilities, actions were deployed to improve fiber separation upstream of the glass processing system in anticipation of the following winter, including adding blowers, modifying other components of the imploder and adjusting the cyclones.

The last quarter of the testing pilot project was an opportunity to make new adjustments, modify equipment and carry out equipment performance analyses. The ÉEQ team was a stakeholder in these improvement and solution-finding projects, collaborating with equipment manufacturers, experts and participating materials recovery facilities.

Overall, more than 150 technical visits were made to pilot projects during the testing periods. These interventions aimed to compile observations, identify challenges, implement solutions and make technical modifications to equipment. During these visits, particular attention was paid to developing workforce competencies, monitoring glass sampling and characterization, as well as to the quality of equipment maintenance and servicing, and finally, to performance indicators compiled by MRF staff.

Throughout the testing period, numerous adjustments, equipment modifications and tests were carried out, all representing over 4,000 hours of expertise and support for materials recovery facilities.

Materials recovery facility forums

Five forums were organized by ÉEQ during the testing period to bring together the managers of the five materials recovery facilities. Three of the forums were held on-site at one of the participating materials recovery facilities, which made it possible to visit the facilities and better understand individual characteristics. The meetings were an opportunity to discuss the progress and results of the pilot projects, as well as operational issues related to glass processing, such as:

- The excessive presence of certain contaminants, such as snow, ice and shredded paper and the means deployed to limit impacts
- Personnel training
- Servicing, maintenance and spare parts management
- Glass quality and marketing
- Management of system waste
- Innovation and improvement of processes

A more specific technical meeting between pilot project maintenance managers and representatives of the ÉEQ technical team and Machinex was organized. It proved to be an effective platform for developing knowledge, sharing insights, building contacts and learning from each other's experiences. Since then, communications between materials recovery facilities have been recurrent and have moved beyond the topic of glass management, particularly in view of the recycling crisis.

3.5. End of the testing pilot projects in materials recovery facilities: September 2018 to June 2019

Transfer of ownership contract to materials recovery facilities

The testing period ended on August 31, 2018. In accordance with the terms of the contractual agreement between ÉEQ and the materials recovery facilities, the latter had could choose to retain the equipment. The managers of the five materials recovery facilities unanimously agreed to become owners of the equipment. ÉEQ officially endorsed the donation of the equipment by contractual agreement, transferring the property at the beginning of September, 2018.

Continued technical and financial support

Because it is aware of the challenges related to operating equipment during the winter, ÉEQ wanted to make certain modifications to the equipment during 2019. To this end, ÉEQ extended its support to the participation per tonne sorted in pilot project materials recovery facilities until June 30, 2019. During this period, ÉEQ will work with materials recovery facilities to identify technical solutions to the problems generated by the presence of fibers, snow, ice and humidity. Technical studies as well as the integration of additional equipment are planned. Actions regarding the development of

markets for the glass from pilot projects will also be maintained in order to diversify recycling opportunities. Considering the closure of the Asian market, the extension of support for participation is greatly appreciated by the materials recovery facilities. The conditions regarding payment of support for participation remain the same as during run-in and testing periods. Thus, only glass sorted and sold to a processing plant or recycler is eligible for a contribution of $28 per tonne. No compensation has been granted for glass sent to landfills for use as an alternative daily cover or road foundation material.

3.6. Performance Indicators

ÉEQ has identified five (5) indicators to measure the performance of testing pilot projects:

1. Purity rate of fine-particle size glass (%)
2. Purity rate of large-particle size glass (%)
3. Glass tonnage produced monthly (tonnes/month)
4. Glass recycling rate (% of glass shipped for recycling versus glass processed in pilot projects)
5. Selling price of processed glass ($/tonne)

3.6.1. Purity rate of fine-particle size glass (%)

A maximum purity rate of 99.85%

Characterization results for fine-particle size glass samples were compiled from September 1, 2017 to August 30, 2018, covering the testing period. For the five pilot projects, a maximum purity rate of 99.85% was recorded for this fraction, a first for Québec materials recovery facilities. The chart below shows the composition of outbound fine-particle glass. It should be noted that infusibles (ceramic, brick, porcelain, etc.) are included in the "glass" category. These materials are tolerated by processing plants and some recyclers.

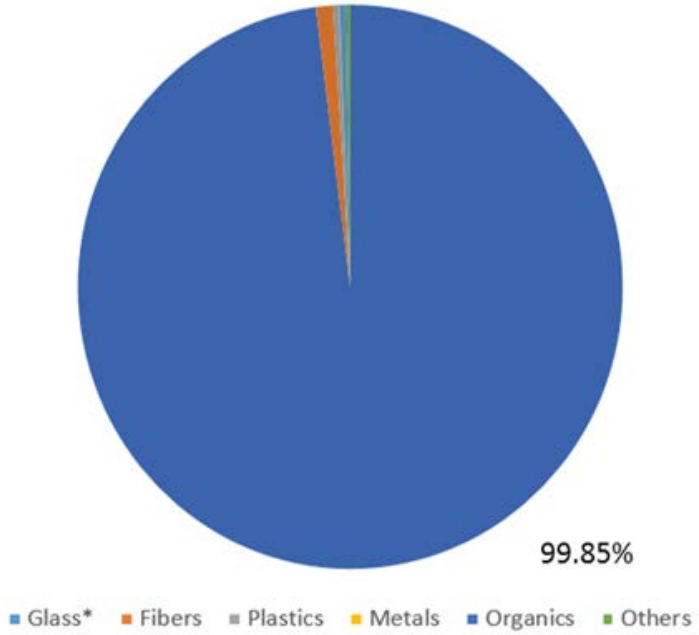


Figure 12: Maximum purity rate of outbound fine-particle glass

Average purity rate of 98.8%

In the 127 fine-particle glass samples resulting from the 12 month period of characterization, an average purity rate of 98.8% was achieved.

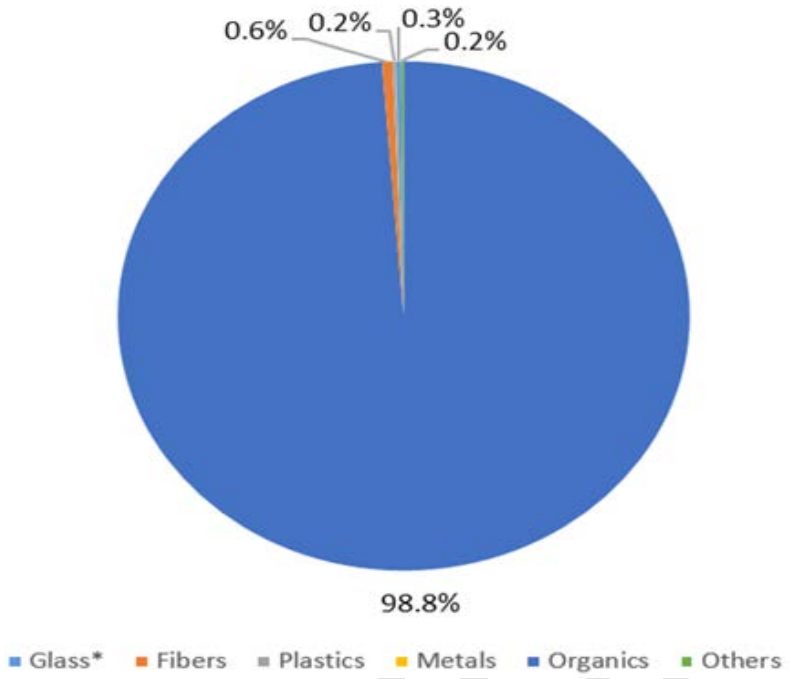


Figure 13: Average purity rate of outbound fine-particle size glass (%)

3.6.2. Purity rate of large-particle size glass (%)

Maximum purity rate of 99.4%

Results of the 103 large-particle glass samples were compiled and analyzed during the testing period. Pilot projects produce quality large-particle glass with a maximum purity level of up to 99.4%, as shown by the maximum purity level indicator after the 12-month characterization.

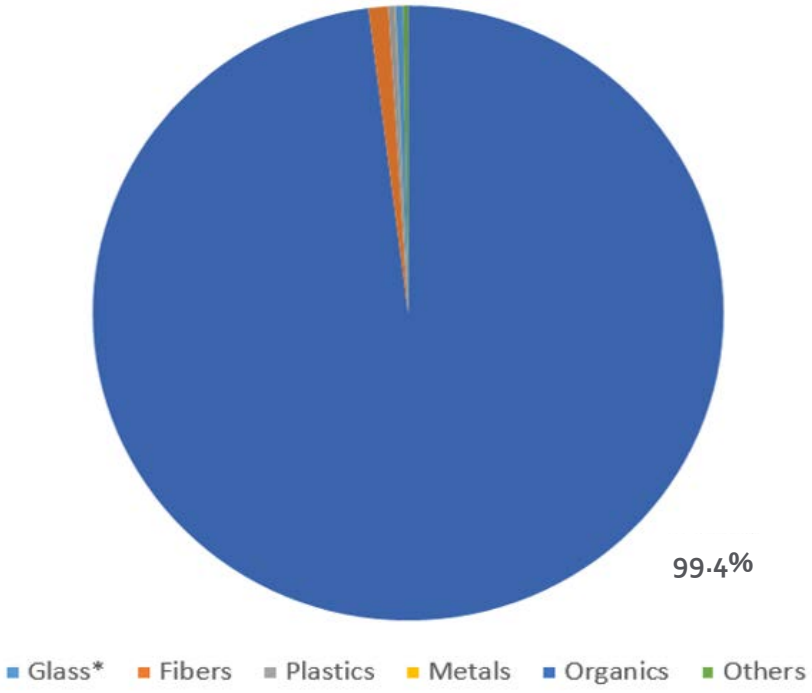


Figure 14: Maximum purity rate of outbound large-particle glass

Average purity rate of 88.6%

An average purity level of 88.6% was recorded for this fraction. This result is due to the type of equipment that facilitates the production of small-particle size glass, reducing the proportion of large-particle size glass produced.

It is important to note that only the sorting and processing systems of large-scale pilot projects have output vacuum equipment for large-particle size glass, which means a higher rate of purity (e.g. the Ville de Québec MRF: 93.2%). This average rate of purity would be higher if small- and medium-capacity pilot project systems were also equipped with this vacuum feature.

The chart below shows the average composition of large-particle glass output.

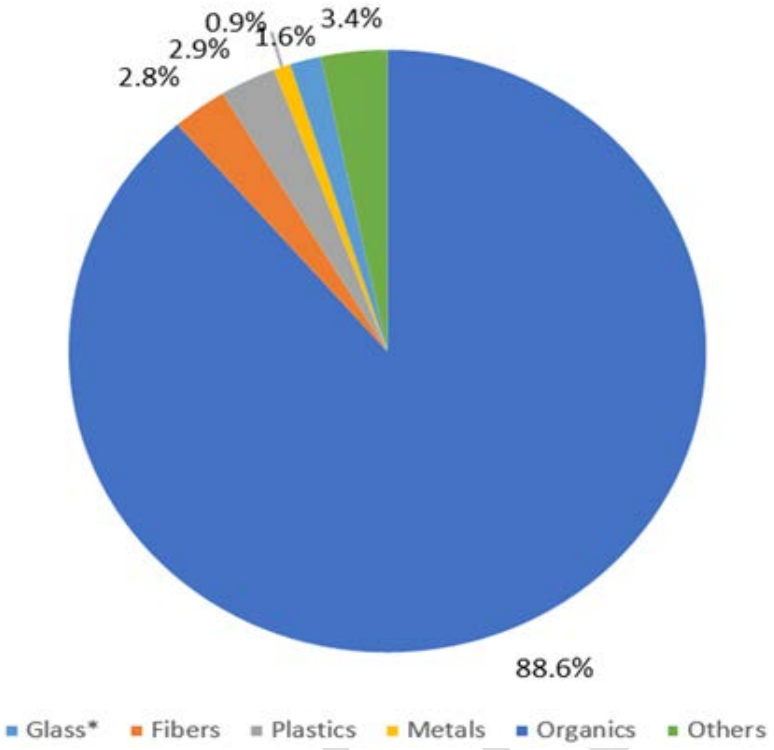


Figure 15: Average composition of large-particle glass output

3.6.3. Glass tonnage processed monthly

The quantities of glass processed as part of pilot projects during the testing period were compiled from weight tickets provided by the materials recovery facilities under our contractual agreement. The data are carried over to a monthly average in the table below. Thus, the capacity of equipment installed in the five materials recovery facilities as well as the operating conditions made it possible to process approximately 23,000 tonnes of glass.

Table 7: Monthly glass production (September 1, 2017, to August 30, 2018)

Materials recovery facility	Glass tonnage processed by equipment	Glass tonnage processed monthly by equipment
RITMRG (Grande-Rivière)	204	17
Récupération Frontenac	3,144	262
EBI Environnement	3,120	260
Centre de tri de Québec (Québec City)	7,116	593
Tricentris (Terrebonne)	9,312	775
TOTAL	22,896	1,908

3.6.4. Recycling rate (%)

With the exception of glass from the Tricentris pilot project in Terrebonne, 100% of the glass from pilot projects was recycled, either for the sandblasting or filtration sand industries, the manufacture of insulating wool, or the micronization into cement additive. It should be noted that the glass of the RITMRG was used for road infrastructure work as well as for local uses, such as trail surfacing and horticulture.

With respect to Tricentris, the project manager had to ship a certain amount of processed glass to landfills as daily cover, because his processing plant did not have the capacity to receive and process all the glass. This portion of glass was therefore not taken into account with respect to the financial support for participation by ÉEQ.

The overall glass recycling rate for testing pilot projects is 73%, instead of the 100% that would have been achieved, had this element not been beyond the control of ÉEQ.

3.6.5. Selling price ($/t)

It is known that materials recovery facilities pay between $19 and $28/t to dispose of unprocessed glass. In the pilot projects, the average selling price of glass was between $0/t and $10/t. In Gaspésie, the RITMRG materials recovery facility was even able to sell its glass for $10/t for local applications. This represents a significant economic gain and a real incentive to continue with the initiative. Low market diversity has helped to keep supply higher than demand in the short term. Market development and greater competition for glass remain the key to increasing the average selling price.

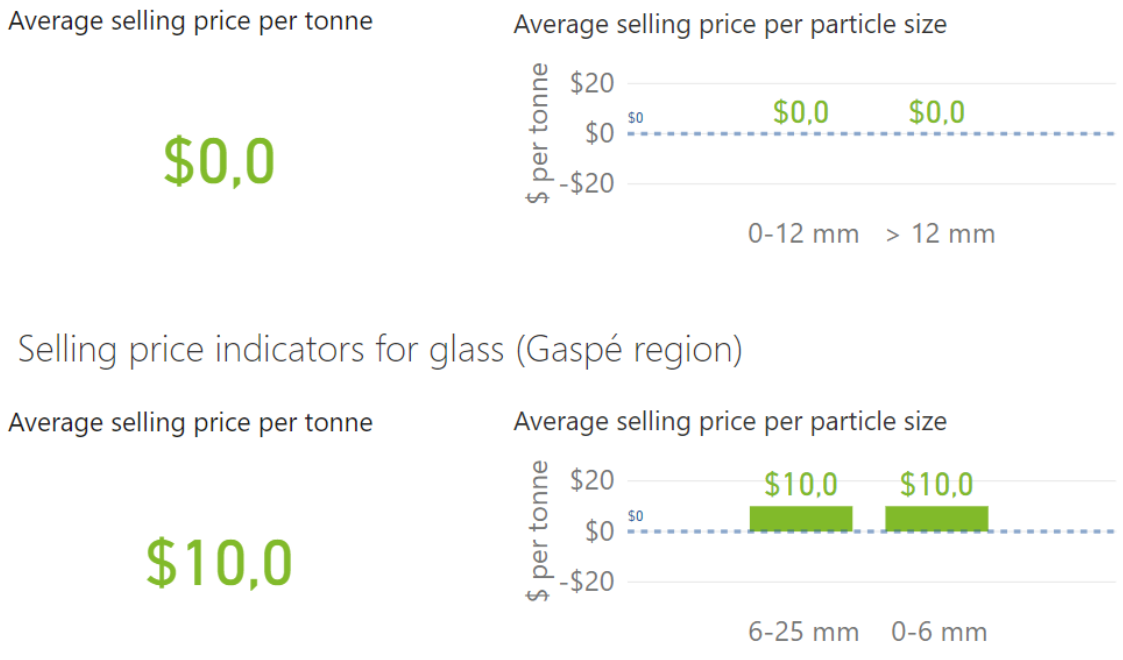


Figure 16: Glass selling price indicators

4. Testing pilot projects: findings and recommendations

This section presents the findings and teachings from the 15 months of testing as well as the recommendations to be implemented in order to deploy the appropriate equipment for processing and recycling 100% of curbside bin glass in all Québec materials recovery facilities. There are four categories of recommendations:

- Glass processing equipment
- Operational aspects
- Communications aspects
- Administrative aspects

4.1. Findings and recommendations by installed equipment

As previously specified, glass processing systems tested during the pilot projects consist of sieving, vacuuming and imploding equipment. Handling equipment (conveyors, falls, hoppers) and magnetic separation (high-density magnet) are also part of the glass processing system.

This section presents the assessment of key equipment in the system, namely:

1. The VibroFlow Flip Flow Screen
2. The Trennso Zig Zag
3. The Krysteline imploder
4. The Krysteline Air Lift Channel Feeder

4.1.1. The VibroFlow Flip Flow Screen

The "Flip Flow" screen separates glass into two particle sizes using perforated mats. Long objects, ropes as well as fibers and large-size plastics pass over the mat. The principle of this type of screen combines the flexibility of polyurethane mats, linear movement as well as opposite direction movement to generate the trampoline effect.

In the case of pilot projects, a Flip Flow screen from the Australian company VibroFlow was recommended by Krysteline. However, as soon as it was started, the equipment's performance was disappointing.

After six months of modifications and tests, Machinex was able to get closer to the desired movement without achieving the expected level of performance. The characterization results for glass from the fraction of large-particle showed that it contained 50% of glass which should have been in the fraction of small-particle size. This poor separation resulted in significant premature wear of subsequent machines. In addition, glass being projected outside the Flip Flow was noted, among other reasons because it does not have a protective cover. A lot of time and effort were needed in order to achieve minimal efficiency of the Flip Flow screen. For these reasons, ÉEQ opted to test other Flip Flow suppliers.

In the fall of 2017, tests were conducted with three other equipment manufacturers: Spaleck, IFE and Bivitec. A protocol was developed and rigorously followed in order to conduct performance tests. The screens of manufacturers Spaleck and Bivitec, despite design differences, showed better performance: the sifting was more accurate as little fine glass was found in the larger-particle size glass. With the Bivitec screen, as little as 2% of fine glass was found in the large fraction, compared to 50% to 70% with the current VibroFlow screen. Similar results were obtained with the Spaleck screen, with as little as 3% of fine glass in the coarse glass.

These tests enabled us to identify five selection criteria for the future acquisition of a Flip Flow screen:

1. The installation of covers on equipment is essential to contain the glass inside the Flip Flow.
2. The addition of a specific component on the screen is recommended to dislodge sheets and other flat materials and allow the glass to migrate properly towards the openings.
3. The mat fastening mechanism must make changing mats easy and quick.
4. The sieving efficiency is closely related to the available area. Flip Flow screens with a minimum of 12 mats are the way to go.

Recommendation regarding Flip Flow type screens

A Flip Flow screen is an essential piece of machinery for materials recovery facilities to separate the glass into different fractions while removing unwanted material. Flip Flow screens by Spaleck or Bivitec have shown superior performance and should be installed in materials recovery facilities.

4.1.2. The Zig Zag

The Zig Zag separator stands out due to its performance. With a tumbling feeding channel, an air flow blower and a separating cyclone to suction out material, the Zig Zag is easy to operate and maintain. It is particularly effective to remove light plastics and fibers. Even with humid materials, this equipment demonstrated an adequate level of performance. High-capacity materials recovery facilities equipped with a Zig Zag separator have achieved a degree of purity that is 4 to 10% higher compared to medium-capacity materials recovery facilities not equipped with a Zig Zag. The Zig Zag separator resists well to abrasion.

Recommendation regarding the Zig Zag

Trennso's Zig Zag separator has proven to be very effective in removing unwanted materials and should be installed in materials recovery facilities due its performance.

4.1.3. The Imploder

The imploder is a glass fragmentation machine that uses a calibrated-speed rotor to send a shockwave that reduces glass bottles or pieces into fragments, while leaving labels, collars, caps and other contaminants intact for easy removal.

The imploder is performs well to produce fine particle glass. Glass implosion allows for easy separation of contaminants such as labels and collars, which can then be more easily removed by suction. It is well suited for small-capacity materials recovery facilities that wish to produce fine particle glass for local markets. In addition, the operator can control the particle size by changing the rotor's rotation speed.

That being said, the imploder's performance varied from one materials recovery facility to another. It requires a high level of maintenance and is very fragile, especially if dense metal parts are present. Indeed, a single piece of metal can damage several of the imploder's components. The accumulation of fibers in the implosion chamber or the presence of snow were also factors that led to breakage, as observed throughout the testing period. The obligation to maintain a sorter ahead of the system in order to remove any non-conforming parts liable to damage the imploder represents additional costs that materials recovery facilities must take into account. The recurring breakage of one of the imploder's models led the equipment manufacturer to make numerous modifications to the rejection mechanism in order to make it more resistant. In addition to being expensive, spare parts cannot be procured locally. Despite a long learning period about operating this machine, operators and maintenance staff consider that they do not yet fully master the equipment in the context of curbside recycling in Québec.

Recommendations regarding implosion

Glass implosion is appropriate for materials recovery facilities in remote regions, as local markets require fine fraction glass.

However, it is imperative to ensure that the equipment manufacturer stocks all spare parts in North America and is able to ship them rapidly.

4.1.4. The Air Lift Channel Feeder (ALCF)

The ALCF is a suction system for lightweight materials to clean small-particle glass. With a moving bed and air nozzles, this machine requires a uniform and constant distribution of glass passing under the nozzles to be effective. This is unfortunately not the case in materials recovery facilities, as flow of materials is often irregular and the quantity of glass can vary considerably, or even double, over a short period of time. This equipment could be equipped with a level sensor in order to control and avoid frequent overflows. The ALCF does not have automated settings that would ensure consistent performance. The Air Lift Channel Feeders used in pilot projects would have required a different design, as they did not have sufficient length to allow for complete migration of fine materials to the surface.

The manufacturer suggested adding heater plates to limit the formation of ice, which proved effective. However, the heat from the plates caused a fibrous pulp to form (fibers, water, dirt and other aggregates), which required frequent cleaning during the winter season. Sealing problems with the junction box and plate connections to the vibrating bed caused stops and required maintenance by the manufacturer. The design of the heater plate system should be reviewed to ensure proper sealing.

Recommendations regarding the ALCF

We recommend replacing the ALCF with a Zig Zag air classifier; although it is more expensive, it offers superior performance.

4.2. Glass Flow Rate Changes

In materials recovery facilities, fluctuations in the flow of inbound materials is a known occurrence. The storage and handling of glass in the receiving area is such that glass tends to end up at the bottom of the pile of inbound materials. This operating method contributes to the fluctuation of glass tonnage entering the processing system, which may lead to the following situations:

- Blockages and overflows
- Poor performance of separation equipment
- Clogged conveyors
- Breakage and premature wear of equipment

In light of these observations, it is preferable to try to achieve a constant flow of materials coming into the glass processing system. For example, it would be possible to add a feed hopper or a Flip Flow type sifter that is oversized for the average inflow, which would make it possible to manage overloads.

Recommendations regarding glass flow rates

Glass processing systems should include equipment at the beginning of the processing line that is capable of absorbing flow variations.

4.3. Equipment servicing and maintenance

Materials recovery facility managers noted the direct relationship between equipment maintenance and the performance of the glass processing system. The Plan was an opportunity to focus on certain servicing and maintenance activities occurring in materials recovery facilities. Thanks to the maintenance, servicing and preventive inspection programs implemented by ÉEQ and equipment manufacturer Machinex, materials recovery facilities can better anticipate breakage before it occurs.

Recommendations regarding equipment servicing and maintenance

A preventive maintenance program for all materials recovery facility equipment must be implemented.

Ahead (upstream) of the glass system, quality control equipment must be installed to limit the presence of contaminants in inbound glass.

Sufficient stock of spare parts must be maintained by equipment manufacturers and available on short notice.

4.4. Unwanted materials

Glass processing during the pilot projects enabled us to identify unwanted materials that had an impact on the quality of the glass produced. Among these contaminants, shredded paper causes jams, which force shutdowns. In order to limit the impact of shredded paper, ÉEQ installed blowers to remove it upstream of the glass processing system.

The presence of biomedical waste, especially syringes, is another security issue for operators. Not only are these hazardous materials, they should never end up in recycling bins.

Unwanted materials, such as small non-recyclable objects (straws, pencils, toothbrushes, Pyrex, pebbles, porcelain, etc.), as well as the excessive presence of shredded paper, are a constant challenge for materials recovery facilities and, more specifically, for the quality of processed glass.

Recommendations regarding unwanted materials

Local awareness campaigns on excluding non-targeted materials from recycling bins must be deployed.

Awareness programs must be implemented by municipalities and RECYC-QUÉBEC.

As much as possible, glass and shredded paper must be removed at the beginning of the sorting line.

Measures must be taken to prevent biomedical waste, such as syringes, from ending up in recycling bins.

Equipment dedicated to removing unwanted objects, such as straws, pencils and toothbrushes, must be installed.

4.5. Snow and winter conditions

The difficulties encountered during the winter season were caused mainly by humidity, temperature variations and the abnormal presence of snow and ice in materials recovery facilities.

In Québec, curbside recycling during the winter months is problematic. Indeed, significant concentrations of snow and ice are collected and transported to materials recovery facilities, which is due in part to bins being left open or snow accumulating on lids and not being removed by collection operators. For example, one of the materials recovery facilities participating in the pilot projects estimated that the amount of snow ending up in their receiving area was approximately 600 tonnes per winter.

We have found that when the moisture content of inbound materials is high, sorting the glass is more difficult because wet fibrous materials tend to clump together, making separating them more complex. Additionally, there is an increase in time required for equipment maintenance.

Some mechanical problems have occurred during significant temperature changes over a short period of time or when the temperature fluctuates around 0°C. The condensation effect, combined with drastic temperature drops and the presence of humid materials caused freezing in some of the glass processing system's components.

Recommendations regarding snow and winter conditions

Preventive measures to avoid snow ending up in materials recovery facilities must be deployed with collectors by municipalities. In exceptional cases, temporary glass storage measures should be introduced.

4.6. Equipment manufacturer after-sales support

The Plan's pilot projects were a unique opportunity to combine equipment that had previously never been installed and operated in North America. One of the key learnings from the testing period is the importance of good after-sales support from equipment manufacturers.

Prompt response to performance issues or breakage is essential to the success of a project such as this. On a few occasions during the testing period, the pilot projects unfortunately experienced the consequences of disagreements between the equipment manufacturer and one of their suppliers regarding responsibility for performance issues and equipment warranties.

Recommendations regarding after-sales support

Before signing an equipment purchase agreement, purchasers should confirm that:

- the equipment manufacturer is responsible for the after-sales service
- the warranty terms and conditions are sufficient
- contractual agreements of the equipment manufacturer with their subcontractors are formalized
- the list of spare parts to be kept in stock is included in the contract
- the equipment supplier or their subcontractor agrees to provide the parts within a short time (48 hours)

4.7. Summary of recommendations regarding testing pilot projects

The table below summarizes the recommendations. Section 7 of this report details the deployment strategy based on these recommendations.

Table 8: Summary of recommendations regarding testing pilot projects

Recommendation regarding Flip Flow type screens	Flip Flow screens by Spaleck or Bivitec have shown superior performance and should be installed in materials recovery facilities.
Recommendation regarding the Zig Zag	Trennso's Zig Zag separator has proven to be very effective in removing unwanted materials and should be installed in materials recovery facilities due its performance.
Recommendations regarding the imploder	Glass implosion is appropriate for materials recovery facilities in remote regions, as local markets require fine fraction glass. However, it is imperative to ensure that the equipment manufacturer stocks all spare parts in North America and is able to ship them on short notice.
Recommendations regarding the ALCF	We recommend replacing the ALCF with a Zig Zag air classifier; although it is more expensive, it offers superior performance.
Recommendations regarding variations in glass flow rates	Glass processing systems should include equipment at the beginning of the processing line that is capable of absorbing flow variations.
Recommendations regarding equipment servicing and maintenance	A preventive maintenance program for all the equipment of the materials recovery facilities must be implemented. Ahead (upstream) of the glass system, quality control equipment must be installed to limit the presence of contaminants in inbound glass. Sufficient stock of spare parts must be maintained by equipment manufacturers and available on short notice.

Recommendations regarding unwanted materials	Local awareness campaigns on excluding non-targeted materials from recycling bins must be deployed. Awareness programs must be implemented by municipalities and RECYC-QUÉBEC. As much as possible, glass and shredded paper must be removed at the beginning of the sorting line. Measures must be taken to avoid that biomedical waste, such as syringes, end up in recycling bins. Equipment dedicated to removing unwanted objects, such as straws, pencils and toothbrushes, must be installed.
Recommendations regarding snow and winter conditions	Preventive measures to avoid snow ending up in materials recovery facilities must be deployed with collectors by municipalities. In exceptional cases, temporary glass storage measures should be introduced.
Equipment manufacturer after-sales support	Before signing an equipment purchase agreement, purchasers should confirm that: • the equipment manufacturer is responsible for the after-sales service • the warranty terms and conditions are satisfactory • contractual agreements of the equipment manufacturer with their subcontractors are formalized • the list of spare parts to be kept in stock is included in the contract • the equipment supplier or their subcontractor agrees to provide the parts within a short time (48 hours)

5. Development of the glass market

Materials recovery facilities generally sell their glass to processing plants, whose role is to transform the glass so that it meets recyclers' requirements. Depending on the targeted market, specifications vary, particularly regarding particle size as well as the type and quantity of tolerated contaminants.

In 2013, as indicated in section 2, the closure of processing plant Klareco left Québec with a very limited recycling capacity for curbside glass. Groupe Bellemare was practically the only company able to process a portion of the glass generated by materials recovery facilities. The processed glass was destined for the abrasives and filtration media market.

Tricentris, who initiated the production of glass powder as a cement additive in Québec, recycled a portion of glass for this purpose.

2M Resources, a third processing plant located in Québec, supplied remelting markets for the production of bottles, containers and mineral wool. According to our information, 2M Ressources supplied these markets almost exclusively with refundable glass from Québec and the United States.

It is in this context that ÉEQ decided to boost market development for recycled glass in order to increase demand and diversify markets. When it was launched, the Plan announced the creation of a marketing support component for recycled glass channels.

The component, launched in March 2016, aimed to cover the expenses of Québec processing plants and recyclers looking to pursue the following activities:

- Testing and prototyping, i.e. the design, optimization or quality control of products or processes using glass from curbside recycling.
- Certification, accreditation and standardization, i.e. the required procedures to secure certification, accreditation or standardization of a product or process, including testing and analysis.
- Business plan and marketing plan, i.e. the drafting and development of business plans, marketing plans or specific marketing tools.

Following a call for applications, nine companies submitted applications, for a total of fourteen glass recycling projects. A selection committee chose nine of the fourteen projects for the first phase. The five projects not selected were essentially in the laboratory research phase and therefore still too far away from a marketing phase.

The goal of the first phase was to confirm the potential of the submitted products and projects. To achieve this, ÉEQ developed, in conjunction with KPMG, guidelines for conducting market studies. Each company had to prepare and provide a market study for the products they wanted to market. For this purpose, ÉEQ granted a maximum funding amount of $20,000 for each market study.

Analysis of the market studies' results showed the relevance of such an approach before proceeding with the financing of market development projects.

- Indeed, four of the nine projects were dropped by the companies in light of the results
- Four other projects did not materialise, mainly for technical or economic reasons
- In the end, only one company implemented the measures for which it sought financial support from ÉEQ.

This first step in supporting development coupled with the analysis of the various market studies enabled us to draw the following conclusions:

- The level of maturity of the recycling sector in Québec is still low
- The importance of reassuring markets with standardized and certified glass eco-materials
- There is a lack of awareness and information on the benefits of recycled glass among target clienteles (ministries, municipalities, architects, engineers, general contractors, etc.)
- The presence of a single company that can process a limited quantity of clean glass from testing pilot projects demonstrates the importance of diversifying glass processors and markets
- The emergence of markets with strong growth potential that will also require investments in order to be developed.

In June 2017, based on these observations, ÉEQ abandoned the format of this marketing support component in order to reallocate budgets to a more targeted market development plan.

5.1. Action plan for the development of glass markets, 2017-2019

The previously-drawn conclusions enabled ÉEQ to devise a market development action plan, the main objective of which is the long-term and viable diversification of markets for 100% of the glass collected via curbside recycling.

The action plan for the development of glass markets aimed to undertake the following actions:

- Develop showcase projects
- Develop product standards, certification and quality control measures
- Stimulate investment development for processing plants and recyclers
- Raise awareness among contract givers (municipalities, consulting firms, infrastructure industries)
- Foster government relations to stimulate financing of materials recovery facilities, processing plants and recyclers

5.1.1. Showcase Projects

Showcase projects aim to demonstrate the added value of recycled glass in specific applications and to promote its use to customers or contract givers. The objectives of showcase projects are:

- To promote successful examples of recycled glass use
- To involve the municipal sector as one of the lead markets for these products
- To accelerate the development of markets for processing plants and recyclers in Québec

The following projects have been or are being developed:

1. Use of glass as insulating backfill for municipal pipelines:
   Conducted in Chandler, Gaspé, this showcase project aimed to measure the benefits of glass aggregate when used as an insulating material to withstand the freeze-thaw cycles in pavements, as glass aggregate is a better insulating material than the limestone typically used in road embankments.

2. Use of curbside recycling glass in the production of containers and bottles:
   Conducted in partnership with Owens-Illinois and a glass processor, this showcase project aimed to demonstrate the technical feasibility of using glass from curbside recycling to manufacture new containers and bottles.

3. Use of glass as a trail cover material:
   Project promoter Moment Factory used glass aggregate to cover a forest trail as part of its immersive night walk experience, Nova Lumina, in Chandler in the Gaspé region. The glass aggregate is used instead of crushed limestone and gives the path a shiny, magical aspect that is in harmony with the theme of Nova Lumina.

4. Use of glass as filtration media for municipal pools:
   In partnership with the city of Plessisville, this project aims to use glass as a filtration media to replace sand in the filtration system of the future municipal swimming pool. This showcase project aims to demonstrate the added value of glass aggregate compared to traditional sand.

5. Use of glass in concrete as part of leasehold improvements made in ÉEQ's offices:

As part of its leasehold improvements for LEED certification, ÉEQ used several eco-materials, including glass embedded in a concrete floor and glass powder as a cement additive in a concrete countertop.

5.1.2. Product standards, certifications and quality control measures

Several products that incorporate glass from curbside recycling, such as cement additives, filtration media or micronized glass for additives, are in their initial years of marketing.

They are often promoted by convinced contract givers. Such innovations are often difficult to market at the beginning. Resistance to change from some project owners and contractors was noted when the products in question were not standardized. In order to overcome this resistance to change, ÉEQ supports quality control and standard development initiatives in order to reassure the various clienteles.

The objectives of supporting the development of standards, certifications and the implementation of product quality control measures are to reassure contract givers and industrial actors regarding the quality and added value of products that incorporate curbside recycling glass.

The following projects have been completed:

1. Integration of glass powder as a certified cement additive:
   As part of consultations to update CSA standard A3000 (Compendium for Cementitious Materials) to include glass powder as an authorized cement additive, ÉEQ, like Tricentris and many other important institutional and corporate partners, actively supported the efforts of Dr. Tagnit-Hamou of the Université de Sherbrooke, the leader of this project. In addition, support from various prime manufacturers was solicited for presentation to the CSA consultation committee. This standard was successfully updated in December 2018 and now includes the specifications for recycled glass powder to be used as a cement additive. This standard will help reassure cement manufacturers and contract givers.

2. Industrial scale glass washing test for the production of micronized glass:
   ÉEQ collaborated with a company specializing in the micronization of glass for high value-added markets, to demonstrate the technical feasibility of an innovative procedure for glass washing devised during pilot projects, to establish a new plant in Québec. Initially, a prototype, developed and owned by ÉEQ, was used to define the technical aspects of glass washing, especially for the requirements of residual water treatment. Then, 30 tonnes of glass from two materials recovery facilities participating in the pilot project were washed in a test unit developed by a company in England. Preliminary results on the purity of glass are promising. Quantitative data will be available in the second quarter of 2019.

5.1.3. Investment development

The solution for 100% of the glass from curbside recycling, i.e. approx. 120,000 t/year, requires substantial investment in materials recovery facilities and processing plants in the coming years.

The objectives of investment development are:

- To synchronize the supply and demand of glass by 2021
- To increase and diversify the number of glass processing plants in Québec
- To guide processing plants/recyclers towards potential sources of investment at the municipal, provincial, federal and private levels

In order to contribute to the development of companies in this industry, ÉEQ commissioned a specialized consultant to list the various existing investment funds in Québec and Canada, as well as the conditions for accessing them. The project started in 2018 and will be completed in 2019.

5.1.4. Raising awareness with contract givers

Most of the contract givers in the sectors we met with did not know about the various existing glass-based products. Municipalities are a particularly promising sector for the use of these products, especially in the public works department.

The objectives of raising awareness with contract givers are:

- To raise awareness about and promote use of eco-materials in trial sections and showcase projects
- To build trusting relationships with partners, and better understand the industry's needs, concerns and standards
- To promote value-added eco-materials that incorporate recycled glass with the help of specialists

Throughout 2018, ÉEQ participated in several conventions, mainly in the municipal sector, with an educational kiosk meant to highlight the different applications for recycled glass:

- Salon des TEQ (Réseau environnemental) (environmental technologies fair), Québec, March 13-14
- Conference of the Conseil de la transformation agroalimentaire du Québec (CTAQ) (Québec Agri-Food Transformation Council), Gatineau, March 26
- Meeting of the Union des municipalités du Québec (UMQ), Gatineau, May 16-18
- Conference of the Association des directeurs généraux des municipalités du Québec (ADGMQ) (Québec association of city chief officers), Rimouski, June 6-8
- Conference of the Association des directeurs municipaux du Québec (ADMQ) (Québec association of city managers), Quebec, June 13-14
- Symposium of the Association des travaux publics Amériques (city managers) (public Works Association, Québec chapter), Saint-Sauveur, September 5-6
- Congress of the Fédération des municipalités du Québec (FQM), Montréal, September 20-21
- PAC to the Future II (packaging industry) Montréal, September 26-27
- Forum des grandes villes (big city forum) organized by ÉEQ, Québec, November 1-2
- Symposium on residual materials management (Réseau environnement), Saint-Hyacinthe, November 7-8

The market development plan was also an opportunity to meet many contract givers. In the margins of the CSA certification process for glass powder as a cement additive, the ÉEQ team approached members of the CSA committee, the Association Béton Québec, the Bureau de normalisation du Québec and the Québec Ministry of Transport. These meetings helped to facilitate the adoption of the standard on glass powder after 5 years of technical work carried out by the Chaire SAQ de valorisation du verre dans les matériaux (corporate-sponsored research chair on glass reclamation in materials).

5.1.5. Government relations

Government relations aim to stimulate investments in this sector and foster exchanges on the various issues regarding the full development of our recycling potential.

The objectives are:

- Raise awareness among elected representatives and encourage government authorities to support the Plan and discuss the legal and regulatory obstacles to innovation in residual materials recovery.
- Identify opportunities, leverage existing innovation and green infrastructure programs and policies from all three levels of government.
- Promote public funding for processors/recyclers (new programs)

ÉEQ submitted a brief on the use of recycled glass in road infrastructures as part of the consultations on the regulations relating to the Environment Quality Act (EQA).

Specifically, ÉEQ commented on the *draft Regulation respecting ministerial authorizations and declaration of compliance in environmental matters*, which proposes to classify the various projects according to four levels of environmental risk, subsequently determining the environmental authorizations to be requested from the government. The use of recycled glass in road structures would be subject to ministerial authorization even though it complies with the *Guide de valorisation des matières résiduelles inorganiques non dangereuses de source industrielle comme matériau de construction* (guidelines for reclaiming non-hazardous inorganic materials arising in the manufacturing process) published by the MELCC in 2002. In this context, ÉEQ's submission suggested that recycled glass used in pavements could be subject not to ministerial authorization, but to a declaration of compliance, due to its low risk to the environment. This classification would make it much easier for municipalities to use glass in this application.

Government and institutional relations efforts have also been deployed in the following areas:

- Research towards achieving certification for glass powder
- Identification of applicable standards under the Building Code
- Identification of showcase project opportunities in municipalities

Several meetings and exchanges were held in this regard with the Ministère des Transports du Québec (ministry of transportation) and its Laboratoire des chaussées (roads laboratory), ÉTS technical school, the Centre de Recherche Industrielle du Québec (Québec industrial research centre), and the Bureau des normes du Québec (Québec standards bureau), to name but a few.

6. Development of glass markets: findings and recommendations

The pilot projects were an opportunity to interact with processors and recyclers both in Quebec and outside the province, and to understand their requirements regarding glass shipped to their plants, specifically in terms of particle size and purity. Thus, once the tests were completed, and after equipment modifications and numerous discussions, it was possible to produce glass to meet their criteria.

This section presents the results of research and tests related to the curbside recycling glass market, the conclusions that can be drawn from the process, as well as the recommendations for achieving a 100% recycling rate for glass collected through curbside recycling.

6.1. Current situation for glass markets

In Québec, there is one main processing plant with the capacity to process and recycle the glass from curbside recycling, and two other companies with more limited processing capacities.

The current markets are:

- Abrasives and filtration media (main market)
- Mineral wool
- Cement additive

However, the three processors mentioned above are currently unable to process all 120,000 tonnes of curbside recycling glass because:

- The abrasives market is on its way to topping out (around 30,000 t / yr.) and is not expected to grow significantly in the coming years.
- There is no mineral wool manufacturing plant in Québec (Ontario and in the United States). In addition, glass is sensitive to fluctuations in the construction industry.
- The cement additive market is still in its infancy and production capacity is limited

Recommendation regarding the current market situation

To achieve a 100% recycling rate for curbside collected glass, priority must be given to market diversification.

6.2. Particle size requested by processors

Throughout the testing period, about thirty tests were carried out with different processors and recyclers. These tests covered samples ranging from a few kilograms to several tonnes. The processors and recyclers were located in Québec, Ontario and the United States.

The glass used for the tests was of two different particle sizes as produced by materials recovery facilities. Fine-particle glass (<12 mm) generally had a higher purity level than that of large-particle glass. However, smaller particle size glass was generally found to be harder to clean, as unwanted materials that had been amalgamated and finely ground were difficult if not impossible to remove without causing loss.

Thus, all of the processors and recyclers with whom we conducted tests preferred large-particle glass with a little more unwanted material than the smaller-particle glass. Large-particle glass is easier to clean and rid of unwanted materials, such as porcelain, pebbles and ceramics.

Recommendation regarding desired particle size for the market

As per market demand, the production of large-particle size glass should be favoured.

Glass implosion should be reserved for small-capacity materials recovery facilities in order to meet local market requirements (see the recommendation in section 6.8).

6.3. Glass container production market

For over ten years, curbside recycling glass has not been used in the production of new bottles or containers in Québec because it has not been processed via materials recovery facilities. It has been mixed with waste from materials recovery facilities and could contain anywhere from 25% to 30% undesirable materials. No processor was able to clean this glass as per the specifications of the bottle and container producer industry.

In collaboration with Montreal glassmaker Owens-Illinois and a glass processor, ÉEQ has been conducting a series of large-scale tests since 2018 to identify the winning conditions for using glass from curbside recycling in the production of new containers and bottles. The glass used for this test is the large-particle glass of the pilot projects.

2M Ressources, a processor located in St-Jean-sur-Richelieu, has a calibrated production line to produce glass for the American mineral wool market. This production line is not suitable for processing glass to be used for making new bottles and containers, because the manufacturers' criteria are not the same.

Additionally, ÉEQ carried out technical exchanges with two American processors who handle glass from curbside recycling. They supply recycled glass to several container and bottle manufacturing plants (Owens-Illinois, Ardagh Glass, Anchor Glass) in a context similar to Québec, that is, the glass comes from commingled curbside recycling.

ÉEQ also had the opportunity to visit one of the processor's facilities. The industrial process relies on optical sorters for color separation and removal of contaminants. The design of the processing line allows optical sorting of fine-particle glass (and the extraction of four glass colours). Tests with the glass from ÉEQ pilot projects are also planned for spring of 2019.

Technically, therefore, there is no reason why curbside recycling glass, once properly sorted and cleaned, cannot be used in the production of new bottles and glass containers.

Recommendation regarding the production of glass bottles and containers

In order to supply the glass bottle and container manufacturing market in Québec, investments must be made so that glass can be appropriately sorted by colour, contaminants can be eliminated and clear glass from curbside recycling can be dedicated to this industry.

6.4. Abrasives and filtration media market

The market for abrasives made from recycled glass has existed in Québec for more than a decade. According to a study conducted by ÉEQ, that market is approaching saturation. There are more than a dozen companies that sell glass abrasives in North America, the largest being an American company, Strategic Materials. In Québec, Groupe Bellemare is the main company for that market.

The market for filtration media made from recycled glass aggregate could experience significant growth over the next few years as glass filtration media has competitive advantages over traditional sand:

- Better entrapment of suspended matter
- Better resistance to the formation of bacterial colonies or biofilm
- Reduced need for backwashing

In North America, glass granulate for filtration is used mainly in the residential pool sector. Other sectors need to be developed. For example:

- Filtering for municipal pools or recreational aquatic complexes
- Filtration for industrial wastewater with high levels of suspended solids
- Filtration of sludge or residential wastewater (as used in Saint-Hyacinthe and several cities in New York State and Minnesota)

One of the barriers to the expansion of this market is the lack of certification for such products, which could cause resistance from prime manufacturers.

Recommendations regarding the abrasives market

Testing projects for filtration media must continue in order to demonstrate the added value of glass aggregate.

Efforts to secure standardization and implement quality control for these products must be supported in order to help commercialize them.

The various water filtration applications for targeted clienteles must be promoted.

6.5. Cement additive market

A cement additive is a component that gives concrete particular properties depending on the type of additive. There are several types of cement additives or supplemental cementitious materials: fly ash, which is a by-product of coal burning plants, and silica fume and blast furnace slag, two by-products of the metallurgical industry.

In recent years, research work done by Université de Sherbrooke's *Chaire SAQ* on the valorization of glass in concrete has facilitated the emergence of a new, innovative added-value cement additive: glass powder. This work was supported by numerous institutional and corporate partners, including Tricentris.

The product is a good substitute particularly for fly ash, the use of which poses two considerable challenges:

- Closure of coal-fired plants

- Transportation costs, as major producers are located in the United States

After several years, glass powder is now fully recognized as a cement additive and was incorporated into the CSA standard, Cementitious materials compendium, in January, 2019.

The next step in the development of this market relates to production issues, namely, increasing production capacity and ensuring quality control of finished products.

In Québec, the usage potential for fly ash represents close to 150,000 tonnes per year, making it one of the most promising markets for glass powder from curbside recycling. For example, a market penetration of 10% (15,000 tonnes per year) seems to be a realistic target for the short-term.

Recommendation regarding the cement additive market

A strategy for quality control and development of this new industrial sector must be developed jointly with all interested stakeholders (cement manufacturers, concreters, ÉEQ, government departments and agencies, processors and recyclers, glass powder manufacturers, prime manufacturers).

6.6. Micronized glass as an additive

Micronized glass can be used to manufacture a multitude of specialized products such as paints, varnishes, grouts, certain fireproof materials, polymers, etc. Micronized glass is a powerful mineral additive that replaces synthetic additives and provides specific properties for the finished products. For example, micronized glass is added to protective coating for its fire-retardant properties. The market for micronized glass as an additive is generally a high added value one, as these are high-tech products that require sustained quality control.

The use of curbside recycling glass for these applications will also require the installation of an appropriate glass processing system, especially to remove organic contaminants such as residual fluids or fibers. Moreover, it will be necessary to increase current production capacity to meet the demand from the various specialized markets.

Recommendation regarding the market for glass powder as an additive

In order to supply glass powder market as an additive, investments must be made to adequately wash or dry and micronize glass form curbside recycling.

6.7. Cellular glass

Cellular glass, also called foam glass, is a pumice stone type material that is both lightweight and very resistant to compression, fireproof and insulating. Cellular glass is mainly used in residential construction (foundation insulation, drainage material for green roofs) and road construction (light embankment for bridges and viaducts). The production of cellular glass first requires the glass into fine a powder, then mixing it with a mineral additive which will produce a foaming effect. The mixture is then cooked in a high-temperature oven, which causes the product to expand and capture gas bubbles that create honeycomb structures. At the end of the cooking process, under the effect of cooling, the foam glass plate breaks into pieces, making it look like pumice.

This market has been established in Europe for some thirty years, with around ten manufacturers. In Québec, there are still no manufacturers of cellular glass. In addition, several companies have already shown interest in setting up a factory, and a project could soon be developed.

One of the main obstacles to eliminate regarding the marketing of these products is to get them recognized by prime manufacturers and, in time, to secure certification for certain applications.

Recommendations regarding the cellular glass market

In order to supply the cellular glass market, investments must be made towards the acquisition of glass heating equipment.

A marketing and awareness strategy for prime manufacturers will also have to be implemented.

6.8. Markets in remote locations

The constraints associated with glass processing operations in remote materials recovery facilities differ from those in urban areas. In remote areas, glass sources are generally smaller and sorting operations are often manual. Moreover, market access for glass processed in materials recovery facilities remains difficult, considering the high transportation costs.

Therefore, local marketing of processed glass becomes an additional and necessary activity for the materials recovery facility. The RITMRG pilot project in the Gaspé region successfully tested local recycling solutions, namely the use of glass as an insulating material for road infrastructures and as landscaping material. These finished products were produced directly without having to go through a processor.

Test-use of glass as a road infrastructure material was successfully completed in collaboration with the City of Chandler, in the Gaspé region and the École de technologie supérieure, in Montréal. The showcase project in Chandler showed that the glass layer installed around a water main increased insulation of the piping. ÉTS has been working for almost four years on incorporating glass granulate in pavement.

ÉTS's work also demonstrates that it would be possible to use glass in asphalt. This application is widely used in the United States and is known as "Glassphalt".

Other municipalities around the world use glass in road infrastructures, in embankments or in asphalt. In New Hampshire and Minnesota (two states with climates similar to Québec's), these applications are overseen by government authorities who have established the required specifications for glass, the conditions to be complied with during implementation in the field and the environmental criteria to be met.

Recommendations regarding remote location markets

Small capacity materials recovery facilities, as well as geographically isolated medium capacity materials recovery facilities, must be equipped with additional glass reduction equipment in order to meet the criteria of local markets such as road infrastructures or trails.

The use of glass in road infrastructures must be recognized as a low environmental risk application of the EQA.

6.9. Glass in landfills

The year 2013 saw the closure of Québec's main glass processing plant. The use of glass as an alternative daily cover material in landfills has proved to be the main alternative. Since then, materials recovery facilities continue to ship their glass to landfills, which is an unacceptable form of recycling.

Prior to the implementation of the Plan, "nearly 86,000 tonnes of glass ended up in landfills", according to RECYC-QUÉBEC's 2015 report on residual materials management (Bilan 2015 de la gestion des matières résiduelles). Materials recovery facilities that use this route only pay between $20 and $30 per tonne to get rid of glass instead of paying over $100 per tonne for landfill disposal. Competition from daily cover has proven to be a major obstacle to glass recycling and market development.

Glass deposited in the recycling bin should never be sent to landfills. We must collectively and gradually put an end to this situation, taking into account the development of markets and the implementation of new sorting and glass processing systems in Québec materials recovery facilities.

Recommendation regarding glass in landfills

The use of glass as alternative material used in technical landfills (daily covering or other) must be progressively prohibited.

6.10. Summary of recommendations regarding market development

The table below summarizes the recommendations. Section 7 of this report details the deployment strategy based on these recommendations.

Table 9: Summary of recommendations regarding market development

Recommendation regarding the current market situation	To achieve a 100% recycling rate for curbside collected glass, priority must be given to market diversification.
Recommendations regarding desired particle size according to market demand	As per market demand, the production of large particle glass should be favoured. Glass implosion should be reserved for small-capacity materials recovery facilities in order to meet local market requirements (see the recommendation in section 6.8).
Recommendation regarding the production of glass containers	In order to supply the bottle and container manufacturing market in Québec, investments must be made so that glass can be appropriately sorted by color, cleared of unwanted materials such as pebbles, ceramics and porcelain, and that clear glass from curbside recycling can be dedicated to this industry.
Recommendations regarding the abrasives market	Filtration media testing projects should be continued to show the added value of glass aggregates. Product standardization and quality control efforts should be supported to facilitate marketing. The various water filtration applications for targeted clienteles must be promoted.
Recommendation regarding the cement additives market	A strategy for quality control and development of this new industrial sector must be developed jointly with all interested stakeholders (cement manufacturers, concreters, ÉEQ, government departments and agencies, processors and recyclers, glass powder manufacturers, prime manufacturers).
Recommendation regarding the market for glass powder as an additive	In order to supply glass powder market as an additive, investments must be made to adequately wash or dry and micronize glass form curbside recycling.
Recommendations regarding the cellular glass market	In order to supply the cellular glass market, investments must be made towards the acquisition of glass heating equipment. A marketing and awareness strategy for prime manufacturers will also have to be implemented.
Recommendations regarding remote region markets	Small capacity materials recovery facilities, as well as geographically isolated medium capacity materials recovery facilities, must be equipped with additional glass reduction equipment in order to meet the criteria of local markets such as road infrastructures or trails. The use of glass in road infrastructures must be recognized as a low environmental risk application of the EQA.
Recommendation regarding glass in landfills	The use of glass as alternative material used in technical landfills (daily covering or other) must be progressively prohibited.

7. Deployment strategy and investment plan

The solution for 100% of glass collected via curbside recycling

In order to achieve the Plan's main objective, that 100% of Québec's curbside recycling glass be recycled, a total investment of approximately $23 million is required to equip materials recovery facilities, as well as approximately $27 million for diversification and market development, communication and awareness campaigns and the measurement of economic and environmental results.

The following section presents the details of the investment plan.

7.1. Deployment strategy and investment plan in materials recovery facilities

ÉEQ has developed an action plan over a 4-year horizon to equip all Québec materials recovery facilities with glass processing equipment. Based on the current situation of curbside recycling materials recovery facilities and on the lessons learned during the testing period, a scenario for the deployment of systems across Québec was developed, defining synergies between certain materials recovery facilities and market accessibility for the glass produced at each of them. This preliminary scenario is progressive and will be adapted according to the frequent changes observed in the industry. It is intended to illustrate the strategy's objectives and determine a budget. It is obvious that when this strategy is implemented, a collaborative work approach between funders, materials recovery facilities, equipment manufacturers, processors and recyclers, as well as ÉEQ and other stakeholders will be recommended in order to develop adequate systems.

This deployment strategy consists in implementing five different system models nationally, including an update of the pilot projects. It is established based on the following benchmarks:

- Materials recovery facility capacity: small, medium and large capacity systems
- Consolidation of glass tonnages (example: partnership between materials recovery facilities run by the same operator): intermediate systems
- Materials recovery facility locations and, more precisely, the remoteness of some of them: hybrid system

This strategy may include consolidating glass deposits to carry out processing at certain materials recovery facilities rather than in all of them. These consolidation proposals would be openly discussed with all the interested stakeholders, first and foremost among them, municipal administrations and the materials recovery facilities involved.

The investment required for the deployment of glass processing systems throughout Québec is summarized in the following table.

Table 10: Summary of investments required for materials recovery facilities

System Type	Number of systems
Small capacity	2
Medium capacity	4
Large capacity	3
Intermediate	6
Hybrid	2
Pilot project upgrades	5
Total costs $23 M	

The description of the systems and justification for the investments are set out in subsequent paragraphs.

7.1.1. System for small-capacity materials recovery facilities

This system is intended for installation in materials recovery facilities that handle less than 1,000 tonnes of glass per year. These materials recovery facilities are located in geographical areas far removed from urban centres Montréal and Québec City. They have low population densities. The advantage of that type of system is that it allows local recycling to be carried out and thus reduces transportation and greenhouse gas emissions. Glass treated with this system goes to local uses, such as glass aggregate for road infrastructures, horticultural mulch and as covering for hiking and cycling trails. For these specific markets, equipment is required to reduce the glass to the desired particle size. The following table describes the equipment that is included this type of system:

Table 11: Equipment required for small-capacity materials recovery facilities

Equipment	Function
Feed hopper	Independent loading
Suction-blowing	Separation of fibres and lightweight materials
Crusher/imploder	Glass reduction according to desired particle size
Flip-Flow type screen	Particle size separation
Eddy current	Removal of ferrous and non-ferrous* materials *(*essential if an imploder is integrated into the system)*
Sorting station	Quality control and removal of contaminants
Conveyors	Transfer of materials
Stockpiles	Storage

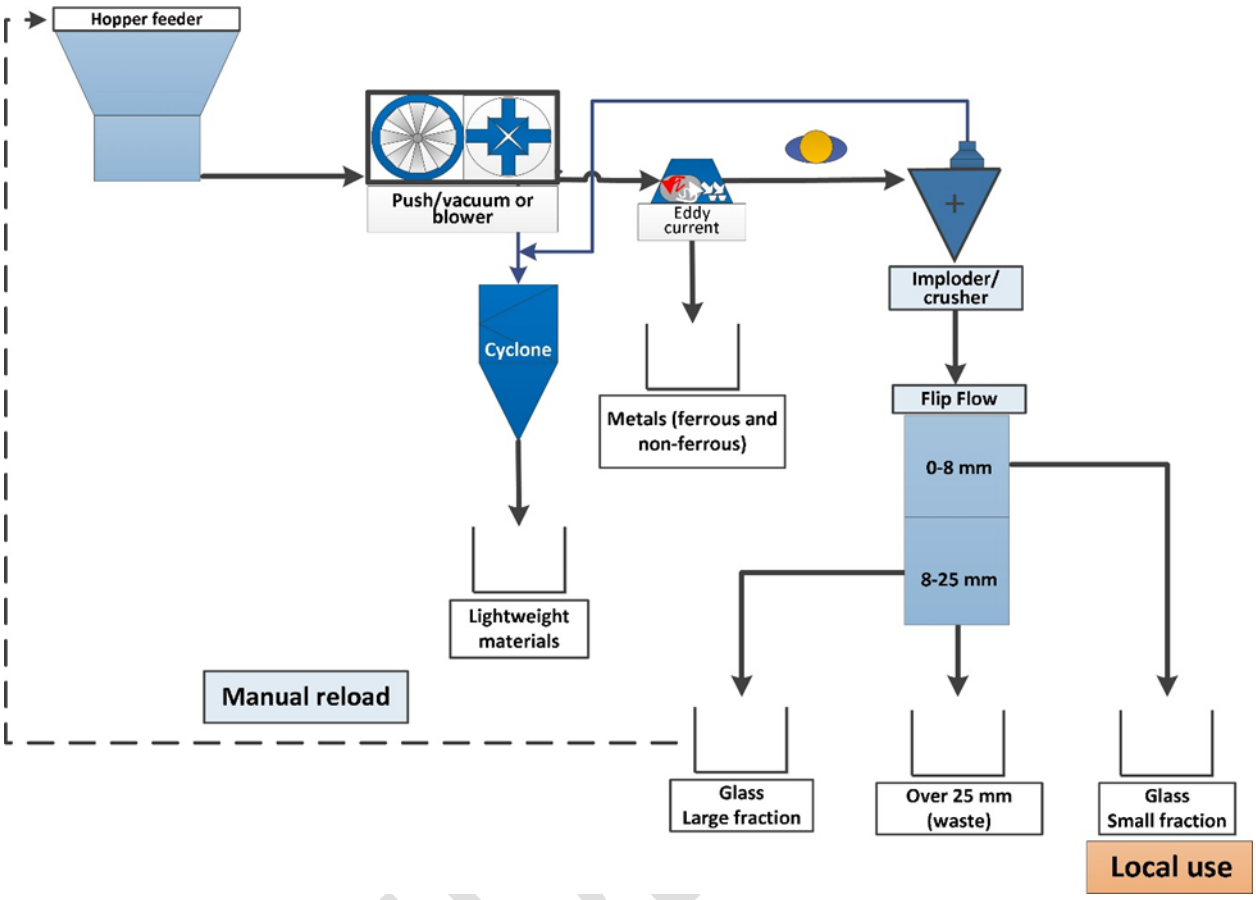


Figure 17: Suggested configuration for small-capacity materials recovery facilities

7.1.2. System for medium-capacity materials recovery facilities

According to the Report's findings and recommendations, medium-sized materials recovery facilities, i.e. those who receive between 1,000 and 8,000 tonnes of glass annually, will prioritize the production of large particle glass. These materials recovery facilities are all located near one or more glass processing plants.

Processing systems will be connected directly to the materials recovery facility in order to minimize handling. The glass will not undergo implosion. Vacuum equipment is provided to remove light unwanted materials (plastics and fibers) from the small particle inbound glass. The simplicity of this system presents a considerable advantage in terms of operation, maintenance and servicing requirements. It also makes it possible to produce glass with a purity rate of 93% to 98%. The following table illustrates the equipment that is included in this type of system:

Table 12: Equipment required for medium-capacity materials recovery facilities

Equipment	Function
Suction-blowing	Separation of fibres and lightweight materials
Flip-Flow type screen	Particle size separation
Zig Zag (2)	Separation of fibres and lightweight materials
Conveyors	Transfer of materials
Stockpiles	Storage

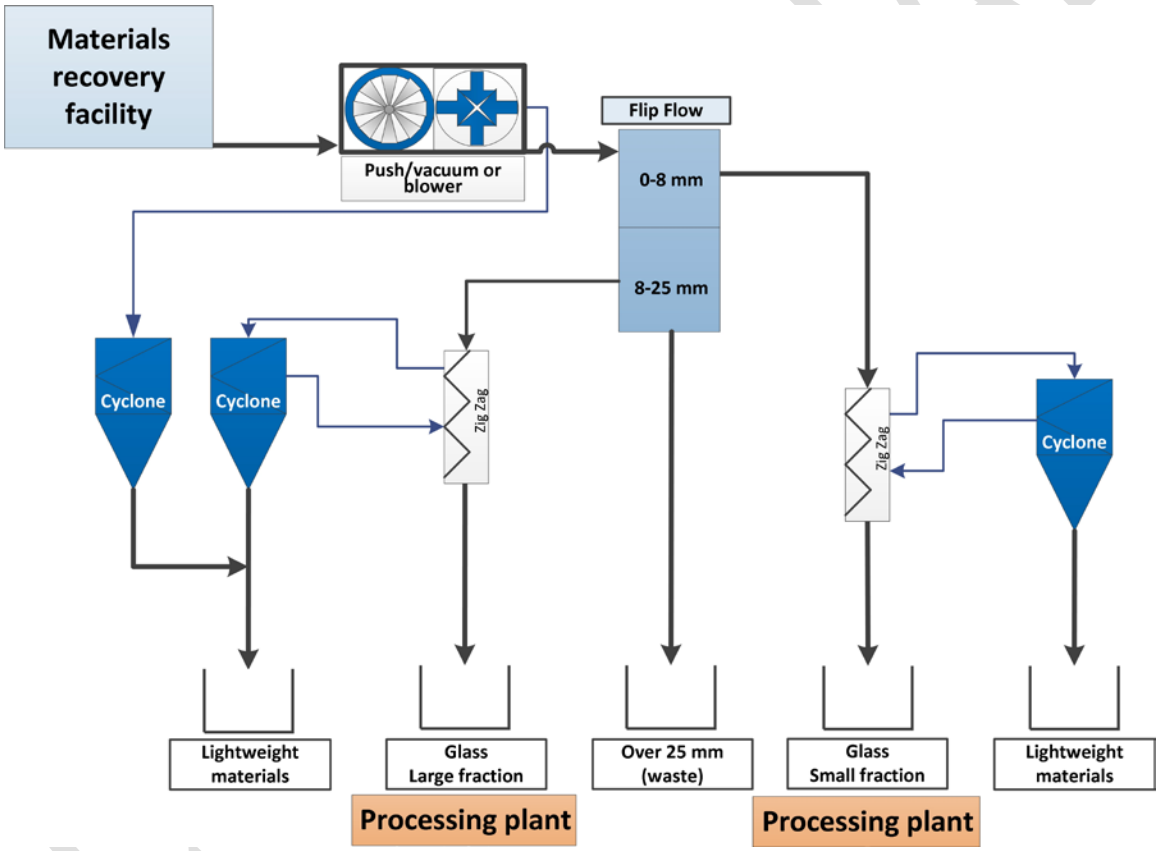


Figure 18: Suggested configuration for medium-capacity materials recovery facilities

7.1.3. System for large-capacity materials recovery facilities

A system for installation in large-capacity materials recovery facilities receives more than 8,000 tonnes of glass per year. Located in densely populated areas and near processors, these materials recovery facilities will produce a maximum of large particle glass according to their criteria. The addition of a 2D/3D sifter will improve the purity of the outbound glass by removing caps, among other things. Similarly to the system for medium-sized materials recovery facilities, the equipment for large-capacity materials recovery facilities is simple and easy to operate. This system also makes it possible to produce glass with a purity rate of 93% to 98%. The following table describes the equipment of the system.

Table 13: Equipment required for large-capacity materials recovery facilities

Equipment	Function
Suction-blowing	Separation of fibres and lightweight materials
Flip-Flow type screen	Particle size separation
Zig Zag (2)	Separation of fibres and lightweight materials
2D/3D sifter	Separation of three-dimensional objects (caps, long objects)
Conveyors	Transfer of materials
Stockpiles	Storage

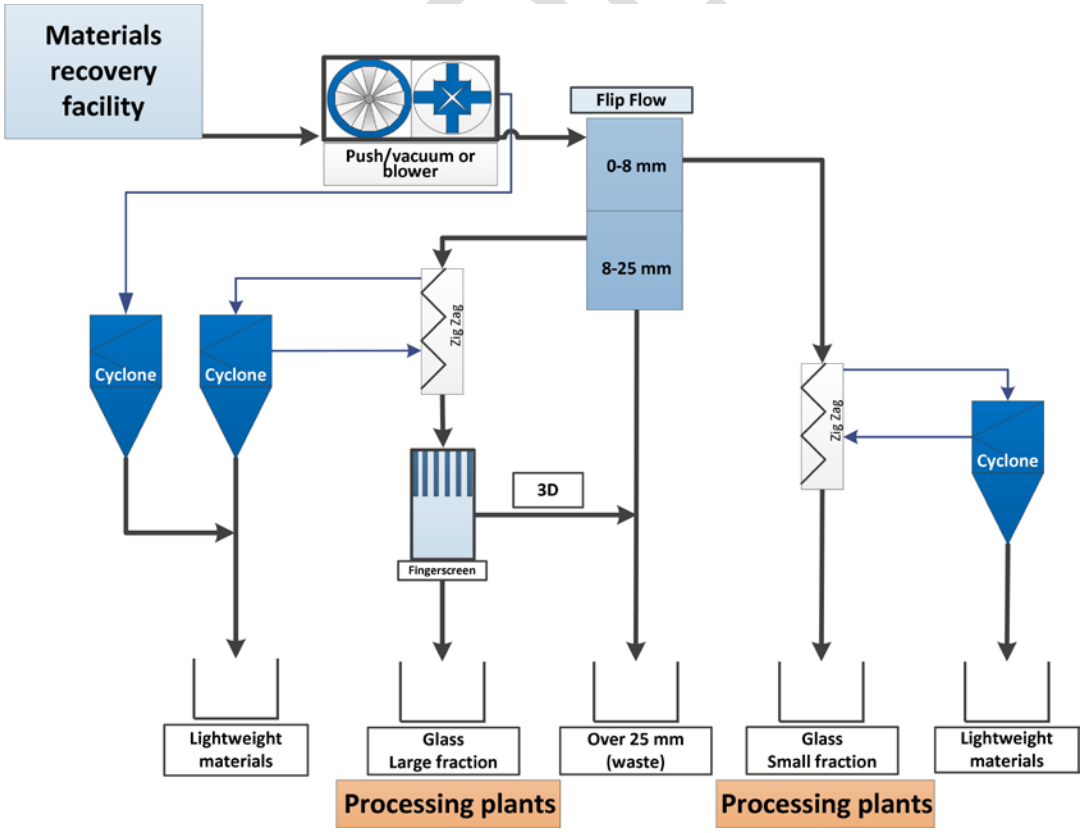


Figure 19: Suggested configuration for large-capacity materials recovery facilities

7.1.4. Intermediate systems

The deployment strategy also includes the implementation of intermediate glass processing systems for materials recovery facilities to transfer their glass to another materials recovery facility to promote local synergies. In such cases, only blower equipment will be installed to remove a maximum amount of fiber from the glass. The fibre thus removed can be directed to the materials recovery facility's existing recycling channels. Glass partially processed using blowers will then be transferred to a larger materials recovery facility to complete cleaning operations.

7.1.5. Hybrid System

The Plan's testing period has highlighted the characteristics of certain materials recovery facilities. These have an interesting volume of glass to be processed. However, their geographical location far removed from processors or urban centres generates significant transportation costs and the emission of greenhouse gases, which represents a limit to possible agreements with processors and recyclers. In such cases, local glass markets are an interesting alternative.

The hybrid system offers versatility as it allows for the production of various particle sizes. The operator of a hybrid system can grind glass for local use or maximize the sorting of large particle glass if a business opportunity arises. In addition, the installation of such a system in a separate building allows glass to be received from nearby materials recovery facilities equipped with the intermediate system.

Table 14: Equipment required for hybrid materials recovery facilities

Equipment	Function
Feed hopper	Independent loading
Suction-push or blowing	Separation of fibres and lightweight materials
Flip-Flow type screen	Particle size separation
Zig Zag (2)	Separation of fibres and lightweight materials
Crushing equipment	Glass reduction according to desired particle size
Eddy current	Removal of ferrous and non-ferrous* materials *(*essential if an imploder is integrated into the system)*
Conveyors	Transfer of materials
Stockpiles	Storage

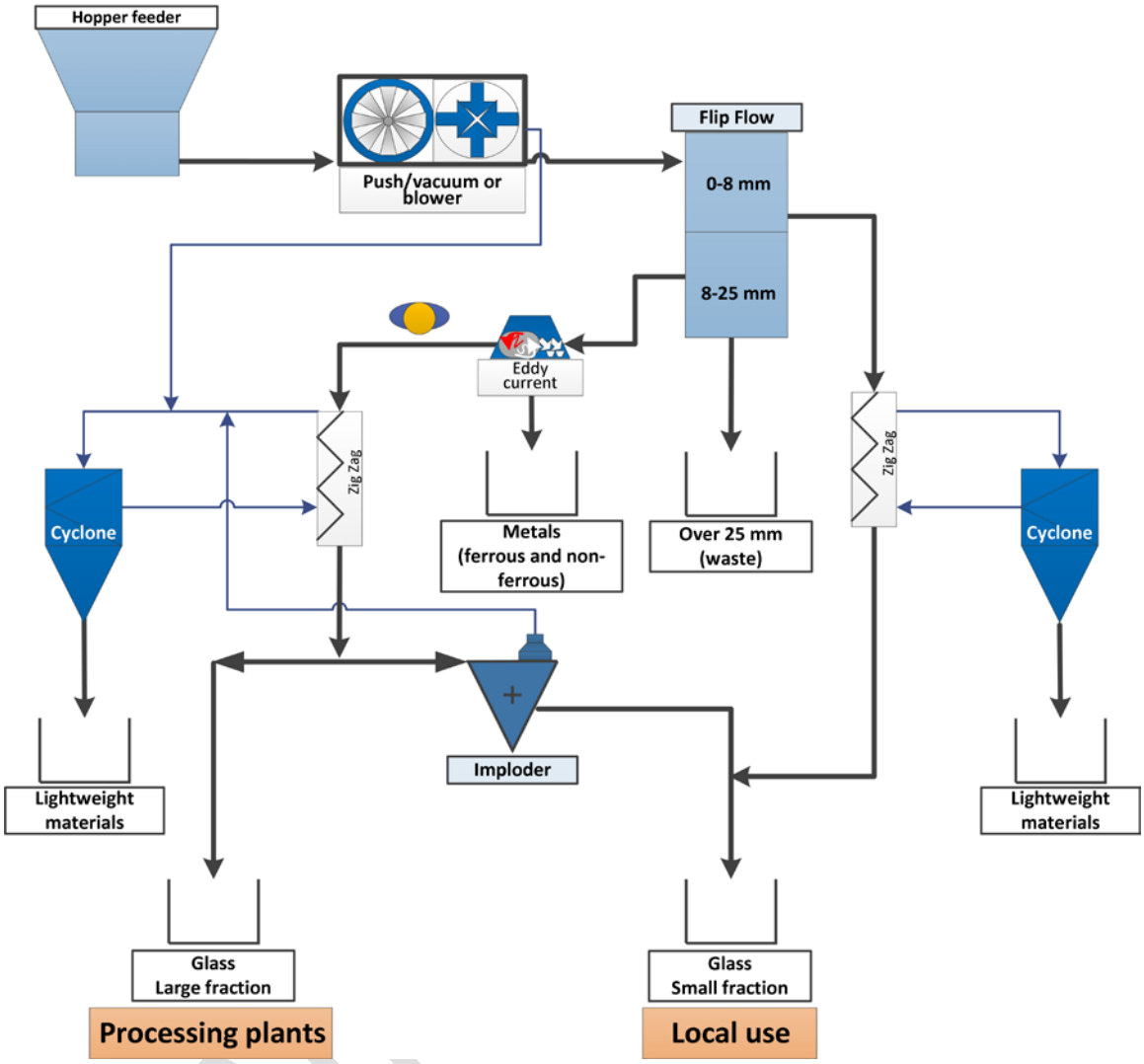


Figure 20: Suggested configuration for hybrid materials recovery facilities

7.1.6. Pilot project upgrades

Pilot project processing systems will also require upgrading. After the testing period and following the completion of external studies, concrete solutions have been identified to improve glass processing, in particular on the following points:

- Efficient removal of a maximum amount of fiber upstream of the system through the implementation of a blower or blower-vacuum system.
- Improved efficiency of cyclones by modifying their structure and rotary valves.
- Increased rate of removal of lightweight materials using the ALCF thanks to the installation of a blower.
- Increased performance during particle size separation by replacing the current Flip Flow screen with a screen with proven efficiency.
- Enhanced system versatility to appropriately respond to market requirements by adding imploder bypass mechanisms in systems not equipped with them.
- Increased purity rate of large particle glass by adding light material separation equipment (blower, Zig Zag, etc.).

7.2. Deployment strategy and investment plan for processing and recycling

ÉEQ has identified six market segments with the greatest potential as a result of numerous exchanges with various glass processors and recyclers. Although the nature of these exchanges is confidential, we can draw an overall picture of the potential market for glass from curbside recycling over 24 to 30 months and estimate the amount of investments required to achieve the objective of recycling the 120,000 tonnes per year of glass collected from curbside recycling.

Based on the current situation of glass markets and discussions with the various processors, a deployment scenario for the Québec industry has been developed. As with materials recovery facilities, this preliminary scenario is progressive and will be adapted to the frequent changes observed in the industry. It is primarily intended to illustrate the strategy's objectives and to determine a budget.

This deployment strategy consists in supporting the growth of the six market segments identified through the acquisition of advanced equipment. It is established based on the following benchmarks:

- Current markets for mineral wool, aggregate for abrasives and filtration as well as cement additives are limited, but their capacity can be increased.
- There is a market for the manufacturing of bottles and containers, which can be supplied with glass from curbside recycling.
- Two other markets are in the development phase
- Many current and potential processors and recyclers have shown an interest in developing one or another of these six market segments through the acquisition of technological equipment.

The following table identifies the six current and potential market segments, the main constraints to their development as well as the recommendations to achieve the goal of recycling 100% of glass collected through curbside recycling.

Table 15: Estimation of investments required at processing plants by market segment

Market	Container production	Mineral wool	Abrasives and filtration	Cement additive	Micronized powder for additives	Cellular glass
Existing markets		X	X	X		
Markets to be developed	X	X	X	X	X	X
Development constraints	Industrial processing capacity is limited to respond to the local demand from Owens-Illinois	▪ Export market for cullet, final production in the U.S. ▪ Market is sensitive to fluctuations in the construction industry.	▪ Market nearing saturation ▪ Filtration media not well known	▪ Limited production capacity ▪ Quality control to be developed ▪ Lack of producer diversification ▪ Lack of communications between stakeholders	▪ Lack of cleaning capacity for glass recovered via curbside recycling ▪ Lack of micronization capacity	▪ New product in a competitive market (construction) ▪ No production plant Québec
Recommendations	▪ Investment support for the development of processing of glass to be used in the production of bottles and containers.	▪ Investment support to increase production capacity of cullet to be used to make mineral wool.	▪ Quality control measures and certification to be developed for filtration. ▪ Promote this type of filtration media with prime manufacturers.	▪ Increase production capacities through corporate financing programs. ▪ Ensure quality control regarding certification. ▪ Structure the industry with partners.	▪ Develop glass washing capacity and increase micronization capacity through corporate financing programs.	▪ Invest in a dedicated processing line. ▪ Promote cellular glass to prime manufacturers.
Examples of equipment required for processing	▪ Sifting, drying and optical sorting	▪ Sifting and optical sorting	▪ Zig Zag separator	▪ Crushing, sifting, cyclone, dust extraction	▪ Washing, crushing, sifting, cyclone, dust extraction facility	▪ Stocking, mixer, kiln

The total investment requirements for processors neighbour $21 million. Amounts by market type are not presented individually in this report due to the commercial aspect.

7.3. Reduction of greenhouse gas emissions related to the *Innovative Glass Works* Plan

A life cycle analysis is currently being carried out by Groupe AGÉCO to measure the reduction in greenhouse gas (GHG) emissions associated with the marketing projects for the 120,000 tonnes of curbside recycling glass in Québec based on different markets.

The life cycle analysis is carried out in accordance with the ISO 14040 and 14044 standards and relies mainly on data from stakeholders in the glass recycling sector and ÉEQ, as well as on the life cycle analysis of glass recycling (RECYC-QUÉBEC, 2015). GHG emissions include glass processing and transformation steps as well as transportation between materials recovery facilities, processors and recyclers.

The environmental benefits of glass recovery can be generally explained by the substitution of virgin materials used in the manufacture of insulating wool, glass bottles and cement additives. The contribution of these benefits to the Québec GHG reduction target will be provided in the spring of 2019.

7.4. Summary of the financing plan and its strategic priorities

Based on the 18 recommendations and the deployment strategy for this Report, 5 strategic priorities have been identified. The financing plan includes the 5 following priorities:

Priority	Investments over 5 years	Period
Strategic Period 1: Equip materials recovery facilities to process 100% of recycled glass	$23 M	4 years
Strategic Period 2: Develop high commercial potential markets for recycled glass	$21 M	24 to 30 months
Strategic Period 3: Deploy a communications plan and an awareness campaign for glass recycling	$6 M	3 years
Strategic Period 4: Ensure that best practices as identified are implemented	(included)	4 years
Strategic Period 5: Assess economic and environmental results and benefits of the *Innovative Glass Works* plan	$1 M (includes characterization, GHG calculation, traceability management)	5 years
Financing plan	$50 M	

Conclusion

The Innovative Glass Works Plan was launched by ÉEQ in January 2016 in order to test equipment that would improve the quality of glass from curbside recycling in materials recovery facilities and to support the development of its related markets.

The ultimate objective of the Plan is to achieve 100% recycling of glass collected from curbside bins in Québec, i.e. the equivalent of approximately 120,000 tonnes per year.

The secondary objectives of the Plan are to:

1. Test processing equipment to improve the quality of glass from curbside recycling and make recommendations to equip Québec materials recovery facilities with the most appropriate equipment.
2. Modernize Québec materials recovery facilities
3. Develop and diversify markets for curbside recycling glass in order to avoid glass being used in any form in landfills in the near future.

Through this Plan, we tested the performance of equipment installed in five materials recovery facilities representative of the Québec industry, worked intensely on materials recovery facility operations and collaborated with processors and recyclers located in the Northeastern United States, in particular, using large-scale testing for the development of their markets.

The main conclusion is that increasing the quality of glass produced by materials recovery facilities improves production capacity for existing processors and recyclers, stimulates their interest in developing other markets and encourages other actors to use glass from curbside recycling in their products.

Several recommendations were made to continue the efforts made so far. These recommendations aim to ensure that the appropriate equipment is installed in materials recovery facilities based on site configuration, market criteria and external factors that affect their operations. They also aim to increase the involvement of municipalities and equipment manufacturers in their responsibilities regarding the performance of materials recovery facility operations. Finally, they aim to prioritize market diversification, the cornerstone of a sustainable process for recycling 100% of the glass collected through curbside recycling.

This report presents the deployment strategy and the financing plan for the optimal solution to recycle 100% of the glass collected through curbside recycling. This solution includes five concrete strategic priorities that must now be deployed throughout Québec.

The *Innovative Glass Works* Plan demonstrates that there is a solution to recycle 100% of the glass collected from curbside recycling and that the solution is within reach.
It is now up to the various stakeholders in the value chain and to the Québec government to support the deployment of the Plan across the province.
ÉEQ wants to take an active role in the implementation of this deployment and will provide its full cooperation to the various bodies involved.

Contact us:

Éco Entreprises Québec
1600, René-Lévesque Blvd. West
Suite 600
Montréal (Québec) H3H 1P9

Phone: 514 987-1491
Toll free: 1 877 987-1491

service@eeq.ca
eeq.ca